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Introduction

This paper surveys and analyzes a range of progressive engineering reform efforts that extend from explicit concerns with social justice, or what Joe Herkert has usefully called questions of "macro-ethics" in engineering.[1] The paper categorizes these efforts and shows how they work at various levels of reform: material change through reforms in how and for whom technologies are designed; situated educational interventions, including both pedagogical and curricular experiments; professional community-building interventions; and lastly scholarly contributions challenging how "engineering" is typically understood and how new understandings might prompt better attention to questions of social justice.

The different approaches to social justice-based reform are identified based on relevant literatures and through initiatives carried out by members of the international network of Engineering, Social Justice, and Peace, including experience with current social justice initiatives at a range of universities including Rensselaer Polytechnic Institute, Smith College, Binghamton University, and the Colorado School of Mines in the US; Queens University in Canada; and the University of Western Australia. The goal of the paper is to provide a introduction to, and categorization of, key initiatives in engineering and social justice that are potentially relevant to a wider range of engineering or educational reform efforts.

Engineering and Social Justice in Context

Questions around social justice are increasingly being asked in engineering and engineering education circles. Perhaps the most noteworthy recent example was a National Academy of Engineering (NAE) workshop with the title "Engineering, Social Justice, and Sustainable Community Development,"[2] which was hosted by NAE's Center for Engineering, Ethics, and Society under the direction of Rachelle Hollander. This workshop covered themes such as engineering for people with special vulnerabilities, ethics and society, and implications for engineering education, but much of the discussion centered on the terminology of "social justice," including its historical and contemporary associations as well as its strategic opportunities and liabilities. The workshop was attended by nearly 100 participants with diverse backgrounds and professional positions (though most were academics), and an NAE report on the workshop's findings followed in 2010.[3]

Featured at the NAE workshop was Donna Riley's (2008) book, *Engineering and Social Justice*,[4] which is part of the Morgan and Claypool Synthesis Lectures on Engineers, Technology, and Society series, edited by Caroline Baillie. Another volume in the series is *Engineering and Society: Working towards Social Justice*.[5] Altogether, this series has over a dozen volumes on social justice topics as they connect to engineering and technology, including poverty, environment, global inequity, development, and ethics.[6] This body of work has galvanized interest in the topic of engineering and social justice both within and outside of the engineering and social justice community.

In addition to scholarly publications, Baillie, Riley, and others spearhead a network of scholars, practitioners, and activists under the banner Engineering, Social Justice, and Peace (ESJP). According to its website, this group

> works toward engineering practices that enhance gender, racial, class, and cultural equity and are democratic, non-oppressive, and non-violent. We seek to better understand the relationships between engineering practices and the contexts that shape those practices, with the purpose of promoting local-level community empowerment through engineering problem solving, broadly conceived.[7]

ESJP has hosted an annual conference since 2004,[8] and promotes a range of activities in international development, professional networking and activism, and educational reform.

Efforts to organize engineering around the theme of social justice are by no means new. However problematic their undergirding assumptions might seem today, the late-1800s to early-1900s Progressive Era is widely cited by engineering historians as one of the early manifestations of social justice-motivated engineering work.[9] During the Progressive Era, scientific methods were promoted as an alternative to corrupt political machines with the goal of "purifying" society both metaphorically and literally (e.g., through pollution controls targeting some of the worst by-products of industrialization).[10]

More recently, and the Committee for Social Responsibility in Engineering (CSRE) grew out of late-1960s and early-1970s radicalism. In the early 1970s, CSRE published the newsletter/magazine *SPARK*, which emphasized the role of engineering in its social and political-economic context, including especially labor relations.[11] *SPARK* highlighted and criticized a range of "oppressive" applications of engineering skills and technology, with particular attention paid to the connections between engineering and military. Instead of working on military projects, *SPARK*'s editors encouraged engineers to employ their skills toward progressive, liberatory ends. One of the editors' major goals was to bring engineers together as a cohesive social force; consistent with its focus on labor issues, engineering unionization was the topic of several articles. Also discussed was the need for loyalty among engineers from around the world, with those situated in richer countries called on to support the reform efforts of engineers in poorer countries in the name of a better and more cohesive engineering profession.[12]

In addition to the work of the CSRE, early "appropriate technology" advocates put forward values under the rubric of social justice ranging from financial independence to environmental stewardship to political autonomy. In one instance, a collection of pro-autonomy technologies was published under the title *Radical Technology*. The social-justice vision of this collection's editors is clear:

> *Radical Technology* encompasses much that is meant by 'alternative technology' but sees these new, liberating tools, techniques, and sources of energy as part of a restructured social order, and aims to place them directly in the hands of the community.
>
> *Radical Technology* is a contribution to the wider dialogue on alternative politics, economics, work-patterns and life-styles, all the more urgent in a deepening global crisis of resource supply

> and ecological stability, at a time when demands for economic justice, self determination and meaningful work can longer be denied.[13]

In his review of the appropriate technology movement, Kelvin Willoughby (1990) also describes a range of social justice implications of what he calls "technology choice." He says,

> It is now widely recognized that technology provides a medium for the development and maintenance of … dependency relationships and that viewing technology as "neutral" in terms of political economy is unjustifiable in view of its tendency to reinforce or evoke international inequity.[14]

Willoughby goes on to discuss intra-national inequities and then a range of domains in which inter- and intra-national inequities arise through engineering activities and technology choice.

Clearly, engineering and social justice as a domain of scholarly reflection, professional practice, and activism is worthy of attention by engineering educators. Not only do such activities point to areas of potential interest and relevance to prospective engineering students, but they connect in interesting and important ways with contemporary engineering educational reform initiatives, such as those revolving around liberal education in engineering; problem- and project-based and service learning, as well as engineering ethics.

Approaches to Social Justice in Engineering

For the purposes of this paper, a range of contemporary approaches to social justice in engineering education are categorized not around the context of intervention but instead around the underlying intervention strategy. Four such strategies are reviewed: 1) material interventions involving designing or implementing new technologies, usually for marginalized social groups; 2) educational interventions including but not limited to formal educational settings; 3) professional networking and other community-building approaches; and 4) scholarly/conceptual contributions to how "engineering" is understood and how its boundaries might be productively redefined to respond better to social injustices.

The empirical material driving this analysis comes from the author's direct participation in a variety of engineering-and-social-justice initiatives, including ESJP, engineering-and-development projects, and closely connected scholarly research initiatives, as well as indirect collaboration with other engineering studies scholars spearheading such projects and literatures in STS, engineering studies, and development studies.

Material Interventions

Perhaps the most obvious "engineering" strategy for addressing social injustice is technology design and implementation benefiting individuals or groups suffering some sort of systematic injustice. In the NAE social justice workshop introduced above, the focus was on people with special vulnerabilities, including poor peoples and those most at risk from natural disasters. The work of Engineers without Borders (independently incorporated in various countries around the global)[15] and Engineers for a Sustainable World (in the US)[16] exemplifies what is sometimes called engineering for development or, more generally, engineering for change (E4C).[17]

Most of these initiatives attempt to provide technology solutions to problems faced by economically marginalized groups, both within a given region and globally, but there is also a range of related approaches that are less widely referenced, including engineering for the disabled,[18] for women,[19] and for workers.[20] A multitude of projects utilizing this approach exist and many have been described and analyzed in a variety of literatures, including in the educational context.[21] The surge of interest in engineering-for-development, in particular, represents the broad appeal within engineering of applying technology to challenging social problems.[22]

Certainly, getting more engineers more interested in designing solutions for marginalized communities is a desirable goal, and one with considerable import for thinking about social justice. While most of the literature covering engineering for development focuses on particular projects, practical and institutional barriers to successful projects, and strategies for coping with those barriers, a minor thread entails more critical appraisal of such initiatives, documenting not only project failures but also some of the limitations—both practical and conceptual—arising from technology-centered solutions to intractable social problems.[23]

Despite non-trivial limitations, this approach to engineering for social justice is both straightforward and widely perceived as desirable (at least as evidenced by the sheer number of initiatives). Designing and implementing technologies to address the needs of marginalized communities, which for a variety of reasons do not command sufficient social or financial leverage to attract market-led design, addresses injustices surrounding whose needs are design for and whose are not. This approach is given "pride of place" in this list, but the paper now moves on to less-direct, less obvious strategies for promoting social justice in engineering.

Educational Interventions

A second category of approaches to engineering and social justice includes educational interventions that extend beyond merely directing engineering effort toward the needs of marginalized groups. Educational initiatives turn the learning environment itself in an opportunity to understand, identify, and then to confront injustices, including both unjust acts and the structural conditions that give rise to them. Educational initiatives include both pedagogical experiments in the classroom as well as more systemic curricular experiments. In this context, ABET plays a special role in enabling or facilitating such experimentation.

In the traditional format, an engineering student might learning about a variety of social injustices though a humanities and social sciences (H&SS) elective, for example an introduction to science, technology, and society or similar course. But even where these courses connect directly to science, technology, and engineering, they are typically disassociated with "engineering" courses—institutionally (e.g., departmentally), in terms of curriculum requirements, and in students' own imaginations (where H&SS electives are often understood to be a "break" from the rigors of their core engineering courses). The best of such electives convey how the influence between technologies and society is a two-way street; the worst emphasize only the "social implications of technology" in a way that suggests technologies are deterministic—with pre-determined development trajectories (set by the inherent characteristics of a given technology) and able to influence society without being influenced by it.

In the domain of engineering and social justice, pedagogical experiments often highlight the forces that steer technology development trajectories, including the political-economic, the institutional, and even the interpersonal. Riley's work on liberative pedagogies in Smith College's Picker Engineering Program is an oft-cited example of engineering and social justice interventions in the university classroom.[24, 25] Based on the work of bell hooks, Paulo Freire, and others, this approach has multiple goals, not least of which is empowering students as learners by legitimating their experiences and perspectives and giving them more authority over the educational process. By challenging the traditional authority structure of the classroom—where students report to instructors—this approach gives students power to direct their own learning. The social justice implications are highly individualized (and highly personalized) but profound, since it transforms the model of education from one in which students more-or-less passively absorb information to one in which students become the primary authors of information. In this model, the instructor's role also changes, from providing information to facilitating student dialogue and interaction.

Of course, the university educational setting provide sharp constraints on the extent to which instructors can structurally empower students—ultimately, the instructor retains authority over course content and process, not to mention students' final assessment via the assigned letter grade or final point count. This ultimate authority is significant, but not necessarily damning of liberative pedagogical strategies, because they can explicitly acknowledge such structural constraints and use them as another opportunity for learning about the educational moment. Reflective instructors can simultaneously acknowledge their structural authority and put that very structure up for reflection and critique.[26]

Derived as they are from the work of hooks (a feminist author and activist) and Freire (a Brazilian educator), liberative pedagogies have relevance for (indeed, were largely designed to reach) audiences beyond the university classroom. In the context of approaches to engineering and social justice, we might understand engineering-for-development material interventions also as opportunities for educational intervention. Participatory rural appraisal is a popular international development technique used to engage rural populations in identifying development problems in their communities. While engineering projects in developing countries often employ similar techniques, there are increasing efforts to integrate affected community members in ways that extend beyond problem forming and into the solution design process as well. The pioneering work of the international non-governmental organization, Practical Action (formerly Intermediate Technology Development Group), takes this approach to technology systems design and deployment.[27]

Increasingly, international development NGOs are engaging the rural poor in solutions to their own problems, and the emphasis on creating development infrastructure has shifted over the past decades to capacity building, or skills development among target populations. This includes development of technical capacity, something which engineers are uniquely qualified to do.[28] By combining educational initiatives as part of material/technological interventions, development projects can address multiple facets of injustices simultaneously.[29]

A second set of pedagogical experiments in engineering education revolves around educational "thresholds" and how engineering students confront and, ideally, pass through such thresholds as they are exposed to increasingly interdisciplinary framings of engineering—both what it is and how it operates in a variety of social contexts.[30] In this model, focus is directed to the key concepts that students must grapple with in order to move beyond deterministic models of technology and decontextualized models of engineering, where engineering decisions are understood to be "purely" technical and without inherent social (and thereby social justice) implications. Threshold theory points the way limitations in curricular models that neatly separate out the technical and social facets of engineering education, assigning each to a distinct disciplinary domain for independent treatment, leaving individual students responsible for integrating the material on their own.

A third pedagogical experiment involves the creation of a set of engineering and social justice course modules, which is being spearheaded by George Catalano at Binghamton University in New York. This project is designed to create easily transportable teaching modules that integrate social justice concerns into traditional engineering courses. The basic logic of this model is to provide impetus for engineering educators who are interested in integrating social justice topics into their teaching, but feel they do not have sufficient expertise to do so in a robust way. The engineering and social justice modules created as part of the initiative include coverage of topics ranging from using numerical methods to understand poverty, thermodynamics of food energy in the context of poverty and obesity, design of renewable energy systems for off-grid rural villages in developing countries, and modeling of smokestack plumbs.[31]

Another dimension of educational initiatives is curricular experimentation, moving beyond the individual classroom and to the larger structure of education, which determines what content is required, in what proportions, how it is to be conveyed, and who decides. Most curricular experiments that address facets of social justice in engineering education either better structure or extend H&SS courses or otherwise integrate what is traditionally considered H&SS insights into core engineering coursework. One example among many such programs is the Humanitarian Engineering minor at Colorado School of Mines. This program integrates a structured set of technical, liberal arts, business courses in a sequence that culminates with an intensive capstone humanitarian engineering design project.

The Programs in Design and Innovation (PDI) at Rensselaer Polytechnic Institute extends and focuses the H&SS coursework under the structure of a dual major, with most students simultaneously satisfying the degree requirements of mechanical engineering and of a specially created major called "design, innovation, and society." By creating a series of interdisciplinary design studios that cover both engineering and H&SS requirements (as well as content in creative design, entrepreneurship, communications), PDI provides a four-year series of design experiences integrating technical, social, and creative approaches to engineering problem solving, all in the context of addressing social problems and meeting the needs of marginalized social groups.

ABET plays a particularly important role in enabling or constraining curricular experimentation, both through its program accreditation requirements and how they are enforced by individual assessors. The ABET's Engineering Criteria 2000 program has been influential in opening

spaces of experimentation in engineering and social justice, as it moved away from emphasis on curricular structure and toward program outcomes and assessment. Many experiments in engineering pedagogy and curricula have been enabled by, and continue to draw on, Engineering Criteria 2000, especially the long list of "non-technical" requirements, including:

(d) an ability to function on multidisciplinary teams
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Under the new ABET requirements, even arguably "technical" criteria involve placing engineering in context, for example:

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(e) an ability to identify, formulate, and solve engineering problems.[32]

Professional Networking

A third approach to engineering and social justice involves professional networking and community building initiatives. This set of initiatives includes a wide range of ordinary professional activities, such as organizing conferences and workshops (e.g., the NAE workshop and EJSP conference series described above); publishing special issues in academic journals (e.g., *Engineering Studies*' special issue [volume 2, number 1] on engineering and social justice and the volume *Engineering and Social Justice: In the University and Beyond*[33]); and special panels at more general engineering education conferences (e.g., ASEE and FIE), including the one in which this paper is presented. In some sense, this approach to "social change" is entirely ordinary for academic researchers and may seem unworthy of notice. But it provides the support and recognition structure necessary for coordinating individual activities by engineering and social justice advocates within the academy, as well as a legitimacy network that is able to extend itself once a critical mass is reached.

The ESJP group (of which the author is a member) is perhaps the best example of using professional networking to advance the cause of engineering and social justice, a fact that is not surprising given that this is the group's mission. In addition to the annual conference and the extensive scholarly publishing carried out by various members of the group, ESJP has experimented with connecting interested engineering practitioners with communities in need, has conducted outreach at professional meetings (via promotional materials, direct action, and activism), and has initiated its own hybrid scholarly/creative, open-access journal (intended to bridge scholars, engineering practitioners, and social activists).[34] ESJP conferences serve as both information sharing and camaraderie-building events, as with the group's journal, following a mixed format of traditional scholarly presentations and workshops, best-practices presentations from practitioners in the field, and creative, artistic, and personal-reflection activities.[35]

Participants at past ESJP conferences are about half academic engineering educators (in engineering and closely related humanities and social science disciplines) and half engineering practitioners from the private sector, government, and NGOs.

The 2008 NAE workshop, "Engineering, Social Justice, and Sustainable Community Development," was an important signal of the increasing traction the concept of social justice has in the broader engineering community, and in this case the established elite of engineering in the US. At that event, there was no singular definition of social justice shared by the participants, especially in the context of "engineering." There was even some heated debate about the appropriateness of the approach, associated as it is with progressive and radical politics, for the NAE. But there was sufficient common ground shared by participants and sufficient enthusiasm to move forward that future workshops are planned.[36]

Conceptual Contributions

The final approach to engineering and social justice addressed here is the least tangible and yet the most important from the perspective of research into engineering thinking and practice. It is what will be called, for lack of better terminology, "conceptual contributions," or efforts to reconceptualize how engineering is understood and how it is practiced. In this category of interventions, we see engineering and social justice scholars inquiring deeply into the assumptions, structures, values, and practices of engineers. Particular attention is dedicated to identifying different and problematic facets of the dominant worldview surrounding engineering—a view traditionally shared by both most engineers and the wider public.

Perhaps unsurprisingly, most scholars of engineering and social justice tend to advocate for change, usually in specific ways and involving specific areas of engineering activity. But they try first to understand the array of forces preventing desirable change, especially those that contribute to the sense of inevitability surrounding how engineering is defined (according to the dominant worldview) in the present. In other words, these scholars attempt to show how dominant understandings of engineering are naturalized; how those understandings are, in fact, contingent; and how changing critical assumptions undergirding the dominant worldview of engineering can result in a radically different understanding of what engineering is and can be.

One important such assumption is the technical-social division within engineering thinking, which is manifest most clearly and directly in the structure of engineering education, with the technical core courses (usually engineering analysis courses) on one hand and the humanities and social sciences electives on the other. Despite current trends to integrate H&SS content into some "engineering" courses (usually design courses or other integrative capstone experiences as described above, but rarely technical-core classes like statics, thermodynamics, or embedded controls), for the most part, an "engineering" course remains distinct in title and form from the non-technical courses, however central their content may be to actual engineering practice, including the situated practice of engineering research.

One manifestation of the generalized technical-social division in engineering is the tendency to see generic engineering practice as separable from the context in which that practice takes place. This approach sees "pure" engineering as distinct from the messiness and contingencies of any

particular application or context. Whether or not justifiable in a philosophical sense, this approach communicates to students that questions surrounding the context of application of engineering expertise are secondary to technical questions, and that as long as one is not "lying, cheating, or stealing," a competent engineer need not direct attention to context. Engineering and social justice scholars take issue with this assumption in particular, both in terms of its veracity and in terms of its impact on engineering training and decision making.

Scholarly research into engineering and social justice as a movement investigates various engineering and social justice communities themselves, how they frame their work, and the opportunities and barriers that exist. Examples of such work include this paper as well as the NSF grant titled "Engineering and Social Justice: Research and Education of (In)commensurable Fields of Practice," currently being carried out by Juan Lucena, Jon Leydens, and Jennifer Schneider of the Colorado School of Mines.

Implications and Conclusions

The rubric of "social justice" serves as a productive alternative to the dominant worldview underlying engineering in several ways. Most obviously, social justice maintains a critical edge, associated as it is with progressive social movements, critical theory, and moral philosophy. It tempers "technical" imperatives by directing attention to social power imbalances surrounding technology decision making as well as inequitable material outcomes; it keeps alive questions of social power imbalances in ways that "the public good" or "safety of the public" (rooted as they are in national politics and priorities) do not.

But as a foundational assumption of engineering—if every engineer were to be educated and practice in environments that questioned the implications of engineering decisions to social justice—the rubric of social justice could play a different sort of role. Because engineers have been habituated to see social context as apart from their core (technical) expertise and as distinct from what it is that makes them engineers, thinking about social justice prompts reexamination of these assumptions. Social justice as a framework forces engineers to step outside of their comfort zone around "the technical," to be sure. But it does more. It forces stepping outside of traditional (hierarchical) authority structures within the engineering profession, including engineering education, and the assumptions underlying those structures.

Because social justice so strongly diverges from the dominant framing of engineering, it might be interpreted as ideological or (to readers who recognize the embedded ideology of the dominant approach) counter-ideological, setting up a conflict between one (right) approach and another, opposing approach. This paper draws attention instead to the expectation, which is especially strong in engineering, of finding "one right answer" to every problem. The analysis is premised on the idea that a dialogue among alternative approaches to engineering is necessary if engineers, engineering educators, and the profession's leaders are to identify current blind-spots in the field and anticipate and prepare for changing contexts of support and practice.

A social justice lens to engineering helps open up the discussion of what engineering is and ought to be—conceptually, pedagogically, and in terms of professional practice. By looking at the range of approaches to bringing social justice more centrally into engineering, this paper

attempts to move beyond analytic assessment of competing views of engineering—however important such assessments may be—by providing a framework for thinking and action by those who would advocate greater attention to social justice questions by engineers. Ultimately, the analysis suggests that engineers need not design solutions to third-world poverty or march in the halls of the NAE to promote greater attention to social justice in engineering. Instead, we need merely to open up the boundaries around "engineering" knowledge, reject the primacy of the technical core (without rejecting its essential contribution), and accept in principle and practice the various social facets of engineering work as equally constitutive of engineering.

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