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Contextualization as Virtue in Engineering Education

Dr. Marie Stettler Kleine, Colorado School of Mines

Marie is currently a Postdoctoral Fellow for the Humanitarian Engineering Program in the Department of Engineering, Design, and Society at Colorado School of Mines. She holds a B.S. in mechanical engineering and international studies from Rose-Hulman Institute of Technology, and an M.S. and PhD in STS from Virginia Tech. She conducts research on engineering practice and pedagogy around the world, exploring its origins, purposes, and potential futures. Marie's interest in values and engagement in professional cultures also extends to innovation and its experts. With Matthew Wisnioski and Eric Hintz, Marie co-edited Does America Need More Innovators? (MIT Press, 2019).

Dr. Kari Zacharias, Concordia University

Kari Zacharias studies interdisciplinarity and disciplinary identities in engineering. She is currently an assistant professor in the Centre for Engineering in Society at Concordia University's Gina Cody School of Engineering and Computer Science. She holds a BSc in Engineering Science from the University of Toronto, an MA in Science and Technology Studies from the University of Vienna, and a PhD in Science and Technology Studies from Virginia Tech.

Dr. Desen Sevi Ozkan, Tufts University

Desen is a postdoctoral researcher in the Tufts Center for Engineering Education Outreach and the Institute for Research on Learning and Instruction. She holds a Ph.D. in engineering education from Virginia Tech and a B.S. in Chemical Engineering from Tufts University. Her research interests are focused on interdisciplinary curriculum development in engineering education and the political, economic, and societal dimensions of curricular change.

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Abstract

How do we combat the "culture of disengagement" [1] in engineering education? How do we effectively prepare students for the sociotechnical nature of engineering practice? As engineering educators, our responses to these questions often emphasize *contextualization*. Efforts to encourage engagement with public welfare, sociotechnical thinking, or social justice among engineering students often begin - and sometimes end - with illuminating the broader context of engineering practice and problems. For socially minded engineering educators, contextualization is nearly always a virtue.

This paper analyzes and critiques practices of contextualizing engineering. Based on a qualitative content review of recent engineering education literature, we first describe and classify different modes of contextualization. In some cases, contextualizing means adding personal context or alternative perspectives to cultivate empathy with users or stakeholders (e.g. [2]). In others, contextualization is part of integrating sociotechnical thinking into engineering curriculum (e.g. [3]). This takes a variety of forms, but often includes examination of the sociocultural contexts of engineering problems and foregrounding the social aspects of engineering problem definition (e.g.[4]). A third mode of contextualization is found in social justice-centered approaches to engineering, which contextualize by emphasizing the often obscured power relations that engineering contains and upholds [5]. The first two approaches take contextualization as their primary end. Adding additional context is intended to deepen students' understanding of a problem, but not necessarily to suggest how they ought to solve it. The third approach, social justice-oriented engineering, takes a stronger normative stance. Contextualization here is a means to help students identify social injustices that engineers can then help to ameliorate [6].

We interpret the results of our content review through our personal experiences as researchers and educators in science and technology studies (STS) and engineering education. We, like many engineering educators, are wary of overly prescriptive ethics instruction which elides power dynamics and places too much onus on individual actors [7]. Contextualization as an end is a tempting solution; however, we also recognize the risks of illuminating complexity without providing direction [8]. We see flaws in our own balancing act, often defaulting to more contextualization in an effort to render content more acceptable to students and engineering colleagues, or to avoid charges of bias. Ultimately, we argue for a balance of contextualization and normativity. We support alternative approaches to contextualizing engineering that emphasize engineers' civic responsibilities and, crucially, the integration of their intersectional roles as citizens and professionals. These modes of contextualization embrace the idea of sociotechnical thinking, but also encourage engineers to work towards public welfare as engaged citizens.

Introduction

"Engineers are just cogs in a machine." As the instructor of a required course for undergraduate engineering students on "social impact," hearing this statement during a class discussion was at once jarring and unsurprising. Jarring, because of the student's matter-of-fact denial of their own agency, and their apparent lack of dismay at the statement's implications. Unsurprising, because our own experiences in the engineering classroom reinforce a message that scholarship on engineering identity and pedagogy consistently provides: despite decades of attempts by researchers and educators to situate engineering work and knowledge within a broader context, engineering students tend to perceive their profession as narrowly technical and disconnected from society and the environment [9, 10]. Even though this scholarship shows how choices and values impact technological design, students also see their work as insulated from personal worldviews and social responsibility.

Erin Cech describes this "culture of disengagement" among engineering students in her 2014 article [1]. Based on a longitudinal survey of engineering students at four institutions, Cech found that students' concerns about public welfare decline significantly throughout their studies and do not rebound when they enter the engineering workforce. Cech identifies three "pillars" that underlie the culture of disengagement she describes: an ideology of depoliticization which holds that engineering work ought to be disconnected from social or political concerns that may bias it; an ideology of techno-social dualism that separates social and technical competencies; and a belief in engineering as a meritocracy, where everyone has an equal chance to succeed. This culture, she proposes, is not unique to specific engineering programs or institutions, but is likely characteristic of the broad engineering profession.

Cech paints a sobering picture of engineering education and its stakes. Engineers' ability to encode social and political power (consciously or not) in technological systems demands a level of civic engagement well beyond that demonstrated by the engineers in the study. If students' disengagement increases as they become socialized into the engineering profession, then combating the culture of disengagement requires significant, sustained changes across institutions and programs. Furthermore, following Cech's argument, any successful attempt to produce engaged engineers must establish understandings of and approaches to engineering that will be maintained as students enter the workforce. Several recent efforts at reform recognize the scale and the importance of affecting widespread, long-lasting change: the NSF's RED program aims to enact culture change within engineering departments, and ASEE President Dr. Sheryl Sorby draws attention to the need for engineering educators to look at how they have benefitted from and perpetuated the professions' exclusive history, asking the Society's members to re-envision the engineering curriculum for a more diverse profession [11].

We view these initiatives with optimism and hope, while also recognizing them as the latest instantiations of decades-long attempts to broaden engineers' understandings of their own profession. In the "long sixties," engineers and technicians led initiatives that ranged from "humanizing engineering through interdisciplinary liberal education" to "teaching systems analysis to produce professional socio-technologists." Some of these initiatives resulted in humanistic engineering programs, STS programs and departments, courses that sought to integrate technical and social contexts, and engineering design pedagogies that included human-centered design and systems thinking ([12], p. 165) In the late 1970s, Miser argued for teaching systems thinking to all engineers [13]. Ultimately, many of these efforts to infuse engineering education with liberal arts education failed [14], however, there has been a reinvigoration of inserting these dimensions back into leading engineering programs.

As engineering educators, our responses to assertions about depoliticization, techno-social dualism, and the profession as a meritocracy often emphasize contextualization. We recognize traditional engineering instruction as decontextualized [15], and seek to situate engineering knowledge and work with respect to its own historical development, other actors, and other ways of knowing. Whether a specific intervention encourages empathy in design, engagement with public welfare, sociotechnical thinking, or social justice outcomes, contextualization is nearly always a virtue.

By "virtue," we mean that engineering educators, ourselves included, tend to view increased contextualization as an improvement to engineering pedagogy. The idea of adding context to course material is desirable and acceptable in ways that other changes to engineering pedagogy may not be. Educators might disagree about the value of teaching strictly codified engineering ethics, the utility of instrumentalist design frameworks, or the appropriateness of normative social justice framings, but we can often agree that contextualizing engineering work and problems is beneficial. In different cases, educators may also understand contextualization as a virtue with respect to engineering design, engineers' own understandings of their profession, and engineers' ability to serve their broader communities. As we describe below, different kinds of contextualization in engineering education contribute to different types of improvement. A wide variety of modes of contextualization results in a variety of bettering strategies, or ways that these forms of pedagogy can improve engineering education, and in turn, larger engineering contexts.

In this paper, we identify and analyze modes of contextualizing engineering. Based on a qualitative content review of recent engineering education literature, we first describe three different ways in which educators attempt to contextualize: a human-centered design (HCD) mode, wherein contextualization is focused on the people involved in the design and use of technologies, and promotes an understanding of the power of technology to fulfill social needs; a sociotechnical thinking mode, where contextualization aims to overcome techno-social dualism

and acknowledge engineering as a sociotechnical endeavor, and a social justice mode, where contextualization is a means to identify, understand, and address injustice, both internal and external to the engineering profession. The goals of each of these modes are not mutually exclusive, and our categorization includes some overlapping texts and ideas. However, we see describing different modes of contextualization as a useful starting point for understanding their applicability and impact.

Methods

We performed a qualitative content review of recent engineering education literature to identify and describe different modes of contextualization in engineering pedagogy. Our review focused primarily on the archives of ASEE conference publications, the *Journal of Engineering Education*, *Engineering Studies*, and the Morgan & Claypool Synthesis Lecture Series between 2000 and 2020, though we have also included several relevant publications that fall outside of these parameters. This review of the literature focuses on studies of engineering education in the United States.

This paper does not represent an exhaustive review of contextualization in engineering education literature, and we hope to present a more comprehensive analysis in subsequent work. The preliminary content review did allow us to highlight three primary modes of contextualization in engineering education, which we label human-centered design, sociotechnical thinking, and social justice. The *human-centered design* mode includes approaches which specifically center the relationships of humans - who are variously conceptualized as "customers," "users," "stakeholders," and occasionally in other ways - with the products and processes of technological design. The *sociotechnical thinking* mode is a broader form of contextualization which often draws from scholarship in STS. This mode includes approaches that expand contextualization from considering additional stakeholders or social goals, to understanding technology and society as intrinsically related and engineering work as inherently sociotechnical. Lastly, the *social justice* mode includes approaches that use contextualization to equip engineering students with the ability to challenge existing structures of inequity. These three themes of contextualization in engineering are prominent threads in the engineering education literature, but they do not compose the entirety of the themes of contextualization, and they overlap with each other to some extent. We use this review to map how engineering educators promote contextualization to further refine our key terms in a systematic literature review that is forthcoming.

Author Positionality

The authors' personal experiences as researchers and educators of and with engineers motivated this paper [16, 17]. All three authors have engineering undergraduate degrees, and all of us have

graduate degrees in fields outside of traditional engineering disciplines. Our graduate and post-graduate research and teaching relates to engineering in a variety of ways, and our professional identities with respect to engineering are complex and context dependent. We depend on our engineering credentials and experience to establish an insider understanding of engineering as a field, and to lend credibility to our work with engineers. At the same time, we rely on other knowledge traditions to inform our critiques and to shape the contributions that we hope to make to engineering [18]. We all aim to use our disciplinarily diverse backgrounds to make engineering more engaged and socially aware. At various times, we ourselves have engaged in all three of the modes of contextualization that we characterize in this article.

Dr. Marie Stettler Kleine's research on humanitarian and integrated engineering programs inspired her reflection on how different forms of contextualization and the vocabulary used to describe them signal different ways to best teach engineers. Her graduate training in science and technology studies and human-centered design prepared her to see that these forms of contextualization are much more nuanced than using particular language, but this varying language fundamentally changes the engineering pedagogy in practice. She continues to interrogate why and how engineering educators learn from other disciplines to explicitly prioritize contextualization.

For Dr. Kari Zacharias, this project has been an opportunity to reflect on the disciplinarities of her own research and teaching. Her graduate training is in STS, and her research has analyzed inter- and transdisciplinary collaborations between engineers, artists, and scientists [19]. She is motivated by the potential for interdisciplinary engagement to change engineers' outlooks on their education and profession. Her experiences as an instructor of STS-based core courses for engineering and computer science students have helped to shape her outlook on teaching and her approach to this paper.

Lastly, Dr. Desen Ozkan's graduate background is in engineering education, specifically in understanding how faculty developed and maintained interdisciplinarity amid university structures. She focused on interdisciplinary design courses that used human-centered design type pedagogies and the parallels between students' interdisciplinary learning and faculty learning to navigate institutional processes to create interdisciplinary courses [20]. Her recent research has been to integrate social, political, and economic contexts into technical engineering courses. As an actor in engineering education working to integrate broader societal contexts into the engineering curriculum at Tufts University, Ozkan's positioning as a practitioner and researcher of pedagogical change informs and motivates her to pursue this collaborative research on contextualization.

Human-Centered Design: Contextualization for Better Design(s)

Research on engineering design education demonstrates how treatment of design within engineering programs has evolved since the 1990s. Since the mid-2000s, design approaches that are human-, user-, or stakeholder-focused contextualize engineering design with respect to human needs and social conditions. This type of contextualization attempts to improve the products and the processes of engineering design, with the goal of creating technologies that respond to industry demand, address the needs of a specific user group, or take on grand engineering challenges.

In the 1990s, a push towards design in engineering education displaced the emphasis on engineering science that had resulted from Cold War-era federal funding. As Bruce Seely reminds us, engineering education in the late 19th century focused on practical skills like drafting, surveying, shop apprenticeship [21]. As training in these areas was replaced by courses in the fundamental sciences and math during the postwar era, educators and practicing engineers worried that practical design skills "began to slip away" from engineering ([21], p. 295). Following the curricular changes, an industry demand for graduates with “hands-on design talent” increased, which spurred American engineering programs to reorient towards design education ([22], pg. 50).

Changes in the review and assessment of engineering programs reflected the same shift towards design. Engineering design became a required student learning outcome for ABET accreditation in the United States, and the accreditation systems of other countries [23-25]. Design courses became important milestones within undergraduate programs. Initially positioned in the final year, capstone design classes offered a problem-based engineering experience where student teams could apply the knowledge they had developed during their previous years of study [26]. Many engineering educators appreciated that design itself is a learning objective that requires scaffolding, and thus, created cornerstone classes in the first year of engineering to introduce students to the concept of real-world problem solving [27].

The changes in engineering education and accreditation parallels increased emphasis on user and stakeholder needs in engineering more generally. Design and engineering scholars, Dym, Agogino, Eris, Frey, & Leifer further reified engineering design as a bounded form of expertise to be taught to engineering students in the engineering curriculum [26]. With 2884 citations on google scholar, Dym et al., has been referenced by a vast majority of engineering education articles around design. In this article, Dym et al., define engineering design as a:

> “systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints” ([26], p. 104)

In these capstone and cornerstone courses, engineering educators have employed a variety of techniques to engage students with users and human experiences of technologies during design

projects. In engineering design education research, authors discuss the need for more user-centered or human-centered approaches in engineering that are rooted in economic liberalism. Specifically, researchers link this mode of contextualization to its potential to increase innovation and productivity, "improve people's acceptance of new products," and reduce costs in development ([28], p. 30). However, within this mode there are variations in how people are contextualized in engineering design education. The two described in this section are user- and human-centered design. User-centered design engages would-be users at the end of the engineering design process, while human-centered design (HCD) focuses more on client participation throughout [29]. In practice, these forms of contextualization can manifest differently across instructors, researchers, and students.

Research on design education exposes the difficulties that students have with contextualizing the user/human/stakeholder [30]. In user-centered approaches, the user is a customer who will ultimately (often financially) support the engineering design work. Students' conceptualizations of the user are often superficial and rarely lead to more than 'band-aid' like changes to their designs [31], [32], [33]. In human-centered design approaches that offer a more nuanced view of human participation in design, students tend to see human-centered design as service work rather than 'real' engineering [29]. With more experience, students perceive HCD as involving stakeholders throughout the design process to allow for contextual information across multiple vantage points [34]. In the "most comprehensive category" of HCD, Zoltowski, et al., introduced empathic design as a sub-category of HCD. Zoltowski et al., use empathic design to describe a more participatory process between engineer and user that helps the engineer avoid preconceived ideas and assumptions through informal interactions with users that build trust [29].

Empathy in engineering design has become an increasingly important research topic as HCD approaches have become widespread. Walther, Miller, and Sochacka draw connections between literature from social work and engineering by developing and presenting a conceptual framework around empathy in engineering. These authors identify empathy as a critical skill for engineers to develop in their efforts to address grand challenges [35], [36] Notably, Walther et al., bring in literature from social work because of their seemingly professional similarity to that of engineering. The two disciplines have a "focus on socio-technical systems as the locus of professional practice" (p. 133), and they share a role as "professions that are sanctioned by, and ultimately intended to, serve society" (p. 124-125).

The authors argue that the inclusion of empathy in the engineering profession shifts the profession's orientation from a "micro to macro focus of engineering work" ([36], pg. 136, [2]) This broader contextualization is also stated in the graduate student outcome 3h, "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal contexts" from ABET, 2013 and used by Sochacka et al., to further justify a curricular need for empathy. The authors point to empathy in engineering as a way to help engineering students challenge assumptions in their work and critically examine the values

of engineering linked to economic growth and military settings [37], [36]. While most empathy-centered design approaches retain their focus on improving engineering products, the shift towards a critical examination of values also encourages students to question dominant narratives about engineering as a profession.

Human-centered design in engineering education takes many forms and has permeable boundaries. Some of the key terms that appear throughout, like 'stakeholders,' 'user-' versus 'human-centered,' have nuanced meanings in the research positions in which they are used and more importantly are not understood or valued uniformly by the students who participate in the studies. Contextualization in these studies is largely used because of industry-demand, market opportunities, and somewhat to address grand engineering challenges. Ultimately, contextualization through human-centered design is *productive*, in that its outcomes that are valued by a particular political economy.

Sociotechnical Thinking: Contextualization for Better Engineers

A so-called "macro focus" is a relatively new feature of HCD modes of contextualization, but this emphasis on the bigger picture is a cornerstone of other approaches to contextualizing engineering education. Appreciating complex interactions not only between designers and users, but also between engineers themselves, other human and non-human actors, and broader social and cultural factors is an important aspect of a mode of contextualization that we describe as sociotechnical thinking. In this mode, contextualization is a key aspect of curriculum because it helps students to understand what engineering *is*: namely, that engineering work is a sociotechnical endeavor [10], [38]. Educators who practice this type of contextualization pursue "sociotechnical integration" as a learning outcome. Their aims are to overcome the techno-social dualism that they observe in dominant engineering discourses, and often to convince their students of the importance of problem definition alongside problem solving in engineering [39], [40]. Their object of reform is the engineering profession, rather than the specific outcomes or processes of engineering design.

Efforts to promote sociotechnical thinking in the engineering classroom exist at different levels. Within a single course or a specific class session, educators design interventions - games, role-playing exercises, projects - that engage students in the social dimensions of engineering problems [41], [3], [42]. These interventions often use tools like stakeholder analysis that are also common to HCD approaches. One major difference between the two approaches is that here, the goal is to recognize the complexity of the engineering problem and the diversity or divergence of stakeholder needs. Rather than presenting stakeholder groups as customers to be satisfied or constraints to be navigated, sociotechnical thinking uses stakeholder analysis - among many other tools - to illustrate context and emphasize the importance of problem definition.

Sociotechnical engineering pedagogy also exists at the level of entire degree programs or institutions. At Lafayette College, the faculty in the Engineering Studies program present engineering "as a component of the liberal arts," and teach students from their first semester to view engineering as one way of understanding the world, with its own approach to problem definition and solution [43], [44]. In RPI's Programs in Design and Innovation, faculty seek to decompartmentalize social and technical knowledge through interdisciplinary design studios and a sequence of STS courses within the curriculum [8], [45]. In these programs, as with the smaller interventions, a central aim is for students to understand their professional identities and the practice of engineering in a particular way: at Lafayette, as "an inherently socio-technical process"; at RPI, as a process that moves between "technical, social, and formal dimensions of a problem," and the problem's potential solutions.

Questions of scale and translation with respect to sociotechnical engineering pedagogy quickly become apparent at both the course and program levels. Bucciarelli and Drew's call for a new program in "liberal studies in engineering" notes that "perhaps the greatest challenge is recruiting qualified faculty" to run it ([46], p. 105). Studies of classroom techniques for achieving sociotechnical integration conclude that these activities tend to place a significant burden on instructors and are not easily moveable [4]. Nearly all of the efforts mentioned in the previous paragraphs required co-taught courses, cooperation between departments or faculties, the involvement of experts from outside academia, or other resources and time beyond that usually allocated to faculty members for course development.

Another persistent challenge for sociotechnical engineering instruction is the evaluation of its effects. Some of the difficulty results from the breadth of educators' goals. Most of these efforts do not define specific desired outcomes beyond increasing students' ability to understand "the technical" and "the social" as deeply connected, and to appreciate that sociotechnical thinking is an important part of engineering work. That is, sociotechnical engineering programs and interventions rarely prescribe desired career paths or other, more easily quantifiable goals for their students. Attempts to measure the success of sociotechnical thinking contextualization therefore require ascertaining how students' thoughts about their work and identities have shifted, if at all. Mazzurco, Huff, and Jesiek show how a specific tool - the Energy Conversion Playground Design Task - was effective at capturing changes in student ability to identify sociocultural and economic aspects of an engineering problem [33]. However, the tool is not designed to measure students' thinking about their profession beyond the particular task, nor to assess the persistence of changes in thinking over time. Researchers at Colorado School of Mines and the University of Colorado, Boulder are working on an ongoing, larger-scale study of change in sociotechnical thinking over time [47], [48].

Beyond the specific challenges of scalability and evaluation, scholars recognize that attempts to produce sociotechnical engineers through added contextualization are not new. Calls to broaden engineering education through integrating the liberal arts have been a persistent part of

engineering discourses since the early 20th century [49], [14]. Wisnioski shows how, despite some successes, many attempts to broaden the engineering profession through integrating the liberal arts and engineering in the 1960s ended up reinforcing existing assumptions and biases. As current researchers and instructors design curriculum and pedagogy to encourage sociotechnical thinking, we reckon with deeply rooted techno-social dualism and with the limited success of past attempts. We discuss this historical context in greater detail in the discussion section.

The idea that engineering has important sociotechnical aspects has become widely accepted in some contexts: certainly, among STS scholars and other social scientists and humanists who study engineering, but also to some extent among engineering faculty themselves. As an engineering dean who is participating in a RED grant project team recounted, "where engineers end up working on solutions and designs that have social context, faculty readily agree that engineering is sociotechnical" [50], p. 2. However, the same dean continues, faculty still "do not embrace the idea that there are educational components that scaffold students to be able to design solutions that are appropriate for a given population." In other words, the type of interventions and pedagogy pursued by advocates of sociotechnical thinking often do not correspond to engineers' expectations and may not be accepted by engineering faculty and students. Nieusma reflects similarly on the PDI model at RPI, noting that "more than a few students retain a degree of discomfort with, and sometimes even hostility toward, the critical social analysis conveyed primarily by STS instructors" ([45], p 431).

Engineering educators using this mode of contextualization present engineering as sociotechnical and encourage students to recognize social and political power within engineering itself, however, most of the approaches described in this section avoid making strong normative claims about what engineers should do with or about this power. In our personal experiences, presenting engineering as sociotechnical, without attempting to prescribe a particular set of actions, can be a defense mechanism for instructors. When faced with accusations from students, colleagues, or administrators about "politicizing" engineering, the sociotechnical thinking mode allows for the response that engineering *is* and *has been* political, without prescribing desired next steps beyond recognizing that fact. This may be an effective or even a necessary strategy in some situations, and there are certainly other good reasons for avoiding normativity in engineering classrooms (for example, the desire for future engineers to draw their own conclusions about their profession and its evolution). However, encouraging students to recognize sociotechnical complexity without suggesting a specific way forward can leave students feeling adrift. We have often experienced this in our own courses, as students recognize the discrepancies between dominant engineering narratives and sociotechnical thinking but feel powerless to affect change. The social justice mode of engineering contextualization tackles this issue head on, by taking contextualization not only as an aspiration, but as a means to an end.

Social Justice: Contextualization for a Better World

Contextualizing engineering problem definition and solving without any clear directives for what engineers should do next can leave students frustrated and feeling defeated. Over the last 15 years, engineers and critical scholars of engineering have critiqued previously described forms of engineering contextualization as not robust, holistic, or critical enough [51], [46]. Scholarship in the area of engineering and social justice aims to eradicate these shortcomings and set the scene for a version of contextualization that is not the end itself, but rather, a means to prepare engineering students to address social inequities and injustices through their work. Increasingly, engineering educators promote contextualization that prepares students to create normative visions for how engineering *ought* to be practiced. Advocates argue that integrating social justice into teaching and engineering practice can meet this call to reform the profession [52], [9], [5]. Here, the aim of contextualization is not only to reflect and critique, but also to act on this critique in the pursuit of social justice goals. Contextualizing as a means to enact social justice provides space to make sense of the many ways engineers can make change, however, integrating social justice into engineering practice comes with its own limitations [53].

Integrating social justice into engineering can be malleable, helping engineers pair their "desire to help" to their ability to help in a variety of ways [9], [54]. Traditional problem-solving strategies equip engineers with the confidence that they are capable of helping others. In fact, recruitment strategies target this desire, coupling it with an emphasis on "real-world" experience, to produce more diverse engineering student cohorts [55]. However, defining and enacting change through social justice is not a monolith. For some, integrating social justice means refining engineering for community development principles with aims to "enhance human capabilities" [56], [57]. For others, diversity, inclusion, and access within engineering practice motivate their participation in social justice, asking what the boundaries of "what counts" as engineering practice and who is left out while these boundaries are being drawn [18]. Donna Riley argues, it is inherently a part of "social justice," especially related to engineering practice that makes it so difficult to define stating, "Its mutability and multiplicity are, in fact, key characteristics of social justice ([9], pg. 1)."

However, social justice provides an accessible framing for engineers that want to make change. In 2008, Donna Riley published *Engineering and Social Justice*, previously quoted, in the Morgan Claypool Synthesis Lecture Series [9]. This book describes the tensions and similarities between engineering knowledge and social justice action. Through a series of jokes and cartoon vignettes about assumptions and stereotypes of engineers, Riley describes "engineering mindsets." These engineering mindsets, which include centrality of military and corporate organization, uncritical acceptance of authority, positivism and the myth of objectivity, technical narrowness, and the desire to help, serve as accessible tools for engaged engineers to analyze their own behaviors against. Readers are encouraged to engage in how these mindsets impact their ability to rebel against their own disciplinary training and culture of disengagement [1]. These applicable "engineering mindsets" provide fodder for other critical examinations of engineers' "desire to help" [54].

Part of "helping" through social justice is expanding who gets to participate in engineering. Diversity and inclusion efforts are often grouped into contextualizing for integrating social justice into engineering education. Alice Pawley provides a unique analysis of interviews with 10 tenure track faculty on the boundaries around engineering practice and identity [18]. This examination shows the importance of more gender inclusion. Engineering education scholars, Wilson-Lopez et al. question whose expertise is and should be considered valid in a study of Latina/o adolescents' funds of knowledges [58]. These efforts were extended to low-income and first generation engineering students by anthropologist Jessica Smith and STS scholar Juan Lucena in efforts to expand participation in engineering [59]. Contextualization in these cases serves as problem definition for the field and professional as a whole, not just a single problem or engineering project. Ultimately, this form of contextualization promotes bettering the profession, similar to the sociotechnical mode described above, but it aims to go further, in effort to better society more generally. Contextualizing marginalization within and because of engineering can lead to further action.

A large part of engineering and social justice scholarship reframes the relationship between engineering and international development. Post-development critiques of engineering for international development spurred a reimagining of what engineering and bettering the world can mean [60]. In *Engineering Justice*, authors Leydens and Lucena reframe the normative criteria of engineering for sustainable community development into thinking about community engagement that leads to social justice [61], [57], [56]. The authors emphasize this criteria aimed to help engineering practitioners and engineering educators that work towards authors' Leydens and Lucena definition of engineering for social justice: "engineering practices that strive to *enhance human capabilities (end)* through an equitable distribution of *opportunities and resources* while *reducing imposed risks and harms (means)* among agentic citizens of a specific community or communities ([57], p 15). This definition, and the practice that it encourages, acknowledges the benefits of engineering problem solving while trying to address some of engineering for development's largest neocolonial critiques. Working in social justice with this model allows for critical reflection on who is in need, who's human capabilities are worthy of prioritization, and when social justice is achieved.

Combining engineering and social justice illuminates the engineering profession's shortcomings. Introducing social justice into engineering education draws attention to the profession's capitalistic motivations and its ability to catalyze environmental destruction [9], [62], [63]. This tension leads to institutional resistance. After all, its engineering's myth of objectivity and meritocracy that makes it hard for engineers to frame issues of inclusion, access, and diversity in terms of social justice [64]. This difficulty, paired with a "culture of disengagement," explains why engineers are less inclined to participate in explicit normative calls to change engineering practice for societal good [1]. Further, ABET accreditation and programmatic structures inhibit engineers to engage with sociotechnical understandings of engineering practice; therefore making it easier to depoliticize and draw further from social justice efforts [65] .

Integrating social justice into engineering classrooms can come with high stakes. Leading scholars conducting engineering equity research report targeted harassment because of their academic interests [53]. These researchers faced insults and slander in response to one of the surveys that they conducted as a part of their data collection that deeply emphasized the techno-social dualism, questioned these researchers' expertise, and threatened their safety [10].

Beyond the risk to individual researchers and educators, engineering and social justice rhetoric is in danger of being spread too thin. Not all the ways in which engineering educators want to make improvements can or should fit within common social justice framings, and there are institutional and political barriers to attend to before social justice approaches are widely accepted and used by engineers. Engineering and social justice scholars are also mindful of these boundaries, because not respecting them dilutes the power that social justice action can exert within engineering. In addition, not all engineering students want to engage in social justice or become activists.

Contextualization as a means to engage in social justice is a way to contributing to making a better world. Between participating in international development more responsibility, advocating for marginalized and minoritized voices in engineering, or working towards "enhancing human capabilities," social justice efforts can span a wide range of practices, visions, and pedagogies. But engineering and social justice is at risk of meaning too many things, diluting itself of its potential. The social justice-oriented mode of contextualization provides a model for explicit normativity. We propose that the inherent normativity of this mode of contextualization brings much needed guidance for engineering students, but an alternative that appeals to more students, and does not reduce engineering and social justice efforts to a universal and generalizable practice, is needed.

Discussion

Clearly, these different modes of contextualization have different intended goals. We can mean many different things by context and contextualization, and some of these uses may be contradictory [66]. Together, these modes of contextualization aim to make better designs, better engineers, and a better world. HCD focuses mostly on the products of engineering design, while sociotechnical thinking prioritizes reflection on the engineering profession, and social justice approaches aim to operationalize critical reflection to affect structural change. Despite their differences, all three modes aim, in their own ways, to improve engineering pedagogy.

Our collective desire to improve engineering education, combined with our expertise and experience in contextualizing engineering practice, leads to our framing of contextualization as a virtue. In some ways, we believe that if we could just have students understand about their engineering context enough, they would make better designs, better professional impacts, and

ultimately, improve wider society. All of these modes, and those that use them, all agree that contextualization is essential to improvement, but to "better" what and how exactly to use contextualization in engineering classrooms is up for debate.

Each mode of contextualization has its limitations. HCD approaches can help to teach students how to deal with uncertainty, complexity, and open-ended problems, but its product-based focus rarely prioritizes reform or structural change, and rarely expands focus beyond the "user," or occasionally other "stakeholders." HCD may better prepare students to be successful after their engineering degree, but most of the discourse surrounding HCD does not provide them the tools to critique what qualifies as success or innovation. Our disciplinary backgrounds reject the tendency of HCD contextualization to stress the importance of "the social," which can further cement well-established engineering ideas about techno-social dualism.

We most regularly encourage contextualization through STS-infused pedagogy that emphasizes sociotechnical thinking. We often default to thinking that if we train better engineers, they will eventually make better engineering decisions because of their experience with contextualized engineering practice. Sociotechnical contextualization, however, often leaves students without a plan for action. This descriptive versus prescriptive practice can leave students feeling helpless, or with the impression that turning away from engineering is the best way to make change. This contextualization mode is also difficult to implement on large scales, and it can be difficult to enroll engineering faculty in pedagogical or curricular changes that prioritize sociotechnical thinking. However, we do not want to be complacent, and we want answers when our students ask how to get their disengaged friends interested in critically questioning engineering and its purpose.

We see an opportunity to learn from the normativity of engineering and social justice approaches. Social justice provides accessible ways for engineering students to engage with normative framings, analyze whether they are working towards "enhancing human capabilities," and have actionable next steps beyond contextualization. We must also be realistic about the limitations of promoting social justice within engineering. Some of our students simply want to minimize their negative impact on the world, not fundamentally better the world. While many students are welcoming of the HCD and sociotechnical modes of contextualization, not all students want to be activists. There is also an issue of scale for engineering and social justice. There is only a small number of engineering faculty that are comfortable speaking and leading discussions about social justice.

While some modes of contextualization aim to improve the products that engineers design and produce, most of these pedagogical strategies aim to improve the people who deploy them, the profession in which they work, and ultimately the world. We argue that engineering educators who prioritize contextualization, like we do, must recognize the limitations of each of these modes and seek out alternatives which encourage engineers to engage with both their

professional and civic identities. In turn, we suggest alternative approaches to contextualizing engineering that emphasizes engineers' civic responsibilities and, crucially, the integration of their dual roles as citizens and professionals.

We recognize and support other approaches to this hybrid identity. Most directly, the pillars and framework for socially responsible engineering developed by Jessica Smith and Juan Lucena provides a hybrid approach of STS contextualization and normative guidance [67]. Others recognize the potential for the humanities and social sciences to be better incorporated in engineering education—which could similarly aid in forming these hybrid modes of contextualization—through promoting "the humanistic side of engineering;" although, we recommend further integration in traditional engineering education to avoid perpetuating techno-social dualism [34], [10], [1].

We embrace the idea of sociotechnical thinking but encourage engineers to work towards public welfare as an end goal (for more engineers' perception on public welfare see [68]). This approach is justice-minded but does not require an engineering project to have specific social justice aims. In other words, contextualizing to prepare for civic engagement is intended to be applicable in a wide range of engineering interests. This is not simply hiding social justice behind tame and acceptable language. This alternative approach to contextualization offers all engineering educators a framework to explore sociotechnical understandings within their students' local contexts while helping individual engineers form their own normative framing of engineering practice and engagement.

Future Work

In future work, we will expand this content review to a systematic literature review. During these next steps, we aim to confirm and/or revise our three main categories and build on them. While we have provided a preliminary sampling of how these modes of contextualization vary, a systematic literature review will provide more nuanced differences and provide more detail for the sizes of these major themes.

As engineering educators, we are actively engaged in helping our students think through making better technology, by better engineers, and ultimately, a better world. We believe that transparent analysis of what it means to be engaged in these three "bettering" strategies is a key piece for any one of them to be a success. We aim to build bridges between these modes of contextualization, to learn from each other, and to push each other to be better.

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