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SOCIAL JUSTICE IS OFTEN INVISIBLE IN ENGINEERING EDUCATION AND PRACTICE

Indeed, prioritizing certain "technical" features (faster, smaller, cheaper vs. quality or sustainability) over others is a social and political choice at its core. Thus, the notion that engineering work can somehow be separated from the social world is itself a cultural frame for understanding what engineering is.
—Dr. Erin A. Cech, 2013 [1, p. 71]

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The Introduction to this book provided an overview of pressing issues for engineering education and the engineering profession that constitute exigencies for making social justice (SJ) concepts visible in engineering education. If that curricular integrative approach is viable and engages students, why is it not more widespread? This chapter engages that question by describing general and engineering-specific literature on sources of resistance to making SJ visible. In fact, most engineering educators do not realize that they may currently render *invisible* SJ dimensions that are inherent in the engineering concepts they teach, simply by teaching engineering courses as they themselves were taught and/or by (un)consciously enacting one of the engineering ideologies or mindsets described below.

Readers may have noticed that we are *not* claiming that SJ should be integrated into engineering courses as (yet another) added curricular component. Rather, we

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claim that at present, SJ dimensions that are *inherent* in engineering systems, models, designs, and more are rendered invisible. Reasons for that exclusion are discussed in three parts. First, we explore generic forms of resistance to rendering SJ visible. The next two sections, respectively, focus on engineering-specific ideologies and mindsets in engineering, which serve as barriers to entry for SJ.

1.1 GENERIC BARRIERS TO RENDERING SOCIAL JUSTICE VISIBLE

Rendering SJ visible can be difficult for engineering educators because they first need to confront normalcy and superiority inherent in unconscious or implicit biases, and generally, those topics have not figured prominently in an engineering education. Among scholars who study privilege and oppression, most acknowledge that *blatant* acts of discrimination and oppression still emerge but are more rare than in the past [2]–[4]. Increasingly common today are more *subtle* forms of discrimination and oppression, along with a growing awareness of them.

1.1.1 Normalcy

As background to understanding subtle forms of discrimination, normalcy and superiority are bedrock concepts [5]. As Goodman explains, *normalcy* raises the question of which social norms and values are considered dominant cultural norms. By definition, such norms vary by culture, so we refer below to US cultural norms, given the context in which we teach and do most of our research. Such cultural norms are shaped heavily by dominant cultural groups, which exercise influence on dominant ideologies as their prevailing values become normal. By becoming perceived as normal, such values become reference points for all alignments with—or deviations from—cultural norms. Cultural norms are then reified—often unconsciously—in institutional settings, shaping policies and practices, including in universities, companies, and other organizations. For instance, Goodman notes that white (often Christian), middle-class, heterosexual norms pervade the larger US culture and shape norms within multiple organizational settings. Whereas those norms generally go linguistically unmarked, Goodman notes, deviations from them are marked. For instance, we would likely not call George Bush a former “male president” or Bill Gates a “white businessman,” yet we might say “female president,” “Latino businessman,” or “lesbian teacher” even in cases in which the gender, ethnicity, or sexual orientation of those individuals is irrelevant to their capabilities [6, p. 18]. Similarly, in engineering contexts, we would likely not refer to astronaut Neil Armstrong as a “male engineer” or Bill Nye the Science Guy as a “white engineer” (though both earned engineering degrees), yet we frequently hear phrases such as “female engineer” or “Hispanic engineer,” even in cases in which gender or ethnicity is irrelevant to individuals’ capabilities or to the context. In short, normalcy goes unmarked, and deviations from the cultural norm are often marked.

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1.1.2 Superiority

Not only are dominant groups' values considered culturally normal, they are also generally considered superior. For instance, Goodman notes that Standard English, which is not a second dialect in many middle- and upper-class homes, is considered not just more socially accepted but superior to other dialects [6]. The social class advantages of learning Standard English from the cradle onwards are often invisible—unless this was not the dialect with which an individual was raised. As another example, heterosexual nuclear families are not just more common (although they are becoming less so); they are also often considered inherently better than a gay or lesbian family.

> Not only are dominant groups' values considered culturally normal, they are also generally considered superior.

Superiority becomes more visible when the same characteristic is applied to dominant and oppressed (or less dominant) groups. For instance, excellent engineering work is inherently heterogeneous and multifaceted, yet excellence in communication, teamwork, and design—often depicted as "feminine" aspects of engineering—tend to be sidelined compared to what are often seen as more "masculine" areas like technical prowess and technicist skills (see Chapter 5) [7], [8].

1.1.3 Unconscious Biases

So what do normalcy and superiority have to do with engineering education? Normalcy and superiority can contribute to and reify unconscious or implicit biases. Such biases occur when we unknowingly make judgments or express preferences about a person's talent, capability, etc. based on characteristics that may be irrelevant to such judgment or preferences (e.g., race, class, gender, sexual orientation, (dis)ability status). Over time, such biases can make a workplace more homogenous and, for some, unwelcoming.

Unconscious biases are commonplace in STEM workplaces. For instance, a common cultural norm is to assume that men are better at math and technical skills than women. That norm can be so prevalent that men and women unconsciously internalize it. For example, in one study, even when math skills were identical, both men and women were twice as likely to hire a man for a job that required math [9]. In another study, science faculty at research-intensive institutions were asked to evaluate fictitious student applications that varied only in terms of a male or female name. Male and female scientists ranked male applicants higher than females in terms of competence and "hirability," even though these applicants had identical credentials [10].

Emphasizing that diverse teams engage in better decision making, proactive efforts to address and/or promote awareness of unconscious bias have been accentuated in the entire tech sector, especially regarding women and underrepresented racial minorities [11], [12] as well as within specific companies such as Google [13].

1.1.4 Personal and Broader Societal Framing

However, a key difficulty with confronting issues of cultural normalcy and superiority—and forms of cultural privilege or oppression that may emanate from them—emerges from how people frame such issues. In our experiences with thoughtful, engaged engineering students, many experience a two-phase framing process that necessarily begins with personalization.

In some ways, framing broad issues of social structure in a personal way makes sense, because they are abstract and may not often ring true in our own lived experiences, especially if we are not conscious of having experienced privilege and/or oppression ourselves. But personalization is also fraught with dangers that must eventually be transcended for discussions of privilege and oppression to become productive: specifically, as Johnson points out, people can become bogged down in guilt ("I didn't mean to oppress anyone") and/or blame ("Check your privilege" or "Your success is due to [privilege X or Y]"). For some, such feelings of guilt and/or blame may be common at first, but become unproductive if they persist. They can result in anger and alienation—further polarizing the very people who need to engage in thoughtful dialogue [2].

But personalization is also fraught with dangers that must eventually be transcended for discussions of privilege and oppression to become productive.

Lived experiences are an important starting place but can also serve to perpetuate denial ("There are no individuals with disabilities where I work, so I don't see this as a widespread problem.") or dismissal ("I do not see any sexist practices in my office. We are all treated the same here."). But even if people manage to move beyond an individual-referenced guilt and/or blame framework, another—often more significant—barrier can hinder progress: identity threat. For many of us, acknowledging the existence of social privilege and oppression can threaten our sense of ourselves, especially our career accomplishments and the accomplishments of friends and relatives who may share many of our same privileges. As discussed below, if we hold to meritocracy, whereby individuals are rewarded in proportion to their hard work and sacrifice, acknowledging privilege calls a meritocratic system into question. That is, recognizing that privilege—and not hard work and sacrifice alone—may have been an asset that leveraged one's chances for various career opportunities and for realizing one's aspirations may require people to change a simplistic, individualistic narrative that indicates that effort and sacrifice lead to some version of success. And that process can threaten a sense of self.

> Recognizing that privilege improved one's chances for various career opportunities can threaten a sense of self.

To counteract non-productive responses that remain only personalized, it is useful to recall a widely cited definition of privilege, drawing from the work of McIntosh [14], as something that "exists when one group has something of value that is denied to others simply because of the groups they belong to, rather than because of anything they've done or failed to do" [2, p. 21]. Many forms of privilege and oppression we inherit, and we do not ask for or earn. To personalize this (irony intended), the authors of this book did not earn or ask to hold privileges as males, heterosexuals, able-bodied individuals, etc., yet we hold them nonetheless. To move into productive dialogic spaces, we need a frame that acknowledges the important "difference between individuals and social categories" [2, p. 37]. Discussions of privilege and power become more productive when we do not forget our lived experiences but focus on how privileges are reified across broad social categories. Overall, what matters is what we *do* with our awareness of *societal* privilege and oppression. In Chapter 4, we discuss several activities that help students move from personal to broader societal frameworks of understanding.

The primary issue we have with the above discussion—of normalcy, superiority, unconscious biases, and framing—is that these generic barriers apply across most professions: medicine, law, engineering, and others. Although these barriers provide a useful *general* foundation for understanding sources of resistance to SJ, they do not tell us what barriers exist that are *specific* to engineering education and the profession. To address such barriers, the next two sections focus on, respectively, engineering ideologies and mindsets in engineering.

1.2 ENGINEERING-SPECIFIC BARRIERS TO RENDERING SOCIAL JUSTICE VISIBLE: IDEOLOGIES

To understand engineering-specific barriers that permeate and influence US engineering cultures, this section focuses on three engineering ideologies. According to Cech, US engineering cultures are bolstered and sustained by three ideological pillars: technical–social dualism, depoliticization, and meritocracy [15]. Each pillar merits additional explanation in its role in rendering SJ invisible within engineering contexts.

1.2.1 Technical–Social Dualism

Engineering problem solving (EPS) occurs not in a social vacuum but always in social contexts, and those contexts shape (and are shaped by) technical problem-solving processes and outcomes. Thus, EPS is never exclusively technical but sociotechnical work; hence, engineering is not a technical but a sociotechnical profession. Commonplace in Science and Technology Studies (STS), the term *sociotechnical* accentuates the complex interplays between the social and the technical in engineering and scientific practices. By contrast, those who hold the ideology of *technical–social dualism* separate the technical and the social by claiming that the two inhabit distinct and separate (and separable) domains [8], [16]. For over 25 years, scholars in STS have pointed to multiple cases in which engineers have assumed technical–social dualism when the two were inextricably intertwined [8], [16], [17].

> Engineering problem solving is never exclusively technical but sociotechnical work. And by dichotomizing technical and social domains, individuals espousing technical–social dualism render most or all social dimensions irrelevant.

Entire fields of scholars have reiterated the existence of technical–social dualism in myriad forms in peer-reviewed journals such as *Technology and Culture* (since 1959), *Science, Technology, and Human Values* (since 1976), and *Engineering Studies* (since 2009). For technical–social dualists, not only are the technical and the social separate, but they exist in a hierarchy: technical dimensions are highly valued and social ones are far less valued or even irrelevant.

Social values can be seen as so messy and complex that they do nothing but introduce noise or excessive ambiguity to an otherwise clearly definable, more readily solvable engineering problem [15]. Also, social dimensions can be seen as so superficial that they can be coined as "soft skills" or the "soft side of engineering," implying that they are easy (not hard), and thus can be taught by almost anyone regardless of credentials.

By dichotomizing technical and social domains, individuals espousing technical–social dualism render most or all social dimensions irrelevant. Thus, when we notice that SJ is largely absent from the teaching of technical or design courses in engineering education, it is consistent with this dualism: SJ has been relegated to the social cellar, disentangled from its inherent connectedness to technical dimensions. As Cech has noted, "the prominence of technical–social dualism means that the most valued realms of engineering work are those that allow engineers to bracket social considerations most extensively" [15, p. 48].

In a series of interviews, one of the authors (Leydens) conducted as part of a National Science Foundation-supported study, third- and fourth-year electrical and mechanical engineering students in an introductory feedback control systems course were asked whether SJ plays a role in engineering practices that occur in industry

[18]. Students consistently indicated that SJ plays an important role in such practices, and they spoke to why those practices are both technical *and* social. When asked at another point of the interview whether SJ has been made visible in their technical engineering courses, students indicated that it had not, and a minority added that they considered SJ irrelevant or out of place in such courses because they are purely technical. These responses serve as both a confirmation of students' enculturation into the ideology of technical–social dualism and a recognition of its resilience in some contexts.

In some interviews, students were asked how engineering students would learn to recognize the SJ dimensions of technical systems and problems—which they indicated were necessary to function effectively in actual engineering practice—if those dimensions are rendered invisible in their technical courses [18]. That question caused many interviewees to experience moments of cognitive dissonance, and it serves as an important question for all engineering educators.

Technical–social dualism is manifested in modern engineering curricula, particularly given the dominance of the engineering sciences, which constitute the vast majority of engineering courses. By comparison, engineering design and humanities/social science (HSS) courses are far fewer in number in most engineering curricula. Not only do students recognize that disparity, it becomes part of their identity as engineers. In a series of interviews conducted by the other author (Lucena) with students in a senior design course, resistance to that course emerged when students identified the kind of problem solving that occurs in engineering science courses as "real" engineering and in contrast to the "less" real engineering that occurs in design courses [19]. Technical–social dualism can be collapsed, but that often occurs less by curricular design and more by chance, as in the case of this student, reflecting on HSS courses at our university:

> I also want to express my gratitude for this course ["Engineering and Social Justice"]. Most students at Mines do not think much about [HSS] classes; they want something easy or something that will not get in the way of their standard, technical classes. I have to admit that I wanted this in an [HSS] class before I took Engineering and Sustainable Community Development. I actually took that course because "community development" sounded more like civil engineering than other [HSS] classes. I unknowingly stumbled upon a course that impacted me more than any other, including my standard engineering courses. That course led me to take this one, which ended up changing my entire engineering prospects and goals. Engineering and Social Justice taught me that engineering is so much more than technical work. I believe a combination of social work and technical work makes the best engineers. [Colorado School of] Mines taught me how to excel with the technical, but this course taught me about the social work. With this course, I can actually be the engineer I wanted to be when I enrolled at Mines. It is ironic how a social course taught me more about what being an engineer is really about than my technical courses—especially in an engineering school—but I will embrace this irony and do my best to bring social justice and engineering together (written by a Colorado School of Mines student, April 2016).

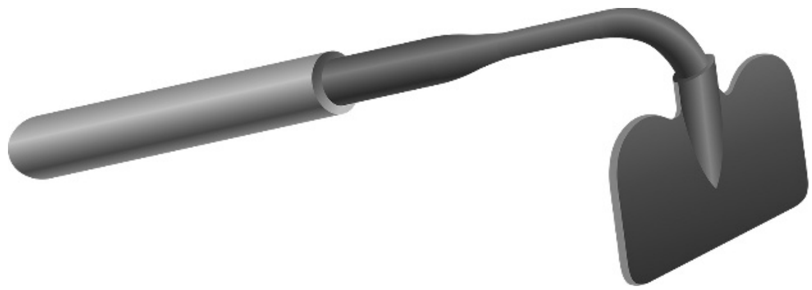

Figure 1.1. A short-handled hoe. The hoe may seem like a technical artifact until we consider its social (in this case historical, cultural, and political) origins. *Courtesy of Tristan Dang.*

1.2.2 Depoliticization

Technical–social dualism overlaps conceptually with the second ideological pillar, *depoliticization* [1], [15]. Depoliticization is associated with a way of seeing that regards technological artifacts as neutral, asocial, and apolitical. Consider Figure 1.1.

We might look at this object and not initially recognize its inherent SJ dimensions. It appears to be an agricultural or gardening tool, nothing more. With any technological artifact, it is useful to inquire into questions of origin: By and for whom was this designed? Under what constraints and social circumstances?

By exploring its sociohistorical origins, we find that it was used as a means of social control. Figure 1.2 shows migrant workers using the shortened hoe, which they called "*el cortito*." The short handle prevented workers from making eye contact and engaging in conversation (which managers suspected as portents of unionization) and allowed supervisors to know who was and was not working. But the short handle also ensured hours of exhausting, ergonomically inefficient, backbreaking work. "Those who are bending over are the ones working; those standing upright are not and the foreman can apply discipline accordingly. In that light, even the length of the handle of a hoe expresses a regime, a regime of power, authority, and control" [20, p. 20].

Like technical–social dualism, depoliticization also accentuates "…the notion that engineering is a purely 'technical' domain, and thus asocial and apolitical… Engineering work is assumed to be carried out objectively and without bias… As presumed 'neutral' actors, engineers defer to the objectivity and value neutrality that are assumed to be part of these methods" [1, pp. 70–71]; see also [16], [21]. In this way of thinking, what occurs in engineering work can be separated from complex social and political issues, which risk otherwise tainting "pure" engineering outcomes. But Cech highlights why such thinking is overly simplistic.

> …as decades of Science and Technology studies research has demonstrated, even the most seemingly objective and neutral realms of engineering practice and design have built into them social norms, culturally informed judgments about what counts as

Figure 1.2. Migrant agricultural workers using the short-handled hoe. The use of the hoe required ergonomically inefficient, backbreaking labor and enabled supervisors to control who was working from a distance. *Reproduced with permission of Leonard Nadel Photographs and Scrapbooks, Archives center, National Museum of American History, Smithsonian Institution.*

> "truth," and ideologically-infused processes of problem definition and solution (see e.g., Knorr-Cetina 1999; Latour and Woolgar 1986; Mackenzie 1990; Traweek 1988). Engineering work is necessarily heterogeneous and "technological" work can never be separated from its social or political influences. [1, p. 71]

Thus, depoliticization occurs when social and political dimensions are artificially separated from—rather than recognized as inherently intrinsic to—engineering practices. For instance, about 200 bridges extending from New York City to Long Island feature unusually low clearances—many as low as 9 feet, as in a similar bridge depicted in Figure 1.3. Like the hoe, that may be unremarkable at first. Yet again, awareness of the sociohistorical origins of such overpasses reveals social and political dimensions.

In his research, Winner has noted that

> Robert Moses, the master builder of roads, parks, bridges, and other public works from the 1920s to the 1970s in New York, had these overpasses built to specifications that would discourage the presence of buses on his parkways. According to evidence provided by Robert A. Caro in his biography of Moses, the reasons reflect Moses's social-class bias and racial prejudice. Automobile owning whites of "upper" and "comfortable middle" classes, as he called them, would be free to use the parkways for recreation and commuting. Poor people and blacks, who normally used public transit, were kept off the roads because the 12-foot tall buses could not get through the overpasses.

Figure 1.3. Photo of one of the actual bridges designed by Robert Moses. Some research suggests the bridges were intentionally designed to prevent bus traffic, which at that time would prohibit mostly the poor, and especially African Americans, from reaching the beaches on Long Island, east of New York City; these bridge designs serve as examples of how technology can have explicit socio-economic and political dimensions and consequences. *Courtesy of Howard Kroplick.*

> One consequence was to limit access of racial minorities and low-income groups to Jones Beach, Moses's widely acclaimed Public Park. Moses made doubly sure of this result by vetoing a proposed extension of the Long Island Railroad to Jones Beach. [22, pp. 123–124].

Although some have taken issue with the above interpretation of intentional injustice [23], the case of Moses' overpasses appears to be an unusually egregious and blatant one. Generally, however, the SJ dimensions of technical artifacts, designs, and systems play more subtle roles. Cech provides insight into why:

> [T]hrough the frame of depoliticization, the political and social foundations of all engineering work are culturally invisible in the meaning systems surrounding that work.

> More importantly, the ideology of depoliticization means that aspects of social life that have to do with conflicting perspectives, cultural values, or inequality are cast as 'political' and thus irrelevant—perhaps even dangerous—to 'real' engineering work (Cech and Waidzunas 2011; Faulkner 2000; Florman 1994). [1, p. 71]

In terms of political dimensions, technologies can range on a continuum from explicit to implicit and on another continuum from intentional to unintentional, and the hoe and bridge examples are on the explicit and (arguably) intentional end of those continua.

Yet many more implicit and/or unintentional examples exist. For instance, tide containment walls in the beachfronts of coastal towns were built with stairs to provide beach access to able-bodied tourists, but excluded some persons with disabilities from enjoying public space [24]. The introduction of information technologies at public libraries was guided by the assumption that they will democratize access to information across social classes when in fact they leave many poor people out [25].

Hence, in engineering education and practice, both sociotechnical dualism and depoliticization serve to render social justice dimensions invisible or irrelevant. But what if both were brought to light—if engineers in their education and practice were taught to recognize how these ideologies serve to artificially separate inherently interconnected sociotechnical processes and artifacts? Cech argues that even in that circumstance, a third ideology—*meritocracy*—would still keep social justice in a marginalized position.

1.2.3 Meritocracy

As the word implies, meritocracy refers to a merit-based system in which rewards are somewhat proportional to effort and abilities—that is, the idea (closely associated with the American Dream) that we get out of a system roughly in proportion to what we put in [26]. The meritocratic ideology is "the belief that success in life is the result of individual talent, training, and motivation, and that those who lack such characteristics will naturally be less successful than others" [1, p. 73].

If we hold to this ideology, in what ways might SJ be rendered irrelevant? Once we convince ourselves that a socio-economic system is fair, that people begin the race on roughly the same starting line and finish in positions that primarily reflect their hard work and individual talent, it is reasonable to cast aside SJ as a needless distraction at best, or at worst as emanating from an ideological agenda.

Yet our common cultural adages also tell us that multiple forces besides "individual talent, training, and motivation" are at work. For instance, we recognize that "it takes money to make money (inheritance); it's not what you know but whom you know (connections); what matters is being in the right place at the right time (luck); the playing field isn't even (discrimination); and he or she married into money (marriage)" [26, p. 1]. Along with many others (intergenerational poverty, etc.), such factors disrupt the meritocratic notion that the socio-economic system is inherently fair. Yet "if the [socioeconomic] system is seen as fair, social injustices arising from that system are seen as legitimate" [1, p. 74]. Thus, often in US engineering education and sometimes in US engineering practice, SJ is cast as irrelevant or even a political, agenda-driven intrusion.

So how does a meritocratic ideology manifest itself in engineering education? As one of the majors with the highest salaries for undergraduates right out of college and a history of social mobility, engineering embodies the meritocratic ideal. In short, you can be the son or daughter of a farmer or mechanic and yet, due to your hard work in high school and in an engineering program in higher education, you will get the grades, the job, and the salary opportunities that you deserve. Yet what this view overlooks is how multiple factors complicate such simplistic explanations. For instance, gender, race, ethnicity, disability, and, mainly, socio-economic class influence your chances for success every step along the way, from standardized tests used in admissions [27], to social and cultural capital [28] needed to succeed in engineering (e.g., as when your parents are engineering alumni, know professors, and have the ability to donate money to your institution). Chances for success are also shaped at other steps: from having plenty of time to do homework and build more social and cultural capital (e.g., many low-income students have to work full-time while attending school and seldom find time to study in groups or attend lectures), to then graduating with the right social and cultural capital to do well in the job interview process (e.g., having the resources to be able to tell stories about, for instance, traveling abroad during job interviews that emphasize international work) [29].

Collectively, these engineering ideologies—technical–social dualism, depoliticization, and meritocracy—circulate in engineering and shape perspectives on what is—and is not—appropriate value added to an engineering education [1]. In addition to the engineering ideologies, mindsets in engineering contribute to rendering SJ invisible or opaque in engineering education [30].

1.3 ENGINEERING-SPECIFIC BARRIERS TO RENDERING SOCIAL JUSTICE VISIBLE: MINDSETS

Riley describes five mindsets in engineering that have some conceptual overlaps with yet are also distinct from Cech's ideologies: *the centrality of military and corporate organizations*, *uncritical acceptance of authority*, *technical narrowness*, *positivism and the myth of objectivity*, and a *willingness to help* [30]. Below, we present both Riley's descriptions of the mindsets as well as elaborate on their broader implications for engineering education and practice. It merits noting that mindsets tend to operate at a more conscious level than unconscious biases, so students, faculty, and others may be better able to recognize them in themselves—and in doing so, change their perspectives.

1.3.1 Centrality of Military and Corporate Organizations

Who does engineering serve? That is, who benefits from the work of engineers? In some senses, we all do, via water, energy, housing, food delivery, transportation, communication, and multiple other engineered infrastructures, systems, and products. Engineered products and systems surround us, and we often take them for granted. Related to this question of who engineering serves is who engineers serve. On that issue, Riley notes where most engineering graduates go to work: in for-profit corporations, many of which, even more than a quarter century after the end of the Cold War, still have deep ties with the military. The centrality of military and corporate organizations speaks of the fact that corporations and the military not only employ most US engineers, as few other employment opportunities exist outside such organizations, but corporate and military rules, norms, and practices shape engineers' behaviors and ways of thinking [31], [32].

Who does engineering serve? That is, who benefits from the work of engineers?

Hence, the interests served by the engineered products and systems, even in the forms of public infrastructure, are the interests of those who can afford to pay for quality products and systems like cities and counties with a wealthy tax base (unlike Flint, Michigan) or affluent social groups like leisure and business travelers. For instance, engineers spend millions redesigning self-cleaning bathrooms for jet liners [33] while a few struggle to raise funds to design bathrooms for the homeless [34]. The D80 efforts (Design for the other 80%) are, in part, a response to the fact that only 20% of the wealthiest clients can afford much of what engineers design and create, while 80% of the planet's residents often have unmet needs [35].

Drawing from Pawley's research [36], Riley notes that this predominant workplace context has salient implications for time and actors. In terms of time, engineers—embedded in corporate and other managerial contexts—experience pressure to maximize work efficiency and profit while solving complex, open-ended problems. So in making decisions, they rely on precedent and tradition. While more efficient, this reliance can also make the profession more resistant to change. In terms of actors, Riley summarizes the stakeholder issues that Pawley raises: key considerations include "who defines engineering problems, who benefits from the solutions to the problems, and who actually does the work of engineering [and] who is left out of the picture" [30, p. 40]. In time-pressured contexts that tend to rely on tradition and precedent, a broad array of actors—communities, people whose social locations and perspectives may differ from project engineers, and others—may be left out of decision-making processes that directly or indirectly affect those actors. Collectively, the spaces in which engineers commonly work, the time constraints they experience, and actors they include or exclude can shape whether (sometimes implicit) SJ issues are framed as important or relevant.

It merits noting that time and actor issues arise across multiple professions and workplaces. Engineers, however, hold forms of expertise about the physical world that many do not. Communication and collaboration conflicts can arise, however, when engineers assume no other professionals hold and more importantly can understand (the implications of) such expertise.

1.3.2 Uncritical Acceptance of Authority

In engineering science courses, the vast majority of problems are given, so the problem definition phase is rendered irrelevant. Engineers-to-be are *given* certain parameters and quantitative information and asked to find solutions using appropriate tools (see Chapter 3). These pre-formed, decontextualized problems can, via repetition, cause engineering students to see problems as purely technical and as having no (important) social dimensions. An *uncritical acceptance of authority* has been partly ingrained via social structures inside engineering education: recurring patterns of social behavior in which authority figures (engineering science professors, who hold the power of grades, ability to provide or withhold letters of recommendation, etc.) generally provide decontextualized, closed-ended problems where questions about social context have been rendered largely irrelevant.

> An *uncritical acceptance of authority* has been partly ingrained via social structures inside engineering education where decontextualized, closed-ended problems are favored and where questions about social context have been rendered largely irrelevant.

An uncritical acceptance of authority is ingrained and perpetuated via multiple other processes and actors in engineering education. Learning to accept the authority of the EPS method as *the* dominant method for solving problems is the first step of socialization of a larger process of accepting authority (see Chapter 3). That step is followed by accepting the disciplining of the mind and body (eat–sleep-study), the disciplining of one's politics, passions, and emotions by learning to keep them outside of the boundaries of EPS [37], the disciplining of one's college trajectory (e.g., a curriculum with very strict flowcharts with prerequisites that leave little room for deviation), and the disciplining of one's career choices (from school to corporate employment where engineers are expected to do as they are told). (For a full elaboration of this process of disciplining and accepting the authority of the EPS method and curriculum, see [38], [39].)

1.3.3 Technical Narrowness

Engineers have plenty of reason to rejoice and feel proud for the machines and systems that they create. As Samuel Florman, in his book *The Existential Pleasures of Engineering*, reminds us, "the engineer's first instinctive feeling about the machine is likely to be a flush of pride… After the engineer's initial burst of pride has run its course, quite a different sentiment reveals itself—his love of the machine for its intrinsic beauty" [40, p. 132]. One problem with engineering education is that it has removed, almost completely, any possibility for making, feeling, or admiring the physicality of machines (what it takes to drill, weld, machine, cut, assemble, transport, etc.) in order to make room for decontextualized science and math-based idealizations of machines or physical systems. As we have shown elsewhere,

> Most engineering faculty continue to significantly value mathematical idealizations of the technical over the nontechnical. This valuation is reflected in curricular practices such as when the social and ethical elements of senior design projects are worth only a minimal part % of the grade in humanitarian engineering projects, clearly signaling to students not to take these seriously. [41, p. 235]; also see [42]

This technical narrowness is also manifested in the engineering workplace where engineers have lost most opportunities to physically and emotionally engage with the machines they design but rarely build. As Robert Zussman, in his book *Mechanics of the Middle Class*, laments,

> Engineering practice today is characterized by a near total absence of that physical, hands-on labor that is a central attribute to craft work. Engineers manipulate symbols that refer to physical objects, mostly equipment and products, but they do not manipulate those objects themselves…physical manipulation is now the work of machinists, repairmen, mechanics, operatives, and technicians. [43, p. 77]

Throughout this process of idealization of machines and systems, from college to workplace, engineers develop a narrow sense of the technical as something that can be imagined and solved on paper (or on screen) without a sense for what it takes to build something (e.g., amount of physical exertion, availability of raw materials, tools, permits) and for its consequences on social justice (e.g., labor conditions required, risks/harms imposed on users and/or the environment). We acknowledge that due to disabilities, not all students will be able to work with all machines or other devices. However, if our curricula do not have any maker (or similar) spaces, we risk depriving students of the ability to at least imagine usability issues that are a crucial step toward human-centered design [44].

1.3.4 Positivism and the Myth of Objectivity

Rightly, engineers are taught the scientific method, including how to conduct mathematically and scientifically robust experiments to generate results that demonstrate both research reliability (consistency of results) and validity (evidence supports inferences or interpretations from data) [45]. A primary aspect of *positivism* is the "postulate that scientific knowledge is the paradigm of valid knowledge, a postulate that indeed is never proved nor intended to be proved" [46, p. 197]. However, it is important to keep in mind that this process of scientization of engineering education did not follow a natural path, but instead it has been a complex historical process through which engineers have adopted scientific methods and behaviors for cultural, political, and economic reasons [47], [48].

An overreliance on the scientific method as the *only* way of knowing or as an *exclusive* method of inquiry becomes problematic when encountering other ways of knowing or alternative inquiry methods designed for other types of research questions (e.g., mixed method or qualitative type questions). As Riley notes, if that approach to inquiry intersects with "a lack of exposure to other ways of knowing, or contexts in which those other ways of knowing are valued, [it] can lead to a lack of questioning of certain types of information" [30, p. 42]. Riley underscores the risks associated with not questioning given information. For example, engineers' commitment to empirical data, which they see as the source (and which fuels the myth) of objectivity, might prevent them from deploying other sources of knowledge or values, such as the precautionary principle, which engineers could have employed when making the decisions around, for instance, launching the Challenger Space Shuttle.

Overreliance on the scientific method can also occur in other fields, such as among chemists and geologists. What makes engineers different is that they take the scientific method from engineering science courses into design and then give primacy to a very narrow set of design constraints (i.e., physical laws, cost, time to delivery, function), at the expense of others (e.g., social justice, environmental sustainability, user friendliness, and aesthetics.) (See Chapter 3 in [49]). Frequently, design constraints are shaped by corporate and military interests, which can reify technical narrowness and the myth of objectivity, which holds that engineering and scientific work is purely objective. Hence, when design is informed mainly by a set of practices deemed "objective" such as the scientific method, instead of viewed as a negotiation among values and interests held by the different stakeholders involved in the design process, students mistakenly reinforce the idea that their design is "true," "objective," and might overlook how it impacts opportunities and risks/harms among the users of the intended design.

1.3.5 Willingness to Help and Persistence

Professors involved in the enterprise of educating engineering students can attest to the fact that such students generally have a strong work ethic, are curious, and have the persistence to see problems through to a solution. We (the authors) began our teaching careers in the early 1990s and have taught students from multiple disciplines, but we have come to admire both the traits mentioned in the previous sentence as well as engineering students' desire to use their capabilities to help humanity. The final mindset in engineering to be discussed is *the willingness to help and persistence to* *do it*. Riley notes, “The helping spirit and strong work ethic of engineers are important traits for engaging in social justice work. There is a certain amount of overlap between the kinds of problems engineers solve and social justice problems, although the engineering approach may not define the problem to be solved in terms of social justice” [30, pp. 39–40].

Whereas the previous ideologies and mindsets generally serve as barriers to defining engineering problems as and engaging in SJ work, this last one should give us hope. Alder argues that engineers are designed to serve [50]; service to a nation, to the profession, and/or to a company has been historically ingrained in engineering cultures [51]. Yet, the growth of Engineers without Borders (EWB) chapters and other related initiatives suggests that service to underserved individuals and communities is a growing dimension of that engineering service identity. That this desire to serve is sometimes muted or obscured by the other ideologies and mindsets mentioned previously can serve as motivation for debunking the myths inherent in those ideologies and mindsets.

Combined, these three ideological pillars and all the mindsets except the last one work together to impede awareness of SJ dimensions that are inherent to engineering practices. However, the final mindset—when added with our capacity to see through the holes in the other mindsets and ideologies—opens critical opportunities for transformation. Among engineering educators, engineering students, and engineering practitioners, awareness of these ideologies and mindsets enables us to see ideological structures that can mask or unveil the capacity to marshal the remarkable capacities of engineering in the service of SJ. After taking our course in “Engineering and Social Justice” and recognizing how the mindsets and ideologies operate in engineering, one student admitted that

> Being able to reflect on all of the mindsets, ideologies and case studies that have been examined this semester, I can say that I have definitely been changed as a future engineer. Originally, I had seen social justice as something I would have to wait to further until after my engineering career. I had fallen into the depoliticization nature of the profession and thought engineering was only about the technical. However, I now understand that I can further the cause of social justice while being an engineer even if I am not working with an NGO, whether it is in my designs, how I work with others outside of the profession, or what I do in my spare time outside of work. As someone who is to be employed by a major corporation, I have already begun to feel the conflict arise in me between social justice and working for a large corporation. However, after reflection, I feel as if I can hold true to my newfound passion for social justice in engineering while working for this corporation. In fact, I feel it is important for all who take this class, or take interest in this subject, to not necessarily run away from these large organizations, but start helping change them from within. If no one who understood the implications of social justice in engineering went to work for these large organizations, then these corporations have no reason to not continue the status quo. Honestly, if anything, the knowledge I have gained about social justice this semester has given my future work as an engineer even more meaning, as everything I do will not just be the simple task at hand, but will be part of the bigger picture of furthering social justice in engineering.

An opportunity to reflect on how to transform latent capacities in engineering students, faculty, and others is described in Reflection Box 1.1.

REFLECTION BOX 1.1

Have you ever wondered why US EWB chapters grew from 1 in 2003 to almost 300 in 2016? [52] And why are more students and professors intrigued by engineering-for-community projects than ever before, as evidenced by the American Society for Engineering Education's Community Engagement division growth (perhaps the fastest growing division in the history of ASEE) [53] or by the emergence of organizations like Engineering World Health, Engineering for Change, Engineering for a Sustainable World, or Engineers Against Poverty? These developments suggest a growing trend and evidence of the engineering mindset that Riley calls "a desire to help."

This mindset elicits one of engineers' most prevalent identity traits—problem solver—as people's needs can easily be framed as problems to be solved. However, as noted above, Riley points out that "the engineering approach may not define the problem to be solved in terms of social justice" [30, pp. 39–40]. So a desire to help does not necessarily translate into SJ. As Cannon reminds us:

> [We] must learn to move beyond compassion [and its associated behavior, helping] and ask, why are so many people homeless?… Why are so many African Americans incarcerated? Compassion responds to the effects of [social] problems. Social justice seeks to address their systemic causes. When we work to solve the roots of these problems, a Band-Aid is no longer being put over the wound. Instead, the emphasis is on getting rid of the disease that caused the wound in the first place. When the disease is eradicated, social justice is being lived out. [54, p. 33]

So along these lines, we must challenge ourselves and our students, especially when involved in EWB-type projects, to consider how our projects are contributing to the eradication of root causes (i.e., social structural conditions), such as of homelessness in a particular area, instead of just providing housing for few individuals. Or how might our adherence to meritocracy be allowing a few individuals from underrepresented groups to excel in engineering while the demographic groups from which they come continue to remain largely excluded from the echelons that hold power in engineering (e.g., full professors, deans, NAE members, CEOs of high tech companies)? Reflect on how your efforts might shift from a focus on helping to addressing the more complex yet salient underlying root causes of problems.

As the rest of this book shows, integrating SJ in the engineering classroom will not only enhance student satisfaction, but their learning as well. As a whole, this chapter has identified the ideologies and mindsets in engineering so we can call them out and be aware of their limiting influences, particularly as we try to construct an engineering curriculum that accentuates sociotechnical interplays at multiple junctures. Making visible SJ dimensions of engineering comes with costs and benefits, wherein we think the benefits outweigh the costs (see Conclusion). We turn our attention now to the engineering curriculum to showcase pedagogical innovations that make Engineering for Social Justice (E4SJ) (see Introduction) visible across multiple institutions in three primary areas: engineering design (Chapter 2), engineering sciences (Chapter 3), and HSS courses for engineering students (Chapter 4). In Chapter 5, we provide guidelines for rendering E4SJ criteria visible in diverse contexts ranging from the problem space to a program space, identify how E4SJ can begin to transform engineering education and practice—including changing who becomes an engineer and how the culture of engineering evolves—and we explore some of the sociotechnical capacities and professional identity challenges and opportunities for the next generation of engineers and engineering educators. Our book concludes with a chapter that serves as a call to engineering educators and practitioners interested in strategically integrating E4SJ into their careers, and an overview of salient research opportunities that merit further exploration.

> Reflect on how your efforts might shift from a focus on helping to addressing the more complex yet salient underlying root causes of problems.

REFERENCES

1. E. A. Cech, "The (mis)framing of social justice: Why ideologies of depoliticization and meritocracy hinder engineers' ability to think about social injustices," in *Engineering Education for Social Justice: Critical Explorations and Opportunities*, J. C. Lucena, Ed. Dordrecht/ New York: Springer, 2013, pp. 67–84.
2. A. G. Johnson, *Privilege, Power, and Difference*. Boston, MA: McGraw-Hill, 2006.
3. M. Adams, L. A. Bell, and P. Griffin, *Teaching for Diversity and Social Justice*. New York: Routledge, 2007.
4. B. Pease, *Undoing Privilege: Unearned Advantage in a Divided World*. London/ New York: Zed Books, 2010. Distributed in the United States exclusively by Palgrave Macmillan.
5. D. Goodman, *Promoting Diversity and Social Justice: Educating People from Privileged Groups*. New York: Routledge, 2011.
6. D. Goodman, *Promoting Diversity and Social Justice: Educating People from Privileged Groups*. Thousand Oaks, CA: Sage Publications, 2001.
7. K. L. Tonso, "Teams that work: Campus culture, engineer identity, and social interactions," *J. Eng. Educ.*, vol. 95, no. 1, pp. 25–37, 2006.

8. W. Faulkner, "'Nuts and bolts and people': Gender-troubled engineering identities," *Soc. Stud. Sci.*, vol. 37, no. 3, pp. 331–356, 2007.
9. E. Reuben, P. Sapienza, and L. Zingales, "How stereotypes impair women's careers in science," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 111, no. 12, pp. 4403–8, 2014.
10. C. Moss-Racusin, J. Dovidio, V. Brescoll, M. Graham, and J. Handelsman, "Science faculty's subtle gender biases favor male students," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 109, no. 41, pp. 16474–16479, 2012.
11. H. Williams, "Becoming conscious of unconscious bias in high tech," *USA Today*, Oct. 10, 2014. [Online]. Available: http://www.usatoday.com/story/tech/columnist/2014/10/10/commentary-unconscious-bias-high-tech/16985923/. Accessed: Oct. 5, 2015.
12. D. Ardalan, "3 Emerging themes from #RaceOnTech," *NPR.org*, Jul. 15, 2015. [Online]. Available: http://www.npr.org/sections/alltechconsidered/2015/07/15/423184069/3-emerging-themes-from-raceontech. Accessed: Oct. 5, 2015.
13. F. Manjoo, "Exposing hidden bias at Google," *The New York Times*, Sep. 24, 2014.
14. P. McIntosh, "White privilege and male privilege: A personal account of coming to see correspondences through work in women's studies," in *Gender Basics: Feminist Perspectives on Women and Men*, 2nd ed. Belmont, CA: Wadsworth, 2000, pp. 30–38.
15. E. A. Cech, "Culture of disengagement in engineering education?" *Sci. Technol. Hum. Values*, vol. 39, no. 1, pp. 42–72, Jan. 2014.
16. W. Faulkner, "Dualisms, hierarchies and gender in engineering," *Soc. Stud. Sci.*, vol. 30, no. 5, pp. 759–792, 2000.
17. W. E. Bijker, T. P. Hughes, and T. J. Pinch, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. MIT Press, 1987.
18. K. Johnson, J. Leydens, B. Moskal, D. Silva, and J. S. Fantasky, "Social justice in control systems engineering," in *ASEE Annual Conference and Exhibition*, Seattle, 2015.
19. G. L. Downey and J. C. Lucena, "When students resist: Ethnography of a senior design experience in engineering education," *Int. J. Eng. Educ.*, vol. 19, no. 1, pp. 168–176, 2003.
20. L. Winner, "Artifacts/ideas and political culture," *Whole Earth Rev.*, vol. 73, pp. 18–24, 1991.
21. C. Seron, E. Cech, S. Silbey, and B. Rubineau, "I am not a feminist, but: Making meanings of being a woman in engineering," in *Proceedings of the American Society for Engineering Education Annual Conference*, Vancouver, British Columbia, 2011.
22. L. Winner, "Do artifacts have politics?" *Daedalus*, vol. 109, no. 1, pp. 121–136, 1980.
23. B. Joerges, "Do politics have artefacts?" *Soc. Stud. Sci.*, vol. 29, no. 3, pp. 411–431, 1999.
24. D. Mongeau, "Public access to the beach: A selective bibliography," *Ref. Serv. Rev.*, vol. 29, no. 1, pp. 81–88, Mar. 2001.
25. L. A. Lievrouw and S. E. Farb, "Information and equity," *Annu. Rev. Inf. Sci. Technol.*, vol. 37, no. 1, pp. 499–540, Jan. 2003.
26. S. J. McNamee and R. K. Miller, *The Meritocracy Myth*. Lanham, MD: Rowman & Littlefield Publishers, 2014.
27. P. E. Davis-Kean, "The influence of parent education and family income on child achievement: The indirect role of parental expectations and the home environment," *J. Fam. Psychol.*, vol. 19, no. 2, pp. 294–304, 2005.

28. M. Schwalbe, *Rigging the Game: How Inequality Is Reproduced in Everyday Life*, 5th ed. Oxford University Press, 2007.
29. J. M. Smith and J. C. Lucena, "Invisible innovators: How low-income, first-generation students use their funds of knowledge to belong in engineering," *Eng. Stud.*, vol. 8, no. 1, pp. 1–26, 2016.
30. D. Riley, *Engineering and Social Justice*. San Rafael, CA: Morgan & Claypool Publishers, 2008.
31. M. H. Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America*. Cambridge, MA: MIT Press, 2012.
32. D. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism*, 1st ed. New York: Knopf, 1977.
33. "Boeing designs self-cleaning plane bathrooms," *Associated Press*, Mar. 7, 2016. [Online]. Available: http://www.foxnews.com/travel/2016/03/07/boeing-designs-self-sterilising-plane-bathrooms.html. Accessed: Apr. 14, 2016.
34. R. Merritt, "Engineers put showers on wheels," *EE Times*, Jan. 9, 2015. [Online]. Available: http://www.eetimes.com/document.asp?doc_id=1325234. Accessed: Apr. 14, 2016.
35. K. G. Paterson and V. J. Fuchs, "Development for the other 80%: Engineering hope," *J. Australasian Eng. Educ.*, vol. 14, no. 1, pp. 1–12, 2008.
36. A. L. Pawley, "Drawing the line: A study of academic engineers negotiating the boundaries of engineering," Dissertation, University of Wisconsin–Madison, Industrial Engineering, Madison, WI, 2007.
37. G. L. Downey and J. C. Lucena, "Engineering selves: Hiring in to a contested field of engineering education," in *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies*, G. L. Downey and J. Dumit, Eds. Santa Fe, NM: SAR Press, 1998, pp. 117–142.
38. G. Downey, "Are engineers losing control of technology? From 'problem solving' to 'problem definition and solution' in engineering education," *Chem. Eng. Res. Des.*, vol. 83, no. 6, pp. 583–595, Jun. 2005.
39. G. L. Downey, "PDS: Engineering as problem definition and solution," in *International Perspectives on Engineering Education*, S. H. Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, and B. Newberry, Eds. Springer International Publishing, 2015, pp. 435–455.
40. S. C. Florman, *The Existential Pleasures of Engineering*, 2nd ed. New York: St. Martin's Griffin, 1996.
41. J. Lucena, "Bridging sustainable community development and social justice," in *International Perspectives on Engineering Education*, vol. 1, S. Hyldgaard Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, and B. Newberry, Eds. Netherlands: Springer, 2015, pp. 225–247.
42. J. A. Leydens and J. C. Lucena, "Knowledge valuation in humanitarian engineering education," in *Engineering in Context*, S. H. Christensen, B. Delahousse, and M. Meganck, Eds. Aarhus, Denmark: Academica, 2009, pp. 147–162.
43. R. Zussman, *Mechanics of the Middle Class: Work and Politics Among American Engineers*. University of California Press, 1985.
44. C. B. Zoltowski, W. C. Oakes, and M. E. Cardella, "Students' ways of experiencing human-centered design," *J. Eng. Educ.*, vol. 101, no. 1, pp. 28–59, Jan. 2012.

45. B. M. Moskal, J. A. Leydens, and M. J. Pavelich, "Validity, reliability and the assessment of engineering education," *J. Eng. Educ.*, vol. 91, no. 3, pp. 351–354, Jul. 2002.
46. J. Larraín, *The Concept of Ideology*. Athens: University of Georgia Press, 1979.
47. B. E. Seely, "The scientific mystique in engineering: Highway research at the bureau of public roads, 1918–1940," *Technol. Cult.*, vol. 25, no. 4, pp. 798–831, 1984.
48. J. Harwood, "Engineering education between science and practice: Rethinking the historiography," *Hist. Technol.*, vol. 22, no. 1, pp. 53–79, Mar. 2006.
49. J. C. Lucena, J. Schneider, and J. A. Leydens, *Engineering and Sustainable Community Development*. San Rafael, CA: Morgan & Claypool Publishers, 2010.
50. K. Alder, *Engineering the Revolution: Arms and Enlightenment in France, 1763–1815*. University of Chicago Press, 2010.
51. J. C. Lucena, "De Criollos a Mexicanos: Engineers' identity and the construction of Mexico," *Hist. Technol.*, vol. 23, no. 3, pp. 275–288, Sep. 2007.
52. "Engineers without borders join the movement" (2016). [Online]. Available: http://www.ewb-usa.org/work-with-us/join-the-movement/. Accessed: May 20, 2016.
53. K. Paterson, "ASEE Community Engagement: February 2013," Email to American Society for Engineering Education's Community Engagement Division (ceee_div@asee.org) from its Division Chair, Jan. 31, 2013.
54. M. E. Cannon, *Social Justice Handbook: Small Steps for a Better World*. Downers Grove, IL: IVP Books, 2009.