Challenging the Hegemonic Culture of Engineering: Curricular and Co-Curricular Methodologies

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Introduction

With over 40-million people living at or below the federal poverty line while more billionaires are created daily, police budgets swell, an eviction crisis looms, and climate change rapidly accelerates, the depth and breadth of the connections of technological advancement to mutually reinforcing systems of oppression in the United States have prompted a need to re-examine engineering education [1]-[5]. Given this dire state, it is critical that the engineering community grapples with the role engineers play in perpetuating fatal couplings of power and difference and the steps that can be taken to disrupt the systems and cycles of violence from which these inequitable couplings stem [6]. As Winner [7] noted, engineers engage in tasks that embed power relations into the technologies they produce and structure the built environment. Engineers create automated systems that put laborers out of jobs, develop transportation systems that tear through low-income urban neighborhoods, design and operate toxic waste facilities that are built in low-income and predominantly Black communities, and rely on infrastructural access to Indigenous Land for the advancement of settler futures [8]-[11]. Rather than re-entrenching inequity, engineers could play an alternative liberatory role if they entered the profession with skills in recognizing and undoing oppression. This shift could be supported through engineering education that fosters *conscientização*, which Paulo Freire defined as the process of "learning to perceive social, political, and economic contradictions, and to take action against the oppressive elements of reality" [12, p. 38]. Expanding on Freire's idea of conscientização, Mejia et al. [13] explain that one develops *critical consciousness* when they understand theories of change, take action, and engage in reflection that aims to liberate oppressed groups. Therefore, we argue that it is critical for engineering education to promote critical consciousness and "change aspects of both the forces and the relations of knowledge production" [6, p. 22] within engineering. One aspect hindering such life-affirming critical consciousness development is the promotion of neutrality and technicality as cultural norms of the discipline [14]. Engineering education perpetuates the unsubstantiated claim that engineering is a politically neutral and objective profession [15]-[18] rather than preparing students to wield the power inscribed in their work.

Along with the false narrative of neutrality and technicality, the culture of undergraduate engineering programs perpetuates an uncritical belief in meritocracy [16]-[18], which creates an oppressive environment for historically underrepresented engineering students and impedes diversity, equity, and inclusion (DEI) efforts [16], [19]-[20]. Secules [19] has highlighted the ways that meritocratic culture in engineering education creates circumstances that marginalize students. Similar to the ways that social systems are often presumed to be fair, a classroom interaction or educational system is often presumed fair and constructed as a competition (common in engineering). The norm of competition and meritocracy construct and perpetuate harmful notions of rigor [21]. In engineering culture, many come to believe that achievements are the result of a well-functioning meritocracy [17] and that DEI initiatives focused on harm reduction would undermine that worldview [22]. Seron et al. [22] identify this way of thinking as a *perceived diversity-quality trade-off*, and they explain that students who take on this meritocratic perspective of engineering view DEI initiatives "as tantamount to opening

professional membership to the unqualified as well as potentially reverse-discrimination (in the context of finite engineering jobs and engineering school enrollment capacity)" [22, p. 157].

Purpose

By functioning on the basis of purportedly meritocratic systems and politically neutral values, U.S.-based engineering education continues to exhibit a hegemonic culture that centers settler-colonial, white supremacist, patriarchal, cis-hetero normative, and capitalist logics [16], [19]-[20], which severely hinder strides toward equity and liberative praxis in engineering education and within U.S. society as a whole. As such, in order to achieve transformative change, the oppressive culture that dominates engineering must be dismantled. In this paper, we review and provide theoretical commentary on efforts to challenge the hegemonic culture of undergraduate engineering education. As engineering educators and engineering education researchers, we discuss pedagogical strategies and co-curricular program structures, focusing on initiatives that help support, liberate, or empower students to challenge normative engineering culture. Then, we briefly introduce our current efforts in piloting an equity-centered, action-oriented co-curricular program that aims to provide space for undergraduate engineering students as they identify and combat oppression in engineering education through scholarship and praxis.

Conceptual Framework

This paper draws on Stein's [23] conception of three categorical theories of change: minor reform, major reform, and beyond reform. These theories of change represent different understandings of oppression in higher education and society and the ways in which challenging oppression is approached based on the respective diagnoses. *Minor reform* theories of change hold a notion that despite the historical and present-day imperfections of higher education, institutions can be refined to reclaim the purpose of higher education for the public good without disrupting existing power dynamics. As such, rather than dismantling the oppressive structures of education and society more broadly, this framing promotes the idea that individuals should change in order to improve the effectiveness, efficiency, and inclusivity of the current system [23].

Major reform theories go beyond making revisions at the level of practice by connecting the production of knowledge with historical and systemic inequities, recognizing that dominant ways of knowing are favored to benefit a select few and sacrifice the quality of life for others. These theories of change open up conversations about who is in control of what constitutes valuable knowledge and viable change-making approaches and center oppressed people's experiences, perspectives, and ways of knowing [23]. By doing so, they seek to learn "from alternative ways of knowing in search of roadmaps that can lead toward more equitable, sustainable futures," enacting the "redistribution of resources within existing systems [23, p. 673].

Beyond reform theories of change recognize the problems in the system are of its own making. Oriented by a sense of disillusionment with the promises offered by the existing system, these theories of change invest "not in the university itself, but instead in learning how to become answerable for our complicity, engaging in collective experimentation with more viable less violent futures, and committing to learning from both the successes and failures of those experiments," [23, p. 678]. They de-emphasize and denaturalize the university in order to

imagine other possibilities. Additionally, beyond reform theories of change adopt strategies of harm mitigation and resource redistribution as short-term responses to crises of higher education, aimed toward "viable but as-yet-undefined and unimaginable futures" [23, p. 673].

Literature Review

Utilizing Stein's cartography of minor, major, and beyond reform theories of change [23], we reviewed curricular and co-curricular methodologies that have been leveraged to challenge the hegemonic culture of engineering education with a focus on the theories of change leveraged. This analysis does not serve to establish a hierarchy of the methodologies. Rather, our intention is to highlight the different strategies and consider their respective possibilities and limitations. As noted by Stein [23], "If we can learn to hold the tensions between distinct perspectives, then we might be able to have different kinds of conversations and ask different kinds of questions without being afraid of the answers, or the lack of answers" [p. 678].

Co-Curricular Support Programs as Minor Reforms

Previous scholarship indicates that interventions offered by diversity engineering programs (DEPs) and minority engineering programs (MEPs) can improve marginalized students' undergraduate experience [24]. In particular, both faculty and peer mentorship programs for historically oppressed students have been identified as powerful support mechanisms in undergraduate engineering education [25]. Through peer mentorship, students establish community with one another, which builds their confidence as engineering students and helps them find a sense of belonging in engineering [26]. Faculty mentorship also supports marginalized students in increasing their confidence, as well as learning to confront the discrimination they face in engineering [27]. These relationships can help students combat feelings of social isolation that they may feel as a result of the meritocratic structures in engineering education. Undergraduate research programs have also been found to provide valuable mentorship experiences for marginalized students [25], [28]-[29]. Because faculty and graduate student mentors take on a collaborative, supportive role in research programs, they are able to provide students with guidance to support their overall development [25]. Also, when students' research mentors have marginalized identities that intersect with their own, the mentors can become supportive role models for the students, which may challenge negative stereotypes students have previously encountered [28]-[29].

Co-curricular programs for minoritized engineering students have the capacity to build marginalized students' confidence that may be torn down by the oppressive meritocratic systems in engineering that Slaton [16] and Secules [19]-[20] describe and to support students in having control of their educational experiences. Both of which mitigate the harm students are subject to by the hegemonic culture of engineering education. However, since these programs are nested within and typically funded by institutions, they often do not challenge the organizational characteristics they operate under [24]. Rather, it is more common for diversity/minority programs to prioritize teaching oppressed students "survival strategies" in order to boost metrics (retention rates, GPAs) than support oppressed students in transforming the dominant culture of engineering education [16], [30]. Thus, mentorship and co-curricular support for minoritized students typically represent minor theories of change because they serve institutional efforts to satisfy quantitative metric student success indicators [31] without requiring that institutions make changes to their underlying structures that maintain oppression.

Social Justice Education and Liberative Pedagogy as Major Reforms

In recent years, Colorado School of Mines has developed two upper-division, humanities-focused elective courses for engineering students, Engineering and Social Justice and Intercultural Communication [32]. Engineering and Social Justice focuses on questioning and challenging meritocracy and depoliticization in engineering through personal reflection and historical and contemporary case studies [32]. In doing so, students learn the importance of the skills and concerns that Leydens and Lucena identify as the Engineering for Social Justice (E4SJ) criteria: listening contextually, identifying structural conditions, acknowledging political agency and mobilizing power, reducing imposed risks and harms, and enhancing human capabilities [32]. Similar to Engineering and Social Justice, Intercultural Communication also utilizes case studies to emphasize the E4SJ criteria [32]. The aim of this course is for students to gain skills in identifying exploitative economic and political systems, understanding social justice issues as products of these systems, and developing approaches to challenge them [32].

Drawing on anti-oppressive and feminist education frameworks established by Paulo Freire [12] and bell hooks [33], Donna Riley introduced the concept of liberative pedagogy to engineering education through her thermodynamics course at Smith College [14]. Liberative pedagogy takes a student-centered approach that empowers students to question authority and challenge oppression, which is critical to "prepare effective [engineering] professionals who have an added critical awareness of the systems in which they work, as well as the ability and desire to act to change those systems" [14, p. 143]. To reform her traditional thermodynamics course, Riley related students' lived experiences to the curriculum, made students authorities in the classroom by giving them teaching roles, encouraged students to take responsibility for their learning by including them in course decisions, provided room for students to make mistakes without penalization, and fostered a collaborative community of scholars. Furthermore, the curriculum focused on my decentering westernization, facilitating critical thought about engineering ethics and how race and class issues intertwine with thermodynamics, dismantling false notions of objectivity in engineering, and exploring historical and philosophical dimensions of thermodynamics [14]. These pedagogical techniques empowered students to develop authority in an environment that is commonly controlled by the instructor and to critically analyze and counter dominant narratives and ways of knowing in engineering that promote neutrality and objectivity. Through this empowerment, students developed critical consciousness and moved forward with the skills necessary to identify and resist oppressive power structures within engineering education and to consider how their engineering skills could be utilized in social justice efforts [14].

Dominant notions of social responsibility that are communicated through engineering ethics coursework primarily concentrate on micro-ethical issues, many of which underscore engineers' obligation to protect the interest of companies [15]. As social justice engineering education centers macro-ethical considerations [32], it has the capacity to challenge these hegemonic values that aim to preserve the power of those who benefit most from the inherent exploitation of capitalism. Additionally, Riley [14] provides a powerful model for challenging the hegemonic culture of engineering education through liberative pedagogy, as upending traditional classroom power dynamics creates space for ways of knowing that have been systematically excluded from engineering education. By focusing on structural oppression and engaging in new ways of knowing, these efforts engage major theories of change. Yet, nesting within a formal classroom

setting is limiting-- How are the structures of the engineering discipline or the educational institution itself problematized in these contexts? This limitation demonstrates the need for complementary pathways to reduce harm inherent to the hegemonic culture of engineering.

Action-Oriented Education and Organizing as Beyond Reforms

Bowen et al. [34] formed the Undergraduate Engineering Collaborative Growth Series (UECGS), seeking to "design a program for marginalized engineering students that reduced barriers to the expression of their whole selves, including the value of their identities within the engineering educational space" [p. 1]. This was done through four two-hour workshops in addition to a series of one-on-one feedback and coaching sessions to provide participants reflective space to discuss the series itself and how it connected to other components of participants' lives. The first workshop consisted of focus groups on naming barriers within and relating to engineering that they perceive and experienced as well as the harm resulting from those barriers, followed by a collective visioning activity of naming false statements they wished were true. The second workshop built on the first, introducing the concept of theories of change [36], [35] paired with institution-specific examples of student organizing campaigns that connected theories of change to tactics used and outcomes achieved. Individual worksheets and focus groups were used to facilitate connections between the statements in the visioning activity from the first workshop, theories of change participants felt they could engage with to make those statements feel more aligned with their lived experiences, and skills participants felt they would need to build to engage with those theories of change. The desired skills were then used to shape the content of the third and fourth workshops, leading to a focus on storytelling and power mapping [37]. In these final two workshops, participants were provided worksheets to scaffold the development of their own personal narratives, public narratives, and power maps and provided space in focus groups to give and receive constructive feedback from each other. Overall, the series was intended to provide participants with "practical, tangible opportunities to build confidence around their abilities to organize for change within the engineering community" [34, p. 7], where the directions, visions, and horizons of this change were shaped by participants.

Forbes et al. [38] developed the Engineering Exchange for Social Justice (ExSJ) framework, which situates community-based engineering projects as exchanges rather than services and holds community partnerships as a key component to this work. The shift in language is critical because it works to dismantle the imperialist, white-centered, patriarchal notions of what it means for engineers to engage with "the community" [38]. The authors note, "The term service connotes a one-directional flow of ideas, resources, and expertise from engineers to community recipients" [38, p. 2], while "exchange connotes equal partnership, and a bidirectional flow of ideas, resources, ways of knowing and being, and expertise" [38, p.2]. Also, ExSJ pushes against the dominant mindset that engineering is a technocentric process in favor of emphasizing its inherently sociotechnical nature [38]. Forbes et al. [38] have put the ExSJ into practice at their home institution, University of San Diego, leveraging eight mechanisms that "support the co-created solving of sociotechnical problems, including community forums, community awards, scholar schemes, professional development events, a pro bono professional network, courses, capstone design projects, and research sponsoring undergraduate engineering" [p. 4]. In particular, they highlight their elective course, Community-Based Participatory Engineering Apprenticeship. This course provides space for students and local communities groups to collaborate with one another "to share knowledge and understanding and to co-create project

briefs related to engineering in support of social justice" [38, p. 7]. In centering relationships of exchange, this framework provides students and community partners space to venture "into the muck" that is "rife with marginalization, privilege, historical and cultural wounds, and beyond" [38, p. 8]. As described by Stein [23, p. 673], these efforts are a "messy, collective process of learning/unlearning that might lead (non-linearly) to viable but as-yet-undefined and unimaginable futures."

Histories of engineering education stemming from labor and community organizing among techno-scientific workers provide examples of engineering workers grappling with issues of workplace governance, self-management, and countering ideologies of professionalism core to hegemonic engineering culture [39]. Valle et al. [40] interviewed engineering graduate student workers that participated in a labor strike where engineers played a key role in the inclusion of non-reformist reform [41] strike demands that sought to disarm, demilitarize, and defund campus police and sever campus ties to local police as well as Immigrations and Customs Enforcement (ICE) [42]. The interviews also indicated that strikes can be a form of liberatory pedagogy in engineering spaces, allowing for the generative questioning of connections between engineering and the prison industrial complex. Valle et al. [40] outlined connections of practices, skills, and tools used in labor organizing with learning methods and assessment methods in engineering education research. In this way, labor unions can serve as critical sites of engineering education, providing examples of space to develop sociopolitical skills de-emphasized in hegemonic engineering education that engineering education researchers can draw inspiration from.

Future Work

At Florida International University (FIU), the first, third, and fourth authors of this paper (Bond-Trittipo, Secules, and Green) are piloting an equity-centered program that centers on undergraduate participatory action research, called the Justice, Equity, Diversity, and Inclusion (JEDI) Ambassador Program or simply JEDI for short. The pilot version of the program was launched in August 2021 with four ambassadors. All undergraduate engineering students graduating in the Fall 2021 semester or later were eligible to apply to this paid ambassador role. Because of funding and personnel limitations, we could only hire five students. Out of the nine eligible applications we received, the five ambassadors were selected based upon their interest in improving equity in the College of Engineering and Computing (CEC), conducting social science research, and being part of local K-12 STEM education initiatives. Out of these five ambassadors, four are women, and all are non-White (including Black, Latinx, and Middle Eastern races/ethnicities). Historically underrepresented groups were not specifically recruited nor selected for in our application process, and the institutional context makes these participant demographics more likely. Nevertheless, we note that many applicants expressed interest in resolving equity issues that they personally experienced, and this was likely a self-selection aspect of who chose to apply to the program.

In October 2021, we held a month-long series of training sessions that occurred twice weekly for two hours at a time. We began the training sessions with the ambassadors describing what justice, equity, diversity, and inclusion mean to them and sharing our own understandings of those terms. Then, we trained them in research methods and educational design through pre-training session reading assignments followed by discussion-based lectures and practice activities during the sessions. Over the course of the training sessions, we encouraged the ambassadors to discuss the various dimensions of their identities (to the extent that they were

comfortable doing so) and reflect on how these identities have shaped their experiences in CEC and society more broadly. They also identified equity issues within the contexts of FIU, CEC, and the local K-12 school system and brainstormed ways in which they could pursue justice regarding these issues through research, educational design, and leadership.

During the last week of training, the ambassadors collaboratively conceptualized their projects. Ultimately, they decided to undertake two research projects and one K-12 outreach project during the Spring 2022 semester, all of which are largely based upon the inequities they had personally faced. For the first research project, the participating ambassadors will employ ethnographic methodology to examine "weed-out" [25] culture in engineering education, with a particular focus on how the structure and environment of barrier courses contribute to the oppression of marginalized engineering students. The ambassadors plan to leverage the JEDI Ambassador Program to initiate conversations with professors in which they share their findings and advocate for students' educational needs. The ambassadors involved in the second research project will conduct a series of in-depth interviews with LGBTQ+ engineering students to understand the extent to which they feel safe to be their authentic selves in engineering spaces and how their experiences in CEC have informed this perception. The ambassadors plan to publish their findings in order to advance the engineering education community's understanding of LGBTQ+ engineering students' experiences. Also, they aim to use the information they gather through interviews to develop resources for LGBTQ+ student support on FIU's engineering campus. Lastly, the K-12 outreach project entails the ambassadors facilitating a STEM field day at a local elementary school. The ambassadors will develop STEM activities for students in third through fifth grade and, in collaboration with their teachers, develop appropriate learning objectives for each activity. Their goal is to stimulate STEM learning in a fun way that is inclusive to all students and takes away the pressures of a formal classroom setting.

The goal of the JEDI Ambassador program is to provide a non-hierarchical space to empower them as change agents who can impact their local and community contexts. We hope that through this process, students will develop an increased sense of agency regarding any marginalization they experience themselves [43]. Moreover, by drawing student leaders into the process of identifying problems, designing programming, and initiating change, this sense of empowerment will reverberate into the student community more broadly.In the future, we will document and reflect upon the outcomes of the JEDI Ambassador Program pilot year and support the ambassadors in disseminating their JEDI research.

Conclusion

The hegemonic culture of engineering education, which centers settler-colonial, white supremacist, patriarchal, cis-hetero normative, and capitalist values, must be disrupted in order to promote equity and liberative praxis in engineering education and society as a whole. Therefore, it is critical to examine the strengths and limitations of current approaches that work toward achieving this goal and consider new possibilities. In this paper, we examined a wide range of reform approaches to creating liberatory change within engineering education. In classifying reform efforts as minor, major, and beyond reform, we do not merely want to create a hierarchy of preference, we also recognize the practical realities and limited agency of many individuals and efforts who may hope to enact local and broad change. While we encourage more substantive disruptions to oppressive engineering culture, we still value the minor disruptions, the work of mentors, and the day-to-day efforts of support personnel. By noticing the variety of

opportunities in and outside of traditional engineering education, we call for collaborations that creatively transcend the limitations of individual stakeholder positions and abilities in order to create more lasting and meaningful change.

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