Teaching the Non-neutral Engineer: Pathways Toward Addressing the Violence of Engineering in the Classroom

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Introduction

Engineering educators point to a persistent problem that positions the engineering profession in apolitical and neutral terms. We call this the "neutrality problem" and describe it as placing moral weight not on the work of engineers but instead the ad hoc uses of engineered artifacts. The problem appears in common assumptions that, for instance, guns are only as violent as their users intend them to be, absolving engineers of moral responsibility for the socio-technical outcomes that they helped to produce. The "neutrality problem" has a long history of being challenged by critically engaged engineering educators. Some challenge the problem by calling for "non-canonical engineering ethics canons,"[1] others advocate for a "peace paradigm" to be included in the Accreditation Board of Engineering and Technology (ABET) criteria,[2 3] and in the classroom they incorporate critical pedagogies to bear on macro-ethics, such as war and globalization.[4 5] Building on this literature we interviewed undergraduate engineering students about the neutrality problem, specifically in relationship to the issue of violence. Based on these interviews, we argue that more nuanced understandings of violence—as conceived of by activists and scholars—can help educators construct pathways for non-neutral engineering education.

This paper begins by defining the neutrality problem through a review of how liberal arts engineering educators have previously addressed it in the American Society for Engineering Education and by other critically minded engineering educators. Next, we build on this literature by inserting a question into the discussion: What do engineers need to know about the enactment and resistance of violence in engineering? Here we pay specific attention to defining the intersections of interpersonal violence (intentional violence between people) and structural violence (the violence of social structures and institutions). Finally, we use interview data from engineering undergraduates enrolled in Programs in Design and Innovation at the Rensselaer Polytechnic Institute to make suggestions for curricular reform.

Literature Review

In 2016, social scientists Diego Gambetta and Steffen Hertog published the controversial book, *Engineers of Jihad: The Curious Connection Between Violent Extremism and Education.* As the title suggests, the book probes why there is a sizable presence of people with engineering degrees in right-wing fundamentalist groups, most notably Jihadi terrorists but also neo-Nazis and white supremacists.[6] While the book offers compelling evidence to support a correlation between violent fundamentalism and engineering education, it is primarily concerned with drawing connections between the two based on the personality traits of individuals. This leaves the practices and curriculum of engineering education black-boxed: are people with personalities prone to fundamentalism attracted to engineering, or do engineering education programs actively foster sympathy for fundamentalist ideologies? By ignoring what engineering actually looks like in the classroom, Gambetta and Hertog provide little insight into how real-time education may actually reinforce violent and fundamentalist mindsets.[7] Missing from their understanding is literature on the neutrality problem in engineering education, which has long revealed how

curriculum and structure are entangled with violence. This literature is also normative, offering avenues to challenge the violence perpetuated by those with the stance that engineering work is and can achieve apolitical neutrality, a political position in and of itself.[8]

Dean Nieusma and Ethan Blue explain the historically violent origins of the term "engineer," as "one who operates siege engines—early technologies of warfare."[9] Tracing this to the present, they argue that "militarism and cultures of warfare" have shaped the relationships between industry (directly connected to war and not) and engineering education.[10] At one level engineering labor is designed to fit into existing power structures and organizational logics. David Noble explores the history of this fit in the U.S., tracing the curriculum and structure of engineering education to military and commercial interests.[11] While much has changed since then, the legacy of "command-and-control problem solving"—a system of military planning that restricts inquiry to strict causation—persists in engineering education today as the demarcations between the social and the technical.[12]

At another level, engineering epistemologies assume an apolitical and neutral stance that much of this history is beside the point of present day practices. Leyden et al. suggest that while many engineers assume that bias-free knowledge is possible by focusing on practices that promote "social cohesion" and "efficient, and interdependent functionality," this illusion of neutrality is only possible because these practices are already so commonplace in the disciplines.[13] Indeed, Donna Riley points out that creating a dichotomy between engineering and politics is based in a political stance that assumes it is possible to separate them in the first place.[14] Alternatively, literature in Science and Technology Studies (STS) reveals that knowledge production is always situated in socio-political contexts.[15] [16]

If we add the legacies of violence that persist in engineering education and industry, to the present-day illusion of neutrality it becomes clear that the disciplines of engineering provide little opportunity for practitioners to be reflective about their roles in perpetuating violence. Still, reflective research on the intersections of engineering/liberal education and engineering/sustainability appears to be growing.[17] [18] This research helps to support a vocal minority seeking alternative forms of engineering education that are not rooted in violence. Upon recognizing the long-standing role of engineers as "hired guns" for the military-industrial complex, these educators and researchers use frameworks of peace[19] and critical pedagogy[20] to propose reforms that help to realize the democratic possibilities of engineering.

The language of peace in these reform proposals prioritizes engineers' social responsibilities to the safety, health, and welfare of humans and the Earth over that of war and corporate profit.[21] [22] This approach includes everything from practical advice on career paths and how to decline working on ethically dubious projects, to more structural critiques of engineering firms' relationships to state violence. One of the most influential efforts to scale the language of peace into engineering education and profession is George Catalano's 2004 proposition to modify the ABET Criterion 3, which deals primarily with student learning outcomes such as "ability to design and conduct experiments" and "ability to communicate effectively."[23] Catalano suggests reorganizing this section so that the ethics of living in peace with others, the planet, and ourselves is brought to the forefront.

Donna Riley and Yanna Lambrinidou extend Catalano's peace paradigm into an ethical principle where engineers reflect on their professions' history with militarism and environmental destruction to ultimately resist historical repetition.[24] For example, Muscat et al. document how engineers are often positioned within "violent conflict situations arising from geopolitical disputes, rival claims over resources, unequal distribution of benefits and costs or power struggles."[25] Consider the US Army Corps of Engineers' role in the decision to save $100 million at the cost of canal wall failures that resulted in the massive flooding of New Orleans from hurricane Katrina;[26] or the Corps role in house demolition post-Katrina, despite community protest.

Critical pedagogies are also at the center of alternative engineering education.[27] [28] [29] Given the racialized legacies of structurally excluding African Americans from the engineering profession [30] and the long-standing struggles of women trying to enter the field,[31] Riley proposes the use of feminist and critical engineering pedagogies. These frameworks help address the need for all students to recognize the political and non-neutral nature of engineering, while also being responsive to the needs of women and minority students. Riley argues that engineering education should be student-centered and problem-based—traditions familiar to many PK-12 engineering educators—with an increased focus on diversity and accessibility that is based in racial justice and gender equity.[32]

This paper will contribute to educational efforts that use peace and critical pedagogies to challenge the neutrality problem. We believe that engineers and engineering educators will be able to deepen their engagement of the neutrality problem with students by drawing on more nuanced understandings of violence that are based in social justice perspectives. We will present a typology of violence, followed by a discussion of research methods and findings, and finally suggestions for integrating issues of violence into a college level interdisciplinary engineering and design program.

Analytic framework

Violence is, unfortunately, something all people understand at some fundamental level. At the interpersonal level, that is between identifiable actors in a discreet scenario, common-sense definitions of violence are accurate. It is obvious to most people that when one person inflicts physical pain on another outside of mutual consent by both parties, violence has occurred. Even harsh or intense verbal interactions can be considered violence, especially if such language has been known to cause psychological trauma. Violence immediately becomes more complicated when structures or even technologies are implicated in sustained violent acts. Indeed, the World Health Organization (WHO) defines violence as:

> The intentional use of physical force or power, threatened or actual, against oneself, another person, or against a group or community, that either results in or has a high likelihood of resulting in injury, death, psychological harm, maldevelopment or deprivation. [33]

The last two results of use of force or power, maldevelopment or deprivation, suggest that violence can occur over a long period, perhaps even being generational in nature or the result of

complex projects that hinder what would otherwise be an expected development. The diversion of a river that is the sole source of drinkable water for a community, for example, constitutes both deprivation and infliction of maldevelopment. In the U.S., We the People of Detroit characterize the continued water shutoffs in Detroit and the poisoning of Flint's water supply as intentional results of austerity to dismantle the wealth and assets of Michigan's African American communities. Following We the People of Detroit's fights against household water shutoffs, the United Nations accused the city of human rights violations.[34]

The neutrality problem intersects with concepts of violence when the construction and subsequent maintenance of engineering projects pose a threat—either direct and immediate or gradual and compounding— to individuals or groups. Violence need not always be as intentional or direct as it is in interpersonal interactions and can, in fact, be obscured by one's mundane work schedule. We contend that when engineers refuse to take an explicit position in such cases, or export concerns of violence to policy makers, elected officials, or managers, they are just as likely to perpetuate violence as prevent it. Not only does assuming a position of neutrality limit self-reflection on the part of the engineer, but it also places the engineer on the side of those who perpetuate it when no critique is offered up as resistance.

A Topology of Violence

Not all situations are as clearly violent as depriving people of their sole source of water. Therefore, what follows is a topology of violence that engineers may use to navigate the ethical situations that they find themselves in. This topology is not meant to be exhaustive nor will it act as a decision matrix for every situation. It is merely an introduction to a complicated topic that has been neglected by the profession for far too long.

Interpersonal

Our working definition of interpersonal violence is a modification of the WHO's definition of violence in general: The intentional use of physical force or power against another person that either results in or has a high likelihood of causing physical or psychological harm. As stated above, interpersonal violence is straightforward and recognizable. Punching someone in the face is violent. Violence can also take the form of psychological abuse that may or may not manifest in physical harm on bodies. It is important to note here that even the most straightforward and clear instances of interpersonal violence (like getting punched in the face) can be seated in and reinforce overarching structures of continued violence and technological development. Technological development, regardless of the intention of the designers, can amplify or increase the likelihood of interpersonal violence. Consider, for example, the adoption of TASER stun guns by police departments. The development of non-lethal weapons was meant to give officers the ability to subdue suspects without resorting to lethal means. However, a comprehensive study of police departments' adoption of stun guns shows a six-fold increase in in-custody deaths in the first year of use.[35] This case demonstrates that not only are direct interpersonal acts of violence embedded in larger structures of power (i.e. the relationship between police officers and minority civilians) but the intentions of engineers is not synonymous with engineering outcomes: the presence of stun guns has increased in-custody deaths, not decreased them.

Structural

George Catalano and Caroline Baillie go as far back as Dante Alighieri to build out their concept of *peace* that includes not only the absence of war or violence but also the active implementation of justice.[36] This is essentially what is needed to overcome structural violence. The concept of structural violence is largely attributed to the mathematician and sociologist Johan Galtung in his 1969 article in the *Journal of Peace Research,* "Violence, Peace, and Peace Research." There he argued that violence is structural in nature when it lacks the obvious subjects and objects of interpersonal violence. Galtung gives the following example, "in a society where life expectancy is twice as high in the upper as in the lower classes, violence is exercised even if there are no concrete actors one can point to directly attacking others, as when one person kills another."[37] The selection of projects, the choosing of which parts of any given project get "value engineered" out of the original plans, and the intended users of a technology can all contribute to structural violence.

Methods

To study how issues of engineering and violence might be taught to engineering students we interviewed five students in Programs in Design and Innovation (PDI) at the Rensselaer Polytechnic Institute. As graduate students in the STS department at RPI, we have co-instructed PDI courses and presented research on the program in the past. The STS department at RPI has a long-standing history and tradition of approaching research topics with a stated political partisanship from which one bases research design. Coming out of this tradition, we see engineering as, by default, not only inherently political but a fairly conservative discipline that we would like to move in a more progressive direction. Such a move is central to the PDI curriculum, which centers social justice concerns within a broader engineering program. As partisans we will be reading students' responses to our questions with an eye toward understanding structural violence as a phenomenon in and of itself and not merely the summation of individuals' behavior or will. In addition to our personal investments in PDI, we sought to interview students from the program because it is the first and still one of only a handful of undergraduate design programs housed within a social science department and coupled with standard engineering curricula. We interpret the inclusion of social science in the PDI curriculum as an opportunity sample to explore issues of engineering and violence, given that social justice and equity are already central to students' studio experiences.

While PDI is not officially an engineering program it is designed with the intent to couple with traditional engineering curricula and is posited as a model for engineering education reform.[38] PDI students' dual major in a STS program called Design, Innovation, and Society, and a technical degree, mostly the engineering disciplines but also computer science, communication, and others. According to Nieusma, PDI works at two educational levels. First, it is the "integration of technical, social, and formal analytic approaches."[39] This means that students are taught both the social analytics found in social science education and the technical analytics of engineering education. The second level is the "integration of analysis and creative synthesis."[40] Design problems are identified as complex, broken down to understand the different interacting components, and built back up to respond to those major components. The result of which is inquisitive, technically adept professionals who understand that their creations are also

arguments: physical instantiations that project a specific kind of politics. Students in this program frequently go on to choose professions in socially conscious organizations.

To recruit informants we reached out to students who previously enrolled in our PDI courses at RPI. Reaching out to students we already knew risked them telling us what we wanted to hear. But on the other hand this allowed us to leverage an existing rapport that provided what we believe are far richer responses than what we would have gotten from students we had no prior relationship. We used a modified snowball sampling method wherein we shared an incomplete draft of this paper—which only included a literature review and analytic framework—with a core group of students who then subsequently shared the paper with fellow students via a closed group on a popular social media platform. Five students agreed to participate and interview times were set up according to each of their schedules. The interviews were semi-structured and lasted between 25-50 minutes, much of which was audio recorded. Due to our limited sample size we do not mean for our findings to be generalizable to engineering curricula but instead aim to make specific recommendations for how PDI and programs like it might use the topic of violence to better educate non-neutral engineers.

The questions sought to gain insight into students' personal understandings of violence at the intersection of engineering and also where they thought this intersection might fit into the PDI curriculum. Our goal in questioning PDI students about violence was to, 1) understand how the PDI program currently prepares students to navigate the intersection of engineering and violence, 2) identify some limitations in the program based off of students' responses, and then 3) use students' responses to find intervention points to enhance the understanding of violence as both interpersonal and structural. Connecting steps two and three is an analytic framework that prioritizes understanding both interpersonal and structural violence as necessary topics for engineers.

A deductive method was used to analyze and group data around three areas of questioning: 1) Engineering and Neutrality, 2) Engineering and Violence, and 3) Curriculum Reform. We first listened to interviews while taking notes on students' responses regarding these three areas. We then discussed and compared responses to the questions in each area to gain a general sense of students' understandings about the relationship between violence and engineering, and where this relationship might fit into their educational experiences.

Findings

Before going into detail about the three question areas, it is important to point out that each of the interviewees expresses commitment to using their engineering and design skills in ways that contribute to social justice and an equitable society. This might not be representative of all students in PDI, but it certainly represents the general goals of PDI to make engineers more socially aware of their responsibilities in producing and reproducing power relationships in institutional contexts.

Each of the three question areas below was designed before interviews took place for specific reasons. The first section, Engineering and Neutrality, gages students' perceptions about the status of engineering as a non-neutral enterprise. Because we assume engineering is political

from the outset we describe and critique students' responses through a lens of how well they do or do not articulate non-neutrality. The next section, Engineering and Violence, also measures students' responses against our own partisan position that violence should be understood at interpersonal and structural levels, both of which engineering disciplines make significant contributions. The final section, Curriculum Reform, treats students as a specific type of PDI expert and uses their expertise to uncover points of intervention. We justify putting students in this position on two levels. First, unlike faculty who only teach a selection of PDI studio courses, students experience them all. This gives them important insight into the real time scaffolding of skills. Second, many students, during the course of their undergraduate careers, make judgments about what was effective and ineffective in the classroom, which may or may not align with the points of view of faculty. Given our positions as instructors, students' recommendations provide a way for us to balance our own goals and interests with these alternative classroom positions.

Engineering and Neutrality

The first area of questioning includes the topics of neutrality and politics in engineering. All students agree that engineering is a political, non-neutral enterprise. Furthermore, all students use definitions of politics beyond electoral systems to include issues of power at individual and structural levels. For example one student explains the political reasons for choosing engineering,

> I went into engineering from a political perspective… I wanted to do stuff to make the world better… You are definitely going to be making things that support a certain system. As a traffic engineer I almost explicitly, almost only always just learn about highways. And I am not really that interested in continuing to make highways a thing, I would much rather work in public transportation but I don't think you can even take public transportation classes as an undergrad.[41]

This student demonstrates a clear understanding that engineering is a political project and at the personal level this motivated entering one of the disciplines. The student also identifies engineering as political at a structural level of making infrastructure to support a certain type of system. Finally there is a combination of the personal and the structural when disagreeing with making highways, but the student has no opportunities for an alternative educational route that might be viewed as more sustainable and socially just.

The idea that engineering is political because it shapes the world where people live and interact is common among all five students, but they vary slightly about how and where politics become part of engineering activities. While three of the students (two juniors and a senior) appear to believe that engineering is inherently political at every level, two students (a sophomore and a senior) suggest that engineering only becomes political when a design is applied or implemented in a given context. A engineering sophomore makes the point clear by contrasting "pure science" with "applied science: "Engineering can be apolitical, but I think the fact that you have to implement it into the world makes it political. But most of the things that people create are used, which makes it… a vehicle for political uses."[42] Similarly, an engineering senior makes the point to contrast the difference between engineering being political verses apolitical as a matter of application: "Anytime you are engineering a new technology… I think it is at first a proprietary

enterprise and once it enters out of… a proprietary zone into the public eye… it immediately becomes political."[43]

In both cases, students reproduce the idea that the political, non-neutral aspects of engineering only occur once users become involved. This is the exact issue at the heart of the neutrality problem. It assumes the initial designers can be devoid of responsibility. However, one only needs to look at the designs behind military drones or mechanisms for financial speculation to see how technologies are created for the purposes of interpersonal (e.g. drone attacks) and structural (e.g. home foreclosures) violence.

Engineering and Violence

Given that all five students identify that engineering is, in one way or another, political, it is not surprising that they also all agree that engineering perpetuates violence. A senior engineering student explains the dilemmas some students face when finding jobs after graduation,

> There [are] all these military companies at RPI's career fair and yeah, my friend just took a job at Lockheed Martin. I know he was relieved when they told him that he wouldn't be working on any sort of like, directly on missiles, or directly on something that would be killing someone. But it's really funny how easily people shift responsibility away from themselves when they are indirectly causing violence… If you want a secure, stable job [as an engineer] its usually more than not, tied indirectly in some way with the military. Even if you are working at a company like ExxonMobile, it is all tied together."[44]

This student clearly identifies that working for the military-industrial complex can directly or indirectly contribute to violence. Even if the employee does not intentionally contribute to the design of violent technologies, all the students agree that the employee still might be implicated. This shows that these students generally understand how structural violence works through the engineering disciplines. Yet, when we ask them to define violence in a general sense, a disconnection emerges between how they think about violence generally and how they understand violence through engineering.

Three out of five of the students define violence interpersonally as actions based on individual intent. A senior engineering student explains,

> I would say violence is almost a disease of the mind because it's someone taking out a sort of emotion and negative energy on someone or something else. And, I compare it to a disease or an illness because I think that violence, at the human level, where it's with malicious intent, or just trying to get some sort of like feeling out, and its not something that, like part of getting your food or defending yourself, like the sort of violence where people will go after an innocent person, I think that sort of violence stems from someone who is not fully present. Basically someone who is stuck inside of their head and they are in a very vicious, negative thought pattern.[45]

Comparing violence to a disease does not necessitate a definition of violence based only at the individual level since the social model of health includes environmental, political, social,

economic, and other structural factors. But this student appears to be using a more traditional medical model of health that focuses on biological processes of normal or abnormal bodies. This is clearly articulated when the root of violence stems not from the context where action takes place but from a person's own thought patterns.

An engineering junior also defines violence as something done at the individual level by contrasting it with creativity,

> So when creativity comes at this utterly relaxed state and violence brings this incredibly tense state, I kind of see them as exact opposites. And, being creative brings happiness and renewable happiness that doesn't go away, you know, after the first couple hits... the result of a violent act is like the same to me as a hard drug, it's quick, it's not lasting, and it's not fulfilling.[46]

Here the student locates violence within his own and other's bodies as something to be consumed, like a drug. Given that creativity is often defined as an inherent individual quality, contrasting it in this way reinforces violence as a personal act. The dichotomy between creating and violence in engineering is not unique to this student. A senior engineering student explains,

> So I think that it is kind of weird in its history it was actually appropriated for violence all the time, but now when we think of it, we think of engineering as like a cornerstone of innovation and technology and, just of building and progress instead of destruction.[47]

Not all students agree with the notion that creation, creativity, and building the material world are devoid of violence. A junior engineering student explains that violence includes,

> Participating in a system, that like, continues to oppress people… I mean everyone is doing that, but like participating in a system that is going to continue to enforce wage inequality and keep certain people down and certain people up, that is violent. Participating in a system that is going to continue to put money into wars or money into capitalism, or all that stuff, it is pretty hard to avoid, but I'd say there are violent components to all those things.[48]

Unlike students who think about violence at the interpersonal level of creativity, this student, who identifies as politically aware and active, uses a definition more in line with structural violence. This conception does not create a dichotomy between productive engineering acts, such as building canals to increase the mobility of capital, and violence. Instead violence is framed as an inherent part of building, not only destroying, the material world.

Curriculum Reform

The majority of students articulate that engineering education does little to address violence and actually reproduces narrow mindsets. As an engineering junior states,

> Engineering is kind of viewed as just listen and do your homework and you'll be a good

> engineer… I think you kind of, sometimes find yourself in this corner where you are not asking questions about your leadership's decisions and you are not wondering whether or not the things you are designing and making are good for human beings, other than yourself and other than the organization you are working for.[49]

An engineering junior also articulates the notion that engineers learn to uncritically accept the status quo due to the structure of education itself,

> …the way that engineering is structured… by people, probably more or less intentionally, to produce a certain mindset, to produce cogs in machines that go out and work in existing structures and don't try to disrupt them. Like not just what we learn but how we learn it. The fact that you don't get to take any classes with less than seventy people until your junior year… last semester was the first semester I got to take classes that were interesting to me and that were small enough I felt like I could talk to my professor.[50]

Alternatively, PDI provides these students with studio experiences that encourage systems thinking in the context of developing professional identities that allow room for taking seriously sustainability and social justice in engineering and design. As one student put it, "It has had us understand the interconnectedness of society and the things that we do."[51]

While all students appear aware that the PDI curriculum is inflected with social scientific critiques of power and injustice, none of the students think that it explicitly or directly deals with the topics of interpersonal or structural violence. However, some suggest that they would not have been as sensitive or open to discussing the topics if not for the analytic skills they learn as PDI students: "I think [violence] is something we talk about but just… not directly… I don't think any one has said engineering is a violent discipline and we are trying to subvert that."[52] Still, each student suggests ideas about where the topic can best fit into the six-studio curriculum.

The youngest student in our study, a sophomore, makes the suggestion that the topic of violence can be introduced during the first year of PDI: "So, like the later we get, I think people get more fixed in how we have our own styles of being designers. So definitely the first year, there would have to be an intervention there."[53] Similarly, a senior and a junior argue that the topic of engineering and violence may be a way to "plant the seed" early on to promote "critical thinking" in PDI more broadly. Students also think it may fit in the later PDI studio courses, most notably Studio VI, which focuses on organizational design. A junior in Studio VI at the time of this study explains, "The prison-complex is an organization and organizations and their design can affect interpersonal relationships and also structural broad affects."[54]

While the studio courses are the core of the PDI curriculum, students also suggest it would fit into supplemental STS courses, including Design, Culture, and Society that is often taught by the prominent philosopher of technology, Langdon Winner. Interestingly enough, when they describe how engineering and politics intersect, multiple students cited Winner's famous case study of the Long Island parkways in New York that are too low for public buses to go under, limiting the access of people who use public transportation to certain areas of the city.[55]

Unexpectedly, two students make the point that engineering and violence might fit into traditional engineering curricula. A senior student explains how the topic might fit into curricular units on safety,

> It might fit back into safety, kind of like a subtopic within there. But I feel that the topic of violence has never been specifically addressed even though I have talked about safety since day one as an engineer… the code of ethics for engineering is the safety of all citizens is paramount.[56]

While this student speculates on how the topic of violence might be generalized across engineering curricula, another stresses that it will only be able to fit into engineering courses that are interdisciplinary, most notably structural and transportation engineering.

It is clear that students vary on how they think the topics of violence might fit into their educational experiences. Despite these variations, each engages with the idea that violence is a legitimate and important topic for students to study and know about in the context of engineering. What is more, each willingly grapples with their personal understandings of violence in and out of engineering education, suggesting it is relevant beyond their specific disciplinary focus. In the next section we will discuss our findings to make recommendations for innovating the PDI curriculum.

Discussion

For the purposes of curricular innovation the data above provides a beginning road map for addressing how PDI might include topics of violence in its curriculum. The three areas of questioning will help us make recommendations for framing how violence can address the neutrality problem in the context of PDI.

From these interviews, it is clear that while it is much less of an issue in PDI than one would expect to find in traditional engineering programs, the neutrality problem persists. The problem is seen in students' responses that restrict the politics of engineering to public application and use, assuming the design process is apolitical. However, all the students, even those who maintain the possibility of engineering being neutral, were adamant that their decisions as engineers and designers have social and political consequences. This suggests that students are open to a view of engineering as an inherently political and non-neutral enterprise but do not necessarily have the analytic tools to make judgments about politics in the early stages of engineering design. The question being: how might the PDI curriculum help students engage with the politics of designing hellfire missiles or nuclear weapons "upstream?" Upstream engagement can be thought of as "compressed foresight," where risks and uncertainties are presented early on in technology research and development.[57]

One possible way to address the need for upstream engagement in PDI is to include the topic of structural violence as an intended or unintended aspect of design processes. Galtung's description of structural violence above—violence that lacks a subject or object of interpersonal violence—can be used to challenge the neutrality problem in PDI on three levels: analyses, frameworks, and practical tactics.

At the first level, students will need to draw greater distinctions between structural and interpersonal violence. Students are currently aware of structural violence, especially when discussing the intersection of engineering and violence, but lack the analytic tools to consider violence outside of an interpersonal framework. Reading, discussing, and doing studio work that challenges students to deliberately think in terms of agency and structure will encourage them to think outside individual intention and other aspects of the neutrality problem.

At a second level, a clear understanding of structural violence will politicize upstream engagement by providing students with a framework for critical self-examination of the assigned projects, commonly used materials, and other factors that go into methodological assumptions about problem solving in design and engineering. The use of historical examples of the decision-making that went into designing infrastructure (e.g. the levees in pre-Katrina New Orleans) or products (e.g. Volkswagen's modification of software used to test carbon emissions on its vehicles) will help students see how violence begins upstream and the importance of thinking about the design process as non-neutral.

Finally, at a third level, PDI and programs like it must make the difficult and reflexive move to think structurally about their own role in producing engineers. As one of our respondents clearly argues, engineering students have very few options when it comes to selling their labor to non-military organizations. These sorts of odds can encourage a kind of fatalism that, as the student observed, encourages people to actively "shift responsibility away from themselves when they are indirectly causing violence." Given Gambetta and Hertog's conclusions that engineering correlates with reactionary personalities, one must also at least entertain the notion that left-of-center ideas and ideologies will need buffering and protecting at an engineering school.

We think that there are a number of entry points for the topic of engineering and violence in the PDI curriculum. While we agree with those students who suggest that the topic will fit well into social science courses that are not project-based, such as Design, Culture and Society, we also believe that to take engineering violence seriously students must begin thinking about it during design projects and activities.

The last of the required studio courses, PDI VI, is a good fit due to its focus on organizational design. For the 2017 iteration of the course, students study how organizations—from democratic workplaces to the prison-industrial complex—exercise varying levels of power. Including violence as part of this power dynamic is a promising point of entry because it supports the PDI goal of showing how engineering and society are interconnected. Yet, restricting the topic to the last required course reinforces the notion that product design is neutral and politics only pertains to design that intersects with specific public interests or organizations.

To truly confront the neutrality problem it will be helpful to begin the discussion of engineering violence as early as possible. Building upon the core PDI II goal to develop skills of stakeholder analysis, the topic of violence can be included to widen the analytic frame, include those who are structurally impacted by environmental injustices of material manufacturing, for example, and uncover the layers of influences designers and engineers have on culture and society. It may even be necessary to shift from a stakeholder model—wherein students are asked to think of

stakeholders which are individuals, albeit usually described in terms of their relationship to groups—to something that forefronts structural analysis.

Conclusion

In this paper, we argue that engineering pedagogy will benefit greatly from deep engagement with theories of violence, both how it works and what role it plays in fundamental engineering design. By making engineers fluent in both interpersonal and structural violence, institutions of higher learning will make a significant impact in a wide range of topics that dominate the news. From ecological disasters to humanitarian crises, engineers, whether they acknowledge it or not, are complicit in both the strident advances and tragic failures of governments and private organizations.

We will conclude with a cautionary note taken from late 2016 headlines. Facebook's executive leadership, in the wake of the 2016 American presidential election, refused to acknowledge its role in spreading misleading or outright false news stories to the public.[58] This is in stark contrast to 2011 when it proudly proclaimed (along with Twitter and other social media companies) that it had been integral to grassroots regime change in the Middle East. This doublethink points to something worse than the neutrality problem: a world where engineers selectively think of their work as inherently politically neutral. It should no longer be acceptable that engineers take credit for successes but brush off negative consequences to political actors. Engineering—because it automates, eases, or otherwise augments social action—is a political discipline and must act as such. Engineers, whether they build bridges or databases, must have the analytical skills to navigate the complex political controversies they are implicated in. Anything less is an abdication of responsibility by their forbearers.

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