The Imperative to Move toward a Dimension of Care in Engineering Education

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Abstract

The push for STEM has raised the visibility of engineering as a discipline that all students should learn. With the release of the *Framework for K-12 Science Education* and the Next Generation Science Standards (NGSS), engineering now has an official place in the science curriculum. In both the *Framework* and the NGSS, engineering is framed as a way to solve the world's greatest problems. Despite this potential, there are troubling aspects in the way that the *Framework* and NGSS present engineering and how engineering is taken up in the curriculum. In this paper, we use critiques of technocracy, utilitarianism, and neoliberalism to analyze the portrayal of engineering in the *Framework* and NGSS. We claim that the *Framework* and NGSS promote a technocratic perspective that engineered solutions can all problems, ignoring the socio-political foundations of many of the world's most pressing problems. Furthermore, both standards documents reflect a utilitarian ethic that promotes all progress as good and ignores issues of justice. Lastly, the *Framework* and NGSS betray neoliberal foundations that undermine education and engineering as public goods. To address some of these issues, others have argued for a greater emphasis on ethics. In response, we raise cautions because ethical framings present further intractable dilemmas. Instead, we draw on feminist theory to argue for reframing engineering education around an ethos of empathy and care. We call for a dimension of care that situates design problems in the full socio-political context and centralizes issues of justice. We provide an illustration of how an NGSS example activity for designing solar cookers could incorporate a dimension of care that addresses issues of harm, power and inequality, and ecological (in)stability to provide students with opportunities to weigh and take responsibility for the real costs and benefits of their designs.

Key Words: Engineering, Technocracy, Utilitarianism, Neoliberalism, Caring

The Imperative to Move toward a Dimension of Care in Engineering Education

In recent years, engineering has taken a prominent role in the K-12 curriculum. The push for STEM has raised the visibility of engineering as a discipline which all students should learn (National Academy of Engineering [NEA] and National Research Council [NRC], 2009). With the release of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), engineering now has an official place in the K-12 science curriculum. States, school districts, schools, and educational organizations have responded by incorporating engineering into state standards (Moore, Tank, Glancy, & Kersten, 2015), building STEM schools and engineering lab facilities (Thomas & Williams, 2009), developing or purchasing engineering curriculum materials (e.g., "Engineering is Elementary," 2017; "Project Lead the Way," 2017), providing teachers with professional development (Guzey, Tank, Wang, Roehrig, & Moore, 2014; Pinnell et al., 2013), and offering engineering courses (Banilower et al., 2013).

Common arguments for incorporating engineering in the K-12 curriculum tout potential benefits including improving students' understanding of science and mathematics concepts, supporting the development of systems thinking and spatial reasoning, promoting collaboration and communication, and developing problem-solving skills (Brophy, Klein, Portsmore, & Rogers, 2008; Moore et al., 2015; NEA & NRC, 2009). Participating in engineering curricula in the K-12 context is said to improve students' motivation for learning, promote awareness of engineering-related careers, and provide an avenue for increased diversity in the STEM fields (Brophy et al., 2008; Moore et al., 2015; NEA & NRC, 2009). More broadly, in a world facing global-scale issues related to environmental quality, health, and availability of energy resources, engineering plays a growing role in finding solutions to sustaining life (NEA & NRC, 2009;

NRC, 2012). Incorporating engineering into the K-12 curriculum can better prepare students to address these issues in the future. The numerous potential benefits and positive impacts make the integration of engineering into the curriculum seem like an obvious pathway towards building a better-educated society capable of meeting the complex needs of the twenty-first century.

Despite its promise, however, there are troubling aspects in the way that the *Framework* and NGSS present engineering and how engineering is taken up in the curriculum. Traditionally, engineering has been seen as a technical field that requires the systematic application of mathematics and science knowledge to develop novel solutions to complicated problems. Yet, in a world where problems are increasingly complex and global in nature, technical knowledge is not enough. Engineering also requires empathy, caring, and compassion to develop solutions that are socially responsible and environmentally sustainable (Canney & Bielefeldt, 2015; Hess, Sprowl, Pan, Dyehouse, Morris, & Strobel, 2012). Engineers must be able to consider both the problems they are addressing and potential solutions they design from the multiple perspectives of the people impacted by their designs. This view is especially important considering that many of the problems engineers address have cross-cultural effects and intergenerational implications. From this perspective, engineering is a helping profession that is as much about building relationships among the people involved and affected by a project as it is about building an object or system to solve a problem. Educating engineers and students to care about the human dimension of problems thus becomes as important as developing the technical expertise to design solutions (Bielefeldt, 2017).

Our primary concern is that in the rush to incorporate engineering into classroom instruction and the gush of arguments about the potential benefits for doing so, there has been little attention to developing social empathy and care as essential aspects of engineering education and practice (Walther, Miller, & Sochacka, 2017). Much of the discourse around incorporating engineering into the K-12 curriculum has focused on the technical aspects of the engineering design process; there has been little analysis of the underlying forces driving the K-12 engineering education movement and little critique of this current technocratic, utilitarian framing of engineering in the science curriculum. This situation is problematic because it limits the potential that including engineering in the science curriculum could achieve.

In this paper, we offer critiques of the technocratic, utilitarian, and neoliberal underpinnings of engineering design as portrayed in the *Framework*, the NGSS, and common engineering curricula. We then draw on feminist ethics and feminist science studies to argue for a reframing of the ethico-political dimension of engineering along the lines of material caring. Finally, we conclude by providing an example for how science educators can engage the issues we have raised in our critique, and embrace a dimension of care in engineering in science.

Engineering in the *Framework* and NGSS

Although understandings of the designed world, technological systems, and the impacts of human activities have been essential content for science literacy since the 1980s (AAAS, 1993; NRC, 1996; Rutherford, 1989), the inclusion of engineering as a discipline in the pre-college curriculum is relatively new. The current integration of engineering in the K-12 science curriculum grew out of efforts in the early 2000s to attract more interest in and increase diversity within the field of engineering (Brophy, et al., 2008; Carr, Bennett, & Strobel, 2012). In response, the American Society for Engineering Education developed guidelines for engineering outreach programs such as camps, after school programs, and internet sites (Douglas, Iversen, Kalyandurg, 2004). In an influential report in 2008, Brophy et al., argued that engineering needed to be more than an extracurricular activity and promoted the idea of including the discipline of engineering the K-12 school curriculum. However, a National Academy of Engineering (NAE) and National Research Council report in 2009, titled *Engineering in K-12 Education: Understanding the Status and Improving Prospects*, noted serious challenges to this idea, including an already-full school curriculum, lack of familiarity with engineering in elementary and secondary schools, and a shortage of qualified engineering teachers.

In the late 2000s, the acronym STEM, for science, technology, engineering, and mathematics, came into the public and political discourse (Bybee, 2013), effectively elevating technology and engineering to the same status as science and mathematics in the curriculum. The acronym highlighted a connection among the disciplines that was greater than each alone. Against this sociopolitical backdrop, the NAE-NRC report proposed that rather than become a new content area with its own set of standards, engineering should be integrated into the science and mathematics curricula. Subsequently, the National Research Council Committee on a Conceptual Framework for New K-12 Science Education Standards included engineering in *A Framework for K-12 Science Education* (NRC, 2012), which provided the research-based structure used to write the Next Generation Science Standards (NGSS Lead States, 2013). The process of writing engineering into the Framework and the NGSS involved negotiations among the many stakeholders about what engineering content to include in the science standards and how. With the publication of these standards documents, engineering gained legitimacy and prominence in K-12 science.

Within the *Framework* and NGSS, engineering is defined as "a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants" (NRC, 2012, p., 202). This definition emphasizes the design function of engineering In both the *Framework* and the 2009 NAE report, the authors argued that because it is an iterative process, open to multiple solutions, and a meaningful context for the application of scientific knowledge, engineering design is both an approach to identifying and solving problems and a useful pedagogy for supporting learning in the classroom.

The *Framework* and NGSS are both organized around three dimensions: practices, crosscutting concepts, and disciplinary core ideas. Engineering has a place in all three dimensions. The practices dimension reflects how the fields of science and engineering produce and use knowledge. While the same eight practices are listed for both scientific inquiry and engineering design, the *Framework* describes how each practice is enacted within each discipline. For example, the practice of developing and using models in science involves constructing and using models to explain phenomena, while in engineering models are developed and used to analyze systems and test designs. Similarly, the crosscutting concepts, which span disciplinary boundaries, are presented for both science and engineering. For example, in science, cause and effect is the concept that events have causes which result in predictable outcomes. From an engineering perspective, cause and effect relationships are useful for designing systems that produce specified effects. The third dimension, disciplinary core ideas, represents the foundational understandings in the disciplines of science and engineering. In the NGSS, these dimensions are intertwined to produce performance expectations that define a progression of increasing sophistication as students move through four grade bands (grades K-2, 3-5, 6-8, 9-12).

The *Framework* identifies two disciplinary core ideas for Engineering, Technology, and Application of Science (abbreviated ETS). Each disciplinary core idea includes several component ideas. Expectations for student performance at the end of each grade band are described for each component of each disciplinary core idea. ETS1: Engineering Design focuses on how engineers solve problems, including how they identify problems (ETS1.A), the process for developing potential solutions (ETS1.B), and how various solutions are compared and improved (ETS1.C). The second disciplinary core idea, ETS2: Links among Engineering, Technology, Science, and Society, addresses how these areas are interdependent (ETS2.A) and how science, engineering, and technology affect people and the natural world (ETS2.B).

In the NGSS, performance expectations are included for ETS1: Engineering Design. However, although the *Framework* includes grade band endpoints for ETS2: Links among Engineering, Technology, Science, and Society, no specific performance expectations are included in the NGSS for this disciplinary core idea. Instead, to indicate where links among engineering and science are present in the standards, performance expectations in the physical, life sciences, and Earth and space sciences that include relevant engineering practices or crosscutting concepts are marked with an asterisk. In total, there are 36 performance expectations that address engineering, of which 14 are specific to ETS1 and 22 of which are asterisked as links to other science content and practices. The NGSS also includes Appendix I that provides more detail on how the NGSS incorporates engineering, including an overview of the progression of performance expectations for engineering design across the grade bands. Finally, sample classroom engineering tasks and assessments are provided on the NGSS website (http://www.nextgenscience.org).

Three Critiques of Engineering as Portrayed in the Science Curriculum

While incorporation of engineering into the science curriculum has many potential benefits, we are concerned with three problematic framings of engineering within the *Framework* and NGSS. In this section, we analyze the technocratic, utilitarian, and neoliberal perspectives that infuse the standards documents, engineering curricula, and the general social response to including engineering in the K-12 curriculum.

Engineering Design: A Technocratic Solution

At its core, engineering design is about solving problems. It is defined by an iterative and systematic process for identifying problems and applying scientific principles to develop and test solutions (NEA, 2009; NRC, 2012). As such, engineering design fills a gap in the overall science curriculum to make it better reflect the value of learning science. We are concerned, however, that the way engineering design is portrayed in the standards depicts a narrow, technocratic perspective of problem solving that does not acknowledge political and social aspects of either problems or solutions.

Technocracy is a decision-making approach that emphasizes technological solutions to all problems (Fischer, 1990). Classically, technocratic perspectives focus on solutions, without addressing social or political aspects of problems (Danforth, 2016; Fischer, 1990). For example, rather than deal with the underlying social and political causes of recent Zika virus outbreaks, such as global warming, overcrowded urban areas, substandard sewage systems, and policies that restrict women's reproductive rights and access to healthcare, the US reaction has been to pour all response efforts into finding a vaccine or genetically modifying mosquitoes (Sered, 2016). These technical solutions address the symptoms of the problem (i.e., the virus and the mosquitoes) and do not attend to the underlying social and political structures that contributed to the disease outbreaks. By reducing problems to technical issues that can be managed and solved by experts, the underlying causes of problems may never be identified and addressed.

The technocratic perspective on problems and solutions is evident in the way that the standards documents portray engineering design as an approach for solving real world problems. The *Framework* and the NGSS define engineering problems as "situations that people want to change" (NRC, p. 220; NGSS Lead States, Appendix I, p. 3). Table 1 lists example NGSS engineering performance expectations that reflect this definition of an engineering problem. This broad definition provides no guidance about what kinds of problems can be solved through engineering fixes and what types of problems may need political and social solutions instead of or in concert with technological approaches. The *Framework* does acknowledge that many challenges that humanity faces require social, political, and economic solutions, but goes on to state that these solutions "must be informed deeply by knowledge of the underlying science and engineering" (p. 22). This framing suggests that all situations that people want to change have science and engineering foundations and need science and engineering solutions, when, in fact, technocratic solutions have failed time and again because they did not adequately address the social and political aspects of problems. As examples, the design of high-yield crops has not solved famine (King, 2016) because famine is a political problem; the design of low-cost computers and cell phones will not alleviate the problems of poverty because income inequality is a political problem (Toyama, 2010); and the design of vaccines will not eliminate diseases like AIDS and Ebola because AIDS and Ebola are as much political problems as they are human health problems (Harman, 2014; Piot, Russell, & Larson, 2007). While science and technology have a role to play in addressing both simple and difficult problems, by suggesting that design can solve any problem that people want to change, the *Framework* and NGSS perpetuate the technocratic myth that societies can engineer themselves out of all complex and thorny situations without addressing the underlying human dimensions that create the problems in the first place.

Defining problems in terms of what people want to change is also decidedly anthropocentric and reflects the Enlightenment ideal that humans can and should appropriate the physical and natural world for their own purposes (Fischer, 1990; Huesemann & Huesemann, 2011; King, 2016). This view of problems and solutions does not recognize the ways that natural forces respond to technological solutions, often spawning new problems that the technocratic perspective fails to foresee. The technological response is to design new technologies that fix the new problems (technological fixes), but that themselves inevitably give way to more problems in an unending chain of disasters (Huesemann & Huesemann, 2011; Rosner, 2004). For instance, climate change is a byproduct of one of the world's most ubiquitous engineering innovations: the internal combustion engine. While the gasoline-powered engine solved many transportation and manufacturing issues and gave rise to other useful innovations, it also created many environmental catastrophes as nature responded to the production and use of petroleum products. Renewable energy technologies seem like an ideal solution to the problems wrought by carbon-based fuels, but the environmental damage created by hydroelectric dams and gigantic solar and wind farms serves as an example of how the technological fix inevitably creates new problems. The *Framework* does argue that many of the greatest issues facing humanity today revolve around climate change and clean air and water, and in this respect, the focus of these problems seems timely, relevant, and significant. Unfortunately, the technocratic framing of these problems does not acknowledge that the source of these challenges are human-caused or that solutions may not be entirely design-based. Instead, the focus on design solutions falsely portrays the physical and natural world as subservient to human needs and desires.

The technocratic perspective is also evident in the way that the *Framework* and Appendix I of the NGSS portray the process of designing solutions. In the *Framework*, emphasis is placed on doing risk-assessments and cost-benefit analyses to determine if solutions fit narrow constraints that define success. At each grade band, the expectations for performance in each of these areas are sharply reductionist, suggesting that the identification of tightly defined criteria for success will lead to optimal solutions to complex problems. By the end of 12th grade, for example, students are expected to be able to consider risk mitigation to quantify constraints to state whether and how designs are successful (NRC, 2012, p. 205). Costs and benefits are treated as an accounting exercise that will lead to clear choices (See Table 1). However, while many of the positive impacts of technologies are immediately visible, the negative impacts may be delayed and less obvious (Huesemann & Huesemann, 2011; Wentz, 1988). Furthermore, how benefits and costs are defined depends entirely on one's values and social position relative the proposed technology (Sagoff, 1988). Moreover, many social values cannot be adequately quantified, monetized, or modeled (Huesemann & Huesemann, 2011; Sagoff, 2008). Values such as life or health should simply not be part of a cost-benefit trade-off (Wenz, 1988). The *Framework* does acknowledge that design constraints are usually reflective of social values; however, it does not suggest that there might be contradictory or pluralistic values that inform those constraints. Instead, "social values" are left undefined as if there is one set of values that represent all social concerns and therefore one accounting of costs and benefits. By neglecting to acknowledge that engineered solutions do not exist in a technocratic vacuum, the standards documents leave students with a false sense of confidence in technocratic cost-benefit analyses and inadequately prepared to engage in the hard social and political negotiations that must be included in any problem-solving process.

Finally, we want to point out that common engineering curricula (e.g., *Engineering is Elementary*) often further refine the three components of design identified in the *Framework* and Appendix I, portraying them as a cycle with specific steps (e.g., Ask, Imagine, Plan, Create, Improve). These steps are used as a heuristic for teaching and learning about engineering design. Similar to the way that reducing science to the scientific method is problematic for its positivistic depiction of explanations emerging directly from data, reducing design to a set of three or six steps is problematic for its privileging of empirical and analytical epistemologies as revealing all solutions. Empiricism and logic do play an important role in developing and testing new designs, but by portraying problem-solving as a set of steps or tightly interrelated components, the engineering design process reflects a crypto-positivistic (Zeidler, et al., 2016) framing that privileges logical empiricism regardless of the social or political dimensions that may exist. The lack of guidance in the *Framework* and NGSS on how social and political aspects of problems intersect with the design process has left open these types of problematic representations of engineering in aligned curriculum materials.

Engineering is by nature technocratic. This characteristic is reflected in the *Framework* and NGSS as well. However, as neither science nor engineering exist divorced from context, we argue that the technocratic emphasis of engineering in the K-12 curriculum does a disservice to students by failing to prepare them to use engineering to deal with the sociocultural and political aspects of the problems that they will face as adults (Zeidler, et al. 2016).

Links to Society: A Utilitarian Ethic

The focus on technocratic solutions in the *Framework*, NGSS, and common engineering curricula also reflects a utilitarian ethic of engineering. Utilitarianism holds that the best moral choice maximizes benefits for the most people (Martin & Schinzinger, 2005). How one defines benefits, or the utility of an idea, ranges across philosophers. John Stuart Mill (1863), for example, argued that the standard for utility was happiness. In the twentieth century, a more rule-based version of utilitarianism emerged, focusing on rules for maximizing the benefits to the most people as the basis for how one judges utility (Martin & Schinzinger, 2005). Either way, utilitarianism underpins technocracy and is evident in the *Framework* and NGSS treatment of the engineering links to society (see Table 2 for examples).

The focus on happiness and benefits as the criteria for utility reflects a deep Western belief that the application of scientific knowledge will reduce suffering in the human condition (Huesemann & Huesemann, 2011). As such, all technological innovations are seen as progress and all progress is seen as good. This idea is evident in the way the *Framework* treats the social impacts of engineering in the presentation of disciplinary core idea ETS2 – Links among Engineering, Technology, Science, and Society (not included as a core idea in the NGSS). The *Framework* authors highlight, for example, the "profound effects [of engineering] on human society in such areas as agriculture, transportation, health care, and communication…" (p. 210). They go on to say that, "Advances in science offer new capabilities, new materials, or new understanding of processes that can be applied through engineering to produce advances in technology" (p. 211). The effects of engineering are all framed as positives, reflecting a belief in the march of progress and techno-optimism. Importantly, these advances are framed as benefiting all people equally. As such, engineering is portrayed as a benefit to society, improving the lives of all people and making the world a better place - a distinctly utilitarian ideal.

The problem with utilitarianism, however, is that what benefits one group of people may not benefit another. Who decides what a benefit is and who benefits means that utilitarianism privileges the majority. As a result, it fails to address issues of justice. This places engineering and design in the center of many equity issues. For example, the design of a hydroelectric dam may solve an energy problem for a municipality, but the consequent flooding of natural habitats and displacement of inhabitants behind the dam can have enormous environmental and social justice implications that cost-benefit analyses fail to recognize. More justice-oriented analyses would consider how impacts of the dam are distributed and whether they are arranged to benefit the least advantaged (Rawls, 1971), who is recognized and has voice in decisions related to the siting and design of the dam (Schlosberg, 2004; Young, 1990), and how the dam impacts humans' obligations to preserve biodiversity and evolutionary processes (Wenz, 1988). These considerations and guiding principles are not available from a solely utilitarian perspective.

The *Framework* and NGSS reflect this problematic utilitarian issue. In these standards documents, criteria for utility are set by the end-user of the designed solution or product. Many engineering curricula go further, emphasizing that engineers work for clients and it is the client who both defines the problem and the criteria by which solutions are judged (e.g., Capobianco, Nyquist, Tyrie, 2013). The *Framework* explains, for example, that criteria for success "reflect the needs of the expected end-user of a technology or process" (p. 204) and that trade-offs are "based on the situation and the perceived needs of the end-user of the product or system," (p. 209). As such, according to the *Framework*, who decides who benefits from engineering designs are those who have the most to gain from the design. There are places where the *Framework* makes nods to the value-laden nature of criteria optimization, noting that solutions to problems often involve making trade-offs because "one person's view of the optimal solution may differ from another" (p. 208). Nevertheless, suggesting that these impacts are trade-offs for solutions dismisses those who do not have a voice in the decision-making process and normalizes the ways that engineering and science can become complicit in oppression and injustice.

Moreover, in the *Framework*, collateral impacts from engineered solutions are framed as "unforeseen or "unintended" consequences. In Disciplinary Core Idea ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World, the *Framework* states that 8th grade students should understand that "[t]echnologies that are beneficial for a certain purpose may later be seen to have impacts (e.g., health-related, environmental) that were not foreseen" (p. 213) and 12th-grade students should understand that "[n]ew technologies can have deep impacts on society and the environment, including some that were not anticipated" (p. 214). The *Framework* does suggest that engineers should predict potential impacts of their designs by using modeling to "provide insight into the consequences of actions," (p. 212) but even this statement is problematic because it suggests that negative impacts are the result of not being able to make accurate predictions. Rather than make visible the connections between engineering and society, these statements relieve engineering from moral and ethical responsibility for the impacts of designed solutions on people and environments now and in the future.

Utilitarian ethics may be a dominant perspective guiding professional engineering (Martin & Schinzinger, 2005). However, in K-12 education, the goal is not only to prepare future scientists and engineers but also to create a scientifically literate public capable of informed and critical decision-making. By ignoring issues of justice and abdicating moral responsibilities in engineering, utilitarianism represents a deficit framework (Zeidler, 2016) for science standards.

Engineering Education: Neoliberal Economics

Another problematic aspect of the way engineering is portrayed in the standards documents is that it reflects and promotes a neoliberal ideology. Neoliberalism is an economic and political system that encourages the privatization of public institutions and uses market forces to control and exploit populations (Carter, 2016). Government regulation is seen as a tool to maintain the function of markets and maximize economic growth (Bazzul, 2012). Far from a recent development, the neoliberal influence on education has been present in various forms from the Clinton through Trump administrations (Patterson, 2015). An important assumption in neoliberal educational policy is that the purpose of education is primarily to prepare students for future jobs and careers in the workplace, a value that privileges education as a private economic good over the public goods of education for participation in a strong democracy (Labaree, 1997;

Patterson, 2015). By often warning that schools are failing to prepare workers who can fill the jobs in corporations and industry, thereby putting at risk U.S. economic domination on the global markets, neoliberalism discourse in education trades on fear and crisis to justify a focus on preparing workers for the twenty-first century workforce (Carter, 2016). Proposed solutions to this supposed crisis often rest on arguments for including more science, technology, engineering, and mathematics in the school curriculum.

Hoeg and Bencze (2017) have identified the neoliberal values evident in the NGSS in general. For example, they critique the NGSS reliance on measurable performance of individuals and emphasis on equal (rather than equitable) access to the standards as evidence of a neoliberal promotion of meritocracy. This neoliberal agenda extends to the framings of and justification for engineering in the standards documents and common engineering curricula. Both the *Framework* and NGSS argue for the inclusion of engineering in the standards because engineering prepares students for twenty-first century jobs (Hoeg Bencze, 2017; NRC, 2012; NGSS Lead States, 2013). For example, in the forward to the *Framework*, the presidents of the National Academy of Science and the National Academy of Engineering state that,

> The percentage of students who are motivated by their school and out-of-school experiences to pursue careers in these fields [science and engineering] is currently too low for the nation's needs. Moreover, an ever-larger number of jobs require skills in these areas... (p. x.)

The insinuation is that including engineering in the K-12 curriculum will save the nation's economy by preparing more workers for the private market.

This justification echoes a common refrain that the nation's schools are failing to produce scientists and engineers for the future. Business groups and politicians complain that schools are not graduating students with the skills and knowledge necessary to fill engineering jobs (Stevenson, 2014). In response, school districts are opening more STEM-focused schools, sometimes using their limited tax-based resources to construct new school buildings to house these special programs. Often highlighting engineering as a curriculum focus, these schools typically advertise that they are preparing students for engineering-based jobs, citing the common statistic that “By the time students currently in elementary school graduate, roughly 60% of jobs will involve skill sets associated with science, math, engineering, or technology” (Innovation Academy, 2017). Charter schools have jumped on the STEM train too, with nearly 20% of all publicly funded charter schools offering a STEM focus (Rees, 2013).

The problem with this framing, however, is that the validity of the engineering-based skills gap is in question. Labor market studies show that there is actually an engineering labor surplus, not a shortage (Stevenson, 2014; Teitelbaum, 2014). Some have even speculated that the push to attract students to STEM degrees and careers is more about a neoliberal economic push to lower wages than filling vacant positions (Tarnoff, 2017) or a push to bolster dropping enrollments in colleges of engineering (Brophy et al., 2008). Nevertheless, publicly-funded schools are becoming the training ground for industry, shouldering the burden of preparing the workforce that will produce profits for private corporations. Because municipalities often give corporate tax breaks to industries, the resulting return on the public investment in schools and curriculum that emphasize engineering is low. Even when industry partners with public schools to provide resources for engineering education in K-12 schools, the message is that private resources are necessary to come to the rescue of public schools incapable of graduating students with engineering potential (Slaton, 2015). This movement leads in the direction of more corporate control over the public school curriculum and greater privatization of the public school system. Retooling the K-12 curriculum to include engineering is an expensive proposition that functions to continue the neoliberal agenda of turning public schools into private institutions.

Hoeg and Bencze (2017) also critique the portrait of innovation and creativity in the NGSS as reflective of neoliberal values. They argue that the discourse of the NGSS restricts innovation and creativity in the service of markets and profits. This is specifically evident in the *Framework's* engineering grade band endpoints for ETS2.B (Influence of Engineering, Technology, and Science on Society and the Natural World) which states that by the end of 12th grade, students should understand that

> Widespread adoption of technological innovation often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. (p. 214)

In this statement, market forces and government regulation are portrayed as arbiters of innovation. As a result, innovation is harnessed to maintain the economy rather than to solve significant problems that result from the social inequities created by neoliberal policies.

Finally, as we illustrated in the previous section, engineering problems and solutions, as portrayed in these materials, are defined by end-users or clients. Framing end-uses as clients restricts engineering and the argued benefits of engineering within the world of business only. Some engineering curricula even direct students to develop a budget for their designs, provide students with prices for materials, and expect students to calculate the cost of their solutions, mimicking the way that engineering works in the business world. This framing depicts engineers as highly trained laborers who work at the pleasure of those who can pay. Unfortunately, this framing undermines the claims in the introduction of the *Framework* that engineering and engineers are needed to solve the world's most pressing problems, such as the need for clean air and water and sustainable food supplies. Rather than being problems that affect all people and that all have a stake in solving, the market-based discourse of the standards documents and curriculum programs reveals that the problems and solutions that engineers are allowed to address are those that have an economic benefit to the definers of the problems. Thus, engineers are reduced from agents-of-change and solvers-of-problems to cogs in the economic engines that maintain the domination of the U.S. economy on the world stage.

Much of our critique of engineering in the science curriculum is also a critique of the engineering profession. Yet, engineering in K-12 standards should be more than about maintaining the status quo of the engineering field. By adhering to neoliberal discourse, the *Framework* and NGSS miss an opportunity to prepare students to use engineering to participate critically, morally, and responsibly in social decision-making and problem-solving (Hodson, 2010; Kahn, 2015).

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> *...if sustainable environments, the worldwide eradication of poverty, and the elimination of political, economic, and social inequalities were actually the values and interests of the dominant groups, and not just what they claimed to believe important when caught in practices that deteriorated movement toward such goals, those threats to human flourishing would have been eliminated long ago...Particular kinds of societies are co-produced with the particular kinds of sciences they want: each enables and limits the other* (Harding, 2015, p. 37).

We are by no means suggesting that technological solutions to social problems are inconceivable; only that in order to engage technosciences such as engineering in real world problem-solving, students need to be prepared to conceive of engineering design challenges as a complex intersection of sociocultural, material, biological, political, economic, historical contexts--versus the technocratic, utilitarian, and neoliberal approach that has dominated engineering in the science curriculum. We recognize that the fields of engineering and engineering education have been working to better prepare engineers to be more accountable to their own imperative of "hold[ing] paramount the health, safety and welfare of the public" (National Society of Professional Engineers, 2007). To that end, they have released an engineering code of ethics (see https://www.nspe.org/resources/ethics/code-ethics). Nevertheless, this turn towards ethics has many problems in its own right. In the sections that follow, we first offer come cautions against turning towards ethics education as an approach to addressing the issues we have outlined. We then outline a dimension of caring that embraces an ethos of social empathy and care and could be incorporated into engineering in the K-12 curriculum to prepare students to solve problems in a more holistic and compassionate way.

The Turn to Ethics: Cautions to Consider

Efforts to address issues of ethics and social responsibility in engineering education at the postsecondary level have been growing, and have become increasingly supported through federal funding programs (e.g., the National Science Foundation program *Cultivating Cultures for Ethical STEM*). These interventions have been largely focused on better understanding of the factors that constrain or enhance engineering students' and professionals' ethical development and socially responsible practices. Many of these interventions have also explored how engineering students apply ethical decision-making models to complex dilemmas that engineers might face. These models are largely designed to help engineering students and professionals apply a sequence of logical steps to help them arrive at more informed ethical and professional decisions (Bero & Kuhlman, 2011; Fan, 2003).

While these recent interventions to bring ethics education into engineering represent considerable improvements, some of these efforts still embody the problematic technocratic and utilitarian principles we have described. First, the ethics standards for the profession as a whole focus primarily on the (neoliberal) ethical responsibilities of the engineer to the client and do not do enough to encompass larger ethical issues related to problems and solutions. Furthermore, engineering education largely still reflects a technocratic, utilitarian approach to social problem solving, whereby ethical engagement is peripheral to engineering education courses and often communicated as logic models, professional norms, or a set of universal guidelines to follow. Sunderland (2014) pointed out that most of the engineering ethics interventions and guidelines have been developed around issues of micro-ethics at play among individuals, such as sharing trade secrets, etc. She argued that engineering and engineering education must engage more with macro ethics at the societal level, with a focus on how engineers reflect on and evaluate their social responsibilities with regard to technological development.

Feminist engineering ethics scholar Donna Riley (2013) has pointed out that some interventions often rely on masculinist and utilitarian assumptions about the rational actor who can be prepared to follow a set of universal ethical guidelines in engineering design across a variety of contexts. Many of these recent ethics interventions fall short of addressing the complex power dynamics that characterize real world problems, largely overlooking issues of power and oppression, and infrequently accounting for contextual and relational aspects of decision-making. Riley argued for a more explicit appropriation of feminist ethics into engineering education, whereby engineers, as well as engineering students and engineering educators, are prepared to explore more critically issues of power, social context, relationships, epistemologies, communications, etc., and are provided with opportunities to engage as ethical actors in ill-defined and context-dependent ethically complex engineering problems.

For example, case studies are common curricular tools that have been developed to help engineering educators integrate a problem-based approach to thinking through ethical dilemmas in engineering fields. Case studies and associated teaching guides have become increasingly prevalent as tools that educators can use to engage students in ethical dilemmas in engineering.[1] One popular example is *Henry's Daughters*, a short film (and accompanying teaching and study guide) produced by the National Institute for Engineering Ethics (2010). In the film, Henry is a retired engineer and part-time lobbyist. He and his two daughters, Laura who works at the DOT, and Julie, who is an intern with a local engineering start-up company, are all involved in a joint highway design project "to develop specifications for smart highways and car control systems--so we won't drive anymore" (NPSE, 2018). During the film, they encounter ethical challenges related to micro-ethics such as sharing proprietary information, sexual harassment of colleagues in the workplace, offering special privileges to public officials when lobbying for a contract, as well as macro-ethics such as negotiating issues of privacy related to tracking vehicle location, etc. (NPSE, 2018; Smith, Herkert, & Nichols, 2010). While this case study may represent an improvement over former interventions that failed to address both micro- and macro-ethics and/or issues of power, and in which gender discrimination was virtually absent, it still--however unintentionally--reinforces gender stereotypes, and does little to address systemic bias or reframe the problem from an ethic of care (see Riley, 2013, for a more in-depth critique of the gender biases reinforced in the film and accompanying curricular materials).

[1] See Ethics Education Library. Illinois Institute of Technology (http://ethics.iit.edu/eelibrary/); IDEESE: International Dimensions of Ethics Education in Science & Engineering. University of Massachusetts-Amherst (http://www.umass.edu/sts/ethics/); National Center for Professional & Research Ethics. University of Illinois (https://nationalethicscenter.org/); Online Ethics Center. National Academy of Engineering (http://www.onlineethics.org/)

Taking up this same example of "smart highways" and "car control systems," JafariNaimi (2017) illuminates how we might move from utilitarian approaches for evaluating the ethical implications of new technologies toward "a genuine caring concern...that transcends false binary trade-offs and that recognizes the systemic biases and power structures that make certain groups more vulnerable than others" (p. 1). In particular, JafariNaimi took issue with the utilitarian and technocratic manner in which attention to ethics plays out in engineering design. In her critical analysis of a 2015 article in the *MIT Technology Review* titled, "Why Self-Driving Cars Must be Programmed to Kill," she argued that important ethical and political dimensions of self-driving cars as an ideal solution to vehicular deaths are hidden by utilitarian principles currently dominating conversations about ethics in these cases. She illustrated how *algorithmic morality,* or the question of how to design machines that can be programmed to act ethically, is becoming more common in the discourses around harm reduction and new technologies. In the case of self-driving cars, designers are confronted with the dilemma that while this emerging technology has the potential to reduce the overall number of people killed in vehicular accidents, it cannot eliminate all accidental vehicular deaths. In response, Bonnefon, Shariff, & Rahwan (2016) proposed that, since the success of self-driving cars rests largely with public acceptance of the risks that this technology presents, it would be prudent for designers to more systematically understand what moral principles the public might agree most with, in terms of issues such as whether or not people might be willing to purchase a car that is programmed to sacrifice or prioritize the lives of its passengers. Bonnefon et al. proposed using experimental ethics (i.e., the trolley problem[2], and variations of it) as a way to tease out "which moral

[2] The trolley problem is a common thought experiment used in ethics education and ethics studies. See https://en.wikipedia.org/wiki/Trolley_problem

algorithms would be more acceptable to the general public" (JafariNaimi, 2017, p. 3) through computerized surveys.

JafariNaimi pointed out multiple problems with this approach. First, its underlying ethos is utilitarianism, in that most people respond to the trolley problem in ways that are characteristic of a decontextualized and distant stance, generally choosing to save the greatest number of lives. JafariNaimi illustrated how most real life ethical dilemmas are far from straightforward; rather, they are organic, situated and relational, as well as broad and long ranging in effect. At the same time, she honored the ethic of care that underlies the public's concern with vehicular deaths, as well as the public's interest in reducing harm caused by vehicular accidents. Rather than pursuing an algorithmic morality that masks a utilitarian ethos and does not reflect the complexity of real life ethical dilemmas, she proposed that technoscientific problems and ethical dilemmas require thinking and acting with care. To do so in this particular situation would require a "radical rethinking of this design space" as well as "breaking free from the narrow framing that implies the adoption of self-driving cars as inevitable" and "restore the deep sense of uncertainty accompanied with this new technology" (p. 14). Secondly, she proposed that thinking with care would mean making visible the histories of transportation, how society came to be so reliant on cars in the first place, and how the astounding number of deaths that occur by vehicle-related accidents came to be accepted as status quo. She encouraged considerations of relations of power, particularly where the automotive industry has been concerned in terms of addressing these problems of mobility. How might society radically rethink mobility in ways that disrupt "car-centric visions"? (p. 15). Finally, she argued for thinking more broadly about the consequences of wholeheartedly adopting self-driving cars, including how public funds and public spaces might be invested, who benefits, who is most at risk of being harmed, etc.

JafariNaimi used this problem of self-driving cars to open a space for ethical inquiry in engineering and technoscience that is radically reoriented toward matters of care, rather than directed by neoliberal investments in "cutting edge" technologies.

We have tried to illustrate here how a turn to ethics can bring its own set of dilemmas. Puig de la Bellacasa (2010) argued that a "concern for ethics can indeed be seen as a form of hegemonic thinking that confirms a dominant tendency" (p. 153). She cautioned against a turning to the ethical in ways that (1) dilute the political, or (2) reduce the complexity of ethico-political decision-making or agencies. She argued further that in today's biopolitical world, the ethical "includes a range of elements, and doings, constantly reconfigured in the function of material conditions in specific situations" (p. 156). Bazzul (2017) also addressed this tension (of ethics or politics): "The problem is similar to a general tension that exists between politics and ethics: how can the better ways of living in relation with ourselves and others (ethos) become the foundation for politics as defined by the principle of equality" (p. 4). He argued that "[o]ur current historical moment demands that we provide as much justice-oriented agency to individuals as possible--even if this agency is very limited" (p.4-5). We argue that in order to enact "justice-oriented agency," students must first come to understand complex non-technocratic dimensions of socioscientific problems as well as learn what it means to engage both empathetically *and* politically within them.

Caring as Empathy and Material Doing: Power/(In)equality, Harm, and Ecological (In)stability in Engineering Practice

"*One can make oneself concerned, but 'to care' more strongly directs us toward a notion of material doing."* (p. 90, Puig de la Bellacasa, 2011).

Engineering as a field has been less attentive to preparing professionals who demonstrate caring and empathy than other professions seen as more inherently “caring” (e.g., social work, education, etc.) (Garibay, 2015; Nicholls, et al., 2007; Rasoal, Danielsson, & Jungert, 2012). In a study of 12,000 entering college students, Nicholls et al., 2007 found that entering STEM majors lacked, as compared to non-STEM majors, “the proclivity to influence social values and the political structure, or be a community leader” (p. 42). These findings are troubling for engineering education at all levels, given the socially and politically embedded nature of engineering projects. Even more concerning is that engineering education can have the effect of lowering students’ sense of social concern and agency. Cech (2014) found that engineering students’ public welfare concerns and commitments were significantly lower at the conclusion of their university engineering education vs. the beginning. She attributed this decline to a “culture of disengagement” in engineering education that tends to present non-technical concerns as irrelevant. Furthermore, this culture of disengagement can have the effect of alienating students who might otherwise demonstrate higher levels of social agency and humanitarian career interests (Garibay, 2015; Litchfield, 2014).

Sunderland (2014) showed how engineering students could be better prepared to reason with empathy through the complex dilemmas and problems that engineers seek to solve. In a course on engineering, ethics, and society, she shared how undergraduate engineering students engaged emotion to explore complex engineering problems through a problem-based learning approach. Valuing emotional engagement played a key role in helping students reason through issues of justice related to engineering. For example, some students were “bothered” and “upset” by working conditions at Apple factories in China, yet did not necessarily feel any sort of personal responsibility about those conditions, which were established in accordance with Chinese labor laws. Nevertheless, students’ emotional reactions served as a springboard into discussions of the (un)ethical nature of many laws and regulations. Sunderland highlighted how grappling with these sorts of dilemmas and problems must be fundamental to engineering and engineering education, given that engineers are often working in "unregulated areas like emerging technologies where the rules don't yet exist and guidelines are being imagined and established" (p. 189). These and other related efforts suggest that engineers need more opportunities to learn how to reason with empathy.

Power and (in)equality. Walther et al., 2017 cautioned that empathy must not become a morally neutral tool for enabling engineers to come across as warm and caring (i.e., a neoliberal approach to empathy). In their efforts to integrate empathy education in engineering education, Walther and colleagues made social empathy, defined as "the ability to understand people by perceiving or experiencing their life situations and as a result gain insight into structural inequalities or disparities" (p. 127, Segal, as cited in Walther et al.) central to their work. They argued that empathy education for engineers should promote both an increased understanding of social and economic inequalities and encourage tangible actions to effect positive change, with a focus on social and economic justice (Walther et al., 2017). We argue that developing social empathy is key to helping students understand and deconstruct contexts of power and inequality in classrooms, in the workplace, in the engineering design context, and in relationships between engineering and society. In particular, students must develop more in-depth understandings of the structural inequalities that play a role how the problem is defined and delimited, as well as what solutions might be beneficial, relevant, and accessible, to whom and for whom. Humanitarian approaches to engineering have incorporated many of these commitments but remain largely absent from engineering education and from the *Framework* or NGSS. Proponents of humanitarian approaches view engineering as serving humanitarian needs, such as creating infrastructure to support basic needs such as access to food, shelter, and healthcare, while evaluating systemic sociopolitical issues that create those needs in the first place (Haselkorn & Walton, 2009; Hess et al., 2012). Engineers without Borders is one example of a non-profit humanitarian engineering organization whose central mission is to help communities meet their basic human needs, by engaging in sustainable practices in partnership with communities *who request their services*. Whereas empathy is “a cognitive and affective process,” care involves “both feeling and actions” (p. 4, Hess et al., 2012). Feminist conceptions of care articulate care as a highly contextualized thinking *and* doing tool that can promote thinking and acting more *carefully* in science-technology-society issues—“a transformative ethos” more than an application of ethics (Puig de la Bellacasa, 2011). Fundamental to this conceptualization of care is “everything that we do to maintain, continue, and repair our ‘world’ so that we can live in it as well as possible” (p. 41, Fisher & Tronto, 1990). Puig de la Bellacasa also underscored the importance of contextualized caring practice, that considers the whole situation, including the perspectives and welfare of those most vulnerable and marginalized because “a way of caring over here could kill over there” (p. 100). In other words, even well intended humanitarian approaches could have harmful effects on local human or more-than-human communities if they fail to address humanitarian needs in ways that are responsive, responsible, and sustainable. For us, care must address politics of (in)equality. Drawing on care and ethico-political principles of equality (Bazzul, 2017), we are interested in how engineering in the science curriculum might prepare students not to follow a prescriptive set of ethical guidelines or standards, but rather equip them with “justice-oriented agency” in acting on sociotechnical problems and developing sustainable caring solutions.

Harm. Harm has been a subject of discussion and theorizing within the fields of medicine, public health, political science, economics, and criminology. We draw on recent conceptualizations of harm from science and technology studies to consider more critically how harm is inflicted by individuals, governments, and corporations, upon human and more-than-human individuals and communities, and manifests as emotional, physical, mental, and/or economic damage, injury, trauma, or pain (MacPhail, 2017; Ottinger, 2017; Ziskind & Ribak, 2017). Harm is an overlooked but integral consideration in engineering design. For instance, the field of medicine is full of examples of harmful engineered solutions to humanitarian problems. While many cancer treatments such as radiation and chemotherapies have shown positive results in terms of preventing or delaying cancer-related deaths, these treatments often have devastating side-effects on patients, severely impacting their quality of life and the lives of the caregivers. As another example, elaborate engineered systems have been developed to “care” for the elderly. Nevertheless, these systems, while transferring the burden of care from family members to trained professionals, often fail to attend to the full socio-emotional context of the affected person or their loved ones. Both of these examples are also examples of technocratic solutions that are often expensive, motivated by profit for healthcare and pharmaceutical corporations, and inaccessible to the majority of the world’s populations.

Ecological (in)stability. Engineering design projects, while often intended to serve human needs, often have as a consequence extremely deleterious impacts on ecological and more-than-human communities. As we mentioned previously, the design of a hydroelectric dam may solve an energy problem, but the consequent ecological impact of such interventions have often been enormous, with severe environmental and social justice implications for which initial cost-benefit analyses did not account. Due to the considerable negative and lasting impacts of human-induced climate change, industrialization, pollution, and mass extinctions, we have entered an epoch of ecological crisis that is commonly referred to as the Anthropocene. Ecojustice scholars have argued that this "ecological crisis is really a cultural crisis brought about by western industrial culture" (p. 14, Martusewicz, Lupinacci, & Schnakenburg, 2010). Caring in engineering education, therefore, should also reflect a commitment to principles of ecological restoration, sustainability, and stability. Fortunately, many students are becoming increasingly interested in sustainability issues, and engineering educators are beginning to try to leverage students' care for the ecological environment to help engage them in "care-ful" engineering design projects that address issues of sustainability (Michelfelder & Jones, 2016). In the next section we use a common high school engineering design problem to illustrate what a dimension of caring might look like in a high school engineering lesson.

A Dimension of Care: Reframing the Problem

We argue that adding a dimension of care to engineering in the K-12 science curriculum requires a radical reframing of the how the engineering design problem space is defined, which then informs what solutions are possible, and which of those solutions are just. Moving beyond the limitations of the *Framework* and NGSS requires attention to contextualizing and even re-contextualizing the problem space to transcend the ways that problems, constraints, and choices are often portrayed in technocratic, utilitarian, and neoliberal terms. It requires making sure that students have opportunities to understand the full socio-historical-politico context of the problems they are trying to solve and to consider the full range of possible constraints and implications of their designs. We claim that it is not sufficient for the authors of the *Framework* to pawn that responsibility off on the social, behavioral, and economic sciences (see pages 13-14 of the *Framework*). Rather, if preparing students to use engineering to solve real world problems is the goal, then a dimension of care that reframes engineering design in this way is needed. *It is* *notable that the core idea in engineering outlined in the Framework that illustrates the most potential for considerations of care and justice (ETS2: Links among engineering, science, and society) was not included in the NGSS.*

To illustrate the possibilities for applying an ethic of care within an engineering lesson that aligns with the NGSS disciplinary core ideas, we now look at an example engineering lesson from the NGSS on solar cookers. We chose this task, *Solar Cookers - High School Sample Classroom Task* (https://www.nextgenscience.org/sites/default/files/HS-PS-Physics-SolarCooker_version2.pdf) because of both its inclusion in the NGSS as an example of an engineering lesson, and its prevalence in K-12 engineering curriculum and instruction. As we have previously explained, caring as a practice of justice requires that students attend to important social and political contexts of the design space, and carefully consider issues of inequality and power, harm, and ecological stability as integral to defining and developing solutions to complex engineering design problems. The high school engineering standard this sample lesson proposes to address is *(HS-ETS1-3) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.* The lesson introduces the lesson with a connection to the fact that "people all over the world use electricity, gas, coal, and wood as a heating source" and that many people are experiencing "decreasing access to the natural resources required for use as a fuel…." The lesson uses this context of "decreasing access" to establish the need for alternative cooking methods, while also mentioning constraints related to cost, use, and availability of materials that may vary by geographic location. The problem of decreasing natural resources is merely mentioned as a background to the design challenge, with no explanation given regarding the sociopolitical issues that led to decreasing supply and/or inequitable access. Students' primary task in the lesson is to use a spreadsheet to test the effects of changes in variables on temperature, then build and revise an oven. This framing reduces a complex socio-political issue to a mere technical problem. Issues of power, inequality, ecological stability, and harm are nowhere to be found in the lesson. In the section that follows, we outline how the solar cookers lesson could incorporate a dimension of care, and derive from that example and our previous discussions of caring ethics and justice, and finally outline how the engineering standards could be rewritten to incorporate this dimension.

Solar cookers and care. Interestingly, the NGSS example lesson lists two sources from which the Solar Cooker task was inspired. One of these sources is taken from NASA and represents a technical approach to the solar oven design challenge, whereby students are asked to investigate whether or not we can cook on the moon before proceeding to develop and test their own solar ovens. The other source is a course paper from undergraduate students at Weslyan University (Fernandez-Burgos, Tracy-Wanck, Schmidt, Hastings, & Gorham, 2008), which represents a much more in-depth and caring framing of the problem. As part of a course on climate change, the students designed and tested three different types of solar cookers but also used them as a context for understanding climate change, its sociopolitical root causes, and how Americans using solar cookers could mitigate inequitable contributions to climate change brought on by overconsumption and overexploitation of Earth's resources:

> In harnessing solar energy for heating food and water, solar cookers take a small step in addressing many environmental inequities exacerbated by climate change and the power structures that facilitate resource abuse...In countries considered at the top of the "industrial food-chain," such as the United States, building and using solar cookers might

> be an initial step in reducing a learned and debilitating culture of disconnected dependence on external resources; a beginning to facilitating the major social changes that a reduction in greenhouse gas emissions will necessitate (Pollan 2008) (Fernandez-Burgos et al., 2008, p. 2).

What is notably caring about the Fernandez-Burgos et al. piece is the way they framed the problem, locating the relationships of power and environmental inequities brought on by climate change as “resource abuse” among those countries “at the top of the ‘industrial food chain.’” The students also integrated dimensions of care to speculate how using solar cookers can improve social conditions for women and economic conditions for communities reliant on firewood as a primary source of fuel:

> Not requiring firewood as fuel also often has huge social implications in developing countries where collecting firewood can mean long hours of work and can be very dangerous. It is not uncommon for women to be attacked when they venture further and further distances from their homes for firewood. In addition, the time normally spent by women and children collecting firewood is freed up by solar cooking, allowing for more potential to do other things with their day, possibly increasing the opportunity to attend schools (Sperber 1990)....Many families living on less than one dollar a day spend a third of it for cooking fuel. This cost often means less food to eat. Solar cookers typically reduce fuel needs by a third and pay for themselves in two months of fuel savings (Solar Cookers International). (Fernandez-Burgos et al., 2008, p. 28).

In Table 3, we outline how the Fernandez-Burgos et al. (2008) lesson integrates a dimension of care with core ideas in engineering (ETS1A, ETS1B, ETS1C) by explicitly addressing issues of power and inequality, harm, and ecological stability. By attending to these dimensions of care, the problem and proposed solutions become broader and more nuanced than what can be simply addressed through a reductionist technocratic approach. Indeed, "good problem-solving depends on good problem-framing, which typically means capturing both the technical and social aspects of the problem at hand" (p. 173, Michelfelder & Jones, 2016).

What we are arguing for is a more radical reframing of the problem, with attention to multiple dimensions of care, much in the same way that the student authors (Fernandez-Burgos et al., 2008) have included in the resource that inspired the NGSS example task. Embedded in and revisited throughout the design challenge, students could consider questions such as: Whom might the proposed solution help? Whom might it harm? What are the sociopolitical conditions that created the design problem in the first place? What are the sociopolitical conditions that deprive some people of access to electricity and allow others to consume without limits? Who "gets" to have clean air/water/energy? How do local politics--including energy and economic policies--prevent some people from access to affordable clean energy? What role might power and positionality play in how we are framing the problem (e.g., Whose problem is it and why do we think so)? Are women and/or minoritized groups such as low-income, queer, Indigenous, Black, Latinx, and/or Asians differently impacted or marginalized over dominant groups (e.g White, ruling class, male, etc.) by the problem and/or proposed solutions? What is the potential of the proposed solution for addressing politics of (in)equality? What is the potential of the proposed solution to either mitigate and/or further exacerbate ecological instability? How does the proposed solution equip engineering students and those they might seek to help with as much "justice-oriented agency as possible?"

Conclusion

Though recent efforts have been growing considerably among engineering educators and ethicists to better integrate dimensions of ethics, empathy, and care into engineering education, these themes are virtually nonexistent in *A Framework for K-12 Science Education* or NGSS. Following Rodriguez' (2015) call for a dimension of engagement, equity, and diversity in the NGSS, we propose that embedded in our understanding of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas should be a dimension of care. We argue that part of our work as science educators must include helping students better understand the underlying historical, social and political causes of problems, while considering issues of power that characterize technocratic problem-solving, and how to think and act more carefully to avoid harm, address inequalities, and address ecological (in)stability. What is needed is an approach to engineering and engineering education that centralizes "attention and worry for those who can be harmed...but whose voices are less valued, as are their concerns and need for care" (P. 92, Puig de la Bellacasa, 2011).

Our primary concern in this paper is that we have yet to see engineering education and engineering fields grapple with these ethico-political matters of care in ways that can be then articulated within a set of standards or K-12 classroom practices, yet we are now faced with translating a set of depoliticized engineering standards into science education and teacher education practice. We see this move as highly problematic, if not dangerous. We must provide students with opportunities to weigh and *take responsibility for* the REAL costs and benefits of their designs, not just the price of materials. Finally, we need to support students as they learn to engage an ethic of caring in applying science and engineering to their own lives. By highlighting one example from the Solar Cooker Task of how this could be achieved, we have provided a template to show how elements of material caring can be incorporated into lessons that still align with the engineering performance objectives present now in the *Framework* and NGSS.

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Table 1

Examples of NGSS Engineering Performance Expectations that Reflect Technocratic Perspectives

NGSS Code	Performance Expectation	Evidence of a Technocratic Perspective
K-2-ETS1-1.	Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.	Defines problems as any situation people want to change. Does not limit the types of problems that engineering can address.
3-5-ETS1-1.	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	Defines engineering problems as any situation that people need or want to change; criteria for success are reduced to materials, time, or cost.
HS-ETS1-1.	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	Suggests that all global challenges have engineering solutions. Societal needs and wants are design constraints rather than underlying causes that need social or political solutions too.
4-ESS3-2.	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.	Reflects a perspective that humans can control nature.
HS-LS2-7.	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	Reflects a belief in the salvation of the technological fix. Does not acknowledge that technological fixes have impacts as well.
HS-ESS3-2.	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	Emphasizes on cost-benefit ratios; focuses on exploitation of natural resources.

Table 2

Examples of NGSS Performance Expectations and Framework Grade Band Endpoints that Reflect Utilitarian Ethics

NGSS Code or Framework End Point	Performance Expectation	Evidence of Utilitarianism
ETS2.A (p. 211) 5th Grade	Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process.	Reflects the march of progress in new and improved technologies.
4-ESS3-2.	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.	Frames engineering as reducing human suffering
MS-ETS1-3.	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	Reflects the march of progress in new and improved technologies.
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	Trade-offs as collateral damage for progress. No guidance on who decides impacts or impacts on whom.
ETS2.B (p.213) 5th grade	Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), to decrease known risks (e.g., seatbelts in cars), and to meet societal demands (e.g., cell phones). When new technologies become available, they can bring about changes in the way people live and interact with one another.	Focus on positives and improvements in the march of progress.
ETS2.B (p.213) 8th grade	Technologies that are beneficial for a certain purpose may later be seen to have impacts (e.g., health-related, environmental) that were not foreseen.	Frames negative impacts as unanticipated and unforeseeable, relieving engineers of responsibility or obligation.

Table 3.

Alignment of dimensions of care with engineering disciplinary core ideas in the Solar Cooker Task from Fernandez-Burgos et al. (2008)

Dimension of care	ETS1A: Defining and delimiting the problem	ETS1B: Developing possible solutions	ETS1C: Optimizing the design solution
Power and Inequality	Industrialized countries are more responsible for climate change than non-industrialized countries	Solar cookers can increase children (and girls') access to education by decreasing the amount of time spent collecting firewood Solar cookers could potentially reduce gender violence among women who have to journey long distances to collect firewood Can be made cheaply and reduce low income families fuel expenses	Provisions for solar cookers to be affordable and accessible to low income communities
Harm	The effects of climate change do most harm to countries least responsible for it	Solar cookers can potentially decrease industrialized countries' reliance on fossil fuels for energy, reducing harm to human and more-than-human communities Reducing harm (e.g., lung disease) caused by proximity to inefficient stoves	
Ecological stability	Climate change due to the burning of fossil fuels has had negative effects on ecosystems around the world Burning wood for fuel contributes to deforestation	Solar cookers are more sustainable than wood or fossil-fuel powered cooking methods Can diminish CO_2 emissions by reducing use of fossil fuels for cooking	Ensure that solar cookers are used with the most sustainable, efficient materials that have the least environmental impact