Localized Solutions to Incorporating Broader Impacts into First-Year Engineering Education

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***Abstract*— This Innovative Practice Work in Progress explores that, despite calls across a range of organizations for educational experiences that help students understand the broader impacts of engineering work, engineering faculty still frequently struggle with how to help students develop this understanding. Literature offers a number of insights, practices, and approaches to what broader impacts means, but faculty are often not prepared to teach in this domain. To that end, the authors are in the process of developing a workshop for faculty at their home institution that addresses local needs and concerns. While the workshop is still in development, the process itself has raised a number of challenges associated with understanding faculty beliefs and experiences, working within local constraints and expectations, and aligning with institutional culture. Because these issues can vary by institution, workshops to support faculty development are not, we argue, a one-size-fits-all option that easily ports from one institution to another. Thus, in this work in progress, we document the process of translating existing research and teaching materials on broader impacts and social responsibility into meaningful, contextualized faculty development at the local level. Using auto-ethnography, we highlight salient features of our experiences that can help guide similar efforts at other institutions. In addition, we will have delivered and assessed the workshop by the time of conference and will share findings on the effectiveness and impact of the workshop in our presentation.**

Keywords— faculty development, first year programs, social justice, broader impacts, holistic issues, case studies

I. Introduction

With changes coming to the ABET accreditation criteria in 2019-2020, faculty need new ways to incorporate broader impacts into their courses. In particular, Criterion 3 Outcome 4 encompasses a constellation of issues that had previously been treated as discreet in the ECE2000 criteria:

> An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts [1].

Despite numerous calls for the type of integrated education needed to meet this criterion, engineering faculty still frequently struggle with how to help students develop this understanding. Literature offers a number of insights, practices, and approaches to what broader impacts mean, but faculty are often not prepared to teach in this domain. To that end, the authors are in the process of developing a workshop for faculty at their home institution that addresses local needs and concerns.

The impact of this paper is two-pronged. First, we highlight the need to educate engineers in ways that enable them to recognize the ethical, global, economic, environmental, and social impacts of their designs and briefly note available resources to achieve this goal. Second, we describe the process of localizing the existing research and literature to develop a faculty workshop relevant to our institution. This localization is key to bridging the gap between research and practice, which Henderson and Dancy concluded was the "biggest barrier to improving undergraduate STEM education" [2]. Further, Finelli, Daly & Richardson emphasize the importance of leveraging local evidence in creating organizational change and instructional development [3].

In this work in progress, we focuses on the salient steps and decisions needed to localized and adapt existing literature on incorporating broader impacts and social justice into engineering education. The resulting workshop, which will introduce a bank of case studies and associated teaching materials, will be offered in Fall 2018. By the time of the conference, we will be able to report results and reflections from the workshop.

II. Literature Review

Engineers possess an incredible power to disrupt existing systems that perpetuate inequalities. However, engineering education curricula do not always emphasize this power, so engineers do not always understand the broader impacts of the systems they design [4]. This lack of emphasis is in direct juxtaposition to both the EC2000 and the pending revision to ABET accreditation criteria, both of which incorporate the need to understand the impact of their work in "global, economic, environmental, and societal" contexts [1, 5]. This lack of emphasis also clashes with *The Engineer of 2020*

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report, which emphasizes how engineers must understand that technological innovations are shaped by social, cultural, political and economic forces [6].

Despite these and similar national calls for graduating engineers to understand the social implications of their work, such understanding is largely missing from engineering courses [7, 8]. To understand why this "social" content is largely missing from technical courses, we turn to literature on the ideologies underpinning engineering education. Here we use *social* as an umbrella term that blends definitions from Cech [9] and Faulkner [10] to capture social considerations that exist outside of technical engineering content including social justice, equity, access, privacy, empathy, and ethics. In Cech's work, such concerns fall under the broad umbrella of "public welfare" that professional engineering codes hold "paramount," but that may be largely absent from professional engineering work or education [9]. Cech argues that this social content is often left out of technical engineering courses due to what Cech calls the *culture of disengagement*, which "defines public welfare concerns as tangential to what it means to practice engineering" [9, p. 45]. This culture is the result of

> "a constellation of beliefs, meanings, and practices that frame the way profession members conceptualize their professional responsibility to the public" [9, p. 47].

Cech focuses on how this culture is developed in engineering programs through three ideological pillars: depoliticization, technical/social dualism, and meritocracy [9]. The first two are most relevant to this discussion. *Depoliticization* frames non-technical aspects of engineering (including those related to social justice and public welfare) as tangential to *real* engineering [9], whereas *technical/social dualism* not only separates the technical and social dimensions, but consistently values the technical over the social [9] – separate and unequal. In fact, the inherent social aspects of engineering are often devalued to the point that they are rendered invisible in technical engineering courses [11]. With underlying ideologies that frame the technical and social aspects of engineering as separate and unequal, it is unsurprising that topics that fall into the social realm are excluded from courses that live in the technical realm [7].

One common approach to bringing social concerns into engineering is through the use of elective courses that students take from Humanities and Social Sciences departments – a division based on the perspective that suggests such material does not "belong" in technical courses. However, when social justice is taught in humanities courses, the links to technical engineering are often marginalized, and the links to the social remain invisible in engineering courses [8, 11]. In other words, while students develop an understanding of social justice in humanities courses, the connections between social justice and engineering are obscured [8, 11]. As a result, students can walk away believing that social justice and engineering are two independent topics that do not intersect. Thus, including social considerations in humanities electives does not effectively enable students to understand the impact of their work in "global, economic, environmental, and societal" contexts, as required by ABET criteria, particularly when those concerns are not equally evidenced in the technical courses that dominate current curricula.

Yet this embedded, integrated understanding is precisely what ABET and other organizations demand. Engineers must understand and value the implications of their designs. When engineering students and professionals perceive the technical parts of their job to be *real* engineering and the social parts to be external or "other," they are less likely to consider the social implications of their work [9, p. 48]. The culture of disengagement is such that students and professionals are not purposefully ignoring social considerations, but rather those considerations are defined out of engineering problems [9]. As engineers move into their professional practice, their lack of consideration of the social aspects of engineering can lead them to design technologies and systems that may be "technically" sounds (i.e. the math is correct) but that perpetuate inequalities and evoke a myriad of problematic unintended consequences [9]. This perpetuation is supported by individual case studies that highlight the biases and systematic inequalities that can be perpetuated when engineers and scientists do not believe social justice is in their job description [12, 13, 14].

Work by scholars such as Cech, Riley, Faulkner, Leydens, Lucena, and other strongly demonstrates that social considerations must be incorporated into technical engineering courses [7, 8, 9, 10]. However, such integration rests on faculty who have the desire, know-how, and resources to achieve it. Studies have found that engineering programs and faculty often resist curricular and pedagogical changes [15, 16, 17]. One study identified a lack of training, time, and incentives as well as tensions with professional identity as reasons faculty resist change [15]. Implementing change at the local level, research suggests [3], requires careful attention to local context. Like any good design, sustained large-scale educational transformation requires careful analysis of needs, stakeholders, and contexts. Few educational approaches magically transfer wholesale from research to practice. As a result, in this paper we describe the process of localizing research on educating students to better understand and consider the broader impacts of their work.

III. Methods

Our goal, as noted, was to localize research on educating engineers for social justice to develop locally relevant resources for faculty in our institution. To document this process, we draw on autoethnography as a method. This methodological choice is itself important: because our work focused, in the end, on developing resources for our own department, we were concerned about using data from colleagues with whom we interact daily as the basis for our own research publications. This concern was exacerbated by the politics of power, in which the lead author is a new graduate student in our program and the second author is one of a very small number of full professors – we are thus, arguably, among the least and most powerful people in our unit, which includes faculty across a range of instructional ranks (including multiple non-tenure track positions) as well as

graduate teaching assistants. The issue here is itself tied to the social implications of engineering work – and in this case, engineering education work specifically. Thus rather than analyzing the information we obtained from our colleagues as "data" to identify barriers and needs, we opted for an autoethnographic approach that made us the subjects of research. Our focus here is thus on the process of developing the workshop. We both kept meeting notes throughout the project, and the lead author kept a journal. Thus the researchers documented the process of reviewing the literature, localizing the findings, and developing locally relevant resources. Both the process and the researchers' reflections are well-documented. We acknowledge this is a limited autoethnography and encourage the reader to focus on the contributions in terms of localization.

IV. Results and Discussion

We organize our discussion of the localization process along three major categories: processes, decision points, and challenges.

A. Processes

Several steps were crucial in our localization process. While some steps are obvious, others – such as consulting experts – may not always be apparent. And even within the obvious steps, we took particular care to approach the work from a broader perspective and explore multiple options and approaches in each step.

Identifying Local Needs: When we began the project, our goals for faculty development were loosely centered on inclusion, diversity, and social justice. As a result, our first step was to review existing efforts at our institution and identify areas of critical need. Because the university currently has a number of efforts underway to support inclusive approaches to teaching, but little work to help faculty address issues of social justice, we focused in on the social justice dimension as the area of greatest need. This choice was further supported by the pending changes to the ABET accreditation criteria, which also helped us focus on local needs as the driving force for change.

Reviewing the literature. Not surprisingly, once we had narrowed the focus, we began with a review of existing approaches to incorporating broader impacts and social justice into engineering. In conducting this search, we found it important to search widely under a variety of terms (social justice, broader impact, engineering ethics, etc.). We also approached the literature review from multiple directions, using not only Google Scholar and databases such as Engineering Village, but also searching specifically through the ASEE PEER database for salient conference papers in recent years. A list of references from the literature review is included beside "References".

Talking with Experts. In addition to reviewing the literature, we contacted two experts – one person who had developed and delivered workshops on social justice in engineering and one who had developed and delivered workshops on change leadership in engineering education. Video calls with these experts helped us put the literature we were reading in context, recognize potential challenges and opportunities, and identify change strategies. Most notably, the social justice in engineering expert described that the term "social justice" can itself be a barrier because it invokes politically charged reactions that may alienate some workshop attendees. Hearing the dangers of marrying our project and workshop to the term "social justice" guided our subsequent decisions. The change leadership expert shared the best way to approach change is to find a way to create a shared vision with stakeholders, which led us to the next step of talking with local stakeholders.

Talking With Local Stakeholders. In light of our findings from both the literature and the experts, we then identified and interviewed local stakeholders, including faculty and graduate students who are currently or have in the past taught one or both of the first-year engineering program (FYP) courses. Interviews were done on a volunteer basis. After the interviews were completed, we held two focus groups: one with the academic advisors who work with and advise the first-year engineering students, and one with the current FYP course instructors. This approach helped us understand both faculty and student needs from a multi-dimensional perspective, since the advising team at our institution is actively engaged in developing resources to help students transition from high school to college, select an engineering major, and identify meaningful co-curricular activities.

We used the interviews and focus groups to explore how the concepts identified in the literature review could transfer to our local context, including what language was most salient. Author 1 presented to the participant a list of terms found in literature that are used to discuss the idea of social justice in engineering, including: social responsibility, social justice, ethics, broader impacts, and an awareness of the social and environmental effects of engineering designs. Participants were asked to define each term and identify which term fit best in the context of the institution's branding of engineering. In the FYP course instructor focus group, our questions were designed to determine what resources faculty would find valuable to help them better incorporate holistic issues throughout their course. In considering not only the feedback from our colleagues but also the broader needs of the program, we recognized the need to develop tangible, localized teaching materials that would enable faculty to engage first-year students in conversations about unintended consequences of those designs. We used the ideas generated in this focus group to guide the next step of our localization process.

B. Decisions

Three decision were crucial in our localization efforts.

Choice of Language. Our first concern was with choice of language. As noted above, in the course of our reading of the literature as well as our conversations with experts, we became increasingly concerned with the polarizing potential of the term "social justice," particularly in the current climate. The concerns were not centered on wanting to hide from or avoid difficult conversations, but rather emerged from a desire to be able to find common ground among faculty at our

university that would enable productive conversations among an engaged group of educators. Thus, "what words should we use?" became an important question for localization.

In searching for productive language, we considered terms such as "global competency," "social responsibility," "broader impacts" and "holistic engineering." Drawing on the interviews in particular, as well as the current language used in course goals and learning objectives, we found that the terms holistic issues and broader impacts most resonated with interview participants. Holistic issues is currently a part of the course jargon, and broader impacts is a familiar term because of its connection to ABET Student Outcomes as well as its use in National Science Foundation proposals. Paying careful attention to language here has helped us further link our work to the local culture in ways that will hopefully make the workshop useful, accessible, and desirable. Nonetheless, we remain concerned that language may continue to create a barrier, and more broadly, that participants may struggle to understand the relevance of these issue to engineering courses.

Choice of Context: We also had to consider a specific context for the workshop. Would it be a general workshop for all faculty in the college? For faculty at a particular point (e.g. professional development courses offered by many departments in the sophomore year)? Because we wanted to create a workshop for those who would be invested in using the materials, but also select a site where we might achieve sustained impact, we selected the first-year engineering program (FYP) in our department. We also selected the FYP because of its size - all first-year engineering students move through the FYP - and its explicit learning outcomes – students are expected to "articulate holistic issues that impact engineering solutions," an outcome that dovetailed with our interests in the social implications of engineering work. This choice also helped us identify language that we could then use to frame the workshop we sought to create.

C. Challenges

We face three main challenges as we implement the case studies activity into our local context with local stakeholders. First, the FYP course targeted is two credits with multiple learning outcomes; historically the department has struggled to "cover" all the required content within the 2-credit scope. While "holistic issues" is a required outcome, it can receive more limited coverage due to time constraints. We thus need to provide materials and strategies in ways that support sustained integration.

Second, our approach uses case studies, but these risk compartmentalizing the concepts inherent in a social justice approach to engineering and work against our desire to emphasize the interconnectedness of the technical and social dimensions of engineering work.

Finally, course personnel include instructors with a wide range of expertise, including some who have taught the course for more than 20 years and some who are new to teaching. Crafting a workshop that can effectively meet the needs of such a diverse group of learners will require integrating a range of strategies to full engage the participants, leverage the existing experience, and scaffold new faculty appropriately.

V. Next Steps and Conclusion

The results of this process led us to a strong understanding of how the FYP community currently viewed broader impacts and we had direction for creating tangible resources to help instructors better incorporate broader impacts throughout their course. Because the department is also simultaneously engaged in the process of generating an electronic repository of materials to support other learning outcomes in the course, we decided to create a bank of case studies and supporting teaching material that could be used as warm-ups in class (see Table 1). The cases were selected based on their accessibility to both first-year engineering students and faculty with diverse disciplinary backgrounds, given that the FYP sits within a general engineering program and supports students in choosing from over a dozen different engineering majors. Each case study relates to emergent technology and examines the unintended consequences of that technology. Some case studies are older, allowing students to tangibly see the unintended consequences of the technology. Other case studies refer to emergent technologies, inviting students to consider the implications of artificial intelligence, colonizing Mars, and more. In addition, some case studies are text-based and others are video-based. In theory, instructors could assign the reading or video as a pre-class assignment and can then lead a classroom discussion about the topic as a warm-up in the beginning of class. Instructor guides are provided for each case study.

The next step of this project is to pilot the case study resources with FYP instructors. We will host a pilot session with instructors to introduce them to the case study resource bank, walk them through a handful of examples, and hear their feedback. The feedback they provide will then be used to design the final bank of case studies. Finally, we will host a workshop with all FYP instructors prior to the start of the fall semester to familiarize the instructors with the bank of case studies and to engage in one example case study as a group. Ideally, the case study model will be incorporated into FYP courses next fall.

TABLE I. Summary of Case Studies Developed to Date

Title	Link/Reference
1. Walking on Water 2. Safety Bicycles 3. Bypassing the Airport Crowds	Graham, S. & Marvin S. (2001). *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition*. New York, NY: Routledge.
4. Sofia Bot	https://www.youtube.com/watch?v=dMrX08PxUNY
5. Unintended Consequences	https://www.ted.com/talks/chuck_nice_a_funny_look_at_the_unintended_consequences_of_technology/up-next
6. Living on Mars (2 parts)	Part 1: https://www.ted.com/talks/stephen_petranek_your_kids_might_live_on_mars_here_s_how_they_ll_survive#t-66183 Part 2: https://www.ted.com/talks/lucianne_walkowicz_let_s_not_use_mars_as_a_backup_planet
7. Bias in Artificial Intelligence	https://www.ted.com/talks/margaret_mitchell_how_we_can_build_ai_to_help_humans_not_hurt_us/

8.	How We Can Build AI to Help Us Not Hurt Us	https://www.ted.com/talks/margaret_mitchell_how_we_can_build_ai_to_help_humans_not_hurt_us/
9.	Self-Driving Car Kills Pedestrian	https://www.wired.com/story/lose-lose-ethics-self-driving-public/

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