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ORIGINAL PAPER

Self-reflection for Activist Engineering

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Abstract

Many blame politicians, governments, and markets for the technically-driven problems the world faces (think war, climate change, surveillance, disinformation, and so on). 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? I offer in this paper practical guidance on how to engage in activist engineering, the goal of which is to get engineers to step back from their work and be able to ask and have a conversation about the question, "What is the real problem, and does this problem 'require' an engineering solution?" Building on research in the history and philosophy of engineering, and engineering ethics and education, as well as current events—all of which highlight important issues of debate within engineering practice—I provide a list of questions that engineers can start with for self-reflection to better understand their motivations for doing engineering work, and to better understand the implications of their work. The questions relate to considerations engineers must make regarding the social, environmental, economic, and peace implications of their work, and relate to alternative and non-technical interventions to the problem at hand. I believe that each engineer should, in the end, be able to answer the questions: Why am I an engineer? For whose benefit do I work? What is the full measure of my moral and social responsibility?

Keywords Activist engineering · Self-reflection · Praxis · Peace · Justice · Environment

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Introduction: Revisiting Activist Engineering

The rich fields of science and technology studies (STS) and engineering ethics have shown how engineers *implicitly* make political and value claims in the engineering work they do, and how engineers often actively distance themselves from these political and value aspects in their work (see, for example, Cech 2012, 2014; Felt et al. 2016; Hecht 1998; Noble 1977; Riley 2012; Vesilind and Gunn 1998). Research has shown how this distancing leads engineers to design technologies and systems that create problems like social and environmental injustices (see, for example, Cech 2013; Leydens and Lucena 2017; Ottinger and Cohen 2012). It is thus vital that engineers understand the political contexts of their work and the values embedded in their work to be able to make sense of the broader impacts of the work they do.

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. Specifically, as I have written elsewhere, activist engineering

> [s]eeks to fundamentally redefine contemporary engineering practice by exposing the political and value-based nature of engineering; by applying socioecological learning to technological design; by imbuing a different sense of responsibility in engineers; and by moving the scope of engineering beyond solely technological development (Karwat et al. 2014).

Influenced by the theory of praxis (Friere 1970 [2000]; Marx and Engels 1845 [1976]; Riley 2008; Smith 1999 [2011]), the goal of activist engineering is to get engineers to step back from their work and be able to ask and have a conversation about the question, "What is the real problem, and does this problem 'require' an engineering solution?" (Karwat et al. 2014). Being able to answer this question can move the engineer beyond merely being someone who takes orders to design a technical system to one who is actively engaged—and will likely have a vested stake in—the system designed.

An example of having a vested stake was recently demonstrated by Google employees, who, upon learning that Google was providing artificial intelligence expertise to a military pilot program called Project Maven [or Algorithmic Warfare Cross-Functional Team (Work 2017)], which aimed "to speed up analysis of drone footage by automatically classifying images of objects and people" (Conger 2018), protested vehemently internally, then wrote a petition to Google Inc. CEO Sundar Pichai, which started off with,

> We believe that Google should not be in the business of war. Therefore we ask that Project Maven be cancelled, and that Google draft, publicize and enforce a clear policy stating that neither Google nor its contractors will ever build warfare technology (Google Employees 2018).

Following the protest, on June 1, 2018, a New York *Times* headline read, "Google Will Not Renew Pentagon Contract That Upset Employees" (Wakabayashi and Shane 2018). Furthermore, Google released a set of seven principles guiding its future artificial intelligence work, which while leaving the door open to military work, said explicitly that the company would not design or deploy "[w]eapons or other technologies whose principal purpose or implementation is to cause or directly facilitate injury to people" (Google Inc. 2018). These are outcomes of activist engineering at work.

I reflect on this story in the context of what I see as the central role of engineers and engineering in creating a world of awe, beauty, connection, and contradiction. We have never had more knowledge and technology than we do today, and the job of engineers has resulted in many of the miracles of modern life like landing on the moon and refrigeration. But that is only part of the picture. The miracles of engineering sit squarely alongside abuse, exploitation, inequity, and degradation in which the pursuits and products of engineering are implicated. Technology—and thus the job of engineers—is implicated in most all of the major social, economic, political, and ecological problems we face today, from the lack of internet connectivity for many Americans (Pew Research Center 2018) to exorbitantly expensive medical treatments one might think should be cheaper by now (Della Costa 2015); from sub-standard drinking water infrastructure all across the US (D'Souza 2019) to a push to develop new, low-yield nuclear weapons because a geopolitical case was made for them (Sonne 2018). Fossil fuel technology is driving climate change (IPCC 2014) and artificial intelligence technology is transforming our understanding of truth itself (Villasenor 2019).

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? A great example of this is seen in this quote from George Ishee of Cast Lighting, a company that in 2017 expressed its interest in expanding the US-Mexico border wall (FedBizOpps.gov 2017a, b):

> There could be a political backlash, but we are in business to make money and put people to work and provide a good service, whether it's a wall or substation or airport or prison. We don't want to approach it from a political standpoint, only from a business standpoint (Adely and Alvarado 2017).

To spark dialogue, debate, reflection, and action in response to the sentiments above, I started writing about what I termed "activist engineering" (Karwat et al. 2014).

What This Paper Is About

This paper is about how engineers can use the process of self-reflection to build and promote activist engineering. I write this paper in an effort to make activist engineering more practical and to generate discussion on how to embed the values of peace, social justice, and environmental protection in engineering. I first describe why activist engineering is important and what the broad agenda for activist engineering is. I then describe the history and theory of self-reflection for activist engineering. I follow that with a set of questions for self-reflection that engineers can answer—by themselves or in group discussion with other engineers and those affected by engineering work—to highlight the assumptions they make in their work, and a fuller extent of the implications of their work. After I discuss how answering these questions can further activist engineering, I conclude with thoughts on how answering these questions is beneficial to all engineers regardless of context, and how to respond to challenges people may have in discussions about these questions.

Why Is Activist Engineering Important?

Just like medicine is about much more than drugs and scalpels and is also about health and employing the suite of tools to promote well-being (Riley and Lambrinidou 2015), engineering should be about the suite of tools and perspectives that shape the design and implementation of technical systems for making the world “more just, more equitable, and more beautiful” (The Architecture Lobby 2017). All engineers need to know that engineering is, as Langdon Winner (1986) says, not solely about the design of *technical* systems, but the design of systems that include tools, systems of meaning, and instructions, of which technical solutions are a *part*. And the idea of praxis—of critical thinking and reflective action upon the world to transform it (Friere 1970 [2000]; Marx and Engels 1845 [1976]; Smith 1999 [2011])—forms a central part of the engineering process (Karwat et al. 2014; Riley 2008). As mentioned in *Activist Engineering*, “[E]ngineers must be active and responsible participants in framing the issues they work on, not only from a technological perspective, but also from a political and value-based perspective” (Karwat et al. 2014). The self-reflection described in this paper is about shedding light on the perspectives engineers bring to this multifaceted framing.

I assume that engineers, like other professionals, are guided by the idea that their profession should have a positive influence on the world, just like Yanna Lambrinidou and Nathan Canney (2017) describe. Given that assumption, and building on a significant body of literature (for example, Catalano 2004; El-Zein and Hedemann 2016; Riley 2008; Vesilind 2010), I believe that the values of social justice, peace, and environmental protection must be at the heart of engineering. Instead of continued investments in engineering driven by militarism and extractivism, engineering should invest more resources in tackling major issues like plastic in the oceans and engineering for the most vulnerable and marginalized in our society. Any expansive notion of the terms “public,” “health,” “welfare,” and “sustainability,” terms that fill engineering codes of ethics, would point to the importance of these issues. Activist engineering is about centering these values and technological challenges in engineering.

While many might say that engineers should just “do their jobs” and not ask questions about what they do and why (see, for example, discussion of the idea of engineers as “hired guns” in Bucciarelli 2008; Johnson 1989; Mitcham 1998; Zandvoort 2008), I think that engineers—including engineering educators, engineering students, practicing engineers, and even those close to retirement—should openly discuss the politics of their work. That is because *all* engineering is political:

engineering is a product of people and organizations competing to set its agenda and have influence over its successes and failures (see, for example, Felt et al. 2016; Hecht 1998; Hughes 1993; MacKenzie 1990). Self-reflection can shape and guide these discussions.

Self-Reflection for Activist Engineering: History (It Is Not New), Theory, and Broad Definitions

People self-reflect for all kinds of reasons. They can be prompted to self-reflection by a simple, unexpected question, or by something dramatic like the loss of a loved one or a hurricane destroying their home. Catholics confess and Buddhists are mindful. Self-reflection is a part of social programs like Alcoholics Anonymous. I take it for granted that human beings self-reflect and that each person has some set of concerns that guide their self-reflection, like family, friends, work, community, metaphysics, nature, and politics.

I define self-reflection as a process of personal analysis of one's beliefs, actions, and outcomes of those actions. This analysis can be guided by pointed questions. For this paper, those pointed questions relate to the motivations and goals of activist engineering, which I define in the Introduction section and elsewhere (Karwat et al. 2014). While there have been recent efforts in promoting reflection to aid engineering education and lifelong learning (see, for example, Mina et al. 2015; Turns et al. 2014), from the earliest days of the profession, self-reflection has also led to professional *activism* in engineering. I draw inspiration from this history, as I describe below.

In important works in engineering studies like *Engineers for Change* (Wisnioski 2012), *America by Design* (Noble 1977), and *The Revolt of the Engineers* (Layton Jr., 1971), one can find detailed descriptions of how deeply reflective engineers have attempted to shape and change engineering by questioning who has authority in and over engineering and what and who engineering is for. Matthew Wisnioski (2012) describes how, even in spite of highly visible advocacy and activism, questioning the goals and motives of engineering through self-reflection and reflecting on the profession has historically been suppressed by companies and professional societies. And so, while it is not surprising, it is certainly frustrating that many of the questions activist engineers raised half a century ago about professional duties and responsibilities, and about who engineering is for, are the same questions still relevant today; while technological capabilities have changed drastically over the decades, the broader economic and political systems driving engineering have not as much. This reality makes the first part of the subtitle of Wisnioski's (2012) book, "Competing Visions," entirely relevant to debates today about what engineering is for, what drives engineering, and about the implications of techno-optimist views of engineering and technological development [see the *Epilogue* in Wisnioski (2012)].

Engineering studies has, through different perspectives, grappled with the questions Wisnioski (2012) raises. For example, while Louis Bucciarelli (1984: 185) approaches the question of reflection through "reflective practice, in which he "pretend[ed] to be an ethnographer while participating as an engineer" to develop ways to understand how values are embedded in the technological design process, Vito Punzi (2017) describes how themes in Catholic Social Teaching (CST)—including ideas like dignity, rights of workers, and solidarity, among others—can be applied to engineering work. Punzi (2017) points to CST documents, including papal scriptures, that can be used by engineers to reflect on their work in service of humanity. Similarly, in describing the importance of self-reflection for activist research for anthropology, which shares many similarities with the goals of activist engineering, Charles Hale says,

> Activist research endorses the contrasting tack of making our politics explicit and upfront, reflecting honestly and systematically on how they have shaped our understanding of the problem at hand, and putting them to the service of our analytical behavior (Hale 2001: 14).

Politics is much more than electoral politics; it has to do with everything people struggle for power over. Self-reflection is not about "politicizing" engineering work, but is about recognizing, putting up front, and acting on the inherent politics of engineering work.

Wisnioski (2012: 96) recounts how Bob Aldridge's transformation from an engineer designing missiles for Lockheed Martin to peace campaigner began with "an amiable confrontation" with his daughter "which went until 5:30 the next morning." He tried to make the case that the "Poseidon missiles he helped design were maintaining the peace." The debate seeded his mind with doubt, leading him to organize discussions at work, leading him to quit working for Lockheed Martin, and leading him to write "The Forging of an Engineer's Conscience" for *Spark* (Aldridge 1973). While there are no data on how many engineers carry such doubt, I bet there are many engineers like Aldridge who question the value and social implications of what they do.

Research has shown, particularly in relation to scientific work related to militarism in the 1940s through the 1970s, how scientists, too, have struggled with questions beyond the solely technical to "reconcile the tension between expertise and popular democracy, the meaning and extent of the 'autonomy' of science, and the obligations of scientists in the face of the growing threat of nuclear war" (Moore 2008: 58). In particular, those belonging to the Society for Social Responsibility in Science (SSRS) followed the Quaker tradition of a "way of conscience" (Moore 2008: 194), which emphasized the importance of personal responsibility over the "uses made of one's work" (Moore 2008: 194). This idea meant that *all* choices made by scientists were on the spectrum of moral to immoral, thus challenging the "universalism of the scientific project" (Moore 2008: 195). Kelling Donald and Jeffrey Kovac (2013) follow Aldridge's (1973) and SSRS's lead (Moore 2008) to say that scientists should have a "civic conscience," and pose three self-reflective questions to science educators and professors:

1. "Do I play an active role in shaping the civic conscience of my students? (By civic conscience we mean an interest in public affairs and a willingness to become involved.)

2. “Should I, as part of my science course, be intentional about making learners aware of historic and contemporary issues at the interface between the academic content and soci-political [sic] realities, such as the use of nuclear technology, or social issues related to stem cell and human cloning research?
3. “More broadly, do I share in the responsibility for how my students will use their knowledge as they advance professionally and begin, perhaps, to influence national policies?” (Donald and Kovac 2013)

Research has also shown how a few motivated individuals can be the seeds of large change in technical professions. For example, as described by Scott Frickel (2004), the field of genetic toxicology did not appear out of nowhere, but was rather created by motivated biologists between the 1950s and 1970s who expanded the scope of their inquiry to question whether chemical exposure could in fact alter the DNA of humans. Self-reflection is about getting to the point where Frickel (2004) and Kelly Moore (2008) *start* their analyses; while they described the broader social and political context that scientists were in, they did not necessarily describe *how* scientists personally defined the contours of their social responsibility to the point of being motivated to be activists (in the manner in which I define “activist”). Frickel (2004), in particular, notes that:

> I am not so much concerned with why some scientists suddenly became motivated to attempt a reorganization of genetic knowledge and practice. I take the answer to that question to be more or less self-evident: they became motivated by their understanding that the science of genetics could do more than it was doing to understand the causes, scope and human impact of chemicals in the environment (Frickel 2004: 16).

While I caveat the references to Frickel’s (2004) and Moore’s (2008) work by recognizing the limitations of using activist movements in science as examples of what is possible within engineering—particularly given the vast difference between engineering and science in organizational, employment, hierarchical, and incentive structures, as well as in motivations behind why engineering and science are done—their work describes a legacy of the broad and lasting effects of self-reflective technical workers. I believe that that motivation for change comes from and is shaped by self-reflection. Next, I present a set of questions that can serve as a starting point for this self-reflection.

Self-Reflection for Activist Engineering: A Set of Questions

Why engineers question and self-reflect is as important as *how* they do it. I have not found an attempt at making a comprehensive list of questions that engineers at any stage of their career can engage with to lay the foundation of activist engineering; I make a small attempt to fill that gap here. Such questions can provide a focused jumping off point to create in engineers a broader awareness about how their work affects and is affected by social, political, economic, and environmental/ecological forces, and to make it clear to them that their personal values in fact do matter in creating an engineering profession that makes central concerns of social justice, peace, and environmental protection.

Why are we engineers? For whose benefit do we work? What is the full measure of our moral and social responsibility? These questions are inspired by *Science for the People*, the activist group led by scientists, engineers, and other technical workers that enjoyed its greatest popularity in the anti-Vietnam years, and one that is now being revitalized (Science for the People, n.d.). Building on these questions, and in the spirit of self-reflection, each engineer should be able to answer: *Why am I an engineer? For whose benefit do I work? What is the full measure of my moral and social responsibility?*

These are big, weighty questions for self-reflection, and so breaking these questions down into other questions can provide inroads into trying to address them. To do so, I made sure that taken in sum, the questions would give the self-reflective engineer an understanding of (1) the idea of engineering as a profession that can advance the ideas of peace, social justice, and environmental protection; (2) the general forces and considerations that shape technological decisions; (3) the stakeholders affected by engineering work and the political power each may have; (4) the notion that engineering is a process and is not the only way in which problems can be addressed; and (5) the notion that there are no easy answers to the complex problems engineering tries to address.

Table 1 is an outcome of this thought.[1] They are, to a certain extent, related to the set of competencies suggested by Nicholas Sakellariou (2013)—namely being able to understand environmental, political, social justice, and legal implications of engineering work.

The approach of grappling with a set of questions is similar to what George H. Heilmeier, former head of the Defense Advanced Research Projects Agency (an agency driven by high-risk-high-reward decisions driving significant technological advancement), instituted to help program managers decide on what risks agency officials should take, and how they could "think through and evaluate proposed research programs." Heilmeier crafted a set of questions (including "How is it done today and what are the limits of current practice?" and "Who cares? If you are successful, what difference will it make?") known as the "Heilmeier Catechism" to help Agency officials answer higher-level strategic questions about funding decisions (DARPA, n.d.).

Similarly, answering a few or more of the self-reflection questions in Table 1 about activist engineering can lead to more open dialogue with collaborators, which may include communities, non-profits, governments, and companies. The questions are meant to expand the scope of what constitutes engineering and what constitutes a good technical decision, invention, and intervention. The list of questions is not comprehensive but is rather a starting point, not least because praxis is flexible

[1] I pilot-tested the questions in Table 1 on students, engineers working in industry, and engineers working in the federal government.

Table 1 A list of questions for self-reflection for activist engineering

Sphere/realm	Questions
Why am I an engineer? For whose benefit do I work? What is the full measure of my moral and social responsibility?	
Social and political considerations	Who is your work for and what are their values and goals? How much social and political capital does your employer have? Who has the most to directly gain and lose from your work? How and why? How quickly will the marginalized in society benefit from your work? Who are you leaving out of your consideration, and why?
Environmental and ecological considerations	How are local, regional, and larger environments and ecological systems affected by your work? What are the material resources used in the design, deployment, maintenance, and subsequent decommissioning of the technology or system? What environmental and ecological concerns are you leaving out of your consideration? Why?
Economic considerations	How is the economic value (revenue, access to capital, etc.) generated by your engineering work distributed? Who owns the products (intellectual, physical, etc.) of your work and for how long? Do particular groups of people have to pay more or less than others to use your technical intervention? Why or why not?
Peace and security considerations	In what ways does your work reduce the potential for violent conflict, obviate the need for weapons or anything else that can cause mental or physical harm or trauma, or death—intentional or otherwise—and increase the ability to promote diplomacy and dialogue to resolve conflict?
Praxis, connections, and feedbacks	How are feedbacks from stakeholders and data from evaluation built into your design and implementation process? How responsive to changing social values and needs are the configuration and performance of the technical systems you design? How might an emphasis on one set of considerations here enhance or detract from another?
Alternative problem-solving approaches	What non-technical interventions (business, community building, resource sharing, etc.) might achieve similar outcomes to the ones you might achieve through your technical work? How do you think existing technologies and materials could be used differently to achieve similar outcomes to your work, if at all?
Personal conflicts	Are you dissatisfied with any of your answers to the above questions? What would you rather the answers be? Why? Is there anything that you are doing that is counter to your values or the values of the people you claim to serve?

(Riley 2008), and so the answers to the questions, and the questions themselves, may change over time.

In the following sections, I describe what the impact of grappling with these self-reflection questions might be for all kinds of engineers, and how engineers might be able to use these questions to promote their own and other's activist engineering work.

What the Self-Reflection-Motivated Group Discussions Can Do for Engineers and Engineering

It may be hard for any single engineer to answer all of the questions in Table 1, and it's likely that not all of them will be relevant for all engineers. Regardless of the fact that there are no right answers to these questions, expanding the engineer's idea of who and what is affected by engineering work is important, and is best done through discussing these questions in groups that include both engineers *and* non-engineers. Also, attempting to answer these questions through such group discussion might address some of the difficulties of activist engineering, as I discuss below:

1. *Unfringing and unothering:* Thinking about issues of social justice, peace, and environmental protection; openly discussing issues of ethics, history, morality, and responsibility; and taking the long view about the profession of engineering is not considered a standard part of engineering education and practice. Rather, decontextualized training and practice is the norm (for example, Leydens and Lucena 2009; Leydens et al. 2014; Nieusma and Riley 2010; Riley 2008). In general, engineering education does not emphasize these issues (e.g., Bielefeldt and Canney 2014; Bosman et al. 2017; Cech 2012, 2014), and neither does the working world, for thinking about these issues can quickly lead down the path of questioning engineering's historical and current ties to extractive and exploitative economic and social structures. Thus, simply creating a compact list of questions and discussing them at every possible opportunity can make thinking about these issues less fringe.
2. *Checking reality:* The list highlights how engineering affects the world and helps engineers reflect on the dominant perception that more technology is assumed to be better than less, and that since engineering is about technological development, engineers are heroes (Cech 2012). For example, the National Academy of Engineering's Grand Challenges for Engineering report (National Academy of Engineering 2017) set forth an agenda for the most important areas of work for engineering over the coming years. But glaringly missing from the report is any acknowledgment of engineering's contributions to the creation of the very problems the Grand Challenges address. For example, what does it mean for engineering to "prevent nuclear terror" when engineering created the tools for nuclear terror in the first place (Riley 2012)?
3. *Building community to act on dissatisfaction:* A lot of engineering work happens in large, anonymous buildings, where engineers might sit in windowless spaces. For example, I know from personal experience how hundreds if not thousands of

engineers who work at GE Aviation in Cincinnati, Ohio, sit in vast windowless basements, few with any content look on their faces. Online discussion forums provide some insight into how engineers perceive their work to be at times intellectually dissatisfying and emotionally disheartening (r/AskEngineers 2014, 2015). Discussing the questions in Table 1 with colleagues and stakeholders can create a community of engineers who can engage in important discussions about the ethical challenges in doing engineering work, can create linkages between individual and collective professional ethical responsibilities of engineers (Herkert 2001, 2005, 2009), and can build networks of support among like-minded engineers. As illuminated by Frickel (2004), Moore (2008), and Wisnioski (2012), such communities are at the heart of collective action that can drive large scale change.

4. *Giving meaning to large concepts:* The list of questions attempts to give engineers a broad sense of what makes up and influences "public welfare," "safety," "health," and "sustainability," concepts that mean different things to different people, but are employed freely when discussing the role of engineering in society, and in engineering codes of ethics (AIAA 2013; ASCE 2017; ASME 1998; NSPE 2018). The questions might also illuminate the blurriness, tensions, and synergies between these large concepts and others like "personal values," "professional values," and the values of the organizations engineers work for.
5. *Expressions in engineering sub-cultures:* Engineering is not monolithic; instead each kind of engineering—mechanical, aerospace, electrical, biomedical, systems, petroleum, and so on—has its own culture. The values and norms that guide each kind of engineering can be significantly different because each was formed with its own constituency, its own ethos, and its own mode of professionalization (Layton Jr., 1971). The broadness of the questions in Table 1 might allow for all kinds of engineers to find their interests and concerns reflected in them. Activist engineering is not a *kind* of engineering, but is a mindset when doing engineering. What activist engineering looks like, and how it is conducted, will be different for different kinds of engineering. It shapeshifts, in the truest nature of praxis, while holding on to the ideals of social justice, peace, and environmental protection.
6. *Recognizing context and complexity, and being holistic and mindful:* The self-reflection process I attempt to instigate with Table 1 is about the recognition of the structural forces at play in the design, development, deployment, and eventual success of the products of engineering. Addressing and solving problems through engineering is itself an ongoing process. This builds on the important work by Dean Nieusma and Donna Riley, who detail how it is difficult to draw bounds to "define" a problem:

   > [E]ngineering problems are difficult to define and to bound; interdisciplinary teams must collaborate on different facets of the problem to ensure robust solutions, and final 'solutions' are rarely achieved, but each partial solution makes people's lives better (Nieusma and Riley 2010: 57).

This challenge implies the need for engineers to be able to understand how their work is shaped by and fits within a broad social, economic, environmental, and political context. It also implies the need to build in engineers the concrete ability to work not only with engineers with different cultural backgrounds and training (Downey et al. 2006), but also with people of all kinds (Karwat et al. 2014), and to build in engineers the ability to ask the right kinds of questions to define "the problem" engineering is needed for. If engineering is about creating the conditions and outcomes of peace, social justice, and environmental protection, as I believe, then it is important to recognize the forces that shape the possibilities of those ideals and goals. While it certainly is true that engineers may construct problems in ways that have "right" and "wrong" answers, I also know, having been a practicing engineer and having done engineering program design and management in the federal government, that engineers are in fact incredibly well-equipped to understand tradeoffs and make complex decisions. Self-reflection for activist engineering pushes to increase the number of variables that influence technical design, building, and analysis. It is, in the theoretical framework of Christopher Sellers (1997), about extending the "gaze" of technical inquiry and work.

This certainly is not a comprehensive list of the possible impacts and outcomes of self-reflecting with the questions in Table 1, since, as I describe below, engineers working in different contexts likely face unique circumstances in grappling with these questions.

What Do These Questions Mean for Engineers in Different Contexts?

Profit drives much of engineering. According to the National Science Board's 2018 Science and Engineering Indicators, 53.7% of engineers and scientists work for-profit companies, 10.8% for non-profit organizations, 6.2% in unincorporated/self-employment businesses, 18.5% in education, and 10.8% in government (National Science Board 2018). For-profit companies create professional contexts that prioritize profit and efficiency without necessarily having a social purpose (Besley and Ghatak 2015) or a social value (Murray 2013; Quarter and Richmond 2001).

Within the business and industry sector, most contemporary engineers work on problems that are small parts of a larger whole, with 32.6% of engineers and scientists working in organizations and companies employing 100–4999 employees, 14.2% working in those employing 5000–24,999 employees, and 17.5% working in those employing 25,000 or more employees (National Science Board 2018). Many engineers are given information only on a need-to-know basis, because may be are part of a team competing internally with another team at a company, or because the company wants to limit who has access to its intellectual property (Elliott et al. 2019; Hannah 2005; Liebeskind 1997). For example, a former labmate of mine who worked at Intel said he was only able to ask questions related to his particular role in chip design and nothing else (and this was the same thing I was told by an engineer working on computer vision at Intel). The same is the case at Apple, which has also been documented to go further and hire for so-called dummy positions, which are roles that are not explained in detail until after someone joins a company (Lashinsky 2012). Such organizational contexts make it difficult for engineers to spend any of their professional time understanding the business they work for, let alone the broader context of engineering itself. Basically, the large bureaucracies that engineers work in "diffuse and delimit areas of personal accountability within hierarchies of authority" (Martin and Schinzinger 2009: 90).

In many instances, the final outputs of engineering work—designed products or infrastructure—are physically removed from the engineers' workplace, lessening the sense of personal accountability and responsibility. Engineers working on a project often do not travel to the place where their design might be implemented. Even in community-based engineering with well-meaning technical interventions, an emphasis on product and process and ensuring that the product meets technical specifications shows how "injustices slip into well-motivated projects and how attention to non-technical dimensions of technology projects is needed to counter them" (Nieusma and Riley 2010: 31).

Educationally, while there has been a push for service learning that does take students outside of the classroom and into places where their work will make its impact (Bosman et al. 2017; Cabedo and Guraya 2017; Karwat et al. 2013; Tsang et al. 2001), most engineering education decontextualizes technical problems (Leydens and Lucena 2009), training engineers to think *a*historically and *a*politically (Karwat et al. 2014). Very little do problem definitions look at the history of the problem that needs addressing, which thus creates separations between the "technical" and the "social" sides of problems.

In recognition of the structural factors mentioned above, I frame the questions in Table 1 in a way that places the individual engineer in a network of other people and in an ecosystem in which the connections between engineering work and its broader effects are apparent. Often, the kinds of organizations engineers find themselves in can affect and limit what they can do and what decisions they can make. Generally, rank-and-file engineers have little influence on large business decisions, but they can still discuss the politics of engineering, and, as history has shown, this has always been a seed of change (Frickel 2004; Moore 2008; Wisnioski 2012). *Who* does the self-reflection can influence the nature and outcomes of the activism. For example, Frickel (2004) notes how the activism conducted by "biochemists, toxicologists, and pharmacologists [in the 1960s and 1970s] whose reputations were firmly established" stood in stark contrast to the activism of students in the same time period. Below, I hypothesize—after having discussed the questions in Table 1 with engineers in academia, government laboratories, and industry—how the questions in Table 1 relate to engineers in different bureaucratic contexts:

1. *For engineers in large(r) companies:* Much has been said about the barriers between engineers and management and the boundaries of engineers' autonomy in large organizations (for example, Garnell 2017; Layton Jr., 1971; Meganck et al. 2018; Various 2018). Along with the individualism that super-specialization in engineering brings (one might imagine an engineer describing their job as, "My job is to run large eddy simulation computational fluid dynamic codes to understand wake effects behind next-generation cars"), the issue of limited autonomy bounds how much engineers can actually challenge management decisions. The resulting breakdowns in communication because of these power dynamics is one cause of the important but messy and ostracizing process of whistleblowing

(Alford 2001; Johnson 2003). In recognition of these complications, at the very least, the questions in Table 1 can be used by engineers to organize outside of work in an effort to more fully understand their roles in large organizations, just like engineers did in the 1960s and 1970s (Wisnioski 2012). More formally, as an engineer working at the Xerox Corporation suggested to me, these questions could be modified to be

> …built into the practice and business of engineering, with strong norms supporting adherence at levels of an organization, akin to the Project Management Professional Examination Specification (Project Management Institute 2019) and Lean Six Sigma (Lean Six Sigma Institute 2018). [The questions can] be packaged and branded into a set of standard practices that will be expected of any enterprise, [and adherence to the practices] can be looking forward and backward in time (planning and reporting) and be reported on internally and externally (public-facing) (Fowler, personal communication, October 10, 2018).

2. *For engineers in small businesses:* Engineers like civil engineers, who might work in small firms, do have more autonomy than other kinds of engineers, like aerospace engineers, who tend to work in larger corporations. Engineers who work in smaller businesses can have more say over what projects they work on, and what specifically their ethos is when working with stakeholders as part of a project. Engaging with the questions in Table 1 could help guide them in the kinds of projects they choose to work on.
3. *For engineers in government* Engineers working for government face a different kind of accountability towards the public (Romzek et al. 1987), particularly given their ability to issue or deny permits for large infrastructural projects (NSPE 1992) and perform risk and environmental assessments; their power over how to direct large research and development agendas that shape academic institutions, industrial relations, and the work done at national laboratories (this comes from personal experiences at the US Environmental Protection Agency and the US Department of Energy); and their ability to design programs that motivate the public to be involved in the technical enterprise in the US (e.g., using the authority of the American Innovation and Competitiveness Act (Gardner et al. 2017) to design prizes and challenges to involve the public in technological research and development). While engineers working in government might face challenges and encounter politics similar to those faced by engineers working in any large organization, since government is intended to serve the public, the questions in Table 1 can help them strategically plan the work they do.
4. *For engineers in academia:* Engineers need to know the history of engineering and how it became a profession; how many engineers have struggled against the dominant economic and political forces that have shaped engineering; how engineering curricula are set and who decides how engineers are educated; and what the social, environmental, economic, and political implications of engineering are. Such knowledge can help engineers better understand the problems they work on,

and can work against recreating the problems and injustices of prior engineering work (see, for example, Cech 2012; Lambrinidou and Canney 2017; Leydens and Lucena 2009, 2017; Nieusma and Riley 2010). Engaging with the questions in Table 1 can help shape the courses professors teach and the research questions they ask in the lab, and can inform how professors advise their graduate students on important social, political, economic, and environmental questions to consider in engineering work.

5. *For engineering students:* The questions in Table 1 can allow engineering students to ask their educators more openly about how they are being trained and for what purpose. Rather than assuming what they are being taught is best for them, these discussions can help engineering students convey to their teachers and professors their passions and their desires, and work with their educators in tailoring their approaches to pedagogy accordingly. These questions can also help engineering students demand more visibility at career and internship fairs for opportunities for doing engineering for social justice, peace, and environmental protection.
6. *For engineers in non-profits:* Engineers working in mission-oriented non-profit organizations such as Engineers Without Borders, Engineering Ministries International, or Lifewater International, might already be required to think about questions similar to those in Table 1. As described by Karwat et al. (2014), however, the idea of praxis is important for all engineers in continually adapting their work to changing needs and circumstances. Therefore, what may be important for engineers in non-profits are the questions related to praxis, feedback, and connections.

It is difficult to speculate on how such self-reflection would actually work in practice and who should be the critical yeast in organizing self-reflection discussions, but discussions might begin in small spaces among trusted individuals to build a culture of honest discussion about difficult questions related to the role of engineering in society. However, once successful, one might envision increasing interest in classes on the politics and philosophy of engineering, classes that already exist in many engineering, STS, and philosophy curricula (see, for example, A. James Clark Engineering School at the University of Maryland 2019; Department of Engineering and Society at the University of Virginia 2019; School for the Future of Innovation in Society at ASU 2019). One might also envision the creation of reading groups; of lunchtime seminars in firms or in engineering departments on how an engineer (or a group of them) is trying to act on learnings from self-reflection; of incentives and value structures driven by the outcomes of self-reflection. One might also envision, as suggested above, the incorporation of protocols on constant self-reflection into an organization's engineering design process itself. As I describe next, there are many possible benefits for all engineers in answering these questions.

The Practicality and Benefit of Answering These Questions

Being able to discuss the questions in Table 1 can make engineers better engineers for the following reasons:

1. *Answering these questions supports technical rigor:* Any technical intervention must be created with the highest standards of engineering research, development, design, demonstration, and implementation. Activist engineering is no less rigorous; it is just for different purposes, to different ends. For example, an approach that centers the idea of peace in technical design can lead to completely different design specifications, or lead to completely different social, economic, and political structures that are created alongside a technical intervention. Different value systems create fundamentally different interventions and solutions to a problem, because the problem is conceived of and constructed in a different way (Karwat et al. 2014). For example, what is the difference between a tomato grown in a community garden and a tomato grown on an industrial farm? Apart from the possible differences in nutrition and environmental and farmer health impacts, the value of each tomato is fundamentally different because the tomato in one instance supports a system of community building and neighborliness, and in the other supports a system of anonymized mass production (Winner 1986: 26–28). In other words, while engineering can produce similar products through different organizational systems, the broader value of each product depends on the system that produces it.
2. *Being able to answer these questions could provide an engineer with increased opportunity and lead to better-informed work:* With the growth in social entrepreneurship and the influence of ideas like sustainable development, engineers who are able to talk clearly about the broad implications of engineering work, and what factors ought to be considered in engineering design, can stand out as prospective candidates for social mission-oriented jobs (Mehta 2015). Further, as mentioned earlier, engineers are indeed well-equipped to study complexity and make tradeoff decisions. Activist engineering is about expanding the scope of what is considered engineering, and thus the variables considered in doing engineering work. Thus, self-reflection for activist engineering allows for better-informed engineering. This is exactly the case that Frickel (2004) makes in detailing the scientist activism in creating genetic toxicology:

   > There is a sense in which activism in genetic toxicology is counterintuitive because much of what these scientists actually did was in many ways identical to what most scientists typically do in professional life: they tinkered, puzzled, innovated, shared and promoted their ideas, and competed with one another for grants and status (Frickel 2004: 142).

3. *Being able to answer these questions can help an engineer be accountable to the public:* "[A] major challenge we face as individuals, as a culture, and as a nation is to reclaim our capacity to articulate, draw courage from, and act upon, public values," says Marshall Ganz (2008), and his approach, called a "public narrative," is a way to learn "how we can translate our values into action." According to Ganz (2008), articulating a public narrative about oneself is important in building strong relationships with a community—perhaps a marginalized one—that is affected by their work. What this means is that people need to know *your story* if you want people to work with you, trust you, and allow you to be accountable to

them. Answering the questions in Table 1 can help an engineer craft their public narrative.

While I have identified what I think the benefits to answering these questions are, I also recognize the challenges engineers may face in doing so. In the penultimate section below, I give my thoughts on how one might reason through these challenges.

Challenges to Activist Engineering and Some Rebuttals

The act of questioning what engineering is about and how it should be done will face challenges by engineering leadership and even by colleagues, just like Wisnioski (2012), David Noble (1977), and Edwin Layton, Jr. (1971) document in their writings. Below, I address some of the challenges a self-reflective activist engineer might face:

1. *Being told by leadership "Just do your job and focus on the technical aspects of your work," or by a colleague, "Hey, leave me alone with these questions. I just want to focus on the technical work.":* Once a particular set of factors for a problem have been established, an engineer or engineering team is going to have to focus on the technical aspects of engineering (see section above on technical rigor). Activist engineering simply requires engineers to think about what engineers should consider as influencing factors for our engineering. As others do (Leydens et al. 2014; Nieusma 2011; Riley 2008), I believe that peace, social justice, and environmental protection should be among those factors. Activist engineering is thus not about being anti-technology, and is not about denying the power that engineering holds to create thoughtful interventions to problems. Further, in the context of research, which can be easily extended to engineering design, according to Hale (2001), "There is no necessary contradiction between active political commitment to resolving a problem, and rigorous scholarly research on that problem." Simply put, engineers need to recognize that problems are framed somehow, either by themselves, their team, or by someone else who in turn has their own motivations or who reflects the motivations of an organization. Any technological system reflects values, aims, or ideals: maximizing shareholder value, national security, planned obsolescence, gaining a market share, reducing violence, or keeping carbon dioxide out of the atmosphere, and engineers need to be clear about and comfortable with what those values, aims, or ideals are. As I have written elsewhere (Karwat 2017),

   > In today's political climate, engineers cannot remain passive and allow legislators and politicians to decide what the 'public good' is. *All* members of a community must be engaged and responsible in deciding what the public good is and how to create it—and that goes especially for engi-

neers and the companies they work for, because they can have a disproportionate and lasting impact on a community.

2. *"How can we engineers do this thinking and analysis if we are not paid for it?" or "I cannot talk about these things where I work. Do you do things on the side?" or "There are no professional or academic incentives to do this kind of work.":* It can be extremely difficult to openly question the political and economic foundations of your employer (academic, corporate, and even non-profit), an engineering organization, or engineering itself. Activists and oppressed people challenging the status quo have always faced barriers in being heard and taken seriously, visible most recently with the #MeToo movement (Burke 2018), which has raised the voices and stories of those who have been sexually assaulted, especially in professional settings. Activists face barriers in their endeavors, because activism is about questioning systems of power and oppression. But in his talk "One Foot In, One Foot Out," Richard Levins (2008: 126–127) describes how important activist work in technical fields can be done, especially by writing in venues beyond the control of those in power, or by working with community groups on the side "to resist the biases and assumptions of our professional communities and to have another community of validation than that on the job." Even a job you do not like can help pay your bills to make activist work on the side possible.

   It is crucial to take advantage of the small openings that do exist for activist engineering. From an academic perspective, apart from the advances being made in engineering education, there are spaces in existing programs—like in the "Broader Impacts" section of National Science Foundation grants (National Science Foundation 2014)—that can be used to signal to leadership and selection committees how you think about the value of the work you do. And while corporate social responsibility (CSR) programs can provide a veneer of doing public good to companies that may in fact be negatively affecting communities (Ottinger 2013), there is immense space for CSR to be used by engineers and managers to co-create more constructive relationships with marginalized communities.
3. *"One engineer thinking this way will not make a difference," or "Self-reflection is too individualistic an approach.":* Engineering education related to the social, political, and ethical dilemmas of decision-making do a disservice to engineering students by focusing on questions like "What is the 'right' thing for an engineer to do in such and such a situation?" Framing dilemmas in this manner implies that dilemmas always have simple and clear answers. It also implies that individual engineers have significant authority to act on the answers they come up with. That clearly is not the case, firstly because engineers tend to work in large teams and organizations and on design challenges that can be large-scale (think of building a large dam that can affect farmland, salmon, and local villages) (van de Poel and Royakkers 2011), and secondly because such dilemmas have no clear answers (Whitbeck 1996). However, individual engineers working for systemic change still need to be clear about the motivations for their own work. I frame the questions in Table 1 in a way that makes an engineer recognize the scale and outcomes of the system they are a part of. Put in historical context, research has shown how movements to reorganize technical disciplinary boundaries and infuse values into

> technical research have been created by collections of a few motivated individuals (Frickel 2004).

The last set of questions in Table 1 point to the possibility of conflicts between personal values and employment situations. Such conflicts exist not only in engineering settings, but in most all work that is normatively driven, like how law strives for justice (for example, Green 1997); how social work pays particular attention to people who are vulnerable, oppressed, and living in poverty (for example, Allen 2018); and how medicine strives to protect human health (for example, Johnstone 1988). Conflicts might also drive one to challenge management, whistleblow, or even quit their job. However, some engineers may not be in a position to change their job, and so it would be important to create informal or formal networks of support with other engineers willing to engage in activist engineering-related thinking to discuss and address conflicts.

Thoughts to End On, and Next Steps

You do not need a PhD to engage in activist engineering. All you need is a self-reflective, questioning spirit and a drive to turn engineering from what it many times is—a profession that has left us with technological wonders like refrigeration and vaccines sitting squarely next to the capacity to destroy the world, its ecosystems and communities—into what it should be—a force applied singularly for deep social good, peace, environmental protection, and inspiration. Self-reflection has always been important to create social change, and the same is the case with the goal of transforming engineering. We need a movement of engineers centering the most vulnerable in society in their work, and creating new values and incentives for such work. To continue to play a small part in creating such a movement, I intend to test the efficacy of this self-reflection tool among engineering students and professional engineers; to understand and create career pathways for engineers who seek to center social justice, peace, and environmental protection in their engineering work; and to generate a larger and more structured conversation among engineers about these issues through more public-facing writing, thought pieces, and workshops. I welcome collaborators in this effort.

Transforming the profession of engineering is a large-scale and long-term endeavor, and some might wonder what the point of self-reflection is. In response, I use the words Bob Aldridge wrote in *Spark* as a starting point for creating a culture of activist engineering:

> When morality is embodied, it is something tangible and is the very strength in a person. It is not a banner to be waved at meetings—it is a lifestyle. Nourished, it will grow, and the pattern of living will change accordingly. We won't convert the world or even the community, but it will have a profound effect on our daily associates, and thereby propagate (Aldridge 1973).

Personal change is still much better than the status quo.

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