Liberatory Potential of Labor Organizing in Engineering Education

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Abstract

Engineering has been a field characterized by a hegemonically depoliticized and meritocratic culture. This has contributed to the demographics of engineering skewing wealthier, whiter, and more male. There is a need for theories of change within engineering and engineering education capable of shifting this engineering culture. In this paper, we draw on theories from within and outside of engineering education, including a Freirian critical consciousness model, to construct a liberatory engineering education model connecting theories of change to educational learning and assessment methods. This model is then applied to the context of engineering and labor.

Drawing on the history of labor organizing, in which labor unions have been a vehicle for workers to engage in social mobility and address injustices, we develop an engineering and labor theory of change to describe the potential of labor organizing to create shifts in engineering and engineering educational settings. This theory of change runs counter to the hegemonic technocratic theory of change present in engineering, which has historically limited engineers' engagement with labor organizing. The resulting liberatory engineering education model connects this theory of change to labor organizing methodologies and a learning method of Bargaining for the Common Good, recognizing that engineers can be community organizers and that labor strikes can be a form of liberatory pedagogy. We also discuss the overlap of skills, tools, and practices from labor organizing with engineering education research methodologies, learning methods, and assessment methods in addition to potential limitations of this theory of change. In doing so, potentials for scholarship, concientização, and praxis via labor organizing in engineering are elucidated in order to provide direction toward liberation.

Introduction and Background

Engineering is a field that both shapes and is itself shaped by oppression and inequitable power dynamics. Engineering education researchers have sought to study facets and intersections of racism [1-8], heteropatriarchy [4-10], capitalism [5, 6, 10], and militarism and colonization [8, 11] within engineering. In many ways, engineering education researchers have shown how these facets are fundamental to what is currently considered engineering epistemology. Owing to that history, peoples marginalized along many and varied axes of interlocking systems of oppression have continually faced discrimination within the field of engineering, a microcosm of their treatment within society more broadly [4-6, 8, 12].

Engineering education researchers have engaged with the means by which the many axes of oppression cause harm. Analogies such as leaky pipelines and pathways are used to describe the ways that minoritized engineers end up 'leaking' out of engineering, as the pathways to success are defined by and exist in overwhelming support of engineers with specific combinations of identities aligned with the hegemonic understanding of who an engineer is: a cis-gendered, heterosexual, middle-class, white male [7, 13]. Discussions of why these phenomena persist in engineering have often been framed from a deficit perspective, which situates minoritized students as "deficient," perpetuating the idea that minoritized students possess motivational or

cognitive deficits [14, 15]. This can limit the perspectives from which engineering education research is engaged.

Engineering education researchers have also investigated means by which marginalized people navigate the culture of engineering. Foor et al. [6] engaged with a narrative research methodology to tell a story about Inez, a first generation college attending, economically disadvantaged, multi-minoritized female undergraduate engineering student, forms of marginalization she faced in her engineering education, and sources of strength she drew from to persist. Martin and Garza [5] used a power-sharing autoethnographic methodology to tell the story of the multitudinous factors in Chavonne Garza's life that shaped her journey to and within engineering. This methodology illuminated ways that many institutions, including academia, were designed and continue to operate without her well-being in mind.

Researchers have investigated epistemological and ontological ways that marginalized peoples engage with STEM. Wilson-Lopez et al.'s investigation of funds of knowledge in Latinx adolescent approaches to engineering demonstrated ways that "participants' everyday skills and bodies of knowledge aligned with engineering practices" [16, p. 278]. Verdín, Smith, and Lucena [17] engaged the funds of knowledge framework to demonstrate ways that first-generation engineering college students' funds of knowledge related to their students' confidence in their engineering performance, classroom belonging, and in graduating with an engineering degree. Samuelson & Litzler [18] utilized the concept of community cultural wealth, based on the work of Tara J. Yosso [19], which uses an asset-based approach to understand minoritized student persistence by examining different types of capital developed by students in their families and communities. Martin and Newton [20] combined the concepts of funds of knowledge and community cultural wealth to connect together multiple forms of capital and wealth present among recent underrepresented and/or socially marginalized engineering Bachelor's degree earners.

These forms of community cultural wealth have been leveraged by marginalized communities in ways that reconceptualize the forms and uses of engineered technologies. Ravyon Fouché [21] defined the concept of Black Vernacular Technological Creativity, the process through which Black people's agency over the design, use, and overall engagement with technology is reclaimed. Fouché outlined three ways in which Black Vernacular Technological creative acts can be seen: redeployment, reconception, and re-creation

> Redeployment is the process by which the material and symbolic power of technology is re- interpreted but maintains its traditional use and physical form … Reconception is the active redefinition of a technology that transgresses that technology's designed function and dominant meaning … Re-creation is the redesign and production of a new material artifact after an existing form or function has been rejected. [21, p. 642]

In a similar vein to Fouché's concept of Black Vernacular Technological Creativity is the concept of *rasquachismo* [22, 23]. According to Ybarra-Frausto,

> To be *rasquache* is to posit a bawdy, spunky consciousness, to seek to subvert and turn ruling paradigms upside down. It is a witty, irreverent and impertinent posture that recodes and moves outside established boundaries…In an environment always on the edge of coming apart (the car, the job, the toilet), things are held together with spit, grit and *movidas*. *Movidas* are the coping strategies you use to gain time, to make options, to retain hope. *Rasquachismo* is a compendium of all the movidas employed in immediate, day-to-day living. Resilience at hand, *hacer rendir las cosas*. [22, p. 191]

Rasquachimso has previously been applied within the engineering education research space by Mejia and Pulido [23], who utilized the concept to center everyday realities of Latinx youth that enable them to bring their embodied knowledge into an engineering context.

E.M. Garroutte [24] coined the term Radical Indigenism based on radix, the Latin derivation of the word "radical," meaning "root." Garroutte explains that "Radical Indigenism illuminates differences in assumptions about knowledge that are at the root of the dominant culture's misunderstanding and subordination of indigenous knowledge. It argues for the reassertion and rebuilding of traditional knowledge from its roots, its fundamental principles," transgressing academic boundaries, "when it requires that researchers also honor the *methods* and the *goals of inquiry* toward which indigenous philosophical assumptions direct us" [24, p. 91]. Julia Watson's concept of Lo-TEK [25] positions itself at the intersection of Radical Indigenism and design,

> [Lo-TEK is] a movement that investigates lesser-known local technologies, traditional ecological knowledge (TEK), indigenous cultural practices, and mythologies passed down as songs or stories. In contrast to the homogeneity of the modern world, indigeneity is reframed as an evolutionary extension of life in symbiosis with nature. [25, p. 18]

Black Vernacular Technological Creativity, *Rasquachismo*, and Radical Indigenism engaged through concepts like Lo-TEK provide powerful examples of ways that Black, Latinx, and Indigenous scholars have developed asset-based theoretical frameworks that serve as counters to the continuation of the notion that, "in engineering, particularly, the material realities of students of color–which are perceived as non-sophisticated epistemologies–are replaced by dominant discourses" [23, p. 7]. From this constellation of epistemologies and ontologies that have been decentered from traditional engineering scholarship, many new futures and modes of interaction can be created.

This paper seeks to build on previous critical and liberative work within engineering education by building a model connecting theories of change to practices, discussing the example of labor organizing as a vehicle for liberative changes within engineering. Engineering in the U.S. context relies on depoliticization and meritocracy as ideologies that underpin current engineering education and practice [26], its positionality within broader systems of production, and its historically low presence of labor organizing [27, 28]. In addition, this study discusses ways that ideologies central to labor organizing sit in tension with existing hegemonic engineering ideologies, describes the ability of the principles of Bargaining for the Common Good to help

engineers and their communities meet their needs, and clarifies that engineering does not inherently require technocratic solutions to communal problems and needs.

Positionality

The primary and secondary authors are both engineers, labor organizers with the American Federation of Teachers (AFT) local GEO-3550, and children of union members from working-class backgrounds. Both were participants in the 2020 GEO-3550 abolitionist strike for a safe and just campus for all [29]. The first author was also taking graduate coursework in introducing the concepts of engineering education research during the writing of this paper, which provided a critical reflective space for learning and grappling with theoretical frameworks and their applications. We reached out to the third author as a major scholar advancing social justice, including discussions of unions in engineering spaces, in engineering education research. The third author is from an upper-middle class background and has also witnessed firsthand the benefits of unions in the lives and livelihoods of family members. She is a member of the American Association of University Professors (AAUP), notwithstanding her middle-management position as a department head. She trained as an organizer with the Industrial Areas Foundation and has applied organizing techniques in pursuit of gender, LGBTQ+, economic, environmental, and racial justice over three decades of activism.

In writing this paper, we draw upon our own forms of community cultural wealth, particularly the familial capital stemming from experience with socioeconomic upward mobility as a result of the American labor movement, continuing with our own training and absorption into the professional class via our own and our familial engineering education. All three authors are marginalized engineers and draw on navigational and resistance capital that we have needed to engage with in order to traverse oppression within institutions of higher education. Importantly, we have also utilized our aspirational capital to conceptualize and envision what a more liberatory form of engineering could look like both broadly and within our own individual forms of engineering practice.

Backgrounds of (Engineering) Labor and Bargaining for the Common Good

Marx and Engels [30] discussed the criticality of workers organizing during the industrial era in order to hold collective control over decision making pertaining to what the workers produce, how it is produced, and compensation of the fruits of the workers' labor. Marx's theoretical work and meticulous research into the industrial capitalist system was rooted in understandings of the dialectical way of thinking conceived of by Georg Wilhelm Friedrich Hegel, using a fundamental component of Hegel's dialectic, the inherent internal contradiction, to produce powerful critiques of the capitalist system [31]. In doing so, Marx laid much theoretical groundwork for industrial unionism in Western Society, with labor unions being the vehicle through which workers were able to advance their ability to control the nature and uses of their labor as well as gain increased access to the fruits of production [32]. Marx [33] deeply understood the value of praxis, integrating theory and action toward the ultimate goal of social change.

Engineering as a nascent field taking root in the industrial age and growing alongside industrialization saw many engineers engaging with questions of their positionality within society and questions of unionization [34]. Throughout much of the industrial age continuing to modern day, engineers have sat with and worked through the internal contradiction of their position as both workers and managers, and thus with their sliding position between the working class and the managerial class [35]. Shortly after World War I, there was an increasing class consciousness within the American Society of Mechanical Engineers which led Thorstein Veblen [36], however erroneously, to posit in *Engineers and the Price System* that if there were to be a workers' revolution in industrial America, it would come via a "Soviet of Technicians." Layton [37] unpacks Veblen's errors in reading the power, position, and organization of the engineering profession.

This internal contradiction has historically led to tensions within groups of engineers, with more managerial-minded engineers veering and lobbying for the growth of professional societies, which largely worked to exclude other technical workers as a means to protect the white-collar class position of engineers, and more worker-centered engineers opting for the formation and growth of engineering labor unions, which often included technical workers [27, 28]. Notably the rise of industrial technologies, and with them the populations practicing engineers during the industrial age, facilitated the rise of corporate capitalism in 20th century America [34]. Engineering saw a boom in unionization during the period of the 1930s-1960s, when roughly 10% of practicing American engineers were union members between 1946 and 1957 [39]. Some of these unions held progressive, anti-racist, anti-military stances, such as the Federation of Architects, Engineers, Chemists, and Technicians (FAECT), which served to weaken ideological, psychological, and organizational ties to management [38]. FAECT members engaged in volunteer activism, questioned their engagement in the Manhattan Project and threatened to move their First National Convention venue after the Allerton Hotel, the convention venue, refused service to a Black member as the conference was proceeding. The threat of relocating the meeting if the Black member was not treated with respect led to the reversal of the hotel's decision [40, 41].

Despite a sharp decrease in engineer unionization rates after WWII, a number of engineers still remain unionized and partake in highly visible labor actions. A strong example is the Boeing engineers strike in 2000, then hailed as the largest white-collar strike in history [8]. In addition to an active picket line, Boeing's 19,500 striking engineers and technologists were bolstered by solidarity actions from across American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) unions, including railroad workers, UPS Teamsters, and Boeing machinists [8].

Recently, we have seen the creation of the Alphabet Workers Union as a means to organize engineers along with other workers at Alphabet and across its associated corporations, including Google [40]. Their unionization push has gained traction not through traditional 'bread-and-butter' issues such as salaries and benefits, but instead through large and well documented problems with corporate culture regarding diversity, equity, and inclusion (DEI). This includes the firing of artificial intelligence researcher and ethicist Dr. Timnit Gebru, one of the few Black women within Google Research, which was connected to raising issues around

racial and gender bias in products Google engineers are producing and posing questions about who their labor is actually benefiting [40, 41].

This form of a DEI-centered unionization campaign, which is seeking to involve not only engineers but all workers at Alphabet and its subsidiaries, lends itself well to a form of labor organizing that Jane McAlevey calls whole worker organizing [42]. Whole worker organizing has roots in the work of unions within the CIO during the 1930s, prior to its merger with the AFL in the 1950s. CIO organizers "understood that workers were embedded in an array of important workplace and non-workplace networks, all of which could be best accessed - and, for organizing on a mass scale, *only* accessed - by the workers themselves" [42, p. 33]. The CIO-era methodology of whole worker organizing is "a bottom-up model in which workers have primary agency and are understood to be their own lever of liberation … [that can] win life-altering improvements," and recognizes that workers "... are *more* structurally powerful when it comes to engaging their community in a fight" [42, pp. 28-29].

The Alphabet Workers Union, as well as many engineering unions, are structurally well positioned to engage in Bargaining for the Common Good contract campaigns. Owing to the forms of white-collar work many engineers engage in, the salaries and benefits packages engineers already receive are high compared to many other workers [43]. Given that salaries and benefits are the 'bread-and-butter' issues that unions have traditionally bargained most intensely over, engineering unions have the unique opportunity to focus their bargaining power toward making improvements within the broader communities impacted by their work. Bargaining for the Common Good is an offensive bargaining strategy which seeks to organize with community partners for contract demands which benefit and invest in the wider community as a whole, not just the bargaining unit of the union, expanding notions of the participants, processes, and purposes of bargaining [44, 45]. Bargaining for the Common Good campaigns also center racial justice in their demands, addressing "the role that employers play in creating and exacerbating structural racism in our communities" [44]. By engaging the wider community, Bargaining for the Common Good allows for a strengthened connection between labor organizing, typically taking place primarily among members of a union's bargaining unit, and community organizing for improvements that seek to address root causes of injustice. Andre Gorz articulated the liberatory potential for a form of campaign like this in *A Strategy for Labor*, stating,

> to fight for alternative solutions and for structural reforms (that is to say, for intermediate objectives) is not to fight for improvements in the capitalist system; it is rather to break it up, to restrict it, to create counter-powers which, instead of creating a new equilibrium, undermine its very foundations [46, p. 181].

Examples of recent Bargaining for the Common Good campaigns include the United Teachers Los Angeles (UTLA) contract campaign, which increased green spaces, put an end to "random searches" of students, provided assistance for immigrant families, and expanded access to nurses and counselors across the Los Angeles Unified School District (LAUSD) [47] and the Minneapolis based Service Employees International Union (SEIU) Local 26 janitors' strike for employer action to be taken to address climate change [48]. Likewise, worker organizing in engineering and engineering education workplaces can produce Bargaining for the Common

Good campaigns and related improvements. Here, we outline an engineering and labor theory of change and create a liberatory engineering education model connecting it to methodologies, learning methods, and assessment methods that would support its implementation..

Theoretical Framework

In this paper, we have constructed a theoretical framework that seeks to blend concepts from within and outside of what has formally been used in engineering education. The goal was to construct a framework that offers a means to engage theories of change, which contain the critical component of power analysis, toward the development of an engineering education model for use in engineering education research and practice. Tuck and Yang have described a theory of change as "a belief or perspective about how a situation can be adjusted, corrected, or improved" [49, p. 13], where "reflecting or imagining a theory of change is an ontological and epistemological activity, related to core questions of being and knowing" [49, p. 126]. Analyses of power are conducted using Hill Collins and Bilge's intersectional analytical framework, which "identifies four distinctive yet interconnected domains of power: interpersonal, disciplinary, cultural, and structural" [50, p. 7]. In this section, we introduce several existing theories that constitute our proposed theoretical framework.

Horton's Popular Education and Freire's Pedagogy of the Oppressed

Myles Horton, founder of the Highlander Research and Education Center, influenced by the Danish folk school movement and John Dewey's [51] idea that education should work to dismantle rather than perpetuate privilege, developed the Center's core principle of popular education - that liberative education must be in solidarity with communities, recognizing people's agency to learn, grow, and act on their own behalf [52]. The Center has provided resources for education and participatory action research for the labor movement, the Civil Rights movement, the environmental justice movement, the LGBTQ movement, and numerous other social justice movements. During the Civil Rights struggle, Septima Clark developed citizenship schools at Highlander that provided literacy education and organizing skills to intervene in racist literacy laws propped up as barriers to voting rights throughout the South.

Paulo Freire similarly leveraged literacy as a tool for political enfranchisement and social justice in Brazil, and developed his critical pedagogy influenced by Fanon, Vygotsky, Gramsci, and others [53]. Freire's critique of the "banking model" of education and focus on upending systems of power and privilege in schooling introduced learning as a practice of freedom that cultivates critical analysis and reflective action for change [54].

Mejia et al.'s critical consciousness approach

Mejia et al. [14] conducted a systematic review of engineering education literature using a methodology based on Freire's principles of critical andragogy and pedagogy. In doing so, they proposed a critical consciousness approach connecting theory, reflection, and action. They identified intersections of scholarship (reflection and theory), praxis (theory and action), and concientização (action and reflection) toward liberation (theory, action, and reflection). They

then provided a matrix guiding questions for researchers to engage with throughout the process of conducting studies, prompting researchers to consider the relationships between scholarship, praxis, concientização, and liberation and theory, action, and reflection.

Hassan's learning-assessment interactions

Hassan [55] created a model that combines assessment with learning, identifying bi-directional relationships between assessment and assessment method, as well as assessment and learning, with both learning and assessment method being influenced by learning method. According to Hassan, an assessment should be "something that affects the students' learning, confidence in themselves and their skills," where "the assessment method can enrich the learning method and they are coupled together by an appropriate methodology of learning and assessment" [55, p. 327].

Riley and Lambrinidou's Canons against Cannons

Riley and Lambrinidou explored the addition of six principles to the values and principles currently expressed in engineering ethics canon, namely the ethical principles:

- Engineers' primary goal is to help people in need and to address social problems
- Engineers challenge social injustice
- Engineers practice cultural and epistemic humility
- Engineers respect the dignity and worth of each person
- Engineers recognize the central importance of human relationships
- Engineers seek to live in peace with their individual selves, others, and the planet [56].

These ethical principles represent a revised framing of engineering purpose as a means to transform engineering practice.

la paperson's scyborg and assemblages

la laperson introduced the concept of a scyborg as,

> a queer turn of word that ... name[s] the structural agency of persons who have picked up colonial technologies and reassembled them to decolonizing purposes …The agency of the scyborg is precisely that it is a reorganizer of institutional machinery; it subverts machinery against the master code of its makers; it rewires machinery to its own intentions. ... It describes a technological condition of being embedded in an assemblage of machines [57, pp. xiv, 55, 62].

la paperson helps to contextualize the decolonizing purposes of scyborgs; "decolonization is, put bluntly, the repatriation of land, the regeneration of relations, and the forwarding of Indigenous and Black and queer futures - a process that requires countering what power seems to be up to" [57, p. xv]. la paperson also expands on the connections between universities and the concept of assemblages as collections of things or people:

(1) the university is an assemblage. It is a giant machine composed of myriad working parts, multiple systems. Each part can still be thought of as a discrete organism to be unplugged and replugged somewhere else. (2) The university is *in* assemblage. It is imbricated with other assemblages. … It is, like all assemblages, discrete from yet amalgamated with other assemblages in an endless matrix of couplings. (3) As assemblages, the priorities of "scale," as captured in the conventional hierarchical dichotomies of micro versus macro, historical versus ephemeral, data versus anecdote, echo into one another. So a small glimpse into a university classroom very quickly telescopes into scales of heterosexism, racial capitalism, and so on. The webs of pedagogical machinery are at once giant and intimate. It may feel like lying face down on a monumental precipice, close enough to see the cracks in the stone as well as the chasm just centimeters away [57, pp. 62-63].

These concepts of scyborg and the university as/in assemblage provide space for engineers, particularly marginalized engineers, to recognize that the oppression we face is rooted in structures that exist across domains of power, or scales, and that these structures are reconfigurable within the spaces we occupy.

Godwin et al.'s critical engineering agency

This concept of a scyborg from la paperson, while relatable to the concepts of Black Vernacular Technological Creativity, *Rasquachismo*, and Radical Indigenism described previously, can also be tied to Godwin et al.'s [58] concept of critical engineering agency. Critical engineering agency connects understandings of 1) engineering and engineering-related processes, 2) modes of inquiry commonly engaged with in engineering and related skills, 3) degrees of expertise related to engineering self-identification, 4) engineering as a foundational site for change. Critical engineering agency may influence professional identity development, how engineers envision the world and their position in it.

Lee et al.'s organizing framework for advancing understanding about supporting underrepresented students in engineering

The use of agency is also present within the organizing framework Lee et al. [59] developed by interviewing student support practitioners across four universities. The purpose of the development of this framework was to advance the understanding of how to effectively support underrepresented students in engineering. This organizing framework encompassed four major themes: context, agency, process, and impact. Lee et al. divided agency into two categories: values, which are factors that motivate students, and choices, which are behavioral patterns exhibited by students. Lee et al.'s organizing framework provides a basis for understanding the university simultaneously as an assemblage and in assemblage through a lens of student support.

Mondisa and McComb's social community framework

The connection of student support to assemblages is also present within Mondisa and McComb's [60, 61] concept of a social community, developed in a context of STEM minority mentoring programs, which is "an environment where like-minded individuals engage in dynamic, multi-directional interactions that facilitate social support" [60, p. 152] and fosters the development of long-term participant outcomes. Mondisa and McComb also posited that the foundation of social community is social support, which they defined, citing Lakey and Cohen [62], as "the connectedness that participants feel to the community, including supportive actions and behaviors, the availability of actual support, global evaluations of quality and availability, and social roles and relationships" [61, p. 95]. They also outlined outcomes for participants, which can stem from social support as resilience, engagement in communities of practice, and the building of social capital. This framework indicates that the intentional organizing of communities can be a support system for minoritized engineering students.

Coit's participationism and local action, not citizen participation

Katharine Coit investigated tactics used by the Community Action Program of the War on Poverty [63]. In doing so, she recognized a difference between the type of citizen participation that the program sought via means that favored middle- and upper-strata groups and local action that seeks "to develop a class consciousness and critical analysis of capitalism …, to work out methods of self-management in associations or groups where leadership is shared rather than hierarchical and elitist …, and to develop a strategy that is truly conflictual …" [63, pp. 302-303]. One of the mechanisms that she saw as highly prevalent in citizen participation groups was participationism, which is characterized by a lack of independence, a mobilization-based ideology, and a limited scope of action which prevents more than token power. She outlined ways in which citizen participation models imposed from above seek to control and co-opt movements. Coit outlined factors that are important to consider when engaging in local action and community organizing that are applicable to the forms of support offered to minoritized engineering students.

Yosso's Community cultural wealth and Solórzano and Delgado Bernal's transformational resistance

Yosso described community cultural wealth as "an array of knowledge, skills, abilities, and contacts possessed and utilized by Communities of Color to survive and resist macro and micro-forms of oppression" [19, p. 77]. Transformational resistance, put forth by Solórzano and Delgado Bernal, is a form of resistance capital within the community cultural wealth framework, which "refers to student behavior that illustrates both a critique of oppression and a desire for social justice" [64, p. 319]. Solórzano and Delgado Bernal used two events in Chicana/Chicano student history - the 1968 East Los Angeles school walkouts and the 1993 UCLA student strike for Chicana and Chicano studies - to develop the concept of transformational resistance. In doing so, they demonstrated how transformational resistance can exist in a mutually reinforcing relationship with local action, where the student behavior characterized as transformational resistance can generate local action, and how local action can build a student's transformational resistance.

Lindsay Pérez Huber built further upon this relationship between transformational resistance and local action by describing the impact of a student group for undocumented students on a group of low income, undocumented Chicana undergraduate students at a top tier university:

> The DREAMS organization was critical in the women's ability to find their way within the university. However, this organization provided much more than navigational skills; it provided the opportunity to come together with a collective agency to resist oppressive conditions in and beyond the university for themselves, their communities, and future undocumented students. This organization was where the community cultural wealth of undocumented students converged to provide a set of navigational skills that could be utilized not only to get through the institution but to transform their current situations, exercising what Yosso (2005) [19] describes as transformative resistant capital [65, p. 720].

This asset-based framing utilized within community cultural wealth and the connection of transformative resistance through community organizing and local action represent connections that can be used to construct a model of education.

Liberatory Engineering Education Model

Collectively, the theories described connect concepts from within and outside of engineering education research, providing us the means to construct a liberatory engineering education model as a template for engaging theories of change within engineering education research through an intersectional analytical lens, as shown in Figure 1. The liberatory engineering education model is developed from Mejia et al.'s Freirian critical consciousness model [14] and Hassan's learning-assessment interactions model [55]. Dialectic relationships are represented by circle overlaps (e.g. between theory of change and methodology as framing), the solid black lines connect the concepts of methodology, learning, and assessment, and the dotted thin blue line connects the concepts of framing, community organizing, and positionality. Mejia et al.'s model is represented in the center of this model, showing relationships between theory, action, reflection, and concepts of scholarship, praxis, concientização, and liberation that result from their overlap. Hassan's model of learning-assessment interactions is overlaid, with the overlap taking the form of reflection as an assessment method and action as a learning method. Hassan's model did not explicitly name the bi-directional relationships of its components (e.g. the interaction of assessment method and assessment was not discussed as positionality), and our model builds on that work by considering bi-directional relationships and considering these relationships as dialectics.

Reconfiguring these bi-directional relationships to be dialectic relationships allows us to consider contradictions that can arise from overlaps of components and identify concepts that may be
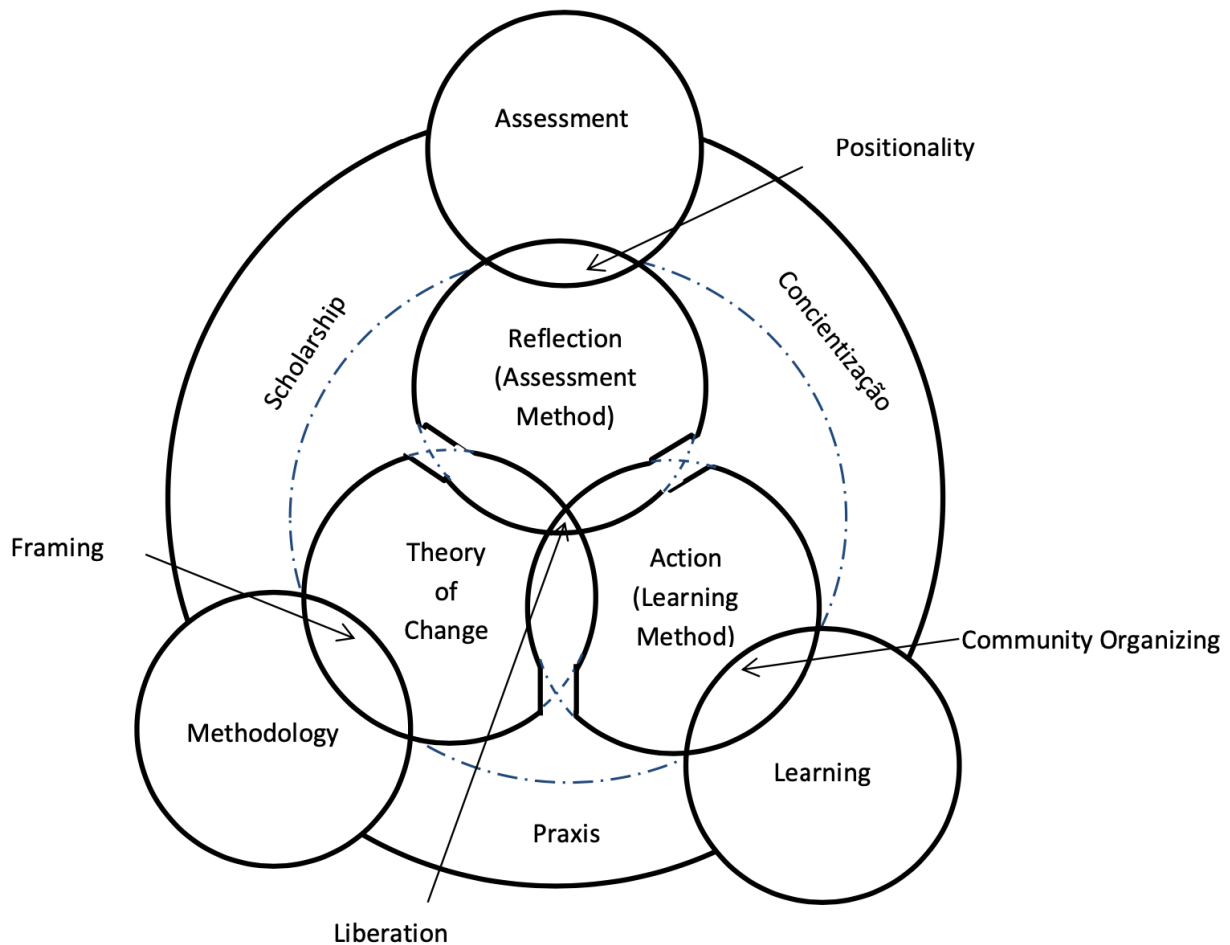
Figure 1: Proposed liberatory engineering education model developed from Mejia et al.'s Freirian critical consciousness model [14] and Hassan's learning-assessment interactions [55].

useful in navigating these contradictions. For example, positionality can be a key component of reflection (assessment method) for both educators and learners that can contextualize contradictions or misalignments that arise from forms of assessment that may negatively impact "students' confidence in themselves and their skills" [55] and make space for less harmful interactions between assessment and assessment method moving forward. Community organizing can be viewed as a means to navigate contradictions between action (learning method) and learning by considering how the learning space and learning community are organized to achieve forms of learning that take steps toward liberation. As mentioned by Hassan, "an appropriate methodology of learning and assessment" helps to couple assessment method and learning method [55, p. 327]. Framing can be a means to navigate contradictions that arise between methodology and theory of change.

In this model, the three regions spanning from the outermost black lines through the dotted thin blue lines to liberation in the models center reflect scholarship, praxis, and concientização. Thus, each intersects with sets of dialectic relationships spanning the regions (e.g. methodology and

assessment, framing and positionality, and theory of change and reflection for scholarship). These dialectic relationships represent contradictions, and the navigation around them can lead to the enactment of scholarship, praxis, and concientização while on a path toward liberation. The dotted thin blue lines are simultaneously configured to represent openings between and/or constraints brought on by constructed (ideological and material) barriers across domains of power. This allows for the model to consider how various approaches can reduce the salience, impact, or power of constructed barriers and create opportunities to navigate towards liberation.

This theoretical framework and model provides us a basis from which to articulate a theory of change based on engineering and labor that spans multiple domains of power in engineering education.

A Theory of Engineering and Labor

In her 2019 JEE guest editorial, "Asking questions, we walk," Alice Pawley drew attention to the fact that our hegemonic understandings of engineering are socially constructed and constrained by a neoliberal mindset, binding engineers to techno-rational arguments [66]. As an example, she discussed the culpability of engineering educators in worsening climate change by failing to "provide students with a moral language to think about engineers' responsibility for climate change" [66, p. 449]. Additionally, she explained that engineering educators

> unwittingly indoctrinate students into neoliberalism as the only possible mode of economic development. Their job will be to work in an industrial machine; we do not articulate alternative modes of thought or help students develop cognitive lenses to conceive of a way of being outside this neoliberal worldview [66, p. 449].

Palwey discusses the learning method engineering educators employ as being one of indoctrination into neoliberalism, organizing students to learn to normalize working in "an industrial machine" [66, p. 449]. Rooting in feminist standpoint epistemologies, Sandra Harding [67] has discussed how the form of objectivity that dominates STEM fields works to uphold often unspoken social values, interests, and agendas that promote this form of indoctrination. Harding denotes this form of objectivity to be "weak objectivity," in which "culture-wide assumptions *that have not been criticized within the scientific research process* are transported into the results of research" [67, p. 446]. In doing so, Harding identified that the objects of scientific inquiry are socially constructed in ways that currently practiced methods of reflection through weak objectivity fail to account for.

Intimately connected to this neoliberal pipelining of students to private industry and the use of weak objectivity as an assessment method are the skills that engineers are taught to believe are key to engineering practice and how those skills are taught. Daly et al. [68] utilized Treffinger et al.'s [69] framework of cognitive operations underlying the creative process as a whole, which included divergent thinking, also referred to as generating ideas, and convergent thinking, also referred to as digging deeper into ideas. Daly et al.'s findings showed that even in exemplary engineering courses, convergent thinking was emphasized while divergent thinking skills were

not very well represented, aligning with Pawley's [66] assertion that engineering educators do not help students to develop the type of divergent thinking that would position them outside of a neoliberal worldview. This in turn creates a feedback loop, as the neoliberal worldview produces a driving force for engineering education to focus students, with overwhelming emphasis, toward technocratic solutions bounded by possibilities within a market economy. In turn, that demand drives engineering educators to emphasize convergent thinking in the form of analytical skills bounded by set problems. This produces engineers who take on this neoliberal worldview bound by a technocratic theory of change, or what Pawley [66] calls techno-rational arguments, as hegemonic engineering practice. The decentering of divergent thinking within engineering practice fundamentally bounds what theories of change engineers are capable of drawing inspiration from and engaging within their engineering education.

Figure 2a identifies connections between the components of the current bounded version of engineering education and practice when it is viewed through the liberatory engineering education model shown in Figure 1. These mutually reinforcing components generate significant constructed barriers to a liberatory engineering (education) practice, as indicated by the reduced size of gaps in the dotted thin blue lines. This represents a contradiction to be navigated through, where framing (methodology and theory of change), positionality (assessment and assessment method), and community organizing (learning and learning method) may provide pathways through scholarship, praxis, and/or concientização that allow for subversion of the constructed barriers that bound engineering education and practice.

The bounds current hegemonic engineering education practice place on theories of change that engineers may engage with, which are reinforced by the neoliberalism governing broader academic structures, have often required marginalized students to draw inspiration from their lived experiences outside of their engineering education, i.e. their funds of knowledge, cultural capital, and/or community cultural wealth, as strategies for survival [16, 18, 20]. This use of these forms of wealth and capital as strategies of survival in the current form of engineering education and practice stands in contrast to forms of engineering practice guided by liberatory theories and frameworks, which provide more spaces for the community cultural wealth of marginalized people to be normalized as strategies to thrive, instead of solely to survive [70, 71].

These groundings in community cultural wealth, particularly transformational resistance, allow engineers to engage their critical engineering agency as scyborgs and reconceptualize who an engineer is and what an engineer does. This results in the ability to align engineering work with the ethical principles advanced by Riley and Lambrinidou [56], breaking engineering from the technocratic theory of change that binds it and the limitations on forms of ethics allowed to be considered within it. Through this reconceptualization, we can draw from our predecessors not only within what has traditionally been hegemonically advanced as engineering, but also those who are emblematic of what we seek engineering to shift toward and what it has looked like in the margins. Fouché discussed this in the way that Black Vernacular Technological Creativity has historically been utilized by African Americans, and the ways in which "in the technological realm, creativity by African Americans is regularly dismissed as cleverness, instead of being interpreted as smart, ingenious, or innovative" [21, p. 647].

a)

Positionality

Assessment: Emphasis on Single, Technocratic Solutions

Scholarship

Conciêntização

Reflection: Weak Objectivity

Framing

Theory of Change: Technocratic

Action: Hegemonic Engineering Education

Community Organizing

Methodology: Scientific Method

Learning: Emphasis on Convergent Thinking

Praxis

Liberation

b)

Assessment: Labor Organizing Practices, Skills, and Tools

Positionality

Scholarship

Conciêntização

Reflection: Scyborg/Critical Engineering Agency

Framing

Theory of Change: Engineering and Labor

Action: Bargaining for the Common Good

Community Organizing

Methodology: Organizing Model of Unionism

Learning: Experiential Through Organizing (Strike)
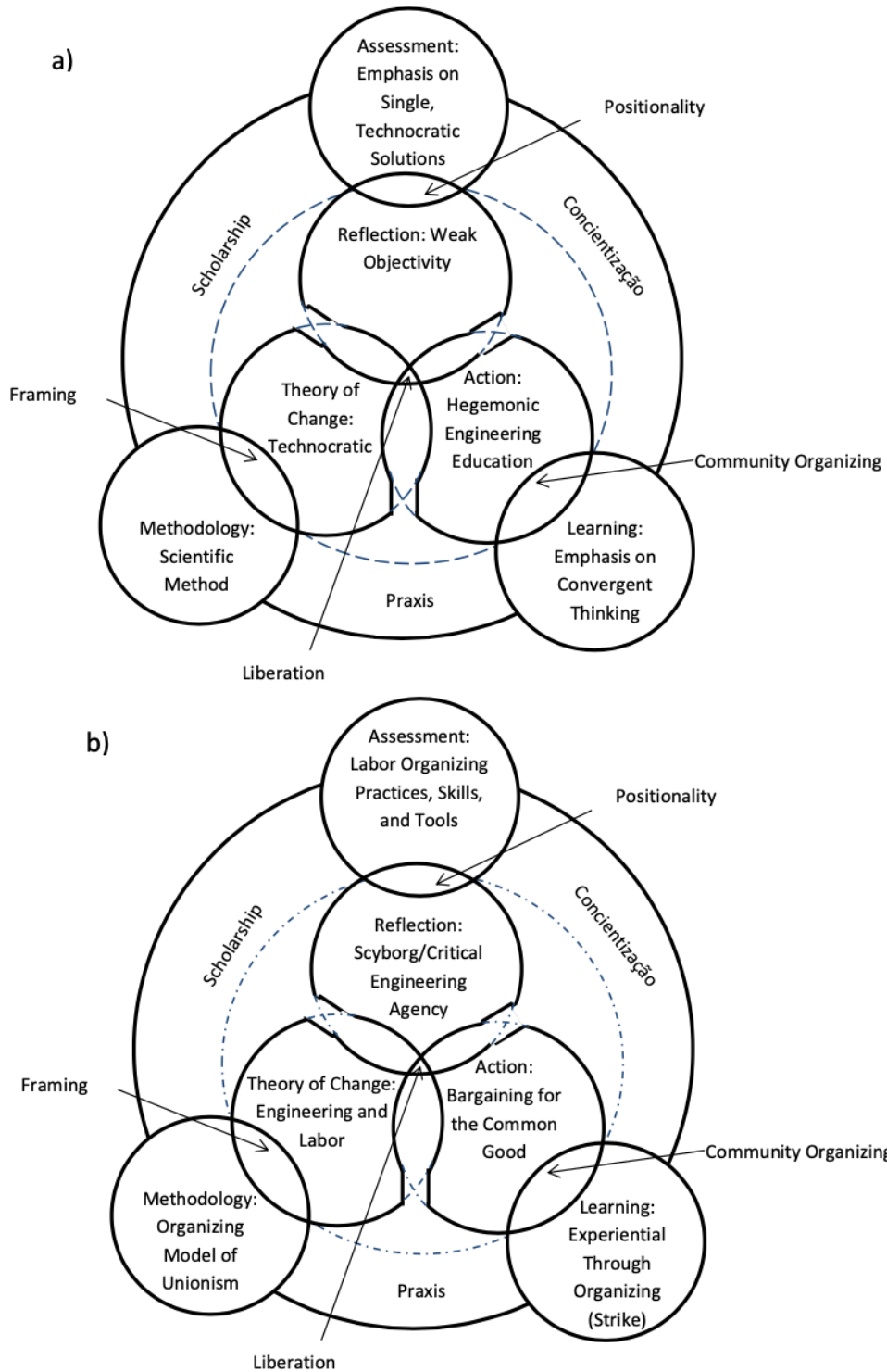
Praxis

Liberation

Figure 2a): Mapping of technocratic theory of change and relevant components to our liberatory engineering education model. Note the increased size of the constructed barriers, b) Mapping of engineering labor theory of change and relevant components to our liberatory engineering education model.

An engineering and labor theory of change can be understood through the framework of critical engineering agency. The technocratic, positivist framing of engineering can be used as a starting point for understanding 1) engineering and engineering-related processes, 2) modes of inquiry commonly engaged with in engineering and related skills, 3) degrees of expertise related to engineering self-identification as components of critical engineering agency [58]. Framing the identity 'engineer' as fundamentally rooted in forms of labor allows for a change to incorporate labor concepts that can provide connection points for engineer(ing educator)s to tap into their scyborg agency, as the engineer(ing educator) is embedded within the assemblage of the university/worksite and engages with their engineering foundation to enact changes [57]. Leveraging an intersectional analytic framework labor organizing is capable of teaching, combined with the engagement of an engineering foundation allows engineers to reconfigure assemblages that allow the technocratic theory of change to maintain hegemonic control over engineering education and practice, thus shifting what engineering is considered to be toward directions more aligned with Riley and Lambrinidou's ethical principles [56]. We use the liberatory engineering education model as a means to connect this theory of change to concepts that can function to make this theory of change actionable (Figure 2b).

The engineer as community organizer (learning method and learning)

For our purposes, we draw on the life and work of Grace Lee Boggs to visibilize connections between engineering and community organizing that are intertwined with labor organizing. Grace Lee Boggs was a Chinese American philosopher and community organizer born to immigrant parents. She received a Ph.D. in philosophy from Bryn Mawr College in 1940, but was de-facto barred from further advancement in academia due to institutional racism [72]. She is most well known for over six decades of labor, Black liberation, and community organizing work in Detroit during industrialization and particularly in the post-industrial decay brought on by factory automation. Much of the theoretical core of her work held its basis in the Hegelian dialectic, where she encouraged "two-sided transformation, both of ourselves and of our institutions" by working through the contradictions present within our current system and ways of being [72, p. 100].

One of these contradictions that Grace and her late husband Jimmy observed was the position unions were in during the 1970s, writing,

> It is very difficult to accept, when so many struggles have gone into their organization, that unions today are the culmination of reformism, and that we have reached the point in history (in the United States) where the more you reform, the worse things get. It has never been so before. In the past, it was inconceivable that struggles for higher wages could act to destroy human rationality. Such struggles were progressive in the past in the sense that the changes they engendered advanced everybody in society … we are talking about understanding, internalizing, recognizing that we are at the stage in the United States today where the changes which have been undertaken are not going to be, cannot be, undertaken by … people who are thinking about how to 'get ours.'

They can only be undertaken by people who know what they want to change [32, p.p. 228-229].

This model of unionism, which focuses primarily on the expansion of wages and benefits for members of a union's bargaining unit, can be viewed in parallel with the political economic phenomenon of majorism, which maintains and reproduces preferential treatment of STEM fields within the academy and broader capitalist logics [73]. Carrigan and Bardini identify linkages between future salaries and class status as components impacting hierarchical rankings among engineering fields as well as across fields of study more broadly. Additionally, their identification of an expectation of students to be trained in skills deemed easily marketable over being educated to think critically and participate in civic society connects to the reproduction of the institutional power of dominant groups and acts as a barrier to potentially transformative social movements by shaping engineering education toward the production of "people who are thinking about how to 'get ours'" over "people who know what they want to change" [32, p. 229].

The drive for "people who know what they want to change" [32, p. 229] described can be connected to the form of community cultural wealth known as aspirational capital, defined by Yosso as,

> the ability to maintain hopes and dreams for the future, even in the face of real and perceived barriers. This resiliency is evidenced in those who allow themselves and their children to dream of possibilities beyond their present circumstances, often without the objective means to attain those goals [19, pp. 77-78].

When aspirational capital is combined with the transformational resistance discussed by Solórzano and Delgado Bernal [64], engineers are capable of not only posing questions of who their labor is benefiting, but also of connecting with means to shift the benefits of their labor toward the broader community. Thus, allowing the learning method of a Bargaining for the Common Good campaign to be enacted. This process is demonstrated visually in Figure 2b. This is particularly salient for minoritized engineers, whose lived experience often allows them to accrue more of these forms of community cultural wealth.

Grace Lee Boggs' community organizing work also holds implications for learning methods leveraged in engineering education. Boggs posited that,

> we need to create a much more intimate connection between intellectual development and practical activity, to root students and faculty in their communities and natural habitats, and to engage them in the kind of real problem solving in their localities that nurtures a love of place and provides practice in creating the sustainable economies, equality, and community that are the responsibilities of citizenship [72, p. 157].

This aligns with the learning method of Bargaining for the Common Good, through which engineers are capable of leveraging and growing their social capital, a form of community cultural wealth, in their social networks through whole worker organizing. An example of a whole worker organizing network for an engineering graduate student is shown in Figure 3. Boggs' assertion that, "the important thing for us was to see the oppressed not mainly as victims or objects but as creative subjects" [72, p. 59] provides a means to link the community cultural wealth of engineers to the growth of practice with the form of divergent thinking discussed by Daly et al. [68]. From this, a social community can be nurtured and grown amongst students, faculty, and other community members, making

Figure 3: An example of a whole worker organizing network for an engineering graduate student, adapted from McAlevey's whole worker organizing network [42].

space for engineers to practice divergent thinking by drawing on their community cultural wealth to solve local community problems. Engineering work centered in local problem solving and rooted in a social community becomes community organizing with the framing of engineering ethics and principles such as those advanced by Riley and Lambrinidou [56].

The strike as liberatory pedagogy (learning method)

Grace Lee Boggs' lifelong work to enact "two-sided transformation, both of ourselves and of our institutions" [72, p. 100] can be the type of critical engineering agency that we co-create with our students [58]. However, a similar neoliberal framework to that which currently binds theories of change students are capable of engaging with in engineering education also operates more broadly within institutions of higher education. A case study of this can be seen in Matthew Johnson's book *Undermining Racial Justice*, in which he details the intentionality of administrators at the University of Michigan with which they upheld racial inequality in response to Black student activism,

> First and foremost, administrators wanted to sustain the university's elite status and preserve a system that measured institutional quality by the "merit" and "qualifications" of its student body. … While preserving racial inequality didn't motivate policies at UM, campus officials usually knew that their inclusion policies would likely maintain racial disparities. If administrators were surprised about the outcomes, they were often surprised by the degree of those disparities, not by the mere existence of inequality. Consequently, racial disparities at UM can hardly be called unintended outcomes [74, pp. 2, 4].

Drawing from Coit's framework of citizen participation and Johnson's example of the maintenance of racial inequality through the diffusion of student organizing power, neoliberal institutions employ comparable tactics to the ways in which citizen participation models imposed from above seek to control and co-opt movements [63, 74]. Coit detailed how citizen participation sought to impart middle class values to the poor, which shows parallels to how neoliberal run institutions seek to bound what forms of change are acceptable via feedback mechanisms and co-opting student movements. In doing so, University administrators consciously and unconsciously act to retain their ability to set boundary conditions on work and forms of protest, shifting the terrain for organizing students from a combination of divergent and convergent thinking to primarily convergent thinking by providing students with a bounded problem of assessing climate and recommending changes without the vested power to enact them. The normalization of this pattern within academia as a whole can be seen in how it propagates to engineering education through the ways in which engineers are professionalized, imbuing engineers with a theory of change in which, "we tell ourselves that through techno-rational arguments we can persuade people in power to make whatever limited changes are needed to excise discrimination and marginalization without touching the rest of the system" [66, p. 450]. In this way, connections can be made between neoliberal University operations more broadly and the technocratic, positivist framework currently utilized within engineering, increasing the size of constructed barriers, as shown in Figure 2a. The technocratic theory of

change, at best, shepherds engineers toward what Solórzano and Delgado Bernal described as conformist resistance, which:

> refers to the oppositional behavior of students who are motivated by a need for social justice yet hold no critique of the systems of oppression. These students are motivated by a desire to struggle for social justice yet engage in activities and behavior within a more liberal tradition. They want life chances to get better for themselves and others but are likely to blame themselves, their families, or their culture for the negative personal and social conditions. They offer "Band-Aids" to take care of symptoms of the problem rather than deal with the structural causes of the problem. In other words, these students choose to strive toward social justice within the existing social systems and social conventions [64, p. 318].

In doing so, the connections between engineering, engineering education, and transformative resistance are obscured, as well as the transformative change these connections are able to bring about if solutions are sought to address root causes of issues. This obscuring of reality that technocratic, positivist frameworks cause has created a pressing challenge for engineers and engineering educators.

Labor unions and organizing can provide members of engineering communities a means to alter university/worksite conditions. Historically, efforts have provided workers a means by which they have pushed for more democratic decision-making at their worksites, particularly around the products workers produce and how they are produced. The theories of change that become accessible through labor organizing can open up opportunities for engineers to engage in transformational resistance. Contract campaigns are opportunities for engineers to channel their aspirational capital through divergent thinking to craft demands that their union takes into bargaining. Divergent thinking is also utilized in the development of strategies and tactics employed in union organizing, including during contract campaigns.

One of the most powerful tactics that workers within a union can employ is the strike. Strikes have frequently been the tactic graduate student workers have needed to resort to in order to obtain union recognition and first contracts from universities [75-77]. Owing to the inherently conflictual relationship between graduate workers and university employers during a strike, the action of striking can map to Coit's concept of local action that seeks to develop a class consciousness, to engage in methods of self-management, and to develop a truly conflictual strategy [63].

Through the action of a strike, space is created for students to engage in divergent thinking while utilizing their analytical skills to solve problems that have been determined by their community. Within engineering, this allows for the enactment of an engineering praxis toward liberation when viewed through the liberatory engineering education model, as shown in Figure 2b. Figure 2b demonstrates how the engineering and labor theory of change could be applied through an organizing model of unionism with a liberatory framing. This opens up potential for engineers to engage their critical engineering agency by reflecting on their positionality and what ways one can reassemble structures as a scyborg through the labor organizing practices, skills, and tools

that are outlined in Table 1. Bargaining for the Common Good is leveraged as a form of action (learning method) in which learning is experiential and is achieved through community organizing, including in strikes. Strikes can thus be viewed as a form of liberatory pedagogy that make space for a type of social community in which engineering work centers in local problem solving, actively practices engineering ethics and principles such as those advanced by Riley and Lambrinidou [56], and enacts changes through Bargaining for the Common Good campaigns. Leveraging this recognition of strikes as a form of liberatory pedagogy, we have concurrently sought to co-develop this theory and understand its implications through a qualitative study with graduate engineering student workers who participated in the 2020 GEO 3550 abolitionist labor strike [78].

Practices (learning methods and assessment methods)

Table 1: Practices, skills, and tools used in labor organizing, the organizing framework of social support outlined by Lee et al. [13], and the social community outcomes outlined by Mondisa and McComb [60] as well as their connections to engineering education research methods and methodologies.

Practice/skill / tool	Description of practice/skill/tool	Connections to Lee et al.'s organizing framework [59] and Mondisa and McComb's social community outcomes [60]	Connections to Engineering Education Research learning methods, assessment methods, and methodologies
1-on-1 organizing conversations	"The 1:1 meeting is a tool to establish, maintain, and grow relationships in organizing" [79, p. 16].	Agency (values), Agency (choices), Process (Institutional Experiences), Process (Affective Responses), Context (Student Attributes), Impact (Intentions) Communities of practice	Think-aloud/ verbal protocols, semi-structured interviews
Coaching	"... the goal of coaching is to help people find their own solutions to meet challenges, and the role of the coach is to ask	Process (Affective Responses), Process (Institutional Experiences), Context (Student Attributes), Agency	Think-aloud/ verbal protocols, semi-structured interviews

	questions to get people to uncover the answers in themselves" [79, p. 21].	(choices) Resiliency, communities of practice	
Storytelling and personal narrative work	"The discursive form through which we all translate our values into action is story. A story is crafted of just three elements: plot, character, and moral. The effect depends on the setting: who tells the story, who listens, where they are, why they are there, and when" [80, p. 11].	Agency (values), Agency (choices), Context (Student Attributes) Social capital, resiliency, communities of practice	Narrative inquiry, autoethnography
Group strategic goal setting	Collectively determine strategic goals that are measurable, focus resources, build capacity, use a point of leverage, focus on a motivational issue, and can be replicated or emulated [79].	Agency (choices), Impact (Intentions), Process (Institutional experiences) Communities of practice	Focus groups, collaborative inquiry, participatory action research
Power mapping	Helps to "identify important people or groups when strategizing, and when designing and implementing tactics" [79, p. 47].	Context (Organizational Characteristics), Context (Student Attributes), Process (Institutional Experiences), Process (Affective Responses), Impact (Intentions) Communities of practice	Focus groups, think-aloud/ verbal protocols, case study, narrative inquiry, participatory action research
Collective bargaining	"Collective bargaining is the process in which working people, through their unions, negotiate contracts with their employers to determine their terms of employment, including pay, benefits,	Context (Organizational Characteristics), Agency (Values), Process (Institutional Experiences) Process (Affective Responses), Impact (Intentions), Impact (Outcomes)	Narrative inquiry, participatory action research

	hours, leave, job health and safety policies, ways to balance work and family, and more. Collective bargaining is a way to solve workplace problems" [81].	Resiliency, Communities of Practice, Social Capital	

Table 1 outlines and describes practices, skills, and tools that are common within labor organizing that the authors have engaged with and used as a source of community cultural wealth to enhance our engineering education research and praxis. These practices, when utilized in the context of an engineering and labor theory of change, can be linked to learning methods, assessment methods, and methodologies that leverage various forms of community cultural wealth to build resistance capital as a form of scyborg agency[56]. Table 1 shows how these practices can be used to build a social community as outlined by Mondisa and McComb [60] and utilize the organizing framework of social support outlined by Lee et al. [59] that can help engineering educators become transformational role models and mentors. Solórzano and Delgado Bernal [64] provide a definition, citing Blackwell [82] and Solórzano [83], for transformational role models who could engage with the practices outlined in Table 1:

> In the context of this study, transformational role models are visible members of one's own racial/ethnic and/or gender group who actively demonstrate a commitment to social justice, whereas transformational mentors use the aforementioned traits and their own experiences and expertise to help guide the development of others [82, 83]. Thus, a mentor is involved in a more complex relationship than a role model in that she or he is someone who participates in one's socialization and development [83, 64, p. 322].

An example of a 1-on-1 organizing conversation and significant personal narrative work indicating how a strike can be a form of liberatory pedagogy is one between the first author and my technical research advisor during the GEO-3550 abolitionist strike. I had emailed my department chair explaining how the strike provided a means to affirm my existence, my validity within academic spaces of communities I am a part of, and struggles I have faced within the department and at the university in ways that official university channels have never provided. That email was forwarded to my research advisor, prompting a frank 1-on-1 conversation that included storytelling and personal narrative work. In it, I discussed the lack of acceptance and belonging that my department allows me to feel, ties these feelings have to systems of oppression whose manifestations within my engineering education experience were driving me toward self-defeating resistance and departure from engineering altogether, and how I was uninterested in becoming another decontextualized statistic of a multipli-marginalized engineering student departing from engineering and/or academia. The forms of community cultural wealth I was able to draw on prevented this departure and the personal narrative work contextualized my situation enough that my technical research advisor and I were able to come to a mutually-agreed-upon understanding that I would engage in more engineering education research that allowed me to

interrogate some the very systems of oppression within engineering education that were driving me to nearly depart from engineering altogether. This was a 1-on-1 conversation, resulting from an abolitionist labor strike, that was critical to the creation of this conference paper. As hooks discusses, "I came to theory desperate, wanting to comprehend - to grasp what was happening around and within me," [70, p. 59] and working with the second and third authors on this paper helped me to engage in theory as a social practice. Collectively, the authors believe that further study into transformative, liberative engineering education is necessary for the principles outlined by Riley and Lambrinidou to be normalized as engineering practice [56], echoing calls from other engineering education scholars for engagement with methodologies that foster scyborg agency such as participatory action research, narrative inquiry, and autoethnography [3, 5, 84].

Limitations (potential barriers)

There are multiple approaches that unions take for change-making, each with differing locations of where and with whom agency for change rests. McAlevey [42] described three approaches to unionism: advocacy, mobilizing, and organizing. An advocacy model holds an elite theory of power, in which existing relations of power are not permanently altered and there is no focus on utilizing worker power. A mobilizing model also utilizes a primarily elite theory of power, relying on staff or activists, setting ambitious goals and declaring wins, even when they have weak or no enforcement provisions. The mobilizing model relies on grassroots activists, defined as those who are already committed, and does not seek to deeply expand their base. Our theory, however, is based on an organizing model, which seeks to "transform the power structure to favor constituents and diminish the power of their opposition. … [This model] prioritize[s] power analysis, involve[s] ordinary people in it, and decipher[s] the often hidden relationship between economic, social, and political power" [42, p. 11]. An organizing model centers its power in workers' agency. Since advocacy and mobilizing models have been shown to center their power in locations other than the workers' agency, they are more reflective of the critique of unions that Grace and Jimmy Boggs offered and could limit the ability for engineers to engage their community cultural wealth to enact change through their union [30].

Bargaining for the Common Good can become especially difficult for technical experts, such as engineers, if interactions with "the Public" are not transformative engagements. Lambrinidou discusses ways in which the interest of technical experts to "do good" can work to "diminish or exacerbate a community's social marginalization, validate or discount its agency and knowledge, and enhance or further undermine its access to and influence on expert research, resources, decisions, and solutions" [85, p. 9]. Failing to recognize power dynamics that can arise between technical experts and non-experts serves only to continue to perpetuate harm and can visibilize contradictions between the intentionality to engage in Bargaining for the Common Good and the impact of the modes of engagement between engineers and the broader community. These contradictions can become especially salient when considering which populations are currently well represented within engineering and how that representation relates to community organizing.

Finally, engineers have continually grappled with the "boundary question" of whether to include technicians within their ranks. This is a manifestation of the contradiction within the professionalization of engineering as a field that has ties to both blue-collar and white-collar work. This contradiction, brought on by understandings of engineering professionalism, has historically served to build up a reliance on management-oriented engineers as leaders, causing a de-identification of engineering with blue-collar labor occupations that are more traditionally associated with labor organizing [28]. The formation of the Alphabet Workers Union serves as an explicit example of how contemporary labor unions can address this; however, there is no guarantee that other engineering labor unions will engage with a diversity, equity, and inclusion-centered union organizing model capable of leveraging a Bargaining for the Common Good framework that the Alphabet Workers Union has positioned themselves to use [40]. An example of union collective bargaining that did not utilize this framework was the Boeing strike of 2000, in which engineering workers engaged in the biggest white-collar strike in U.S. history to that point, but strike demands centered only on improvements to the wages and healthcare benefits of those in the bargaining unit [8]. This strike centered its power in workers' agency, allowing engineers to engage in community organizing and constructing the opportunity for the strike to be liberatory pedagogy by growing solidarity and connections between the striking engineers and technologists and other workers and community members. However, the strike demands did not necessarily correspond to benefits to and investment in the wider community. An explicitly communicated approach utilizing a Bargaining for the Common Good framework would position unionized engineers to contribute to liberative organizing efforts, both inside and outside of academic spaces.

Conclusions

Engineering is currently a field shaped by systems of oppression that are antithetical to the lives and needs of people engineering technologies are intended to serve. Many other forms of engineering could exist that center localized community needs and break rank with the overreliance on technocratic theories of change. If we are to shift this conception of engineering, we need to engage with theories of change that consider current structures of power and move the field in liberative directions. However, we must also be mindful of the engineering field's interactions with and legacies of impact on broader communities.

In this paper, we have sought to outline one form that this process could take by creating a liberatory engineering education model as a container for conceptualizing how to make theories of change actionable. We created and applied a theory of change combining engineering and labor organizing as an example use of this model . Labor organizing can serve as a vehicle for power, allowing marginalized engineers to leverage their community cultural wealth not only toward surviving hegemonic engineering culture, but also toward coming into a scyborg agency that reshapes what engineering is and outlining potential ways that a transformed engineering praxis could look. We have identified Bargaining for the Common Good as a learning method that can enable engineers to leverage community cultural wealth in community organizing and described how strikes can be a form of liberatory pedagogy. We have also demonstrated a further need to explore the class dynamics of engineers and the dialectic relationship of class to engineering education and practice. We have deliberately chosen to couch this paper within the

Equity, Culture, and Social Justice in Education Constituent Committee during its first year owing to its potential to critically engage with relationships underlying the ongoing bifurcation of wealth between poor and working class communities and the owning class further exacerbated by the COVID-19 pandemic as well as continual environmental devastation throughout the world. Additionally, the Black-led rebellions and uprisings for racial justice, multiple graduate student worker strikes across the U.S., and the fascist insurrection of the U.S. Capitol both have occurred since the committee's inception. With this in mind, we leave the reader with the following questions:

- As space is made for a more intersectionally representative engineering student body and workforce, how are we situating ourselves to provide students with the space to engage with the practices, skills, and tools needed to leverage their engineering education toward undoing structural harm instead of reinforcing it?
- What forms of pedagogy could be developed to engage engineers and engineering educators in transformative resistance, and how could they effectively be utilized toward liberation across multiple domains of power?
- What forms of daily praxis, scholarship, and concientização are we, can we, and/or do we need to be engaging with to become students' transformational role models and mentors?
- How can framings, positionalities, and community organizing be leveraged to visibilize frequently invisibilized components of the terrains of struggle in which engineering as a field and its practitioners engage?
- What theories of change can we engage that move beyond helping marginalized students to just survive their engineering education and instead make space for their relationship with engineering education to be a liberative one of healing and thriving?

Acknowledgements

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