Activist Engineering: Changing Current Engineering Practice Through Innovative Praxis

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Abstract

In this paper, we reflect on current conceptions of engineering practice by examining some motives for engineered solutions to the problem of climate change. We draw on fields such as science and technology studies, the philosophy of technology, and environmental ethics to highlight how dominant notions of apoliticism and ahistoricity ingrained in contemporary engineering practice change only the kind of technology being developed but do not question the social, political and cultural tenet of infinite material growth through efficiency. We (re)introduce the concept of *praxis*, which allows for more ecologically sensitive, just, and sustainable technological interventions. Within this framework we define an activist engineer as someone who steps back from their work and tackle the question, What is the real problem? This newly enriched context creates space for authentic alternatives, solutions that differ from the current paradigm of constantly technologizing our way out of problems. By reflecting on social justice and ecological sustainability concerns, the notion of praxis raises awareness in engineers of the inherent politics of technological design. This reevaluation of the problems that engineers deal with can fundamentally change the nature of technologies developed, and raises a radical alternative rarely considered—*not* "engineering a solution." Activist engineering goes to the heart of the problems with and offers a solution to contemporary engineering practice that results in social injustice and ecological degradation by asking not, Can we do this? but instead, Should this be done?

1. Introduction

Contemporary engineers frame climate change as a "carbon problem" requiring a technological solution (Karwat, 2012). In this paper, we investigate this ethic toward climate change and highlight the absence of historical and political discourse in engineering education. Given a desire to change what Thomas Kuhn (1962) would call a 'paradigm', we examine, some of the challenges we face as educators, practitioners and activists in proposing authentically alternative solutions to contemporary engineering practice. As we rethink engineering, a new framework grounded in the concept of *praxis* emerges, which produces activist engineers imbued with a different sense of responsibility, and equipped with tools and ethics to define problems not only as technological problems, but also as social problems guided by specific knowledge gained from communities and places where socioecological problems exist. We then return to the problem statement and explore how an activist engineer might address climate change. By challenging the current engineering paradigm through praxis, the activist engineer can radically transform the engineering profession to align its interests with social justice and ecological holism.

2. Contemporary engineers on ecological problems and climate change

Climate change, which is likely to show significant and increasing effects over the coming century and beyond (Beck, 1986; Princen, 2012; Nixon, 2011) represents a fundamentally different and new kind of problem to society, and to engineers in particular. Dealing with climate change demands a new spirit of socio-technical interaction (Jonas, 1984) (in essence the theme of this 2013 EESD conference, *Rethinking the Engineer*). How might it be addressed—or "solved"—according to contemporary engineers? The following quotes are responses to this question taken from interviews that one of the authors of this paper conducted with practicing engineers at the third Sustainable Alternative Fuels in Aviation Workshop organized by the International Civil Aviation Organisation (Karwat, 2012).

> "I have always believed people are smart enough to do what they want. As soon as we figure out that we have a problem, we usually can muster up the resources to solve it. [Technologically] is the only way you are going to solve [climate change], I think."
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> *CEO of a genetic engineering company that makes biofuels*

> "Technology can't solve climate change because we don't have the political will to get started. If we do, when we do, the technology will be there...We are not bringing technology to bear on the problem today…Other than an unwillingness to apply technology, it is not clear to me that there are [ecological problems that technology cannot solve]."
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> *Aviation and environmental consultant, and winner of the 2007 Nobel Peace Prize as part of the Intergovernmental Panel on Climate Change*

These quotes show how many engineers view and frame problems of climate change and sustainability as technological deficiencies, in line with the thinking of René Descartes and Francis Bacon, two Enlightenment philosophers, who believed we must constantly move away from an imperfect past through technological development (Davison, 2001).[1]

According to the current engineering paradigm, the imperfect past and the current reality is that carbon dioxide emissions are causing climate change. Solutions to climate change thus take the shape of technologies that absorb carbon dioxide or do not emit carbon dioxide—for example, biofuels, mountaintop removal for coal coupled with carbon capture and sequestration, seeding the oceans with iron to create algal blooms that will absorb carbon dioxide, and so on. These technologies, however, unless accompanied by requisite social change, are just another turn of the old technological crank, for these technologies still have ecological costs, and are designed to provide infinite material growth and consumption into the future while providing a placebo of action in response to climate change.

3. The current engineering paradigm

As technology developers, engineers are essential in supporting the paradigm of infinite material growth through increasing resource utilization (for example, by improving efficiency and reducing process

[1] Davison (2001, p. 69) writes, "In the world Descartes and Bacon saw, external limitations are overcome, and thereby progress attained, to the extent that rational knowledge about natural machinery takes over from the inefficient meandering of evolution. A lack of rational development in existing social practices, a lack of material advance, i.e. a lack of progress, appeared as backwardness, idleness, moral decay. Yet, notions of progress and stability do not stand over and against each other so much as they inform and shape each other. The Enlightenment idea of stability was derived instrumentally from the antecedent metaphysical conviction that the purpose of social life was to develop the raw stuff of existence into a rational form, a Paradise on Earth."

waste). This has created a paradigm of constantly technologizes our way out of problems. The political, economic and social structures that this paradigm supports falter if technological development cedes. Thus, engineering is not politically or value neutral as engineers and lay people are led to believe. Instead, engineers constantly make political and value claims by virtue of the work they do (for example, Noble, 1977; Hecht, 1998), and they must accordingly 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.

Metrics to evaluate engineering outcomes can morph socioecologically unjust, violent, or degrading outcomes into results that have the air of positivity—for example, as we continue to produce greenhouse gases, the current economy continues to grow positively. Engineers play a pivotal role in affecting the outcomes and impacts of technologies, and they continue to be educated in ways that perpetuate the interests of materialism, of consumerism, of abundance-from-scarcity, of distributed costs and highly individualized benefits, and of violence (Riley, 2008).[2] Contemporary engineers typically operate in top-down organizational hierarchies (Karwat, 2012) and obey authority (Riley, 2008), and many claim the problems that work on are framed and handed to them by their superiors with vested interests (Karwat, 2012). These claims make it seem that engineers lack agency;[3] that they are subservient to the demands of their bosses and a technological culture. At fault is how engineers are trained to think *ahistorically* and to act *apolitically*.

Engineering education does not focus on the history of engineering and technological development, or on the larger context of the socioecological impacts of technology. Instead, technological development is ahistorical to engineers, and they tend to dissociate the shape and form of technologies from political and social pressures. To engineers, technological development is made to seem cumulative and progressive, as if the shape and form of technologies is deterministic, always linearly forward-looking with each iteration better than the last, and always capable of producing more from scarcer resources. For example, new designs of solar panels or computer chips or car engines, while of course resting on knowledge gained through previous technical exercises, are to the engineer "the best we can do given what we know, *technologically*" as opposed to "the best we can do given what we know *technologically, socially, and ecologically*." Similarly, the fact that many common eras in human history have been metonymized through technological development (like "The Stone/Bronze/Iron Age") effectively marks the passage of history by our technology development, and infers that such transformation is inevitable.

Apoliticism is what engineer and writer Samuel Florman calls an "existential pleasure of engineering" (Florman, 1976); engineers actively distance themselves from the non-technical aspects of engineering work. Reductionism,[4] empiricism, positivism (Vesilind and Gunn, 1998),[5] and dualism,[6] form the

[2] For example, in 1987, the World Commission on Environment and Development noted that more than half a million of the world's scientists worked on weapons research that accounted for 50% of all research and development expenditures (WCED, 1987). Also, as boasted by an executive vice president of Lockheed Martin in 2005, "We are the largest single supplier to the U.S. Department of Defense and the largest provider of information technology services to the federal government. We also happen to be one of the nation's largest employers of engineers and scientists, with about 50,000 of our 130,000 employees around the world holding some sort of technical degree or credential. To sustain this critical mass of talent, we will hire approximately 9,000 engineers this year, including 3,700 new graduates. In fact, in any given year, Lockheed Martin hires about one of every 20 engineering baccalaureates in the United States—four to five percent of the entire nation's undergraduate output" (Riley, 2008).

[3] We take "agency" to mean the capacity to make decisions and choices for themselves given their knowledge.

[4] We understand reductionism as the division and discretization of complexity into well-defined parameters that can therefore be adjusted. An example of reductionism is how federal engineers converted the storage reservoir problem

cornerstones of modern engineering and technological development, and engineers tend to ignore or dismiss considerations of intangibles like politics, emotions, and other ethical concerns (Vesilind and Gunn, 1998). For engineers, the discipline is fundamentally about the design of technology through material construction and manipulation of artifacts (Mitcham, 1994), and the technical is considered "fact" while the political is considered "value" (MacKenzie, 1990). Therefore, the socioecological and political implications of engineering work are left to be evaluated by politicians, lawyers, and business people, that is, the users, and any ill-effects of the technology can be attributed to user error.

Ahistoricity and apoliticism leave very little space in the current engineering paradigm to incorporate meaningful considerations of socioecological outcomes. A truly sustainable existence has at its core a social and engineering paradigm that creates a culture of peace, satisfaction, and sufficiency, a paradigm that is ecologically sensitive and holistic. It is the role of the activist engineer to create a new paradigm of engineering in which the engineer is equipped with not only technical tools and knowhow, but also with the requisite socioecological perspectives, knowhow and ethics that allow for activist engineering. If engineers have been essential in building and maintaining the current sociotechnical order, they must be the ones engaged and empowered to forge a new order.

4. Paradigmatic change—a new kind of engineer

Activist engineering is engineering that seeks to fundamentally redefine contemporary engineering practice by applying socioecological learning to technological design, exposing the political and value-based nature of engineering, and imbuing a different sense of responsibility in engineers through direct work with communities. The activist engineer, however, faces significant barriers to change, such as engineering's historical associations with violence, militarism and empire building (Baillie, 2006; Tucker, 2010; Misa, 2011).[7] Many technologies and large-scale infrastructures that were promoted under the guise of providing "freedom" have also resulted in significant (some might argue crippling) reliance on those technologies. The automobile is the quintessential example of such a technology deeply entwined with modern society, having played a large role in the development of suburban sprawl, decaying urban cores, and so on. In light of this, how can engineering be reimagined as a discipline legitimately concerned for socioecological welfare? Engineers must critically examine and understand engineering's historical roots and impact on socioecological welfare, as well as grapple with and question current realities.

In *The Structure of Scientific Revolutions*, Thomas Kuhn argues that "the decision to reject one paradigm is always simultaneously the decision to accept another". The new paradigm subscribes a field or profession to new fundamentals, and changes the methods and applications of the field or profession. These changes lead to "a decisive difference in the modes of solution…[and] a change in view of the

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into a differential equation with terms that could be manipulated. Reductionism thus sets up cause-and-effect relationships. Also referred to as "atomism" in Hauser-Kastenberg *et al.* (2003).

[5] Positivism, which is the application of the empiricist tradition of Francis Bacon and Isaac Newton, allows the engineer to stand as a supposedly neutral observer to the forces of nature that dictate empirical outcomes.

[6] Dualism is related to positivism—it is the separation of humans from the environment, the distinction, particularly in Western philosophical traditions, of mind and matter.

[7] In the contemporary world, technological development and investment by the American military can be viewed for the purpose of maintaining the vast empire of American neoliberal influence, just as the British used technologies such as steam engines and telecommunication to consolidate its empire in the Indian subcontinent. Misa (2011) discusses how the British developed steam engines, quinine, railroads and telegraph systems to maintain control over the Indian subcontinent. Baillie (2006) describes how famine in India was worsened because of the development of railroad infrastructure.

field…and its goals". Kuhn contends, rightly, that these transformations are only possible with the advantages of hindsight, and the explicit guidance attained from the outcomes of the paradigm being replaced (Kuhn, 1962).

According to Kuhn (1962), no two paradigms leave the same problems unsolved. Indeed, the differences in goals and approaches between paradigms reshape and recast problems (such as climate change and sustainability) differently, leading to fundamentally different outcomes. Furthermore, the criteria according to which the outcomes of the two paradigms are evaluated are fundamentally different; the criteria for evaluating the work of the activist engineer lie outside the scope of the current engineering paradigm, making the activist paradigm revolutionary. If the current paradigm is focused on the quarterly profit and liability, the activist paradigm is focused on long-term resiliency. If the current paradigm is based on extractive industry and efficient growth, the activist paradigm is based on modularity, repurposeability, and sufficiency. If the current paradigm is based on reliance on large corporations and capitalism, the activist paradigm must, in large part, be based on community-scale works based on community engagement, democracy, and equality.

5. From current engineering practice to engineering praxis

To effect these revolutionary paradigmatic changes, the activist engineer might employ what Karl Marx (1976) and Paolo Friere (1970) call *praxis*—the critical thinking and reflective action upon the world to transform it (Smith, 1999). According to Donna Riley (2008), praxis draws on the understanding of how engineering work affects communities and the world, and is guided normatively through moral and ethical guidance, which in the activist paradigm focuses on social justice and ecological soundness. Importantly, praxis involves an openness to change. While technical work may be guided by traditional engineering principles and learning,

> no assumptions are made about what the right process to follow is…[p]rocess and product, ends and means, thought and action, the general and the specific, the theoretical and the practical are in constant exchange and dialogue. As we think about answers or solutions or goals for change, the process for getting there may change. As we go about the process, the end goals may change…[Praxis] requires critical thinking and ethical judgment. It is "not merely the doing of something (Riley, 2008).

In this paradigmatic change, the "existential pleasure of apolitical and ahistorical engineering" is replaced with technical development that applies political, social, and ecological learning from the past and present.

5.1 Problem definition through praxis

In this new paradigm, problems are defined not from corporate bureaucracies, lawyers, or businesspeople, but rather surface from the communities of people where problems exist, and from observing how human actions impact ecosystems. Instead of large-scale technological solutions, the activist engineer has the ability to design technological systems to focus on basic requirements and services—such as heating and cooling, lighting, clean water, and mobility, to name a few—that smaller communities of people need, even in the Global North. Activist engineering does not render claims of social injustice or ecological degradation through technology as illegitimate; rather, the activist paradigm allows the activist engineer a more detailed view of socioecological interactions by expanding the group of stakeholder—such as the disenfranchised and impoverished, animal and plant life, and non-living parts of ecosystems—involved in and affected by technological development.

Importantly, activist engineering is not a blanket rejection of technology. A constant reevaluation of process and goals and an understanding of engineering history temper attempts to technologize and reformulates technological designs accordingly. Profoundly, authentic alternatives to technology such as the radical—and perhaps necessary—possibility of *not* "engineering a solution" arise. This is analogous to surgeon who decides not to perform an operation on a patient given the tradeoffs between the risks and the potential outcomes. During this process, engineers learn about the actual political and social nature of problems and act upon that learning. Concurrently, the demands of the community may change given its direct involvement in the technical design process. Such efforts make it easier to understand the political, socioecological, and cultural contexts where the technologies will be used and allow more community input in technological design.

5.2 Responsibility and praxis

The activist paradigm imbues a different sense of responsibility and accountability in engineers. Most contemporary engineers that work on large problems work on small parts of the larger whole, and many of engineers are given information only on a need-to-know basis. Often, final engineering products and infrastructures are physically removed from the engineers' workplace, lessening the sense of personal accountability. The large bureaucracies that engineers work in "diffuse and delimit areas of personal accountability within hierarchies of authority." The frequent pressure to move on to new projects before immediate projects have been operating long enough to observe outcomes carefully lessens the sense of accountability over the long term (Martin and Schinzinger, 1996). In the activist paradigm, instead, an engineer builds strong relationships with the places and people. The activist engineer thus follows a piece of technology, from its design to its implementation, studies the outcomes and weighs the outcomes given an ethic of social justice and ecological soundness, and changes the technological design process accordingly. This process transforms the relationship between the engineer and society, holding the engineer responsible and accountable for her actions, while also creating an environment in which society becomes more and more accepting of engineering with political and socioecological purposes.

5.3 Learning from other knowledges

Through praxis, there is much to be learned from other knowledge bases that have inextricable ties with technological development. For example, the profession of urban planning, which provides the templates for the design of technological infrastructures such as roads, transit systems, energy grids, and water treatment facilities that engineers design, is founded on principles of social theory. A significant portion of urban planning education is dedicated to learning historical contexts of urban planning, equality, and planning for organizational and community change. Since engineering actually creates and builds urban infrastructures, it is absolutely essential that engineers understand social theory and are able to evaluate socioecological outcomes. Important questions have already been and are continually raised about why past efforts in urban planning have led to inequity, structural poverty, and ecological degradation, and engineering's role in these outcomes must be part of the dialogue. The activist paradigm can be inspired by new models of urban gardening, which provide case studies in how alternatives to traditional industrial paradigms tackle head on problems of climate change while being sensitive to local socioecological conditions. Given the inertia of trying to combat the ill-effects of industrial agriculture such as decreasing crop diversity, water pollution from chemical fertilizers and pesticides, and long-distance transportation, urban gardening projects have the capacity not only to provide access to fresh fruits and vegetables grown in an ecologically sound manner to the needy, but also have the capacity to remediate brownfields, provide opportunities for at-risk youth, and build neighborliness. Activist engineering approaches to solving problems must also incorporate broader concerns than just the technical when addressing large problems like climate change.

6. Climate change and sustainability: practice versus praxis

Climate change—unbounded in space and time—does not fit within the current paradigm (in a Kuhnian sense) of short-term thinking and technological solutions that can be uniformly applied the world over. Climate change has been created by a particular socioeconomic and political order founded on greenhouse gas-emitting technologies—technologies that have been subsidized and bolstered by nation states and corporations (Mitchell, 2011)—and current responses to climate change rely on this very order. Climate change is consequently a problem driven by coal- and fossil fuel-based energy technologies, and an outcome of the political and social interest—such as geopolitical wrangling and economic growth—embedded in technological systems and infrastructures (Mitchell, 2011).

Climate change represents a system destabilizing (Hughes, 1987) problem, and the framing of climate change as a "carbon" problem is "possibly the greatest and most dangerous reductionism of all time: a 150 year history of complex geologic, political, economic, and military security issues all reduced to one element" (Princen, forthcoming) While from a purely scientific perspective carbon dioxide is causing climate change, through praxis, it is apparent that addressing the root causes of climate change requires an overhaul of political, economic, and social structures. Through praxis the activist engineer couples technological solutions to climate change with requisite social changes, such as a reduction in large-scale energy consumption and the promotion of locally-based lifestyles that are as necessary if not more so than the technological solutions. We posit that the outcomes of such social changes obviate the need to take the risks of geoengineering (Jamieson, 1996) or other large-scale technological solutions to climate change, responses that still envision infinite material growth into the future. Guided by social justice and ecological soundness, the goal of activist engineering is to effectively incorporate the concerns of stakeholders such as people whose lands are being lost to rising sea levels and biofuel plantations and extractive mining for rare earth metals used in alternative energy technologies. Solutions to climate change under the activist paradigm are hence not just another turn of the technological crank. Rather, the solutions provide meaningful alternatives to technologies inspired by the contemporary engineering paradigm.

By incorporating historical and contemporary political, technological, and social knowledge, the activist paradigm frames climate change differently, and therefore the solutions stemming from the activist paradigm cannot be judged according to metrics from the current paradigm (GDP increase per unit carbon dioxide emissions, for example), because the activist paradigm is solving a different problem. The activist paradigm allows non-technological solutions such as "leave it in the ground", as Thomas Princen (forthcoming) suggests for fossil fuels. In the activist paradigm, metrics to evaluate the efficacy of engineering work are morphed from corporate quarterly profit and material growth into ones like community resiliency, self-sufficiency, neighborliness, and equality, thereby redefining the interests of the engineering profession.

7. Concluding thoughts

We envision vigorous discussions about how to incorporate notions of praxis into our engineering practice. Mary O'Brien (O'Brien, 1993) provided her own suggestions for scientists (10% of your money and 10% of your time) to work in the public interest and we find these suggestions readily transmutable to engineering praxis. Engineering praxis can involve learning new knowledges by working actively on projects with sociologists, urban planners, historians and psychologists or working with public interest groups; serving on local, state, or national committees or task forces and lending engineering expertise to citizen activists, thereby taking responsibility for engineering work; reframing the problems engineers work on by insisting that the public be included in technical decision-making, and designing technologies that provide impoverished and underserved communities such as those living close to industrial sites with the real, timely data, knowledge and knowhow to challenge local municipalities about their living conditions.

Current engineering practice by its nature offers only technological progress as a solution to any future problem. With regard to climate change and sustainability, engineering work takes the form of developing technologies that do not question the paradigm of infinite material growth, and do not take into account social justice and ecological holism.[8] In essence, engineers are asked to move society away from an imperfect past of carbon dioxide emissions without understanding why from a political and social standpoint climate change is occurring, and how engineering is complicit in it. This problematic framing highlights notions of ahistoricity and apoliticism ingrained in engineering education and contemporary engineering practice. The notion of engineering praxis, however, transforms contemporary engineering practice and reframes problems such as climate change and sustainability as socioecological ones that cannot be exclusively addressed as technological problems. Engineering praxis empowers activist engineers to be aware of and act on the political and value claims of their work and to be creative thinkers capable of offering a range of authentic alternative solutions to problems, thereby aligning the interests of engineering work with social justice and ecological holism.

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[8] Hydraulic fracturing for natural gas is a fitting example of how large-scale "clean energy" alternatives to oil and coal still result in social injustice and ecological degradation and do not fundamentally change society to be less energy intensive and materially consumptive.

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