

**Supporting Aspirations for a More Just Future:
Exploring Equity Centered Engineering and Design Practice**

by

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Dedication

For my past, present, and future students who inspire me with stories of strength and perseverance, and who challenge me to always work towards being a better teacher, researcher, mentor, and person.

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Abstract

Design is a process for problem solving and creating artifacts that is leveraged across multiple disciplines and is critical to shaping many facets of society both past and present. As such, designers have immense power in influencing outcomes and opportunities that impact the wellbeing of individuals and communities. Thus, without an intentional focus on equity, design can exacerbate existing harms and reinforce injustices. This dissertation, through three distinct research projects, seeks to investigate ways to prevent or alleviate these injustices by supporting the formation of equity-minded designers and engineers who are prepared to center equity in and through their design work.

The first research project investigates the approaches used by transportation practitioners and the barriers they faced when addressing equity through their work. The project used qualitative research methods to elicit detailed descriptions of practitioners' everyday experiences. Three key findings came out of this work: 1) most practitioners have a desire to address equity, 2) practitioners discussed utilizing 12 distinct approaches to address equity, and 3) practitioners discussed 10 distinct barriers when trying to address equity. Findings suggest that practitioners can use the identified barriers to anticipate and better prepare themselves to face challenges in addressing equity.

The second research project identifies external factors that pose as barriers students face when they try to achieve equitable outcomes during curricular and co-curricular community engaged design experiences. To reveal the way these factors operate, the work used critical event

narrative methodology and data-driven composite counter storytelling grounded in a critical conceptual model to identify external factors and situate them in four domains of power: interpersonal, curricular, institutional, and hegemonic. The findings are communicated through the creation of a semi-fictional story about a student named Ash, who grapples with achieving equitable outcomes during community engaged design experiences. Findings can support student decision making, and opportunities for educators to increase student agency.

The third and last project explores opportunities for asset-based teaching, specifically culturally sustaining pedagogy (CSP), to address and alleviate the violences and harms that equity-minded students of color are subject to and experience during their engineering undergraduate education. By preventing these harms from occurring, equity-minded students can persist through their engineering education and become equity-minded practitioners. This project used an asset-based research approach to collect and analyze qualitative data with 14 undergraduate engineering students of color. Themes from the interviews were coded by their relevance to the five principles of CSP. Findings from the analysis aligned the violences and harms with specific strategies that the principles of CSP suggest to directly connect opportunities for CSP in engineering higher education.

Collectively, the three projects suggest that it is necessary to address structural barriers within engineering higher education and design practice in order to support the formation of equity-minded practitioners. The dissertation also demonstrates potential transferability of knowledge, practices, and frameworks across design education and practice, and has broader implications for practitioners, instructors, students, and researchers. Contents of the dissertation can be used by practitioners to integrate shared tools and approaches for addressing equity, by instructors to make transformative changes to their classrooms, by students to find empowerment

and validation of their own experiences, and by researchers to inspire future work in the formation of equity-minded practitioners.

Chapter 1 Introduction, Key Concepts, Organization, Chapter Summaries

1.1 Introduction & Background

In its most tangible definition, design is a practice for problem solving and creating artifacts that is leveraged across multiple disciplines (e.g., engineering, product design, systems design, human computer interaction, architecture, policy, education etc.) and is critical to shaping many facets of society both past and present. It is by design that we have digital technologies that allow us to access information, communicate globally instantaneously, and model scientific experiments. It is by design that we have modern infrastructure for transportation, healthcare, clean water, and power. And it is by design that we have systems, programs, and policies that determine the every-day experiences of individuals and communities. However, design, especially in engineering, is often discussed, taught, and practiced as a value neutral [1] and apolitical activity [2], despite its power to influence social realities and the distribution of wealth, opportunities, and resources. This distribution, without an intentional focus on equity, will continue to maintain the inequitable status quo of who holds power, and where it is located. Thus, if a designer's values are in alignment with fair and just social outcomes, they must acknowledge and consider the power of their design practice.

This intrinsic relationship between design and power is also supported through delineating the abstract concept of design itself, where it is impossible to disentangle design from social equity and justice (particularly equity-minded designers) if we conceptualize design across disciplines as the abstract process by which practitioners and students devise courses of action aimed at changing existing situations into preferred ones [3], and conceptualize social equity as a

fair and equal society in which each person and all groups are valued and affirmed. Social justice is the approach to working toward social equity and encompasses efforts to end systemic violence and racism and all systems that devalue the dignity and humanity of any person. It recognizes that the legacy of past injustices remains all around us, so, therefore, promotes efforts to empower individual and communal action in support of restorative justice and the full implementation of human and civil rights [4].

There are many dimensions to the argument as to why designers should be equity-minded. From a social responsibility perspective, a designer should be concerned with how things ought to be in order to attain goals and to function [3], and because designers are situated in an inherently inequitable society, design should work towards equitable social realities. Foundational design scholar Victor Papanek stated that “the only important thing about design is how it relates to people” which supports the idea that design should work toward social betterment [5]. Yet this idealized perspective has not played out in reality. Designs, and by extension designers, have frequently and directly shaped society in harmful ways [5]–[7]. Engineering, in particular, is a design discipline that primarily handles large-scale projects with significant social, political, and economic impacts due to its close ties to the military, government, and commercial industry [8]. Due to this, engineering design specifically has a long legacy of enabling and enacting oppressive social outcomes [9]. From white supremacist eugenics [10] to racist law enforcement facial recognition software [11], there is an overwhelming amount of historical and contemporary evidence that design plays an active social and technical role in perpetuating injustices.

Design has the immense power to define dynamics of power and privilege and as a result, has amplified many social injustices, even when the intentions of these designs were presumably

for public benefit [12]. Examples include racism that occurs through the low efficacy facial recognition systems when identifying Black and Brown individuals [13] and the sexism that occurs in the design of automotive safety systems that disproportionately protect men from injury or death [14]. Further, as society is stratified in such a way that minoritized and marginalized individuals suffer the burdens of an inequitable society, design that prioritizes the majority often causes harm to Black and Brown communities. As such, a key aspect of equity-minded design is to center the needs, priorities, value, and sustainability of communities of color. One example of a design that disproportionately disadvantages marginalized communities are micro-mobility product-service systems such as scooter and bike-share. Micro-mobility solutions are meant to reduce emissions and congestion in cities, and though they accomplish these important sustainability goals, they primarily benefit wealthy people in gentrified city centers. However, not only does the technology not support the needs of low-income communities of color, but micro-mobility partnerships have also dramatically decreased funding for public transportation which is detrimental to low-income communities of color who mostly rely on public transit to access important resources such as employment, healthcare, education, and food [15], [16]. There are also inequitable implications based on payment for micro-mobility services. Payments can only be made through credit cards on mobile applications, meaning people of color who are the largest share of the credit-less population cannot access the service. Micro-mobility services also often have high additional costs associated with riding a bike or scooter away from the city center towards low-income Black and Brown neighborhoods.

There are designers and engineers that care about and want to address equity, so why do inequities continue to occur, especially in projects that appear to have equity-oriented objectives but produce inequitable outcomes? By engaging in design, designers have the power to benefit or

harm individuals, communities, and society at large. However, most design processes lack articulation of strategies that attend to equity, and even those processes that recognize impacts to people and the environment as a result of the design process or outcome, explicit approaches are limited, especially approaches derived from real designers' experiences considering equity throughout their work [6], [17]–[20]. These harmful designs are the outcome of design processes that leave out a focus on equity in engagement during the process and implications of what is designed.

Simultaneously, there lacks the inclusion of equity as a central element in engineering education in both pedagogical approaches and curriculum topics, thereby influencing how and if students' equity-mindedness is cultivated. The Accreditation Board of Engineering and Technology states that a necessary student learning outcome is “an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors” [21]. This has been a motivating factor for existing research towards making the society-facing aspects of design a more significant part of engineering curriculum [17], [19], [22], [23]. However, many efforts to teach students about the social nature of their work use pedagogical approaches that do not center equity are harmful and do not address underlying systems and structures of inequity that engineering upholds. One example of this is the use of engaged-learning which results in students gaining valuable experiences at the expense of underserved communities [24]–[28]. This highlights the need for alternative equitable pedagogical approaches to authentically and effectively teach equity-mindedness in engineering. Additionally, efforts to incorporate equity into design and engineering curriculum are often treated as a separate task from working toward

making engineering education more equitable in and of itself. This dissertation treats these two efforts just as related and interconnected as the relationship between education and practice.

Ultimately, there are parallel gaps regarding equity in practitioners and students. Without equity-centered design processes, practitioners will not achieve equitable design outcomes. Likewise, without equity-centered engineering education, students will not persist to become equity-minded designers. This work seeks to address these two gaps among practitioners and students with the purpose of exploring ways to support the formation of equity-minded designers and engineers. The research gaps are addressed through three distinct research projects discussed in this dissertation which investigate: 1) how transportation practitioners engaged in design activities use approaches and face barriers when addressing equity through their work, 2) how engineering students' agency to address equity is limited by external factors during engaged design experiences, and 3) how equity-centered engineering pedagogy can support the persistence of students of color.

1.2 Key Concepts

1.2.1 Defining Equity and Justice

The master's tools will never dismantle the master's house - Audre Lorde

The terms equity and justice have become part of our national vocabulary, such that it is commonplace to see these words appearing in social media posts, as parts of the titles of books, and the aims of institutional efforts in policy, education, and industry. However, what these words actually mean in each of their used contexts is often ambiguous, or so many different definitions are used that they have lost meaning. This has made me think critically about the importance of being both specific and having clear epistemological roots for the language I use. So, what should equity and justice mean in my dissertation? In my journey toward achieving

clarity and context specificity, I sought to identify conceptualizations and definitions of equity and justice, all of which relate to broader dynamics of power within society that establish racial and gendered hierarchies regarding knowledge production and validity.

The canon of philosophical work regarding justice and equity approximately starts with Aristotle's conception of *Epikeia* [29], and ends with Rawl's Theory of Justice [30]. Thus, since the late 90s, dominant foundational views and understandings about equity and justice have not changed, particularly within education and the other disciplines leveraged in this work, despite significant ongoing philosophical development by people of color in and outside of the academy. One potential reason for this ideological stagnation is that those who created this philosophical canon (i.e., White European men) are still the ones who determine what types of knowledge hold validity. Challenging the canon would mean disrupting the power of White men which is unlikely to occur in scholarly spaces where White men continue to reside and dominate [31]. Thus, dominant theories of equity and justice were determined by scholars whose humanity, dignity, and livelihood did not depend on how those terms were defined and upheld. This is not the epistemological tradition under which I engage in scholarly work, so while I want the way I use equity and justice in my dissertation to have clarity and validity, I refuse to use a Eurocentric, White patriarchal framing to do that even if it is more broadly accepted.

Furthermore, beyond divesting from the White philosophical tradition because of its' limited relevance to today's racialized society, these definitions limit the possibilities through which we can challenge unjust prevailing systems and structures of power. Black feminist writer and philosopher Audre Lorde aptly described this saying "What does it mean when the tools of a racist patriarchy are used to examine the fruits of the same patriarchy? It means that only the most narrow perimeters of change are possible and allowable"[32, pp. 110–111] As such, I

propose definitions that I have synthesized from the ways in which scholars and activists of color whose' writings I am inspired by (e.g. bell hooks [33], James Baldwin [34], Patricia Hill Collins [35], Mari Matsuda [36]) have utilized these concepts in their work. The conceptualizations of equity that inform my research stem from these scholars and activities of colors' experiences as marginalized people in the struggle for liberation, wherein they bring their knowledge from outside of the academy into it to legitimize the value of their lived experiences.

Equity: The achievement of uniform outcomes evaluated by the same metrics regardless of gender, race, ethnicity, or other social classifications [37]. Additionally, it takes into consideration the historical marginalization of certain social classification groups in different contexts (i.e., education, engineering industry, political participation) [36].

Social classifications: Sociological features and characteristics that impact the way individuals are perceived by themselves, others, and society broadly, and thereby experience privilege, power, and oppression in different ways in different contexts. Social classifications can include but are not limited to gender, race, ethnicity, sexual orientation, social class, religion, age, disability, and citizenship status [38].

Systems and structures of power: Social systems and structures are well-established and often invisible social relationships, practices, and institutions that have self-perpetuating attributes. Power is inherently part of social systems and structures, as power is distributed through them to benefit or privilege certain people and disadvantage others. We assign names to the ways certain social classification groups are disadvantaged through systems and structures of power such as sexism, racism, or classism [39].

Social Justice: The pursuit of equity across all aspects of society, while emphasizing the value, dignity, and autonomy of communities and groups that have been historically silenced,

oppressed, and marginalized. Social justice requires action and language regardless of risk [34]. Social justice frequently addresses and seeks to dismantle systems and structures of power that cause oppression, after which includes reparations of tangible resources [40].

1.2.2 Defining Equity-Mindedness

In the dissertation, I discuss at length practitioners and students who are equity-minded. I draw this term and definition from Bensimon, Dowd, and Witham [41], who in the context of higher education, describe characteristics of an equity-minded individual as someone who has an awareness of the historical exclusion of certain groups from educational opportunities and outcomes or marginalization of these groups in systems and structures that levy those opportunities. Because my dissertation also includes design practice, I broaden this awareness to not only exclusion from *educational* opportunities and outcomes, but also all opportunities that are needed to sustain quality of life. This includes but is not limited to employment, transportation, healthcare, and housing. Equity-mindedness requires a consciousness of how equity is directly related to historical and political stratification of power.

Bensimon et.al. describe equity-minded individuals as being four characteristics: “1) color conscious in a critical sense, 2) aware that beliefs, expectations, and practices assumed to be neutral can have outcomes that are racially disadvantageous, 3) willing to assume responsibility for the elimination of inequality, and finally 4) aware that while racism is not always overt, racialized patterns nevertheless permeate policies and practices in institutions” [41, p. 3]. 1) Being color (or race) conscious entails questioning unexplained differences in outcomes (e.g., educational, socioeconomic, etc.) between dominant and minoritized groups with a context of historical discrimination and oppression. 2) Being aware that beliefs, expectations, and practices assumed to be neutral can have outcomes that are racially disadvantageous means not

attributing unequal outcomes to racial and cultural stereotypes about Black and Brown individuals' predisposition for capacity, ability, aspirations, and motivation. 3) Being willing to assume responsibility for the elimination of inequality means identifying the status of equity as something that can be changed through practices, policies, increased knowledge, cultural know-how, and institutional support. 4) Being aware that while racism is not always overt, racialized patterns nevertheless permeate policies and practices in institutions means when policies, rules, or norms cause disproportionate impact on people of color, they maintain racial hierarchies [41].

It is important to note that I did not, using Bensimon's four criteria, gauge practitioners and students' level of equity-mindedness, but rather used the criteria to identify a certain set of beliefs and attitudes. Within the projects discussed in this dissertation, practitioners and students who expressed caring about equity did exhibit some of these characteristics but not necessarily all of them. This is because bounded by the scope of research, I only obtained glimpses of participants' beliefs, values, and practices. Additionally, Bensimon's original framework was grounded in the inequities of Black and Latinx students. However, I extend this analysis to include other racially minoritized groups as they too can embody equity-centeredness. Thus, I still name these participants as equity-minded to represent their awareness of some of the characteristics, commitment to bringing about equity through positive social change, and action toward doing so in their practice and education.

1.3 Positionality: How I Came to This Work

“Knowledge rooted in experience shapes what we value and as a consequence how we know what we know as well as how we use what we know” - bell hooks [42]

My intellectual philosophy, academic training, and experiences as a mixed¹ Taiwanese American woman shape the personal research paradigm that the work documented in this dissertation is grounded in. My mixed identity is a lens through which I both experience the world, and shapes how I embrace overlaps and intersections of knowledge. Much of my work contends with issues of race, which I argue is an inherent dimension of conceptualizing equity. Being both East Asian (a group that has a complex relationship with being labeled over-represented in STEM but still systemically oppressed), and conditionally White presenting, has given me unique insights into the different dimensions of Whiteness in engineering higher education. This duality means that my proximity to Whiteness has offered me the privilege of being able to blend in more and be a palatable token person of color allowing me access to White spaces. However, because of systemic oppression, I am silenced, inadvertently harmed, and excluded especially when I raise concerns about justice and equity in those same White spaces. This phenomenon of erasure is also a result of my status as a model minority, where the expectation is for me to remain compliant and assimilate to White norms. I combat this stereotyping and oppression by being vocal about the need for urgent change and transformation through my work. Thus, in my research, I bring the perspective of understanding what it means to both benefit and be disadvantaged by White supremacy.

My intellectual philosophy of mixed-ness has led to my formal training as an interdisciplinary scholar embracing the overlaps and intersections of knowledge from different disciplines. Pulling methods, conceptual frameworks, theories, and epistemologies from multiple fields to study equity and design is a core part of my research practice. My affinity for critical theories and narrative research comes from my training as a political scientist and education

¹ I choose to use “mixed” as interchangeable with similar racial identity terms such as mixed race, biracial, or multi-racial because “mixed” better captures the meaning of the mandarin descriptor 混血 which I identify as.

researcher, and my desire to study design and engineering comes from my technical training as an industrial designer and industrial operations engineer. I embarked on my journey to equity work during my attempts as an undergraduate student to combine principles of equity and justice from my political science classes into engaged engineering design projects. While this was marginally successful, I graduated and found that as an engineering design practitioner in industry, there was no space for equity to be even a part of every-day conversation. This tension motivated me to enter graduate school to challenge the depoliticization of design processes and practices, an underlying motivation observable in the dissertation.

Lastly, being in a place of learning through my doctoral studies has given me the opportunity to use my research to make sense of the trauma I have experienced. Through my studies I developed literacy in critical theories and writings by Black and Brown scholars giving me a voice to interrogate and problematize oppression. I center Black feminist theories in my work to follow the tradition of Asian American activists [43] that organized in solidarity with Black activists as co-conspirators toward racial justice. I faced many barriers during the process of conducting the projects within and the writing of this dissertation. Struggle colors the work in invisible ways. My completion of this endeavor was done despite these harms, and I present my dissertation as a form of persistence as resistance.

The pieces of my positionality inform specific research questions, theories, and analysis processes that are discussed in this dissertation. Chapters three and four have positionality statements embedded in the methods sections that detail how my position influences each part of the specific project. Chapter two does not have a positionality statement because I had little agency regarding the research questions, framing, and methods. However, my closeness to issues of equity because of my identities allowed me to engage with the participants more deeply

during data collection and provided a meaningful lens with which to code the interview transcripts to elicit the findings.

1.4 Organization of the Dissertation

The work in this dissertation came from three distinct research projects with an intentional ordering to contextualize how each project informed the next. The second chapter describes a research project exploring the approaches and barriers practitioners face when they address equity. The third chapter extends the identification of barriers to addressing equity by revealing the way students' agency to achieve equitable outcomes in their design work is limited by factors aside from their individual capabilities. Both chapters two and three contend with barriers to the formation of equity-minded practitioners and students within design practice while the last project, discussed in chapter 4, explores opportunities to support the persistence of equity-minded engineering students of color through classroom interventions.

The research project discussed in **Chapter 2 Approaches and Barriers to Addressing Transportation Equity: Experiences of Transportation Practitioners**, explores transportation as a complex design context wherein practitioners' decisions have major equity implications for large and diverse stakeholder groups. This project sought to understand how equity-minded practitioners behave when they try to integrate equity into their everyday practices, as well as what prevents them from achieving the equity outcomes they desire.

The findings from this paper drew me to consider approaches and barriers in an educational context to investigate students who cared about equity and the barriers they faced in their efforts to become equity-minded practitioners like those in Chapter 2. This is problematized in **Chapter 3 The Students Are Doing the Best They Can: Reframing Why Inequitable Stakeholder Engagement Happens in Engineering Higher Education**. Many equity-minded

students intend to create broad social impact through their design work which they practice in engaged design experiences. However, like practitioners, students also faced barriers to achieving the equity outcomes they hoped to. As such, Chapter 3 distills a variety of data types to identify the external factors—outside of what students can control—which act as obstacles to equitable outcomes for engaged design projects. Chapter 3 also highlights the current status quo curricular and co-curricular interventions to sustain equity-mindedness in these students, and how because of their lack of agency, the interventions were detrimental to their persistence.

Chapter 3 noted that equity-minded students are often students of color which informs how crucial it is for students of color to persist in becoming practitioners if integration of equity in engineering practice is a priority. **Chapter 4 Needs and Opportunities for Culturally Sustaining Pedagogy in Engineering Education** explores supporting the persistence of students of color through an asset-based teaching approach that goes beyond specific interventions like engaged learning, to address the sustaining of equity-minded students' ability to maintain their hope and desire to use engineering as means for creating a more just, pluralistic society. Section 1.5 below describes each of the chapters in greater depth.

1.5 Chapter Summaries

Chapter 2 centers how the importance of advancing transportation equity has become more visible as other structural inequities in our society have received increasing attention. As such, articulating approaches that practitioners use to address equity in their work, including experience-based strategies and research-developed equity metrics, contribute to supporting the achievement of transportation equity goals. Chapter 2 addresses the research gap between knowing these approaches and integrating them into regular professional practice, in part because of barriers that span across different transportation-related contexts.

To investigate practitioners' approaches to transportation equity, as well as barriers they encounter in trying to achieve improved equity, we conducted semi-structured interviews with 59 transportation practitioners from the public, private, non-profit, and academic sectors. These interviews sought to answer the three research questions: 1) To what extent do practitioners address equity? 2) What approaches do practitioners use to address equity? And 3) What barriers do practitioners face in their efforts to address equity? Our findings revealed that most of the transportation practitioners in our study engaged in addressing equity in their work, including through collaborating with other organizations and sectors, integrating non-transportation-related data, and considering the contextual needs of vulnerable communities. They identified key barriers to their implementation of transportation equity approaches, including the lack of sufficient and quality equity-related data, challenges accessing and collecting data, and a lack of standards and metrics for measuring equity-related outcomes. These findings can guide work that supports the explicit integration of transportation equity approaches into practitioners' practices.

In **Chapter 3**, we explore how engaging communities is a core part of socially engaged engineering design processes, and that undergraduate engineering programs are increasingly providing curricular and co-curricular opportunities for students to develop community engagement skills. And, if not conducted and managed with an intentional focus on equity, these opportunities risk exploiting communities and exacerbating existing problems regardless of student efforts or skill level. While prior research has mainly explored students' skills and mindsets related to community engagement, this study uses an agentic framework, combined with Domains of Power [38], to investigate how factors beyond students' control substantially impact the equitable nature and outcomes of students' community engagement experiences.

Using data-driven composite storytelling, we present the findings as a semi-fictional, transferable narrative grounded in collected data and our educational, professional, and research experiences to explore the research question: How do interpersonal, curricular, institutional, and societal factors influence engineering students' stakeholder engagement activities and outcomes in curricular and co-curricular design project contexts? The data-driven composite narrative describes the experiences of a student, Ash, during two pivotal stakeholder engagement opportunities: a design project during their first-year Introduction to Engineering course, and a co-curricular community-based service-learning project. Analysis of Ash's story highlights how external factors impact the equitability of engineering students' stakeholder engagements. The outcomes of the analysis suggest different ways that faculty and administrators can support students, in addition to developing new stakeholder engagement pedagogies.

In **Chapter 4** I identify how violences and harms frequently dealt by deficit-based teaching approaches are detrimental to the persistence, well-being, and lives of students of color within engineering education. I propose that these harms and violences can be prevented or alleviated by asset-based teaching approaches, specifically, culturally sustaining pedagogy (CSP). CSP is a unique asset-based pedagogy because it explicitly seeks to decenter the White gaze and shift the purpose of education toward life and love. While prior research has identified the types of harms and violences, little work has been done to explore the needs and opportunities for CSP in engineering education. Additionally, the research that has been done does not link principles of culturally sustaining pedagogy to the real experiences of engineering students of color.

Chapter 4 engages with two conceptual frameworks: defining types of epistemic, affective, ontological, violences and harms, and the five principles of Culturally Sustaining

Pedagogy [44] to demonstrate this link between experience and alleviation, and ground two research questions: 1) What violences and harms do students experience that could be alleviated or addressed by each principle of CSP and 2) What recommendations to their engineering education do students suggest that show opportunities for instructors to integrate CSP in engineering classrooms? Using an asset-based research approach, I conducted semi-structured interviews with 14 students of color from diverse backgrounds to understand their cultural practices, interests, values, and experiences in engineering education related to their ability to show up as their whole selves in and outside of the classroom. Additionally, students contributed their own feedback on ways to implement culturally sustaining pedagogy that would have improved their undergraduate experiences. Findings from this are explicit examples of opportunities for instructors to apply principles of CSP in their classrooms. These opportunities demonstrate that despite ideological and logistical challenges to CSP in engineering education, there are tangible ways and benefits to doing so.

Chapter 2 Approaches and Barriers to Equity in Transportation: Experiences of Transportation Practitioners

2.1 Introduction

The availability and quality of transportation has profound impacts on social equity, as people's lives are directly affected by the accessibility of destinations and the associated travel costs. Because transportation can be conceptualized as the movement of people to resources [45]–[47], individuals who cannot travel out of food deserts are left with options that can lead to long term health issues [48], disabled individuals and those with chronic medical concerns who cannot get to the doctor will not receive adequate care [49], and students in under-resourced school systems who are unable to travel are forced to attend poorly funded schools [50]. These types of transportation inequities are a testament to how policy, infrastructure, and planned transportations systems are not impervious to the structural and systemic inequities that are ingrained in the history and culture of the United States. Clear examples of oppression in transportation contexts throughout history include the Montgomery Bus Boycott spearheaded by Claudette Colvin and Rosa Park's protest of segregated busing [51], the racialized shooting of Oscar Grant by Bay Area Transit System police officers at Fruitvale Station [52], [53], and the planning of many highways that have divided neighborhoods predominantly populated by Black communities, immigrants, and low income individuals. Black Bottom and Paradise Valley were two such neighborhoods in Detroit that were cut off from crucial resources to support their quality of life by the Chrysler Freeway [54]–[57]. Like hostile architecture, which restricts and

discourages the equitable use of public spaces [58], hostile civil engineering discriminates, oppresses, and segregates, exemplified by Robert Moses' design of highway overpasses that discourages transit usage [59]. Less visible oppression resulting from transportation inequities manifests as exclusion from employment [60], racial bias in pedestrian safety [61], and indirect barriers to healthcare access [62].

Transportation decisions have the ability to perpetuate injustice, but also to mitigate the discriminatory harms of past services, infrastructure, and investments. As dimensions of social equity continue to come to public attention through reactions to acts of violence and ideological movements, including the police brutality that sparked the #BlackLivesMatter movement, intersectional feminism emerging from the #MeToo movement, solidarity for Asian Americans and Pacific Islanders in response to the dramatic rise in hate crimes during the COVID-19 pandemic, as well as long-standing efforts for LGBTQ+ and disability rights, there is increased visibility of oppressed communities. This increased visibility may translate to a broader recognition in the field of who and what should be considered when addressing transportation equity. Furthermore, transportation is directly bound to policies that emphasize social equity, such as Title VI of the 1964 Civil Rights Act, which prohibits discrimination on the bases of race, color, and national origin, and applies to federally funded transportation programs and activities [63]. Transportation programs and activities are also subject to Executive Order 12898, an environmental justice order that protects minoritized and low-income populations [64]. The growing prominence of social justice in the public sphere as well as pre-existing transportation equity policy requirements demonstrate that it is the responsibility of transportation practitioners to actively reduce the ways current systems oppress vulnerable and historically under-resourced people and communities.

Transportation equity scholars describe equity as the fair distribution of costs and benefits across society [46], [65], [66]. While scholars vary in what they name as transportation costs and benefits, across the literature, costs include but are not limited to monetary costs, detrimental health impacts, and time, while transportation benefits focus on the opportunities and resources communities and individuals can access such as employment, social inclusion, and education [67], [68]. Within this definition, transportation equity is also framed as having *vertical* and *horizontal* dimensions. Horizontal equity evaluates the transportation costs and benefits across individuals and communities who are of equal ability and wealth, while vertical equity assesses transportation costs and benefits across communities that have different needs and abilities [69]. These definitions provide a foundation for developing approaches for considering potential and existing equity impacts of transportation planning, policy, investments, and systems.

There are multiple transportation equity approaches developed within and outside of academic research contexts that are documented in a body of literature consisting of scholarly articles and public reports. This literature provides some consensus on the relevant types of structural inequities: race, ethnicity, gender, ability, national origin, citizenship, and class. Several scholars describe a cost-benefit analysis framework as an approach to transportation equity [66], [69], [70]. For example, Martens [65] applied a justice theory framework to propose a cost-benefit threshold relative to social class. Another method developed and explored by scholars such as Grengs [71], [72], Levine [73], and Hansen [74], focuses on measuring accessibility quantitatively as a means of evaluating transportation equity. Accessibility considers the level of choice individuals and communities have based on their proximity to necessary resources and the affordability and variety of mode options to travel to those destinations [71], [74]. Other scholars such as Karner and Niemeier [45] suggest critical

adjustments to four step activity-based modeling, while also providing policy approaches such as participatory budgeting, which gives communities the agency to self-determine how capital investments are distributed [75]. Other scholarly efforts have continued to advance ways to measure transportation equity [16], identify gender variations in travel [76], and recognize the relationships among race, accessibility, and life outcomes [71], [77]. However, this body of work has focused primarily on measurement and does not attend to other aspects of holistic approaches to transportation equity [78].

Beyond literature-based metrics that can be leveraged to support transportation equity, approaches developed outside of academic research contexts, such as within non-profit organizations [79], [80], [80] and public agencies [81], [82], have their own methods and goals for application to addressing equity that often differ from each other, but sometimes include elements from theory- and metric-based research. Across approaches developed outside of the academic sector, common premises include centering efforts on racial inequities [79], [80], [83], framing transportation as community-focused, and translating socially informed equity approaches to transportation planning language. **Table 1** outlines key characteristics from five non-academic approaches developed outside of academic research contexts.

Table 1: Summary of transportation equity approaches outside of academic research with associated characteristics distilled from published work or publicly available sources (e.g. non-profit website)

Approach	Characteristics
Untokening Principles [79]	(1) Resist one-size-fits-all approach, (2) prioritize people, (3) see structural barriers, (4) discard best practices, (5) reject policing, (6) value community voices, (7) co-create new decision-making processes, (8) cultivate collective cross-community power
Greenlining Racial Equity Toolkit [83]	(1) Gather information, (2) engage stakeholders, (3) identify policy holes, (4) fill in holes, (5) examine sustainability evaluation
National Equity Atlas [84]	Collection of data on social indicators: (1) race/ethnicity, (2) nativity and ancestry, (3) people of color, population growth, (4) racial generation gap, (5) diversity index, (6) median age, economic vitality, (7) readiness, (8) connectedness, (9) economic benefits, with some geographically specific analysis
Racial Equity Toolkit [80]	(1) Be impact focused, (2) use data and let it inform rather support existing strategies, (3) engage communities, (4) consider the benefits and burdens, (5) plan

	for implementation, (6) ensure accountability, (7) communicate with stakeholders, (8) evaluate results
Advancing Transportation Equity [82]	(1) Design engagement processes that facilitate community leadership and inclusive participation, (2) support programs and policies that increase access to social and economic opportunities, (3) create policies and programs that support active transportation, safe, smart, afford alternate modes, (4) integrating equity promotion as a standardized practice, (5) collaborate and coordinating across transportation and non-transportation agencies, (6) incorporate quantitative and qualitative methods
Evaluating Transportation Equity [81]	(1) Evaluate horizontal and vertical equity with specific measure, (2) direct user charges for road and parking pricing, (3) implement distance-based insurance and registration fees, (4) increase transport system diversity, (5) advocate for more accessible land use and location efficient development, (6) offer more affordable automobile options (7) correct policies that favor automobile travel over other modes, (8) improve public involvement in transport planning, (9) improve data collection

Though the literature and non-academic examples detailed above outline several approaches to addressing transportation equity, little research has been conducted to evaluate how applicable and appropriate these tools and frameworks are to transportation practitioners. Another concern is that although approaches and definitions of equity are well established in the discussed literature, it is unclear how they can be utilized within the constraints of the existing traditions, structures, and systems of transportation practitioners' organizations, disciplines, and sectors. Further, though prior research has explored the current state of transportation practitioners experiences, these efforts have primarily focused on the experiences of transportation planners and the environmental considerations within their planning practice [85]. Beyond this work, limited research has explored the experiences of transportation practitioners with regards to transportation equity. This study contributes to a better understanding of equity practices in transportation work through in-depth interviews with transportation practitioners about their experiences addressing equity.

2.2 Methods

This study investigated ways transportation practitioners address equity, the approaches they used to address equity, and the barriers that hinder them. The study was guided by the following research questions (RQ):

1. To what extent do transportation practitioners address equity?
2. What transportation planning, policy, and management approaches are used to address equity?
3. What barriers do transportation practitioners face in their efforts to address equity?

To appropriately answer these research questions, we used best practices in qualitative research [86], [87], to gather rich descriptions of the experiences of transportation practitioners. One goal of qualitative research is to capture descriptive accounts of experiences and perspectives as well as the contexts that shape these accounts [86]. Using rigorous qualitative approaches, we addressed our research questions using semi-structured interviews.

2.2.1 Participants

We conducted interviews with 59 participants from four sectors of the transportation industry which included a diverse set of occupations: (1) academic [n=10]: e.g., university professors, research faculty, (2) private [n=9]: e.g., automotive company project managers, transportation network company policy analysts, (3) public [n=33]: e.g., urban planners, city transportation managers, and (4) non-profit [n=7]: e.g., special interest policy advocates, special issue consultants. Participants represented a diverse set of occupations within the transportation space. Fourteen (24%) of the participants were women and 45 were men. This gender imbalance is a reflection of the disproportionate number of men in the transportation field across all sectors

(44,45), but the relatively small number of women means that we cannot compare responses by gender.

Participants were recruited through primarily purposive sampling methods by leveraging existing networks of the research team and researching contacts from online public records. In addition, some recruitment happened through snowball sampling where participants were asked if they could recommend other transportation practitioners as potential participants. Participants were invited to participate in the study through email after they were strategically screened for adequate power to make equity related decisions, the potential ability of their professional position to engage in equity issues, and their prior use of transportation-related equity data. The selection process for inviting participants also considered diversity in geographical location including all regions of the contiguous United States as categorized by the United States Census Bureau and a bordering Canadian Province. Other diversity criteria included city sizes, types of transportation companies, and types of transportation related non-profits. Participants from the academic sector were selected based on their expertise in transportation equity.

2.2.2 Data Collection

Data were collected using semi-structured interviews. A semi-structured interview approach follows a sequence of predetermined questions but allows for follow-up questions and “deep dives” based on participant responses [88]. Compared with a fully structured interview or survey, this approach provides flexibility to collect important details in participants’ descriptions of experiences [86], [87], [89]. The interview protocol design for our study was based on these best practices as well as others: asking open ended questions, pursuing depth in relevant topics, and building trust and rapport [90]. We also reviewed protocol approaches used in other qualitative transportation research to include discipline specific practices [52], [91]. The

interview protocol included other questions that were not focused specifically on equity approaches, but an equity subsection was explicitly designed to ask questions focused on participants' background, general experiences in their daily roles as transportation professionals, and their specific experiences related to the three research questions. The interview protocol also included other questions that did not relate to equity approaches but a main sub-section was focused directly on A definition of equity that was derived from foundational literature—the fair distribution of cost and benefits across a population—[46], [66], [69] was provided to participants near the beginning of each interview and was used consistently throughout. We refined questions through four rounds of pilot testing, revising the questions for clarity and alignment with the goals of our research. Pilot participants included transportation faculty and industry partners who had professional positions similar to the intended participants.

Interviews were conducted by 6 members of the research team via telephone and video conference. Interviews lasted an average of 40 minutes each. All interviews were recorded; in total, the data collected consisted of 3,786 minutes of audio yielding 664 transcript pages.

2.2.3 Data Analysis

All interview recordings were transcribed by a commercial service with additional verification and error checking by the research team. Interview transcripts were de-identified at this stage as well by removing names and other potentially identifying information.

Because the protocol included some questions that did not relate to equity, the first stage of analysis consisted of identifying instances of the word “equity” in the transcripts as an initial step in identifying the relevant parts of the interview to analyze for answering the three research questions posted for this study. In addition to the keyword search, other parts of the interview transcriptions that supported answering the research questions were included by identifying

instances in the transcripts where equity related topics were discussed without the use of the specific word “equity” e.g., These portions were primarily continuations of the same topics that participants were discussing when they initially said the word “equity,” but did not continue to repeat the word as they elaborated. The transcript excerpts surrounding, but not necessarily containing, the “equity” keywords included content such as the detailing of equity-related projects, explanations of equity related difficulties, and rationale behind equity-related decision.

After identifying relevant parts of the interview data to support answering the posed research questions, these parts were analyzed using an inductive analysis approach, where common themes, called codes, among the transcripts parts were identified, labeled, and categorized for each research question [92], [93]. Analysis reliability was established through three rounds of an identification process that consisted of noting evidence to support the themes. A code book was refined during each round of analysis that represented the themes discovered and included a definition of the theme based on the data patterns. A distinct codebook was developed for each of the 3 RQs. For RQ2 (equity approaches) and RQ3 (equity barriers), individual participants could have responses coded in more than one theme, while for RQ1 (addressing equity), participant responses could only satisfy one of the four codes. The frequencies of all codes were tabulated and analyzed based on participant sector.

2.3 Results

2.3.1 RQ1: Addressing Equity

A large majority of the participants (93%) said they addressed equity in their work, while only (7%) reported that they did not address equity. Within the *yes* response, two themes emerged that divided the responses: participants who said they *yes, directly* addressed equity and participants who were *yes, indirectly* motivated by equity needs or core understandings but did

not report specific projects or initiatives with explicit equity considerations. Participants who directly addressed equity used language that aligns with existing tools and definitions of equity. Examples of the code *yes, directly* show some of these equity related keywords such as “racism,” “privilege,” and “white supremacy.” Participants who indirectly addressed equity also used this type of language but included rationalization or explanations of how or why equity was not addressed directly. Participants who did not address equity because they were unable to had similar responses to the *yes, indirectly*, participants, but they expressed more barriers, and an explicit statement that noted they were not doing equity related work. Examples of how participants reported addressing equity are shown in **Table 2**.

Table 2: Results for RQ1: Categories of participants’ descriptions of addressing equity

Category and Definition	Example Interview Excerpts
Yes, directly- 48 participants (81%): Participant worked specifically to address questions of social equity and fairness	“I have lots of conversations about racism, institutional racism, how it works, how our organization reflects institutional practices that are rooted in white supremacy, and white privilege, and white ideology. If we don't change that, we just continue to perpetuate and commit institutional racism. That's a big part of what I do every day.” <i>P48, Director of community engagement at a transportation policy non-profit</i>
Yes, indirectly- 6 participants (10%): Participant was motivated to and tried to address equity but not in explicit ways	“So, that's [racial disparities] of course, a concern. It is something that we ask questions about. We don't necessarily, I think, in the scope of the work that we've done thus far because answering the aggregate questions is difficult enough, to dive into why is there this difference? There was a variety of plausible reasons related to exposure of infrastructure and user engagement. It's not something that we have made a major focus on in the interim.” <i>P17, Investment Manager at a state Department of Transportation</i>
No, unable to- 2 participants (3%): Participant did not address equity because they felt there were too many barriers in their position or organization	“I think when you start to talk about implementing ride service, for example, in an automated fashion. I mean, that's a tough one to try and crack because it's something that we're essentially, at least at my level, assessing and allowing and supporting from a technology perspective, but we're not really in the conversation around how it's being implemented kind of in an equitable context, I guess. Like, we're not subsidizing ride sharing services. We're not supporting transit applications because that's not really in what I do and within the department.” <i>P15, Project Manager at an urban tech company</i>
No, no desire to- 3 participants (5%): Participant believed addressing equity was not important, relevant, or part of their role	“I don't directly consider social equity...I don't know whether that's a conscious decision or a subconscious decision. We own and operate in highways and by their nature, highways with a very few exceptions are open to everyone. And so, I guess they're socially equitable in that it doesn't matter who you are, you can drive on our roads... Although I'm familiar with these issues and I occasionally talk to people about them, it's not in my job description to say, ‘Hey, we're not getting buses to these disadvantaged populations, we have people who have these impairments and they need transportation, we need to provide it to them.’ That's not really my job.” <i>P10, Transportation Engineer at a state Department of Transportation</i>

All the non-profit sector participants responded that they *yes, directly* addressed equity. All private sector participants also responded *yes* but were divided between *yes, directly* and *yes, indirectly*, with most of them responding as *yes, directly*. The public and academic sectors were the only two sectors where both *no* themes appeared, with participants in the public sector the only ones who reported that *no, they were unable* to address equity.

2.3.2 RQ 2: Approaches for addressing equity

The twelve distinct approaches were identified from participants' descriptions of how they addressed equity in their work. These approaches are named and defined in **Table 3**, with examples excerpts from the interviews. Two approaches named by most of the participants: *collaborating with other organizations and sectors* (84%) and *integrating non-transportation related data* (80%). Participants who described the collaboration approach did so through sharing data, or co-investing in projects, where both groups had an incentive to collaborate due to shared goals. Often, participants in the public sector described collaboration with entities that managed non-transportation related issues. Six approaches— *considering vulnerable communities' contextual needs* (71%), *improving level of service* (69%), *improving data quality* (68%), *engaging stakeholders* (63%), *bottom-up decision-making* (61%), and *proposing equity-related projects* (58%), also had high reports by participants. Fewer than half of the participants reported using the four remaining strategies: *using qualitative and quantitative data, policy advocacy, implementing pilot projects*, and *considering environmental impacts*. Participants from all sectors engaged in each of these approaches, except *implementing pilot projects*, where there were no participants in the academic sector reported it.

Table 3: Results for RQ 2: Approaches for addressing equity

Approach and Definition	Example Interview Excerpts
<p>Collaborating with other organizations and sectors- 50 participants (84%): Relying on other sectors and/or organizations for data, capacity, skills, or expertise</p>	<p>“We are just starting to form a really good relationship with our health department and starting to look at the connection between transportation and health, which relates to the active transportation stuff. Also, it is an access and equity question as well. The health department has tons of datasets that I think we haven't fully leveraged yet in terms of people's lifestyles. Then how integrating what mode of transportation they're using as a way to improve both an overall community's health in terms of feeling connected and part of a community, but also personal wellbeing in terms of physical activity that relates to heart disease and diabetes.” <i>P16, Program Manager at a state Department of Transportation</i></p>
<p>Integrating non-transportation related data- 47 participants (80%): Using data such as demographic, socioeconomic, race, health, and employment to inform transportation decisions</p>	<p>“The other kind of data that we survey our members, and we use that to better inform our city relationships and our city partnerships. So, we ask things like, "Did you sell a car after joining [car sharing service]? Were you going to buy a car and because of [car sharing service] you didn't buy a car?" We dig a little bit deeper and ask questions about demographics so we can understand income levels of our members and whether or not they have children in their household.” <i>P47, Senior Manager at a mobility company</i></p>
<p>Considering vulnerable communities’ contextual need- 42 participants (71%): Thinking holistically about how history, culture, race, ability, gender, and other social factors can shape outcomes</p>	<p>“I've been doing some work comparing the travel behavior of low-income US workers and low-income Mexican workers because the ways they interact with the city are so different. In the US even the bottom quintile of workers, even in the biggest cities, it's 80% commute by car, which is just very different from the situations where you have a lot more walking, you have a lot more transit.” <i>P19, Professor of urban planning</i></p>
<p>Improving the level of Service- 41 participants (69%): Working to expand on existing projects, modes, and services to improve the quantity, quality, reach, or accessibility of transportation</p>	<p>“Bus service needs to be prioritized and we need to be putting more resources into bus service... The majority of our riders are transit-dependent, and we know there is a disparity between the amount of transit-dependent people that are riding buses, versus the amount of transit-dependent people that are riding our rail service. There is a consensus that focusing more resources on bus service would be a more equitable model of looking at investing our resources.” <i>P8, Senior Manager at a major city's transit system</i></p>
<p>Improving data quality- 40 participants (68%): Improving analysis, accuracy, quality, and granularity of transportation equity and related data</p>	<p>By weeding the survey responses, you can basically summarize this data in a way that it can say something about the population as a whole as well. You can develop descriptive statistics about how many people are taking transit, versus driving in a particular region or for a particular travel market. We are planning to use data that we have gone out to the field and collected, and they are in the process of cleaning, to do an equity study focused on transportation network company users and non-users.” <i>P29, Transportation Manager of small city</i></p>
<p>Engaging stakeholders- 37 participants (63%): Actively seeking feedback from groups and individuals who are directly and indirectly involved</p>	<p>“We went to a lot of senior centers, handed out surveys, helped them fill out the surveys, took the surveys back. We did stakeholder interviews with service providers, with advocacy organizations. We did staff interviews at the homeless shelters and that was really a much better basis of information for finding out kind of what some of the issues were for those populations” <i>P34, Transportation Engineering manager of a major city</i></p>

Approach and Definition	Example Interview Excerpts
<p>Bottom-up decision-making- 36 participants (61%): Engaging with community members and letting their needs drive transportation decisions</p>	<p>“From our perspective when you're developing any kind of equity analysis or some kind of, even like an evaluation tool for how the mobility service worked, you really should be relying on your trusted community partners to tell you which indicators we should select to make sure that we're measuring what matters to folks. And especially on the evaluation piece, you know, what kind of data and metrics should we be collecting, what's useful for people? So really putting that decision-making power in the hands of people most impacted by these decisions as opposed to the traditional top-down measures.” P22, <i>Equity Program Manager at a national non-profit</i></p>
<p>Proposing equity-related projects- 34 participants (58%): Advocating for projects whose intent, execution, and expected outcome is to target historically under-resourced communities</p>	<p>“Mobility or the freedom to move is pretty central to the life outcomes of an individual. There was a project... that was about getting bicycles to junior high and high school aged kids in disadvantaged areas. The experiences that the staff of that program shared about the ability of those students to be able to leave their neighborhood when they wanted to, because they wanted to do something that was healthy for them or wanted to pursue something that would help them choose a different path, was empowering for them, and really important.” P49, <i>Principal Planner for a regional transit system</i></p>
<p>Using qualitative and quantitative data- 31 participants (53%): Employing methods such as surveys, interviews, or town halls in conjunction with traditional data analyses such as travel demand modeling</p>	<p>“We do collect feedback from the neighborhoods on an annual basis, getting their top three transportation priorities. That's one touch point we have with the public, so a neighborhood board, and I think we had like 30-plus neighborhoods officially recognized throughout the city. We ask every year, ‘Give us your top three transportation priorities,’ which we then submit to the [metropolitan planning organization] and our annual [funding] request list.” P59, <i>Transportation Planner of a small city</i></p>
<p>Policy advocacy- 29 participants (49%): Supporting and pushing for policies that directly address equity issues or structures ways to address equity</p>	<p>“I think for a city like (major US metropolitan city), we have articulated our top values as being the equity of our transportation system, safety, wanting everyone to be able to rely on a bus, a car, a bike, or a scooter or walking and better maintained to just be reliable” P40, <i>Transportation policy advisor of a major city</i></p>
<p>Implementing pilot projects- 20 participants (34%): Focusing on very specific communities with the intent to make preliminary observations about outcomes and impact</p>	<p>“We put connected devices on motorcycles in (country), that was specifically dedicated to extending the health services available to people through the national health service... Because of just the simple availability of one cell phone, one driver, one vehicle, there were even several lives saved” P18, <i>Mobility technology specialist at an automotive company</i></p>
<p>Considering environmental impacts- 15 participants (25%): Aligning with EO 12898, the Environmental Justice Executive Order and/or considering environmental factors such as pollution, air quality, emissions etc.</p>	<p>“Our first couple projects were looking at big transportation infrastructure projects and the associated environmental impact reports and digging into things like the potential air quality impacts or the potential traffic impacts, and really taking apart some of the assumptions the project sponsors were making. And in many cases, they're not very realistic, they're often selected to put the project in the most favorable light possible. But they're often trying to obscure potential equity impacts rather than eliminate them.” P4, <i>Professor of urban planning</i></p>

Frequencies of these approaches reported by participants in our study from each sector (public, private, non-profit, academic) are illustrated in **Figure 1**. Public sector participants

[n=26] most frequently (79%) engaged in two approaches: *collaborating with other organizations, disciplines, and sectors*, and *integrating non-transportation related data*. These two approaches were also the most frequent across all sectors. Four approaches that were reported least by public sector participants were *using qualitative and quantitative data* (39%), *policy advocacy* (45%), *implementing pilot projects* (30%), and *considering environmental impacts* (27%). All private sector participants [n=9] commonly named three approaches. These included the two most frequent approaches used by the public sector participants, and also included *engaging stakeholders* (100%). All non-profit sector participants [n=7] employed four approaches: *collaborating with other organizations, disciplines, and sectors*, *improving data quality*, *proposing equity-related projects*, and *policy advocacy*. The approaches with the least number of total occurrences by non-profit participants were *using qualitative and quantitative data* (52%), *policy advocacy* (49%), *implementing pilot projects* (34%), and *considering environmental impacts* (25%).

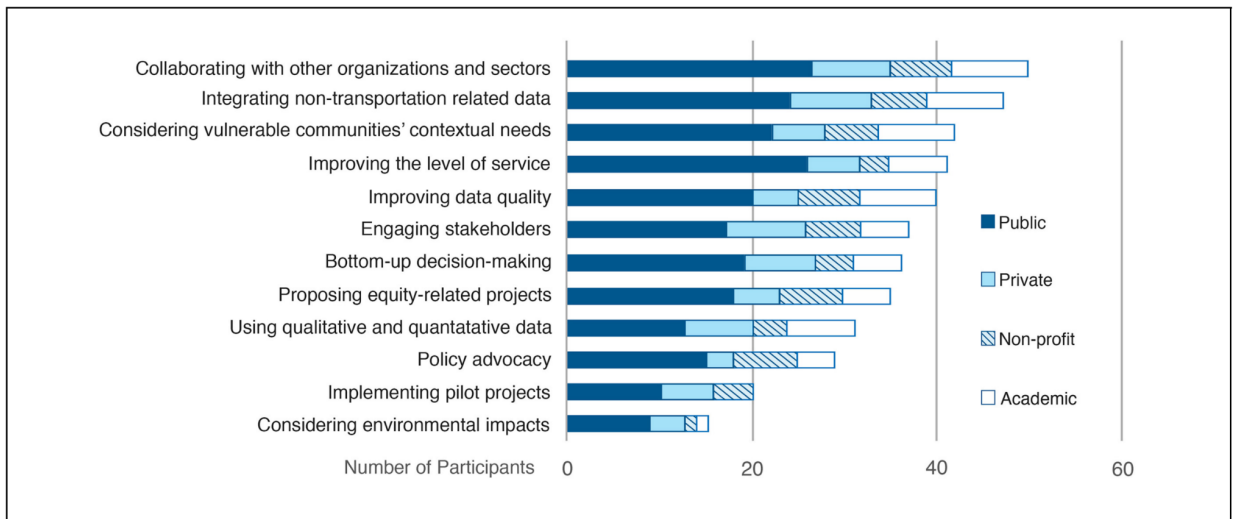


Figure 1: Participant Counts for RQ2: Approaches used to address equity

2.3.3 RQ3: Barriers to addressing equity

The ten barriers participants described facing when trying to address equity are listed in **Table 4**. Two barriers— *more or better data is needed than available* (80%), and *challenges with accessing or collecting data* (78%)—had higher frequencies compared to the other barriers. A majority of the same participants who faced the barrier *more or better data is needed than available*, also experienced *challenges with accessing or collecting data*. Examples of these two barriers suggested a potential relationship between them. For example, *P23* not only expressed that there were no data about individuals with disabilities, but that there were no data *because* there were challenges with collecting it.

Table 4: Barriers to addressing equity

Barrier and Definition	Example transcript excerpts
More or better data is needed than available- 47 participants (80%): Existing information deemed insufficient for effectively addressing equity	“This is the fundamental challenge: We don’t collect good and reliable data on people with disabilities. We’re really quite limited... This [data collection] has not happened because [people with disabilities] have been seen as less than. There’s a long history of discrimination related to disability status.” <i>P23, Technology Policy Consultant at a national non-profit</i>
Challenges with accessing or collecting data- 46 participants (78%): Data exists but cannot be obtained, or there are too many obstacles to collect it.	“Twice before we had a tremendous challenge getting [trip data]. That data all exists but it’s held privately by a number of private companies that get it from cell phone providers, and they want a lot of money for it that no one in the public sector has.” <i>P44, Manager of Green Initiatives at an MPO</i>
No standards or clear metrics for outcomes- 36 participants (61%): Lack of widely accepted standardized measure for understanding and accomplishing equity goals	“Some limitations of the low-income component of that [state funded project] were it seems like everybody has their own way of deciding what low income or vulnerable populations mean. I think there’s a standard threshold, but in looking at what [State] agencies do, then looking at some other studies, it seems like there’s not a lot of consistency.” <i>P33, Transportation Planning Consultant for a consulting firm</i>
Little to no legislative support or public process- 33 participants (56%): Lack of legal or regulatory process to require investing in equity related topics	“[Addressing equity] is just dependent on the good will of that individual or set of individuals or organization to do because it’s the right thing to do, which I think is the vast majority of the time, you don’t really get to the solution point there.” <i>P41, Head of Transportation for a mid-sized city</i>
Lack of skills or tools for data integration and analysis- 30 participants (51%): Inability to process and analyze data due to knowledge and resources gaps	“I know there’s an easier way [to integrate data on aging populations], because I’ve worked with researchers, and I marvel at some of the things they’re able to do to analyze their data and I don’t know how to do any of that.” <i>P13, Assistant Vice President of a national non-profit</i>
Little to no inter-organizational and/or broader systemic support- 27 participants (46%): Direct mention of existing norms of an	“The way equity has entered in the transportation planning field is sort of in the background, but not at the forefront. I think people in the new generation coming up may be a little more progressive, but it’s going to take time and we’re not there yet.” <i>P26, Transportation equity researcher</i>

Barrier and Definition	Example transcript excerpts
employer, or overall sector which prevented pathways to pursuing equity	
Not enough allocated funding- 21 participants (36%): Budgets were too constrained to include equity focused investments	“We are forced to do as much as we can with a spare amount of resources. The issue is it's very entrenched and it gets very political very quickly. And oftentimes cities have just said it's not worth it. Eventually money may come, but we can't continue to rely on waiting for that. If we do, it's never going to come.” P29, <i>City Transportation Manager for a major city</i>
Not enough capacity- 18 participants (31%): Because of limited staffing, resources, and time, efforts must be prioritized elsewhere	“We don't again have the capacity or resource on our staff. We're a small non-profit organization so it's not like I can hire a person to just look at data for me. So, I think we would use it [equity relate data] a lot more if we had the resources to be able to focus on that.” P32, <i>Founder of a grassroots non-profit</i>
Not part of the job- 10 participants (17%): Social equity considerations are not a responsibility	“We don't go into one neighborhood in favor over another or one type of driver of a different type. The data that we collect is ubiquitous across the city. It is based on transportation need not on social expectations.” P34, <i>Professor of urban planning</i>

Frequencies of responses by sector (public, private, non-profit, academic) are illustrated in **Figure 2**. Public sector participants most frequently named the two barriers: *challenges with accessing or collecting data* (85%) and *more or better data is needed than available* (76%). Though not high in frequency, there were three barriers that 42% of public sector participants encountered: *lack of skills or tools for data integration and analysis*, *little to no inter-organizational and/or broader systemic support*, and *not enough allocation funding*. For the barriers *not enough allocated funding*, and *not part of the job*, the frequency of public participants was higher than all other sectors. Private sector participants responded most frequently to three barriers: *challenges accessing data*, *better data is needed than available*, and *no standards or clear metrics for outcomes*. No private sector participants experienced barriers related to job description and motivation. The barriers with the lowest frequencies that private sector participants did experience, were *not enough allocated funding* (22%), and *not enough capacity* (22%). Nearly all non-profit participants (86%) experienced three barriers: *more or better data is needed than available*, *little to no legislative support or public process*, and *lack of skills or tools for data integration and analysis*.

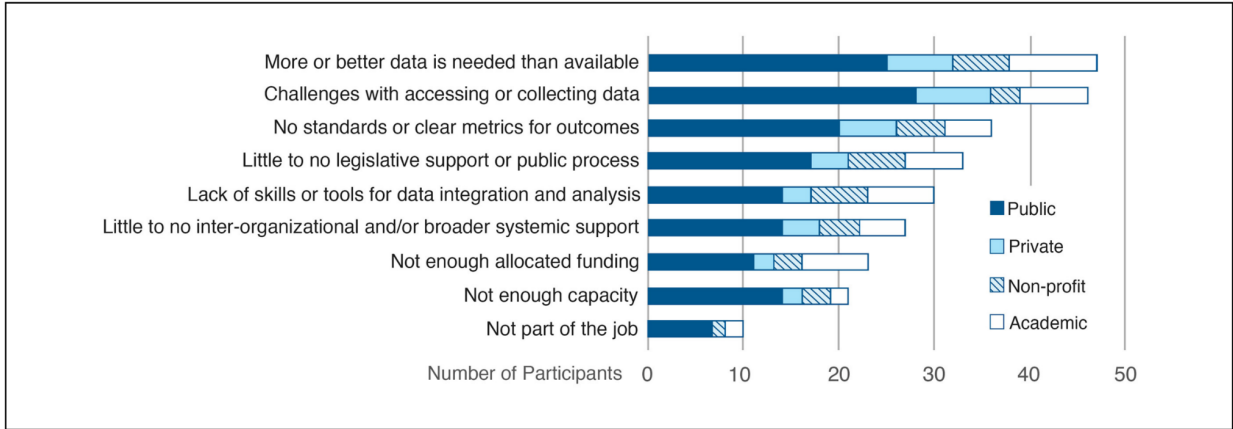


Figure 2: Participant counts for RQ 3: Barriers to addressing equity

2.4 Discussion

Findings for RQ1 revealed that almost all participants believed that transportation equity was important and made efforts to address it. A majority (81%) of these participants addressed equity directly, while 10% of the participants described addressing equity indirectly. The two participants who reported being unable, despite expressing a desire, to address equity due to existing barriers, were both from the public sector. This finding may be explained by the difficulty and complexity of the landscape of public transportation funding can be [94]. In addition to these structural factors, public transportation investments are becoming increasingly more difficult to fund [95]. In contrast, private and non-profit entities may have greater freedom and flexibility to shift organizational approaches.

All participants in the private sector addressed equity. Several private sector participants were part of smaller groups that specifically worked on equity related projects, including demonstrations of how their technology or services could mitigate inadequate transportation resources in specific communities. Other private sector participants noted that they directly addressed equity because it increased their user base and improved the geographical distribution of the service they provided.

All of the non-profit practitioners in our study addressed equity directly, consistent with the sampling approach of inviting participants from non-profit organizations established to address problems of access or inadequacy in systems, services, and technologies. This explanation is consistent with the purpose of the non-profit groups described in **Table 1** which were all organizations that have an explicit mission to address equity.

Three participants, two from the public sector and one from the academic sector, reported that did not engage in transportation equity work and had no desire to engage. Though the participants were from different sectors, all three held engineering technology-specific positions and described equity as an important social issue but not related to their work or day-to day responsibilities. Literature describes (mis)conceptions of engineering as excluding social dimensions [2], [96], which aligns with these three participants' rationale for not engaging in transportation equity work.

Findings from RQ2 revealed that there were 12 approaches participants reported to address equity. The approaches most frequently reported were *collaborating with other organizations and sectors* (85%) and *integrating non-transportation related data* (80%). These approaches were commonly linked, as many participants reported needing data shared from other organizations, which included non-transportation related data. The approach of considering *environmental impacts* (25%) had the least number of responses. This finding could be concerning, particularly in the public sector, where federal equity guidelines focus primarily on environmental impacts. However, another explanation could be that transportation practitioners who primarily consider environmental impacts were not explicitly recruited for this study. Practitioners who specifically address environmental impacts are often employed in environmentally- focused organizations such as the U.S. Environmental Protection Agency, or

environmental justice focused advocacy groups instead of traditional transportation organizations like metropolitan planning organizations or state departments of transportation. The specification of “social” equity in the interview protocol might have also caused an unintentional distinction between environmental justice and social equity which otherwise are often identified as linked in the literature [75], [97], [98].

Some approaches that participants reported, including *stakeholder engagement* (63%), *bottom-up decision-making* (61%), *using qualitative data* (52%), *collaborating with other organizations and disciplines* (85%), and *identifying vulnerable communities contextual needs* (71%) are similar to the named approaches developed outside of academic contexts e.g., valuing community voices [79], communicating with stakeholders [80], and collaborating and coordinating across agencies [82]. Additionally, *collaborating with other organizations and disciplines* and *identifying vulnerable communities’ contextual needs*, were both among the approaches most frequently reported by the participants, and similar to characteristics of the named approaches developed outside of academic contexts. The similar approach from the study, *collaborating with other organizations and sectors* in particular, relates to collaboration as a broader characteristic found in several of the named non-academic approaches. This similarity could support the notion that collaboration involving organizations co-investing funding, capacity, and resources could make overcoming barriers easier.

Other approaches that emerged in this study have not been commonly named in both the literature and the approaches developed outside of academic contexts, including *policy advocacy* (49%), *implementing pilot projects* (34%), *proposing equity-related projects* (58%), and *improving level of service* (69%). The current study likely identified these strategies because policy advocacy and pilot projects are more general activities that can potentially include any of

the approaches named in this study, approaches from scholarly literature, as well as approaches developed outside academic contexts. Though policy advocacy and pilot projects were employed by several participants who held positions such as policy advisors, non-profit project managers, and mobility strategists, policy advocacy and pilot projects are both activities in which engagement is less likely in specific disciplines. For example, a transportation engineer is unlikely to engage in policy advocacy, or a transportation equity researcher may not regularly run pilot projects. This discrepancy could suggest that policy advocacy and implementing pilot projects should not be considered individual approaches, but rather activities where multiple approaches from the findings and from literature can be applied.

The approach, *supporting equity-related projects that target historically under-resourced communities*, was reported by 58% of the participants but is distinct from how transportation equity approaches are framed in the scholarly literature and the named non-academic approaches. While this difference in framing should be noted, the approaches from literature do highlight related methods such as, seeing structural barriers, cultivating cross-community power [79], designing engagement processes that facilitate community leadership and inclusive participation [82], and collecting data on the racial generation gap, and using a diversity index [84]. These methods target specific inequities and groups that align with the recognition that equity related projects targeting historically under-resourced communities are necessary.

Findings from RQ3 revealed that the most frequent barriers that all sectors faced were *more or better data is needed than available* (80%), *challenges with accessing or collecting data* (78%), and *no standards or clear metrics for outcomes* (61%). Several participants who experienced *challenges with accessing or collecting data* said that they faced both issues of access, but also expressed the concern that no large efforts were being made to collect the

necessary data. Among the data types that participants felt were missing were transportation data for indigenous communities, origin and destination data for disabled populations, and information on aging rural populations. Participants also named the inaccessibility of data from transportation network companies as a barrier, which was due to high costs, legal anonymization concerns, and unwillingness of these companies to collaborate. The frequency of the barriers related to problems with data could be a reflection of how reliant practitioners across sectors are on using data in their jobs. A lack of appropriate data can lead to predictions, models, and investments that do not meet the needs of stakeholders. These results align with calls for more work similar to the National Equity Atlas [99], which supplies expansive non-transportation datasets on social indicators.

Participants who expressed *no standards or clear metrics for outcomes* (61%) as a barrier explained that having no metrics to measure and model equity outcomes directly impacted their ability to communicate the importance and efficacy of equity-related work to decision-makers and governing bodies. Other participants explained that a lack of standards in metrics caused difficulties when sharing data across sectors, cities, and jurisdictions. In some instances, participants disclosed that difficulties sharing data prevented them from learning details about external equity related efforts which might have improved their present work. Participants who experienced problems with sharing data due to lack of standards indicated that processing and translating data can require additional costs and resources such as software literacy, employing staff with specialized data skills or outsourcing data management.

Though data related barriers had financial implications, fewer than half of public sector participants mentioned *lack of funding* (42%) as a barrier. The frequency of this barrier is inconsistent with the perception that public sector organizations do not often have operating

budgets that include the cost of starting equity programs, purchasing data, and hiring staff to do more than basic operations. From the transcripts, participants noted that there was funding to do projects, but the difficulty was in building enough support within the organization to reorient project goals to include equity. Based on these responses, addressing the barrier *no standards or clear metrics for outcomes*, might also simultaneously address some of the nuances surrounding *lack of funding*. One public sector participant noted that diverting project funding was difficult because the traditional design of transportation funding structures ensures that “legacy” investments such as highway management consistently receive attention, even if there are more urgent transportation equity issues directly impacting under-resourced communities. This could align with the theory that barriers are often embedded in systems and structures that continue to perpetuate inequities even if practitioners make sincere individual efforts to address equity [100]. Consequently, addressing equity is not only an issue relative to individual practitioners, transportation networks, or communities and stakeholders, but also to the changes that need to be made to the culture surrounding equity in transportation organizations and institutions [101].

One limitation of our study was the relative lack of gender and racial diversity across our participants. While the transportation field is predominantly composed of white males, a more diverse group of participants might have reported or prioritized other approaches and barriers than the ones we found across participants in our study. The researchers acknowledge the importance of conducting research with a diverse set of participants so as to not perpetuate the historical over-representation of white male participants in research. Further, a more diverse group with regards to geographical location, sector, and position types could also result in additional or a change in frequency of reported approaches and barriers. Participants included in the study only included those that were willing to engage in conversations about equity, were

available to participate, and worked in organizations that would permit their involvement.

Practitioners who would have wanted to participate, but could not, may have contributed unique barriers and approaches distinct from participants in this study. Another limitation was that the interviews were done by a small team of 6 individuals; differences in interview style or social relationship with the interviewer may have affected participants' responses. Also, data analysis was completed by a single member of the research team.

As this study followed best practices in qualitative research, the goal of the work is transferability over generalizability, which means providing rich description to facilitate an understanding of the extent to which the research can be applied in another context [102]. For this study, transferability is supported through the detailed descriptions of approaches and barriers as well as excerpts of participants' interviews about their experiences. These descriptions can facilitate, for example, practitioners in transportation work that were not included in our study in their evaluation and work toward transportation equity as well as practitioners in related fields in understanding their own approaches and strategies to address equity.

Many of the transportation practitioners in this study expressed concern for equity across job types, sector, and geographical location. The prevalence of attention on equity could imply that transportation equity is not just an interest in theory, but a growing part of practice. The findings from this study add to a growing body of research on transportation equity that continues to shape the approaches to transportation decision-making and analysis. Practitioners seeking to address equity in city government, planning organizations, equity focused teams in private organizations, and non-profit policy organizations might benefit from this research, as the identification and description of potential barriers can improve the planning for new initiatives

and projects. This study adds valuable insights into practitioners' experiences by naming and collecting approaches and barriers to addressing equity, advances existing transportation equity research, and contributes a foundation for future related work.

2.5 Conclusion

Although numerous studies have suggested changes in policy, planning, and management to address transportation equity, little research has been done to consider how new approaches compare and contrast with current practices. Though some participants engaged in approaches that were similar to those reported in the literature and in the named developed approaches, no participants in this study directly cited the use of metrics and measures that researchers have established, such as accessibility measurements, cost-benefit style equity analyses, and a context specific equity threshold. Given that transportation equity continues to be a significant consideration during transportation decision making processes, the transportation equity approaches such as metrics, frameworks, and tools developed by scholars, are becoming more relevant for widespread use. However, few systems are in place to directly communicate the best practices in transportation equity research literature and integrate them into the approaches currently used by transportation practitioners.

The study findings identified approaches and barriers that can serve as a foundation for further understanding of the existing landscape of transportation equity as addressed by practitioners, with the intent of highlighting potential knowledge gaps between literature and practice. Through in-depth interviews we found that a large percentage of these practitioners are interested in addressing transportation equity, but several barriers deterred them from doing so. This study categorized approaches to addressing equity and identified three common approaches to address transportation equity used by practitioners: 1) collaborating with other organizations and sectors,

2) integrating non-transportation data, and 3) considering vulnerable communities' contextual needs. Other approaches from the study could increase in frequency as more practitioners become familiar with them. Barriers most frequently experienced by transportation practitioners were 1) the necessity of better or more equity related data, 2) challenges with accessing or collecting data, 3) and the lack of metrics to measure the outcomes of addressing equity. Key unanticipated observations were the lack of participants who cited considering environmental impacts as ways they addressed transportation equity, the low emphasis of funding as a major barrier, and the potential interrelationship of the three data related barriers. This study provides a broad understanding of transportation practitioners' experiences addressing equity from which future work can be done to normalize conversations surrounding equity in all transportation decision-making processes.

Chapter 3 The Students Are Doing the Best They Can: Reframing Why Inequitable Community Engagement Happens in Engineering Design Higher Education

3.1 Introduction

Engineers engage communities and stakeholders in their design processes for myriad reasons, including to define their design problems, identify possible solutions, and evaluate solution feasibility [103]. Research on equitable design processes has also emphasized the importance of engaging communities and stakeholders to avoid perpetuating harm towards marginalized communities [104], [105]. Thus, it is crucially important that engineering students develop skills for equitable stakeholder and community engagement as part of their undergraduate education, and engineering programs are increasingly providing curricular (e.g., capstone [106] and co-curricular (e.g., community service-learning) [107] opportunities for students to develop these skills. These curricular and co-curricular opportunities often involve communities with real-world problems. Literature has shown that such opportunities, if not conducted and managed with an intentional focus on equity, risk exploiting stakeholders' time and resources for the sake of educating privileged White students [27]. This unintentional exploitation is rooted in a legacy of charity-based White supremacy and paternalism which historically has and presently can exacerbate existing problems, or worse, create new ones [108].

This paper explores how factors outside of students' control impact the nature and outcomes of engineering students' community engagements. Borrowing from the underlying concept of many agentic theories [109], [110], we title these factors outside of student control as

“external factors” - ranging from interpersonal relationships to structural supports or barriers - that influence student project outcomes irrespective of “internal factors” such as individual student knowledge and mindsets. Prior work has deeply explored internal factors including students’ knowledge gaps and challenges related to stakeholder engagement [111], their successful practices [112], and their mindsets related to stakeholder engagement [113]; these prior studies have provided valuable insights for supporting student learning. However, relatively few studies have additionally investigated specific ways that external factors impact the nature and outcomes of engineering students’ stakeholder and community engagements as well. This research gap is important to address because several reported student challenges with engaging stakeholders equitably, such as limited interaction with stakeholders outside of problem scoping [114], [115] and limited use of stakeholder perspectives in decision-making [115]–[117], could reflect logical student responses to the external, structural constraints of their projects, rather than student deficits. In other words, external project factors must be accounted for, in addition to developing improved pedagogies for stakeholder engagement, to expect significant changes towards more equitable community and learning outcomes from community engaged student projects. Therefore, we aim, through data-driven counter storytelling, to demystify and problematize how power operates through external factors to impact student agency.

3.2 Background

3.2.1 Barriers to Equitable Outcomes in Undergraduate Community Engaged Engineering Projects

Prior work has identified several external factors that can potentially impact how undergraduate engineering students engage communities and stakeholders in their design projects - although specific details about *how* these factors impact student agency and

community outcomes are limited. For example, co-curricular service-learning design projects represent one common pedagogical setting where students engage stakeholders. In many cases, these projects serve communities that are geographically distant from the teams' home universities. Assuming that students wish to graduate within four years, this distance means that students are constrained by semester schedules in terms of how much time they can spend in their communities [118]–[120]. In addition, students may wish to research their partner communities in advance but find scant information available in publicly-accessible sources such as the internet, particularly for rural communities [118], [121]. Program-related factors can also influence how students approach their work. Thompson and Jesiek [122] examined three domestic undergraduate engineering engagement programs and identified six structural themes, such as program purposes, partnership structures and project deliverables, that influenced interactions with project partners.

Engineering students also engage stakeholders in engineering classes such as capstone design and, increasingly, cornerstone (i.e., first-year) design. Studies of capstone engineering design students have suggested additional external factors, such as assignment timelines and grading rubrics, that influence how engineering students approach stakeholder engagement. For instance, Loweth et al. [115] examined the information gathering meetings of six capstone design teams to determine with whom teams met, when their meetings took place, and the strategies that teams used to gather information during meetings. The authors found that teams tended towards early meetings where they confirmed design goals and parameters and tentatively concluded that course constraints may have played a role in this behavior. As another example, Guanes et al. [117] studied how capstone engineering design students employed empathic behaviors (i.e., behaviors related to understanding stakeholder needs) in their projects. They

found that while their participants considered a wide variety of stakeholders, they ultimately prioritized the perspectives of faculty members and other individuals whose perspectives would directly impact their course grade.

Engineering culture represents another factor that influences engineering students across curricular and co-curricular engagement contexts. For example, Cech [123] has described a culture of disengagement in academic and professional engineering contexts that positions public welfare concerns, including community engagement, as tangential to real engineering work. This culture of disengagement has been corroborated in other studies of engineering students and may include symptoms such as: viewing inequitable social outcomes as resulting from fair distribution of resources [124], [125]; discounting social solutions to engineering problems in favor of technical solutions [126], [127]; discounting community knowledge in favor of technical engineering knowledge [116], [127]; and positioning technical engineering work as unrelated to social or political concerns [123]. While these norms may exist within individual mindsets, they also exist structurally within academic engineering environments and may affect a range of factors including curricular and content choices, assessment, and funding options.

In addition to documenting external factors that influence student projects, literature has also provided recommendations for successfully navigating these factors. For example, Wood and Mattson [128] examined failure reports published by Engineers Without Borders Canada and identified seven pitfalls that contributed to project failures, including “Lacking the contextual knowledge needed for significant impact” and “Neglecting to make a plan for or developing partners for long-term sustainability.” To avoid these pitfalls, the authors proposed a “Design for the Developing World Canvas” that design teams could use to think through the impacts, customers, product, delivery, manufacturing, and revenue models of their projects. As another

example, Leydens and Lucena [129], synthesizing their prior work, identified six “Engineering for Social Justice” criteria to guide engineers in performing equitable work. These criteria included 1. Listening Contextually, 2. Identifying Structural Conditions, 3. Acknowledging political agency/mobilizing power, 4. Increasing opportunities and resources, 5. Reducing imposed risks and harms, and 6. Enhancing human capabilities. The Center for Socially Engaged Design at the University of Michigan developed a socially engaged design process model that emphasizes how power and positionality impact designers’ processes, the goal of this process model is to scaffold student learning and support reflection [130]. Furthermore, Ozkan and Hira [131] proposed a “For Whom? - With Whom? - As Whom?” model to encourage critical, justice-oriented conversations in first year engineering courses.

The above recommendations and frameworks all are useful for supporting designers in thinking through the broader implications of their design decisions, planning in advance for navigating external project factors, and practicing more equitable design behaviors. They also encourage designers to think about how their personal and social identities influence their stakeholder and community engagements. However, a common limitation of these recommendations is that they primarily focus on designers as individual or team decision-makers, rather than as actors within broader curricular, institutional, or societal contexts. In other words, these recommendations do not make clear how societal power structures operate behind the scenes, often through multiple external factors, to constrain engineering students’ agency and outcomes in community engaged contexts regardless of students’ knowledge or mindsets. This is a substantial gap; as described by Nieusma and Riley [132], it is entirely possible for engineers to engage stakeholders with the best intentions and try to follow equitable practices as individuals (i.e., follow all the recommendations and models outlined above), but still produce

inequitable outcomes overall because they cannot individually overcome the structural challenges that they experience.

3.2.2 Models for Equitable Community Engagement in Higher Education Literature

Several contemporary models for community engagement were developed outside of engineering to address how power operates within community engagement experiences to constraint student agency to achieve equitable outcomes. These models start from the premise that the origin of all service learning is rooted in charity-focused models that perpetuate neo-colonial, White supremacy, and paternalistic relational norms between students and the communities they seek to serve [27], [133]. These models thus recognize and address the logistical, ideological, and power related barriers that characterize traditional engaged learning experiences. For example, Clayton's SOFAR framework [25] highlights how inequitable power dynamics manifest in relationships between (S)tudents, (O)rganizations in the community, (F)aculty, (A)dministrators, and (R)esidents of a community. The SOFAR model addresses barriers rooted in power by explicitly evaluating whether a service engagement is exploitive, transactional, or transformation through mapping the players involved and describing how power moves between and through relationships.

Other scholars have turned to approaches and frameworks that aim for the greater goal of social justice to address barriers related to how engaged learning reproduces hegemonic oppressive power relations such as racism, classism, and sexism. Consequently, these models decenter students to center communities. For example, Mitchell's critical service learning framework "pays particular attention to social change, its questioning of the distribution of power in society, and its focus on developing authentic relationships between higher education institutions and the community served" [134, p. 101]. Critical service-learning emphasizes the

development of critical consciousness in students instead of solving a community's assumed need. By being community led, critical service-learning addresses barriers of cultural difference and class/race based saviorism by aiming for students to understand how their social identities impact their and their community stakeholder's relationship to power, oppression, and privilege.

Iterations of critical service learning have centered specific structural barriers to social justice such as Clark-Taylor who proposed the integration of intersectional feminist pedagogies [135] that introduce a power analysis about the “interconnectedness of racism, sexism, and classism, that replicates the dominant model of community engagement” [136]. Likewise, through a decolonizing lens, Santiago-Ortiz [137] posited that critical service learning, despite its' investment in social justice, maintains a deficiency in addressing the significant unrecognized power of settler-colonial logics, thus experiences should intentionally take an anti-colonial stance. Lastly, Telles explored barriers to equitable community engagement through issues of racial inequities where the invisible burden of facilitating and mentoring community engagement activities disproportionately falls on faculty and staff of color [138].

In summary these approaches and frameworks take into consideration how power, and by extension agency, create or prevent pathways for students and faculty to achieve equitable community outcomes. By comparison, comparable approaches in engineering education have typically focused on addressing barriers as individual problems versus seeing barriers as structural, intertwined, and interrelated. While translating critical engaged learning approaches to engineering education contexts might be feasible, there are unique barriers to engineering stemming from cultural norms around creating technical rather than social solutions [116], [126] and viewing societal deficits as resulting from individual failings rather than structural oppression [123], [125]. Because of this layer of engineering culture, it is necessary to deepen

our understanding of how external factors and barriers operate in relation to dynamics of power to affect outcomes specifically in engineering before we can develop new approaches to more equitable engaged engineering design experiences.

3.3 Methods

This study investigated the ways external factors impact student agency and community outcomes. Guided by agency and Domains of Power as conceptual frameworks, we used data-driven composite counterstorytelling and critical event analysis to answer the following research questions.

3.3.1 Research Questions

1. How do external factors influence engineering students' community engagement activities and outcomes in curricular and co-curricular design contexts?
2. How do these external factors reveal how power operates through different domains in the context of curricular and co-curricular engineering engaged projects?

3.3.2 Conceptual and Analytical Frameworks

Our research study was grounded in two conceptual frameworks: Domains of Power [38] (Patricia Hill Collins addition to Intersectionality originally developed by Kimberle Crenshaw), and Archer's conceptualization of agency [139]. These frameworks allowed us to understand how power manifests in different ways at different scales and is levied through different structures, as well as how human agency is controlled by internal and external factors (structures). Other scholars outside of engineering education have applied Intersectionality and agency in conjunction with each other for a variety of different purposes. For example, several scholars have noted how agency and power are intrinsically connected through identity and the

matrix of domination, and have therefore used agency and Intersectionality to study the complexity of privilege and disenfranchisement of Latinx students [140], Latina pathways to graduate school [141], and gender bias toward South African women school principals [142]. While diverse in existing application, contending with the way engineering culture impacts learning environments differently than other disciplines is outside the scope of these papers. As such, these existing approaches to employing agency and Domains of Power together are limited in transferability to the context of our research study.

3.3.3 Agency

While conceptualization of human agency has emerged in different fields, we leveraged the intellectual foundations of agency in sociological theory, which explores the relationships between individuals, structure, and power. Giddens [143] developed the theory of structuration to understand how individuals and social forces interact to determine our social reality. Giddens' core argument was that social structures and individual action cannot be discussed separately as they both simultaneously impact human agency. While Giddens' theorizations of agency primarily focused on examining social structures, Archer's [139] approach—which is the theorization we use in this study—instead posited a separation between individual and social environment to allow for a deeper investigation of the relationship between individuals, social structures (i.e., external factors), and culture. Archer also explored the internal considerations, beliefs, and decision making processes individuals have when they interact with their social reality. More postmodern approaches and variations in other schools of thought include diverse ways to understand agency through considerations of power, identity, and rationality [144]. Our work is grounded in this conceptualization of student agency with external factors limiting the number of rational choices students can make.

3.3.4 Intersectionality: Domains of Power

Intersectionality is a Black feminist analytical framework developed originally to identify the distinct ways that Black women were oppressed due to the intersection of their minoritized racial and gender identities [145]. However, applications of Intersectionality as an analytical framework have expanded to include social categorizations beyond race and gender such as socioeconomic status, disability/ability, sexuality etc. to provide a more holistic understanding of how our social world is constructed. Broadly, intersectionality provides us with “a lens through which you can see where power comes and collides, where it interlocks and intersects” [146]. This study focused specifically on Intersectionality as a lens to understand how external factors are manifestations of power wielded at different levels and in different forms. Patricia Hill Collins formalized this lens by building upon Intersectionality through her framework, Domains of Power [38], which is used to situate power relations that shape external factors that facilitate oppression. These domains intersect and are inter-related.

To formalize the different ways that power is organized, Collins’ contribution to Intersectionality used four interrelated Domains of Power – 1) structural, 2) disciplinary, 3) hegemonic, and 4) interpersonal. The structural domain of power is the large scale social institutions that reproduce inequities (e.g., K-12 public schools funding from income taxes perpetuates racism). The disciplinary domain of power relates to the organizational practices of social institutions or the rules of the game (e.g., standardized tests disproportionately exclude students of color from higher education). The hegemonic or cultural domain of power includes “ideologies such as White supremacy, patriarchy, and heterosexism are constructed and shared” (e.g., the false narrative that low-income students of color do not want to be in school). The interpersonal domain “shapes social relations between individuals in everyday life” (e.g., White

teachers tone policing Black women for expressing their opinions) [38], [147]. While Intersectionality was meant to study the interlocking forms of oppression that Black women experience based on their identities as being both Black, and women, our analysis uses Domains of Power adjacent to its original application, with a stronger alignment with Patricia Hill-Collins' re-conceptualization of Domains of Power [38] who applied it as a means to analyze power in any context. As such, our theoretical framing shifts from the relationship between social classifications and oppression to the intersecting nature of how power operates in the academy to privilege some and disadvantage others.

3.3.5 Data-driven Composite Counter-Storytelling

Data-driven composite counter-storytelling is a critical research method that uses multiple data sources to capture and convey the dimensions of subordination within the lived experiences of minoritized people. Several scholars have used this method to understand and explore the experiences of students, teachers, and other education stakeholders of color that deviate from dominant narratives of Whiteness [148], [149]. We follow in the tradition of these researchers by creating a character composed of data from several participants as well as autobiographical information, and situate this character in a particular social context to illustrate/highlight a specific phenomenon of oppression [150]. There are multiple benefits to composite counter-storytelling such as providing cohesion by sifting through many participants' lived experiences and communicating shared themes through one continuous narrative. However at its core, composite counterstories “expose barriers that inhibit success and derail social consciousness, creatively position quotidian experiences as critical cultural commentary, teach those unfamiliar about marginalization, and challenge and transform the imposition of domination” [151].

As with other composite counter-stories [150], our data collection and analysis processes were guided by our theoretical sensitivities as researchers. Theoretical sensitivity is “a personal quality of the researcher that indicates an awareness of the subtleties of meaning of data” [152]. Theoretical sensitivity can be developed through the researcher's own experiences relative to the research topic as well as exposure to literature or even through reflection during the research process. Theoretical sensitivity guides the researchers in identifying themes and incidents to include in the counter-story to best communicate answers to the research questions in alignment with the guiding frameworks.

We employed data-driven composite counter-storytelling to directly address dominant narratives in engineering education that 1) student learning outcomes are more important than community outcomes or student personal outcomes and 2) that co-curricular project failures mainly stem from student knowledge gaps, rather than structural or institutional factors. Dominant narratives are the existing status quo assumptions, occurrences, and priorities that are unchallenged by the majority. Dominant narratives inadvertently contribute to inequitable experiences or outcomes because they erase the experiences and perspectives of those with less power [153]. In studies of community engaged learning opportunities, dominant narratives are perpetuated through research questions that focus on student learning outcomes over community outcomes (e.g., [118], [154]) and/or student failures (e.g., [128]), as well as through methodological and analytic choices that de-link student perspectives from their lived realities. This study contributes to the growing body of work (e.g., [155]) that explicitly challenges dominant narratives related to community engaged learning opportunities in engineering, in our case by using counter-storytelling to elucidate crucial details within the lived realities of

engineering students that explain student actions or outcomes but have often been overlooked in previous research as being out of scope.

Another advantage of composite counter-storytelling as a research approach is that individuals may not always be aware of how their thoughts and actions are guided by external factors beyond their control. While individuals can come to recognize these factors through guided reflection and praxis [15], such reflection is difficult to achieve within the constraints of a traditional interview study. Composite counter-storytelling provides a way for the authors to engage in this praxis and generate a research artifact that supports the praxis of other students and instructors. Furthermore, composite stories allow us to protect the identities of the various individuals who took part in our experiences, which is necessary given the potentially sensitive nature of some of our subject matter. Lastly, we chose to portray our findings through a story, because “theory of all types is often presented as being so abstract that it can be only be appreciated by a select few” [35]. This is particularly important as the story demonstrates the interconnectedness of the external factors we identified. The experience of the external factors was not ubiquitous to all our participants, thus a story allows us to capture the nuance collectively, while simultaneously using a communication medium valuable to a wider audience.

3.3.6 Data Collection

Following the practices outlined by Solorzano and Yosso [150], we built the data corpus for our composite counterstory from a range of sources including data gathered from student teams, curricular and co-curricular artifacts, data published in prior literature, and autoethnographic reflections on participation in educational opportunities involving stakeholder and community engagement. KC contributed the following unique data: previously unpublished interview data with eight undergraduate engineering students from four co-curricular student

design teams; over 100 blog posts from a single undergraduate co-curricular community engaged engineering design team recounting project updates over the course of seven years; daily journal entries during field visits that included photos; over an hour of video footage of prototype construction and testing as well as interviews with project stakeholders; travel planning documents such as budgets for three field visits; logistical documents such as emails between students and advisors, notes from calls with community partners, and reports compiled for annual design review. RL contributed anonymized, previously published data on six mechanical engineering capstone design teams' stakeholder engagement practices [115], [156]–[158] and the needs assessment practices of a co-curricular community engaged design team [118], [159], [160].

The two authors also leveraged data from shared or similar experiences, including: syllabi, course schedules, and assignment descriptions from three first-year engineering design courses; reflections on teaching those first-year courses; reflections on mentoring over seven co-curricular community engaged design teams; reflections on facilitating over 100 (across both authors) one-off socially engaged design workshops in first year and capstone design courses and for co-curricular design teams; reflections on facilitating 12 workshops about equitable service and engagement across multiple disciplines; and reflections on participating in curricular and co-curricular engineering projects as undergraduate students (previously described in part in Cantilina & Loweth [161]). We collected reflection data through verbal and text conversations and through individual written reflections on our experiences; verbal conversational data, which was not audio recorded, was entered into our data corpus via written notes.

3.3.7 Positionality and Our Theoretical Sensitivity

Our approach to this work was influenced by our theoretical sensitivity, cultivated by our experiences and perspectives on how we have participated in aspects of community and stakeholder engaged teaching, learning, and design practice. Our social identities such as cultural background, gender identity, and race/ethnicity, also influenced our broader roles as researchers, how we made sense of our own experiences relative to the research topic, our motivations for doing the work, and the ways in which we chose to analyze the data. While our individual theoretical sensitivities contributed to our respective approaches to conducting this work, the way we harnessed researcher triangulation through leveraging our differences also strengthened our analysis.

KC's theoretical sensitivity in relation to this work is rooted in her values and experiences as a student, engineering design educator, and researcher. As a student, KC was driven to community engaged design because it combined her values surrounding fairness and global equity, with the strong culture of making from her family and design undergraduate studies. Additionally, KC's social identity as biracial meant she was socialized in a multiethnic household where discussing global and social issues of race, gender, and class were normalized. This socialization and "outsider status" make her acutely aware of the White supremacy and paternalistic elements of engineering culture, key themes that show up in this work. This dissonance motivated her to participate in socially engaged design projects, one of which was an international service-learning team, an experience similar to this study's participants. This project, while rewarding, highlighted the limited power of students and inequitable default nature of engaged engineering experiences. As a researcher, KC has investigated a wide body of literature relevant to the research questions, and as an educator, has had access to student experiences through teaching and mentoring many engaged engineering design teams. Having

been on the inside and outside of these experiences has given her insights into where and how power operates within the academy to influence student agency and community outcomes.

RL's theoretical sensitivity related to this work stems from his experiences as an engineering student, an engineering design educator, and as an engineering education and engineering design researcher. RL originally pursued an engineering degree because he enjoyed making and because he wanted to make the world a better place. While his educational journey ultimately took him outside of engineering (as described elsewhere [161]), he was still ultimately socialized into dominant ways of engineering thinking and knowing, in part because he was a straight White man operating in a straight, white, and masculine academic space. Later, in graduate school, RL's engineering education research led him to recognize how his undergraduate engineering experiences in engineering were raced and gendered, and also to recognize how broader curricular, institutional, and societal factors may have shaped his experiences beyond his immediate awareness at the time. Furthermore, as a design mentor, instructor, and researcher, RL had access to the experiences of many other students with diverse identities; these additional experiences highlighted aspects of RL's undergraduate experiences that were transferable to other contexts, and elucidated the role that instructors play in shaping students' experiences. In this work, RL's theoretical sensitivity facilitated his identification of the sometimes-subtle ways that engineering students' agency is affected by external factors beyond their control and, relatedly, how white men are privileged in engineering academic environments.

3.3.8 Data Analysis

The first step in our analysis process involved us sifting through our data corpus for examples of the concepts of agency and power we were seeking to illuminate. We modeled our

analysis around critical event narrative methodology, also known as critical incident technique [162], in which researchers search for moments and incidents where an event significantly changed the participant. Changes can include the shifting understanding or belief about a certain thing, or new realizations about the world around them. Webster et al. note that “Because events are critical parts of people’s lives, using them as a main focus for research provides a valuable and insightful tool for getting at the core of what is important in research” [163]. Critical events are also supported and surrounded by “like” events that are moments which further reinforce the themes and impacts illustrated through critical events. Our research sought to identify critical events supported by “like” events in our participants and our own stories to capture key shared experiences across students who participate in engineering community engaged design. Lastly, by focusing on the most important events, this methodology is also particularly effective for the analysis of large bodies of data that come in diverse modalities through reducing the need to examine every detail of a narrative [163]. We chose to select both critical events and “like” events because the external factors we identified had contextual and situational relevance that would otherwise be lost if the external factors were pulled out of the data in isolation.

After identifying critical events and “like” events for contextual relevance, we coded these data for external factors that impacted student agency and students’ ability to create positive impact on community stakeholders through their design work. We recognized these external factors by leveraging our theoretical sensitivity and by the fact that the same factors repeatedly emerged across critical events in our multiple data sources and participants.

To answer our second research question, we used our conceptual framework of Domains of Power to organize the external factors into corresponding domains to demonstrate various ways that power operates to influence student agency. We initially sorted external factors into

Domains of Power according to Patricia Hill Collins' framework (structural, disciplinary, hegemonic, and interpersonal) [38]. However, as we reviewed our data, we realized that our analysis process would benefit from a greater tailoring to the specific academic context we were studying. For example, PHC's structural domain of power describes how systems and structures impact individuals; however, we realized that in academic engineering contexts, students experience the structural domain of power largely through curricular and institutional structures. Thus, we sorted factors into curricular and institutional Domains of Power, rather than a single structural domain of power. We also realized that PHC's disciplinary domain of power, which relates to how disciplinary rules and regulation maintain the status quo, maps onto engineering disciplinary culture. Engineering culture pervades multiple aspects of engineering educational environments as the metaphorical "water we swim in" [164], [165]. Thus, we did not assign external factors to an explicit disciplinary domain of power; rather, we treated this domain in our context of study as closely intersecting our other Domains of Power: individual, curricular, institutional, and hegemonic.

To write our counter-story, we worked collaboratively to arrange the narrative themes across our data types using our joint interpretations to create characters, dialogue, critical events, and artifacts that mirrored as closely as possible the insights from the experiences of our participants [151]. Several aspects of the story directly reflect data points such as quotes from interviews and videos integrated into dialogue and slightly altered artifacts shown as figures in the following sections. However, it was important to maintain anonymity of our participants and the other individuals they discussed in our data. As such, it was crucial that most data points be adjusted to support answering the research questions and constructing the counter-story. Our process was iterative in that we revised and revisited the data continuously until we felt our

counter-story accurately represented our findings and demonstrated external factors across interpersonal, curricular, institutional, and hegemonic Domains of Power.

3.4 The Story as Findings

3.4.1 The Main Character

Ash is an engineering student of color who chose a career in engineering because they believed engineering could make the world a better place. Ash attended a university whose engineering curriculum placed a strong emphasis on understanding the societal implications of technologies. Every student took a one-semester cornerstone design class, ENGR101, in either their first or second semester. While the syllabi of different ENGR101 sections were ultimately up to the instructor, each section was required to introduce students to “the engineering design process” and provide opportunities for students to practice designing for stakeholders. After their experience in ENGR101, Ash wanted to further act on their motivation to use engineering for good by joining a socially engaged international design team.

3.4.2 Welcome to Engineering 101

“Hello everyone, and welcome to ‘Engineering 101: Engineering for Social Impact’!”

It was the second day of the semester, and Ash was sitting in their required first-year engineering class, ENGR101. They’d had several sections to choose from, and felt lucky to get their first choice option: Engineering for Social Impact. The syllabus had promised some sort of “socially engaged” design project, and Ash couldn’t wait to get started. Already, the course seemed more interesting than the large-lecture calculus and physics prerequisites that Ash had sat through on Monday.

“My name is Dr. Taylor, and I use she/her pronouns. Today is syllabus today, so I’m gonna introduce myself and the rest of the teaching team and then talk a bit about what the semester will look like. As for me, I am a lecturer in the College of Engineering here at State University. I got my Ph.D. in Mechanical Engineering from the University of Central Valley, where I studied engineering design, and I am so excited to get to know you all better this semester.”

Dr. Taylor’s enthusiasm was palpable - by Ash’s guess, she couldn’t be older than 30, maybe 35 tops. Definitely a significant change of pace from the middle-aged men who were teaching the rest of their courses this semester.

“...anyways, about the semester. The first several weeks we’ll teach you about basic engineering analysis processes using Excel. I know, I know - not the most interesting stuff, but the College says I have to teach this for ABET. It’ll all be worth it though when we get to the second half of the semester, which is my favorite part - the design project! We’ll be designing technical solutions for a local food bank, so you’ll get a chance to practice the engineering design process, including problem definition with real stakeholders, idea generation, engineering analysis, the works. Any questions?”

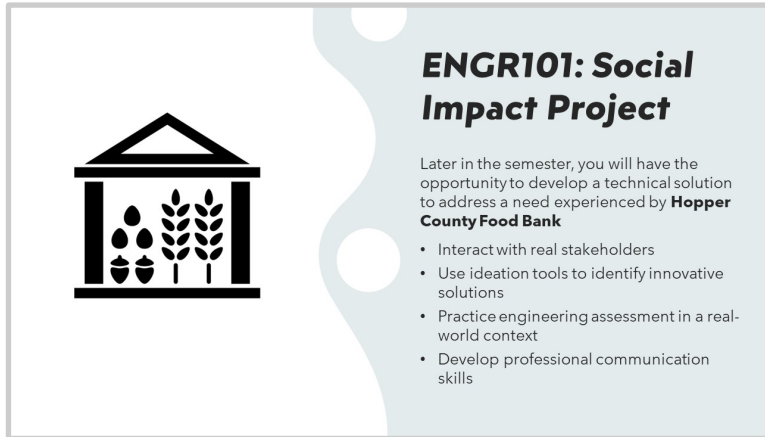


Figure 3: Project intro slide

No questions thus far. Ash looked around the room - typical engineering classroom. Roughly 60 students. Majority White of course, maybe slightly more women than in Ash's math and physics classes. Regardless, Ash had already started to get used to being one of the few people of color in their engineering classes. The important part was that this section of ENGR101 seemed to be everything that Ash wanted from their engineering degree. They came to college wanting to make the world a better place. At least so far, Dr. Taylor seemed to be promising the tools to do that.

“Alright, so with that out of the way, I’d like you guys to get to know each other better. So, I’ve prepared this icebreaker activity...”

3.4.3 Defining the Problem

Ash felt that they were really starting to get the hang of this college thing. They were doing well in their classes, and after what seemed like an eternity of dull Excel problems they had finally started working on their design project in ENGR101.

Teamwork was a core part of the course, and Dr. Taylor had used some survey - CATMA or CATME or something like that - to make teams. Dr. Taylor was pretty mum about what the survey actually did, beyond mentioning something about aligning schedules. Regardless, in a class of mostly white students, Ash had ended up on a team with another person of color, a Latina named Maria who dreamed of being an aerospace engineer. Ash's other teammates included Mark, who was interested in electrical engineering, and Stacey, who was interested in biomedical engineering.

Milestone	Date Due
<i>Project Start - Oct 12th</i>	
1. Problem Definition	Oct 24th
2. Idea Generation	Oct 31st
3. Concept Evaluation	Nov 14th
<i>Thanksgiving Break - 11/21 to 11/26</i>	
4. Iteration	Nov 30th
5. Final Report	Dec 9th

Figure 4: ENGR101 Project Schedule

The first deliverable for the design project related to “problem definition.” Dr. Taylor had spent the last two lecture periods first discussing what students were expected to produce - a needs statement along with criteria and constraints - and then reviewing recommended practices for conducting effective interviews. Each team was required to interview two stakeholders of their choice associated with the food bank and use this information, along with secondary research, to complete their first design report - which was due in the following class period. Mark and Stacey had interviewed a volunteer at the food bank, and Ash and Maria had interviewed one of the homeless Black men who used the food bank. They were now meeting to go over their findings and complete their design report.

Mark: "Alright, so, looks like for Monday we gotta write up a problem background, needs statement, and identify criteria and constraints. What do we got?"

Stacey: "Well, I remember the volunteer we talked to, they mentioned how during Covid it was sometimes really tough because they needed to minimize contact between volunteers and the homeless folks to avoid spreading the virus, but also they didn't want to just leave all the food out to get stolen."

Mark: "Yeah, that's good that's good. So, we wanna design some sort of system that can help with that, right? Ash, Maria, what are y'all thinking?"

Ash had been partially following the discussion, partially reflecting on their interview with the homeless food bank patron. Their experience was so different from Ash's! Rather than talk about their experience with the food bank, the patron had mostly discussed how it was so difficult to find stable employment given their arrest record. They had at least been able to count on the local shelter for a bed, but things had gotten even worse during Covid. Now they were out on the street again, quickly running out of remaining cash, desperately looking for opportunities. Ash had heard stories about the "New Jim Crow" - who hadn't, growing up as a person of color? Their dad had always been extremely strict that Ash needed to stay on the right side of the law. For the most part though, they'd been protected from the actual implications. Ash was deeply moved from the interview. As they were wrapping up, he noticed Maria slip a \$20 bill to their interviewee. But, back to the meeting.

Ash: “Oh, uh, well, something Maria and I’s interviewee mentioned actually didn’t really have to do with the food bank at all. They talked a lot about how employment was so rough, especially having an arrest record. I wonder if there’s a way to hit two birds with one stone, you know? Can we figure out this contact issue and do some sort of employment thing?”

Stacey: “Like employ the patrons at the food bank maybe? That would potentially get rid of that contact issue - then the homeless are just interacting with each other, and the volunteers are safe.”

Maria looked visibly uncomfortable at this suggestion, but neither Stacey nor Mark seemed to notice.

Mark: “Yeah... I think this has potential. But is it a technical solution? Cause you know, we’re engineers. Making social systems isn’t really our thing. What’s the need that we’re addressing?”

Ash: “How about something like ‘The food bank needs a way to reduce contact between volunteers and homeless patrons while preventing theft of food.’ but then our criteria and constraints could focus on employment of patrons as a core criteria?”

Mark: “That’s dope. Let’s write it up! Ash, let’s you and I nail down our needs statement and criteria. Stacey and Maria, can y’all finish up the project background?”

3.4.4 ENGR101 Epilogue

After turning in their first design deliverable, Ash’s ENGR101 class swiftly moved to idea generation and development of low-fidelity prototypes. Dr. Taylor provided useful feedback on Ash’s problem statement, which helped their team develop a novel solution: a low-tech food checkout and monitoring system that was constructed by homeless patrons and that could be mass produced for other food banks, thus offering a steady stream of employment. Since none of the remaining design deliverables explicitly required Ash to interact with stakeholders, their team never actually tested their solution for feasibility. Nevertheless, Ash ultimately received an A in the course and their team won an in-class award for developing a highly creative solution.

3.4.5 Co-curricular Design Team

While Ash enjoyed their ENGR101 experience, there ultimately weren’t any resources to keep working on their team’s design project after the semester ended. Instead, in their second semester, Ash joined a pre-existing and institutionally funded co-curricular design team focused on improving the quality of life for a village in Ghana through the development and implementation of low cost water filtration systems. The team hoped that, through their efforts, they could reduce the amount of daily work required by local women. The project was co-sponsored by the College of Engineering and by an alum of the university, with the alum hoping that the project would fulfill their company’s corporate social responsibility requirements. Over their sophomore year, Ash becomes a core member of the team and, using design skills learned

in ENGR101, spends months developing concepts and prototypes based off of observations and stakeholder interview data from the team's previous two-week annual trips to the village. It is now their Junior year and Ash, as the new team lead, is planning and budgeting the team's annual site visit tentatively scheduled for two weeks around the university's Spring Break.

3.4.6 Preparing for the Trip to Ghana

Around Thanksgiving, Ash and their team finished a comprehensive draft of their plan for accomplishing their design goals in Ghana. The last step before they could start booking flights was to clear their plan with their project mentor, Dr. John White. Dr. White was an ambitious assistant professor who would soon be up for tenure review. He could give great feedback... provided you could get his attention or fit into his schedule. Ash had thus far only interacted with Dr. White in passing, although older team members passed down stories of alternately being embraced and absolutely ripped apart during meetings. Hoping to make a favorable impression on Dr. White, and anxious to start booking flights, Ash takes several hours to craft an extensive email with multiple documents and details to give Dr. White a complete picture of how much work the team has done to prepare for their trip.

Several weeks later, in the midst of a late night of work, Dr. White finally skims Ash's team's plan and documents and sees several red flags. Too tired to document all of the issues that he sees, and given that Ash has already sent him a reminder email, Dr. White decides it is better to just meet with the team ASAP. He sends a quick email to the team from his phone.

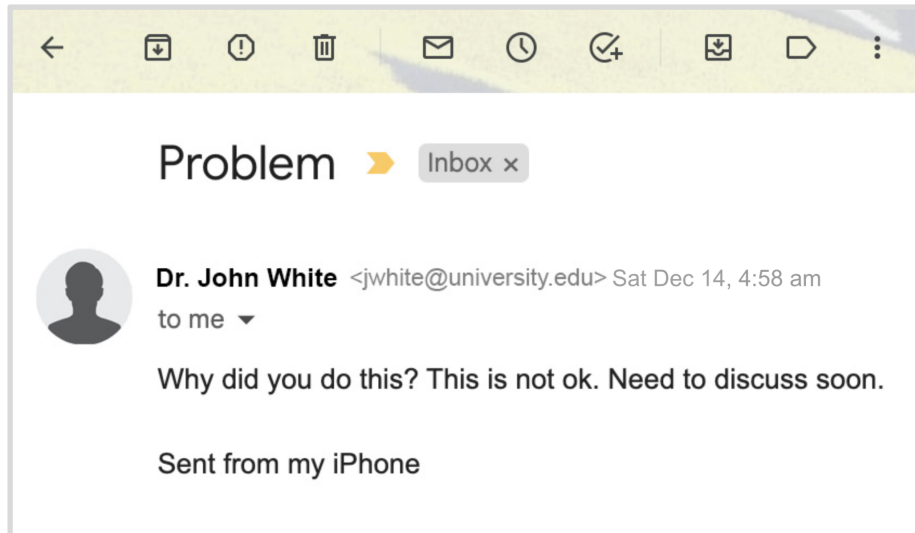


Figure 5: Email Response from Dr. White

The email sends the team into a panic. It’s already the end of the semester, and several team members, including Ash, had already traveled home for break. They had thought they had done a good job thinking through all possible issues - especially since they hadn’t heard from Dr. White for several weeks. Ash responds and sets up a Zoom with Dr. White for Tuesday morning.

Now, it’s the morning of the meeting. Dr. White emailed that he would be a few minutes late, and Ash is on the Zoom call chatting with their teammates Jackson, the project design lead, and Hannah, Ash’s project co-lead.

Ash: “I’m really nervous about how this is gonna go down. I already spent way too much time on all this planning instead of working on my exams.”

Jackson: “Dude I know, why do we even meet with this guy in the first place, it’s not like he’s ever actually helpful, he just trashes what we do and makes things even more confusing”

Hannah: “We don’t have a choice though. We need Dr. White’s approval to actually travel to and work with the community. That’s like, kind of the whole point of this project you know?”

Dr. White shows up 10 minutes late, flustered after having come from an important meeting about his upcoming tenure review.

Dr. White: “Sorry I’m late. I’ve been running on coffee all day but I also have to leave a few minutes early so I only have 15 minutes for this. Remind me, what are we talking about again?”

Ash reminds Dr. White about the team’s plan for field work in Ghana.

Dr. White: “Oh yeah, you guys are grossly unprepared to do this work in the field and several things need to be changed in order for this to be up to my standards for approval. Where’s your daily engagement schedule? Where’s your risk assessment? Your interview protocol is all closed ended questions, and your validation plan isn’t actually measuring any of the specifications you identified. Um.. what else? Oh yes, I was expecting to see a stakeholder map or something similar... Background research was good... Trip history was good... Nice work on the prototypes so far... Yeah I think that was it. Any questions?”

Stunned silence from Ash, Jackson, and Hannah. Ash’s head is swimming with anxiety.

This sounds like so much extra work. Dr. White takes the silence as a cue to continue.

Dr. White: “I just want you guys to be successful but it seems like you are all lacking in some skills and knowledge that you should have by now. I know time is short, so I can sign off on your travel to allow you to book airfare. However, my condition is that you need to make time to attend some workshops to update your travel plan before... when were you planning to travel again? Ah yes, I see. Spring Break.”

Taking Dr. White’s advice, the team signs up for four workshops to supplement their knowledge of cultural sensitivity, entering, engaging, and exiting communities, needs assessment, and appreciative interviewing. These workshops were conducted by centers on campus that catered to a wide audience. Thus, the workshop content focused on transferable skills that could apply to any service-learning context, not Ghana or even Africa specifically. The workshops helped Ash and their teammates feel more prepared for their fieldwork. They learned a lot; Dr. White wasn’t wrong. After the workshop, Ash and Hannah iterate on their target agenda for the trip.

Ash: “I feel like we need at least 5 days to just get to know our stakeholders. I want to make sure people actually trust us. I’ve literally never been to Africa.”

Hannah: “Yeah but spring break is only two weeks and we also have to prototype, test it, get user feedback, and actually try to solve this water filter problem. We have to prioritize.”

3.4.7 Fieldwork Trip to the Community Stakeholder Village in Ghana

Ash and 5 members of the predominantly White team travel to Ghana to engage the village community members. When they land, they are guided by Kofi, a manager of the factory the university alum (Mr. Mensah) owns who will act as their Akan to English translator. Kofi expresses how impressed he is with the students and hopes his children can someday go to the United States for college. The next day, Ash and the team are introduced to the community stakeholders by Kofi.

*Kofi: *in Akan* "I would like to introduce you to this team of students from America sponsored by Mr. Mensah to work on a project for the village. Mr. Mensah hopes you, as his employees, will treat them as his guests"*

Ash: "We are here to support your efforts to access clean water more conveniently through the design of a water filter"

There is chattering amongst the villagers and Ash hears the word "Oburoni" said a few times but assumes it probably means students or something. Eventually, many villagers offer to take time off work and procure supplies with their own resources to help prototype the design concept in the field.

During the first week of interviewing, the team tries to talk to a diverse group of people. However, most of the conversations with men in the village are short. Kofi explains that it's because accessing water is a "woman's issue" so the team finds themselves mainly working with a woman named Efia with whom they rely on Kofi to communicate with.

Halfway through the last week, Ash and the team are gathered around Efia as they observe her using their water filter prototype. Ash asks a series of questions, after each question, pausing to hear what Efia has to say.

Ash: “Do you like it? Is it easy to understand how to use it? Is it filtering fast enough for you to get the amount of water you need to cook and clean?”

Kofi translates Ash’s question but Efia does not respond. She continues to pour unfiltered water into the device and just smiles. Silence lingers for a while as Ash and the team try to make sense of her reaction.

Ash: “If she had a problem with our design I feel like she would have said something about it... but since she didn't, that means she probably likes it... right?”

Kofi nods and the team agrees. At the end of the second week, Ash and their team have identified that access to clean water was indeed a need that the community stakeholders had, they were able to build some relationships with the villagers, and they produced three different prototypes of their design, all of which filter water successfully. However, the filters do not work fast enough to actually save the women more time and effort than their original process.

3.4.8 Aftermath of the Trip to Ghana

While sitting in the airport waiting to board their flight, Ash recalls how when they were first introduced to the village stakeholders, they said the word “oburoni” and decided to look it up on their phone. Scrolling, Ash pulls up the Wikipedia page for “oburoni” and learns that it’s

the Akan word for White or light-skinned foreigner, as well as one heavily influenced by foreign cultures. Though contemporarily not used in a derogatory way, the word is potentially derived from a similar word to “wicked people” in reference to the history of White colonizers that enslaved Ghanians between the 16-1800s. Putting their phone away, Ash turns to Hannah.

Ash: “Do you think we really helped those people? Like, will they use any of our prototypes?”

Hannah: “I don’t know, but we tried our best I think, and that’s all that matters right?”

Something doesn’t sit right with Ash, and they spend the following weeks trying to gather their thoughts and make sense of their feelings. As Ash sorts through documents to fill out reimbursement forms, they think about how Efi did not work and therefore lost two weeks of wages to help the team; same with Kofi. After doing some calculations Ash is absolutely blown away by how much the trip cost in total, with each team member’s flight cost alone being over \$4,500.

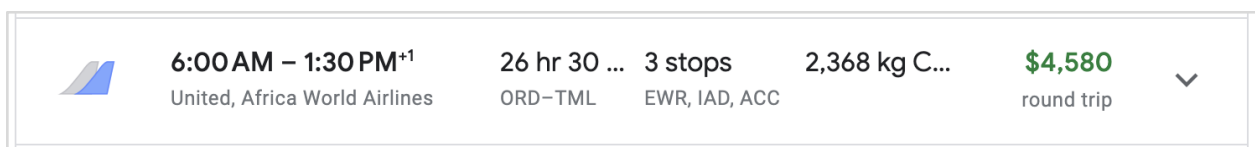


Figure 6: Ash’s Flight to Ghana

After the trip, Dr. White requests a meeting with the team to debrief.

Dr. White: “This looks great guys, a really well put-together report and I am impressed you were able to make multiple prototypes. You know, I got an email the other day from

the College's marketing office asking if I could recommend exemplary students involved in international co-curricular projects for them to profile for the alumni magazine. I'm happy to send them your names. You should hear from them soon."

Ash: "But none of the prototypes worked... in fact, we spent so much money sending students on this trip that the money we spent could have been more than enough to give every village stakeholder's household a water filter."

Dr. White: "Yes but that's not the point. This is supposed to be a learning experience and it's clear you all really matured as designers. And plus, it's not like you could have used the university's funding for that anyway, the money is earmarked for sending students abroad and cannot be used for anything else."

3.4.9 Epilogue

After the trip debrief with Dr. White, university marketing reaches out to Ash's team to ask if they can write a news story about the project and its success and use some of the photos the team took in a few brochures. Multiple faculty members congratulate the team for how rigorous their design process was. Though Ash and the team feel like they learned a lot from their trip and are better engineers and people because of it, the fact that they did nothing to actually solve the community stakeholders' problems with their design weighs on Ash for months. Having wanted to become an engineer to help minoritized people like them, Ash's experience on their design team fell short of proving this goal. After their Junior year, Ash steps away from the co-curricular design project and spends the summer pessimistically reflecting on

whether social change can *actually* be achieved through engineering. Upon graduation, Ash is faced with the choice to either stick with their values and leave engineering for good or leave their values behind and accept a lucrative engineering job offer at a defense contractor.

3.5 Zooming out from Ash’s Story

Throughout Ash’s story, their agency was constrained by external factors representing different Domains of Power. While we started with Patricia Hill Collins’s Domains of Power as our inspiration for describing these domains, we ultimately adapted PHC’s framework to better reflect Ash’s specific circumstances within an academic engineering environment. Our main change was to reinterpret structural and disciplinary Domains of Power into curricular and institutional domains. Additionally, Intersectionality centers the idea that power intersects and each domain impacts the others. However, we first explain how the factors facilitated power in each domain separately and then discuss the nested nature of the domains further in the paper. Below, we highlight how external factors, organized by domain of power, influenced Ash’s agency.

Table 5: External factors in Ash’s story organized in domains of power

Domain of Power	Definition	External Factors
Interpersonal	Relationships and interactions between individuals	mentor-student, Instructor-student/class, teams of students, student-stakeholders
Curricular	Course structure, content, expectations, and outcomes	Syllabus, assignments, grading criteria, workshop constraints, letter grades
Institutional	Institutional norms, rules, and procedures	Funding, tenure requirements, academic calendar, time to graduation, financial aid, ABET
Hegemonic	Dominant social ideologies that reinforce oppression	White Supremacy, hetero-patriarchy, neocolonialism, neoliberalism

Interpersonal: The interpersonal domain of power related to relationships and interactions between individuals. External factors within this domain of power include interactions between students, between students and mentors, and between students and stakeholders. For example, in Ash's first year engineering course, their individual agency was influenced by their teammates. Mark (a White man) took charge of their team meeting and established an early project direction. At that point, the only ways for Ash to make their voice heard on an equal level as Mark would be to openly disagree with Mark or to try to blend their ideas with Mark's. Ash ultimately opted for the route with less interpersonal conflict. Note that Maria never talks during the interaction.

During Ash's time in their co-curricular design team, their individual agency was influenced by the power dynamic between the team and their advisor Dr. White. Dr. White had limited time to engage with the team and his communication style was received by students as harsh and anxiety inducing. This introduced a substantial obstacle in Ash's trip planning because they felt they had to shape their behavior around Dr. White and his expectations. Additionally, in the field, interpersonal factors impacted Ash's team because of the underlying power dynamic between Mr. Mensah, the village stakeholders, and the students. Not wanting to upset their employer, the village stakeholders did not provide honest feedback to Ash's team necessary for adjustments to their prototype.

Curricular: The curricular domain of power relates to course and curricular structures, content, expectations, and outcomes. External factors within this domain of power include syllabi and assignments, grading criteria, and curricular resources. For example, in Ash's first year engineering course, their individual agency was influenced by the 8-week timeframe of their course project. Ash was only given two weeks to define their design problem, and none of their

later assignments graded them based on further stakeholder interactions. Thus, while Ash could have gone above and beyond the requirements of ENGR101 to engage stakeholders equitably, doing so would not have produced course-relevant benefits.

Another factor operating in the curricular domain of power was the wide-scope and one-off nature of the workshops that Dr. White sent Ash's team to supplement their preparation to travel to Ghana. These workshops were meant to be transferable to different contexts and thus could not explore specific cultural, political, and social nuances of Ash's community stakeholders. The workshops also did not involve extended support for Ash's team. Thus Ash's team were on their own in translating the workshop material to be relevant to their project; their agency was constrained by their limited knowledge and curricular support in navigating tricky and unexpected situations - such as the men in the village said getting water was a "women's problem."

Institutional: The institutional domain of power related to departmental and university-level norms, rules, and procedures. External factors within this domain of power include departmental funding, academic reporting requirements, tenure requirements, and academic calendar. In Ash's first year engineering course, institutional external factors emerged through 1) the need for the design project to fit within a one-semester course, meaning that Ash had no resources or practical incentives to work further on the project after they'd received their final grade, and 2) the need for that course to fulfill multiple ABET requirements within the overall engineering curriculum, thus further shortening the project timeline. Another institutional factor that limited Ash's agency to make a positive community impact was the financial structure of the college and its obligations to alumni donors. The college set aside finances to support international student activities and Mr. Mensah donated his money for a specific educational

purpose. As a result, the money available to Ash's team could only be used for a limited set of purposes - plane tickets and semi-functional prototypes were valid expenditures, but not setting up a community resource fund or buying and shipping water filters to the community.

Hegemonic: The hegemonic domain of power is related to dominant social ideologies that reinforce oppression. External factors within this domain of power include ideologies of white supremacy, hetero-patriarchy, neocolonialism, neoliberalism, etc. For example, Ash's first year engineering course relied on the uncompensated labor of homeless Black men to achieve student learning gains. Given Ash's position within the course, it is highly unlikely that they would challenge this inequity; on the contrary, Ash's team was validated by an in-class award for incorporating the perspective of a homeless Black man into their solution. During Ash's co-curricular project, their presence in Ghana, regardless of their intentions, was laden with a legacy of western countries "saving" "impoverished" communities from their "needs." This underlying White saviorism pervaded Ash's project and their interactions with their stakeholders. Even if Ash's team had been aware of and taken deliberate steps to counter this white saviorism, they still would have encountered substantial barriers to achieving equitable, just outcomes since addressing centuries of colonialism is outside the scope of a single student project. There were also notions of White supremacy that impacted how stakeholders like Kofi viewed the students. While Ash and team were student designers, they were perceived and treated as experts due to stakeholders' beliefs about primarily White American universities. Thus, despite Ash's team's best efforts, their communications with stakeholders frequently resulted in one sided default agreements.

Intersecting Domains: While Ash's critical events demonstrate how external factors operate in each domain of power, the theoretical foundation of our conceptual framework,

Intersectionality, specifically emphasizes that these domains operate simultaneously. Each external factor in Ash's story intersects with and relates to other external factors across domains. For example, ABET represents an institutional factor that sets curricular learning goals and influences course content. The need to fulfill ABET requirements at the department level influenced curricular choices made within ENGR101, including the timeline of the course project and the emphasis on generating a technical solution. Thus, while Ash's agency in ENGR101 was most directly influenced by curricular factors, these curricular factors in turn stemmed from and conveyed influences from institutional and hegemonic factors. As another example, tenure requirements enforced by the institutional domain of power impacted Dr. White's capacity and lack of incentive to mentor Ash's team interpersonally. Ultimately, the factors we described in each domain are only some of the ones that can be identified in Ash's story. The purpose of Ash's story was such that these intersecting domains and factors are multifaceted, and a story allows for the nuance to be explored and discovered by the reader.

3.6 Discussion

Ash's story highlights how external factors across four Domains of Power - interpersonal, curricular, institutional, and hegemonic - influenced Ash's individual agency in the context of community-engaged engineering design work. The external factors experienced by Ash align with findings from prior work. For example, Ash's story resonates with findings from Thompson and Jesiek [122] that individual relationships with partners and advisors, project assignments and deliverables, and overarching partnership structures all influence how undergraduate engineering students interact with community partners within engineering engagement programs. Thompson and Jesiek did not analyze their data using an intersectional framework; however, their findings did broadly suggest the intersectional, curricular, and institutional Domains of Power that we

described in greater depth in the present study. Other studies of stakeholder-oriented engineering student design projects have, similar to this study, identified semester and curricular timelines [115], [118], [166], grading criteria [166], and project funding [167] as crucial factors that can affect student approaches and project outcomes. These examples align with curricular and institutional Domains of Power.

Prior research on engineering culture has discussed external factors that in Ash's story we defined as relating to interpersonal and hegemonic Domains of Power. For example, Loweth et al. [168] investigated how engineering students conceptualized social aspects of engineering work. They found that their participants, on account of their curricular experiences, distinguished "social" and "technical" aspects of teamwork and tended to prioritize the latter. The authors, citing studies of technical/social dualism in engineering [169]–[171], suggested the perception of teamwork observed in their participants could perpetuate interpersonal inequities that disadvantaged women and students of color - which is a dynamic we demonstrate in Ash's interactions with their ENGR101 team. At the hegemonic level, Niles et al. [116] studied how engineering students adopted, rejected, and grappled with public welfare engagement efforts in two engineering programs. They found that their participants, in order to engage equitably with communities, often had to overcome default power dynamics and epistemological hierarchies that systematically devalued community knowledge. Ash's team struggled to navigate similar hegemonic factors in their trip to Ghana.

Compared to prior work in engineering education research, the unique contribution of our paper is to situate discussion of external factors within an analysis of power and to demonstrate how different Domains of Power operate *together* to make it difficult for students such as Ash to achieve equitable design outcomes. These Domains of Power affect student agency and the

outcomes of their work regardless of the quality of their individual community engagement practices or mindsets. Our analysis of Ash’s story suggests an emergent conceptual model for understanding student agency in engineering education, shown in **Figure 7**. This model does not propose a new theory but rather illustrates the combination of Domains of Power and agency to specifically describe student agency; we use the term “Critical Agency” to discuss the amalgamation of these theories.

3.6.1 An Emergent Conceptual Model for Critical Agency

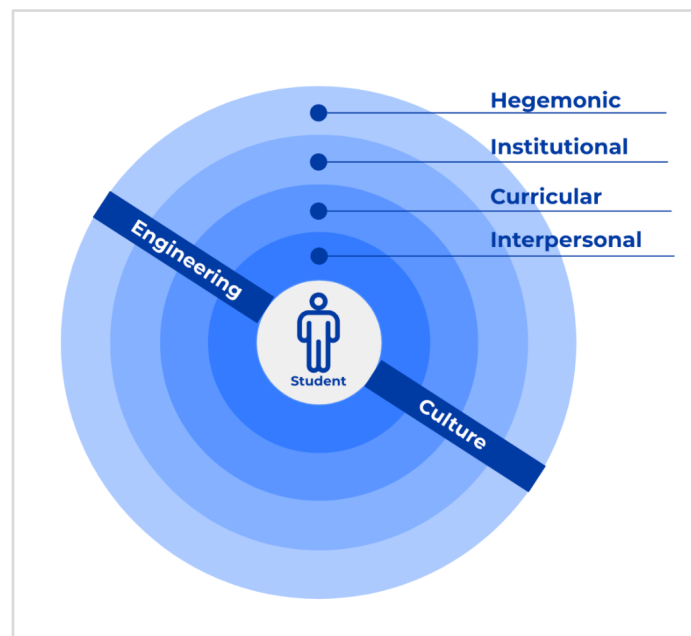


Figure 7: A Model for Critical Agency in Engineering Higher Education

The model shown in **Figure 7** has several key characteristics that illustrate how Domains of Power act as a mediator for student agency. First, the student is at the core of our model, representing how the model is centered around impacts to student agency. The rings in our model reflect nested layers of scale and proximity, with the interpersonal domain of power positioned closest to the student and the hegemonic domain, which operates at the level of societal structures, positioned furthest from the student. However, as described in our findings, all

Domains of Power can directly impact student agency, and can also impact factors in other domains. Examples of factors that fall within each ring are shown in **Table 5**.

The rings in our model visually resemble ecological theories in higher education that explain how factors operating at different levels impact student outcomes such as identity development [172]. However, ecological theories are primarily deterministic and do not take into account the agentic role of individuals. In contrast to ecological theories, our model explains relation, explicitly applies a critical lens through Domains of Power which challenges dominant narratives of agency and outcomes and illustrates a hierarchy of power that impacts all individuals in the academy, not just students.

The cross-cutting band of engineering culture in the model represents the way norms and beliefs are internalized by students and faculty and function at different levels, in different Domains of Power, in different ways. For example, relative to the hegemonic domain of power, in Ash's first year engineering class, their instructor and teammates repeatedly referred to the need for a "technical" solution. Ash's teammates interpreted this technical emphasis as a constraint on their solution possibilities, and this impression was reinforced by the course assignments and grading criteria. This cultural norm of engineering as a technical discipline thus operated across interpersonal and curricular domains.

While we discussed the factors and their respective domains separately as typologies, the model in **Figure 7** seeks to capture and explain the complexity of how a student's agency can be impacted by multiple domains at the same time. For example, if Dr. White had identified his role as a White man in reproducing hegemonic norms, he could have cultivated a more inclusive mentoring relationship with the team. Similarly, through an institutional push toward equity, Ash's first year class curriculum could have shifted course outcomes from an artifact to building

critical consciousness. Students and individuals broadly are not “stuck” in each domain and though factors limit their choice, with varying degrees of risk, they can use their agency to engage in resistance to the external factors which as a result, can shift outcomes.

3.6.2 Limitations

One limitation of this study was that while we think the model is transferable to engineering education contexts outside of engaged design projects, it is unclear how the external factors we highlight will remain the same, and impact agency the way they do in Ash’s story. For example, we used data from a specific engineering educational pedagogical context, engaged design projects, with a specific set of data from students and ourselves heavily grounded in the recounting of personal experiences. Student and faculty experiences can vary greatly as curriculum, project, class, and institutions create different circumstances where engaged learning happens. Therefore, it is possible that a different set of narratives from different institutions or educational environments could lead to different research outcomes.

This extends to the role that social identities have in shaping the findings. Ash has a certain set of identities as a student of color from a middle-class background, thus our story demonstrates how they individually experienced external factors. Ultimately that experience is impacted by their identities as that is the perspective they fundamentally view the world through. As such, students with different identities might experience factors differently due to their place in the matrix of domination. Our goal in the paper is to provide examples with enough details such that students who *do* share identities with the characters in our story can see themselves and identify which parts are transferable to them.

Another limitation is that this work is a product of our respective positionalities and theoretical sensitivity. Similar to how Ash’s experiences may be relatable to students, the transferability of

the findings is impacted by how much of our experiences transfer to other contexts. One example is cornerstone, where Ash's experience represents an engaged project with stakeholders that differs from typical cornerstone experience. Despite this, Ash's cornerstone is still rooted in an amalgamation of data with the way we created the story best highlighting the external factors. Thus, institutions with other cornerstone learning goals might produce a different set of factors. Lastly, the factors we identified are not exclusive to cornerstone and co-curricular design projects and can show up in other learning contexts. However, our experiences as researchers, teachers, and students informed which editorial choices we made, such as focusing on Ash's preparation for their co-curricular design project instead of capstone design.

3.6.3 Implications

Students can use the model and Ash's story to develop critical consciousness surrounding how their agency is influenced by external factors so that they can more effectively navigate and push back on these factors. There were several points within Ash's story where they might have been able to shift outcomes provided, they had a greater awareness of external factors. For example, agency shifts could have happened during their teamwork during first year if Ash understood the dynamics behind Mark taking over group conversations and that speaking up would lead to a more equitable outcome. Likewise, a greater awareness of external factors might have led Ash to recognize situations where their agency would be significantly constrained, such as the inherent exploitative nature of their co-curricular design project, and instead pursue other opportunities. This emphasis on understanding external factors can lead to a praxis of choice and every-day resistance to enact new ways of doing and being, counter to existing dominant practices. This notion is described as "generative refusal" [173]. Rooted in feminist and anti-colonial thought, refusal gives agency to individuals to oppose the way things are, imagine new

ways of achieving social change, and alleviation of oppression [174]. Our model and counter-story can be used as a scaffold for students to cultivate their own politics of refusal where it becomes possible to find value-driven ways to work toward social justice through engineering.

Both the model and Ash's story can also be used as interventions in education practice for belonging and persistence. Counterstories are frequently used as a way to build solidarity amongst minoritized students, help them make sense of their experiences, and validate them [150], [175]. Many students like Ash unknowingly participate in inequitable engaged design projects, after which they realize their complicity in exploitation and become disillusioned about their ability to create impact. Ash's story can guide these students in making sense of their experiences, help them understand that they did everything they could to act based on their values, and that the inequitable community outcomes were not their fault. This sense-making and validation contributes to an understanding of the "hidden curriculum" that outlines systems and structures of power that oppress them, and through that understanding, use their agency to navigate toward holistic success. While the model was developed through an analysis of community engaged learning, it is potentially transferable to other engineering education contexts to help students in a variety of situations understand their agency and where power manifests within the academy.

Faculty can use our model to think critically, move across structures, and use their agentic power to support equitable outcomes for both students and communities. Faculty are in a unique position to navigate Domains of Power freely, given their institutional location. Thus, faculty can use our model to develop a plan of action that accounts for all four Domains of Power. The model and story can also encourage faculty to think critically about their own positionality, and how their relative perspectives may lead to different uses and interpretations of

the model. This might lead to reflecting on ways to re-consider interactions with students and to set up engaged learning experiences without reproducing inequities or causing harm. Ultimately students depend on faculty to guide and facilitate their growth in partnership with their own efforts. Faculty may not realize the power they have to give students more agency and challenge the way institutions limit the agency of their students. Our model can help faculty strategize approaches to advocate for students through knowledge of which domains they carry the most influence.

Lastly, findings from this paper point to broader implications about research. The theories that grounded our study and model - Intersectionality/Domains of Power and agency - have had broader application in engineering education research [176], [177]. As such, we anticipate that our model may have broader application as well. As a tool, researchers can use this model to study the agentic role of individuals in other engineering educational contexts as well. Our findings can also motivate future work to explore the transferability of our model.

3.7 Conclusion

We generated a semi-fictional collaborative counterstory describing the educational experiences of a middle-class engineering student of color named Ash. Through this counterstory, we illustrated how interpersonal, curricular, institutional, and hegemonic Domains of Power affected Ash's ability to engage stakeholders equitably. These Domains of Power operated through a range of external factors including curricular and semester timelines, teammates and mentor relationships, institutional incentives, and societal norms. By several traditional metrics, Ash's experiences were successful - they achieved stated learning goals in ENGR101 and their co-curricular project was celebrated by Dr. White and featured in the alumni magazine. However, Ash's efforts also produced essentially no benefits for stakeholders (and in

fact, imposed costs on them), and left Ash emotionally devastated and seriously questioning their motivations for becoming an engineer. Our goal with this paper was to demonstrate how disparate outcomes for students, stakeholders, faculty, and institutions can occur simultaneously - since power in the academy operates in intersecting ways and at multiple levels - and to propose a conceptual model to describe critical agency for thinking through relevant Domains of Power in greater depth. Ultimately, students *are* often doing the best they can within the constraints of the external factors that they experience. Our model can help students and faculty reimagine alternative ways of structuring engaged learning opportunities to center equitable outcomes for both students and stakeholders. Our model can also be used to identify critical structural and societal barriers that make equitable outcomes impossible and thus suggests important questions: Should student projects be done at all if equitable outcomes are impossible? How might faculty use their agency to push back on institutional incentives that prioritize student learning outcomes over community well-being? We invite others to consider how our model relates to their own stories and other issues of agency in the academy, to find closure on past experiences that resemble Ash's and to ignite change toward social justice in engineering education.

Chapter 4 Exploring Needs and Opportunities for Culturally Sustaining Peedaaogy in Engineering Education

4.1 Introduction

Besides broad social implications of engineering practice, the nature of engineering as inequitable, oppressive, and specifically White supremacist also has significant impacts on the persistence and well-being of engineering students of color. Formal assessment approaches such as standardized tests favor White students, and hinder access to resources for academic and professional advancement [178]. Lack of representation of faculty and students of color allow the field to remain racially and culturally homogenous [179]. Students of color leave engineering because they face regular micro-aggressions from predominantly White peers, teachers, and mentors [180]. The concerns that students of color voice and the misconduct they report often goes ignored, unaddressed, or misconstrued [181]. They do not see themselves, their values, or their culture reflected in their course content increasing a sense of outsider status [182]. Students of color often must carry the unnecessary burden of educating their peers and faculty on racism and other injustices simply to be treated better [183]. Students of color are dehumanized through tokenism by being invited to White spaces for the purpose of optics rather than as authentic equal contributors to engineering classes and teams [184]. These are only a few of the many oppressive factors students of color experience in engineering school that contribute to their spirit murdering. Spirit murdering is a concept that describes the long term psychological, physical, personal, and spiritual impacts of racial discrimination, violence, and aggressions on students of

color. Originally coined by Patricia Williams in the legal field [185], and adapted to the education space by Bettina Love [186], spirit murdering includes the process of erasing or devaluing the cultural identities and experiences of students of color in educational settings, and refers to the ways in which traditional education systems and practices harm the spirit or sense of self of students from diverse backgrounds.

While research has been conducted to understand the persistence and trauma of students of color in engineering education, much of this work particularly that which has not been conducted by minoritized researchers, operates under a deficit-based paradigm which focuses on student shortfalls or inability to meet standards for success under a White gaze versus encouraging transformative change and student empowerment. As a response to deficit-based approaches, in this work I suggest that asset-based teaching, specifically culturally sustaining pedagogies (CSP), can mitigate multiple facets of the spirit murdering of students of color and as a result, make incremental and radical pedagogical recommendations. This study seeks to answer two research questions regarding the needs and opportunities for implementing CSP in engineering classrooms. Through semi-structured interviews with students of color, I examine the narratives students describe of who they are as holistic people, the way they negotiate the tensions between their beliefs, values, cultural identities, and technical-focused engineering education, the ways that existing engineering education hegemonic norms have caused various types of harm they must cope with, and ideas for more transformational teaching, mentoring, and learning to address these harms effectively.

4.2 Background

4.2.1 Deficit Based Teaching Approaches

Many engineering education instructors implicitly use deficit framing, as they are often grounded in traditional theories of learning such as Piaget’s cognitive constructivism [187], which operates on a base assumption that students are missing some kind of knowledge. Deficit based teaching approaches operate under the guise of objectivism, and “one size fits all ” curriculum where the “size” is Whiteness. Thus, students of color are perceived as having deficits where they must leave their cultural knowledge, identity, experiences, and interests, outside of the classroom in order to be “filled” with engineering knowledge entrenched in White supremacy [188]. In practice, deficit based teaching can include memorization based exams, problem sets focused on technical computation without application, not grouping assignments based on class time, assuming baseline knowledge, and focusing on levying the same assessments across all students instead of working toward the same course outcomes [189]. Deficit mindsets emphasize personal deficiency and when evaluating parity in performance across diverse students, does not take into account the previous barriers to achievement that students who are not White, middle class, men may have experienced. This is particularly detrimental in engineering, where students of color who entered college under-resourced are quickly forced out of engineering programs due to poor grades in “weed out” classes [190].

4.2.2 Defining Violences and Harms in Education

A significant body of research explores the many different violences and harms that minoritized students experience within higher education [186], [191], [192]. Deficit based teaching approaches are one type of these violences enacted by institutions to harm students of color. As such, many scholars in higher education discuss the ways students of color and other minoritized students experience violences and harm [191], [193], [194]. However, we find it important to define what we mean by “violences” and “harms” in this work to create a clear

framing for understanding the lived realities of students and do so based on De Bie et. al.’s conceptualization of epistemic, affect, and ontological violences and harms as shown in **Table 6**. De Bie et. al. defines violences as “what is done by institutions and individuals to preserve dominant structures and processes” and harms as the way students experience those violences [195] p. 14. Epistemic violences and harms relate to the validity and legitimacy of students’ knowledge and ability to be knowers. Affect violences and harms relate to the emotional burden and labor that students of color take on as the result of inequity and exclusion. Epistemic and affective violences constitute and are constituted by ontological violences [195].

Table 6: Violences inflicted on, and harms experienced by students in higher education (De Bie et. al. 2021)

Type	Violence	Harm
Epistemic	<ul style="list-style-type: none"> • Students’ knowledge and capacity as knowers are discounted. • Diverse epistemologies are not recognized. • Epistemic labor is dismissed and/or exploited 	<ul style="list-style-type: none"> • Students feel unrecognized as knowers. • Experience their diverse epistemologies as illegitimate. • Experience their epistemic labor as invisible and not valued, or as unfairly used
Affect	<ul style="list-style-type: none"> • Students are subject to multiple forms of discrimination and oppression (e.g., microaggressions, abuse) • Are expected to conform to dominant norms 	<ul style="list-style-type: none"> • Students experience emotional effects of discrimination and oppression (e.g., isolation, non-belonging, self-doubt, uncertainty, fatigue) • Carry burdens of emotional labor
Ontological	<ul style="list-style-type: none"> • Epistemic and affective violences constitute and are constituted by ontological violences. • Students are dehumanized-their very beings are negated or inhibited, blocking them from being who they are. • Normalized and institutionalized academic ontologies restrict possibilities of being 	<ul style="list-style-type: none"> • Students internalize epistemic harms and dehumanization (i.e., experience negative impacts on sense of self, personhood; deny and limit who they are and can be) • Engage in self-suppression through adaption to dominant ontologies, becoming unable to be fully themselves. • Experience a profound lack of agency

4.2.3 Mental Health and Spirit Murdering Among Engineering Students

Violences and harm have tangible impacts on the mental health of students of color, which contributes to the broader phenomenon of poor mental health amongst all types of students in higher education. This is an increasingly concerning crisis in the United States, with rates of diagnosed health conditions increasing from 21.9%-35.5% and usage of mental health resources increasing from 18.7%-33.8% since 2007-2017 [196]. Mental health struggles such as stress, depression, anxiety have severe impacts on quality of life, daily functionality, physical harm, all of which inhibit a student's ability to engage in learning and being an active member of their community. Because spirit murdering strips students of colors' humanity and dignity and leaves injuries to the mind, body, and spirit, struggles with mental health are an intrinsic outcome. Research supports this, with mental health issues more commonly occurring amongst students of color and higher levels of functionality in White students [197]. Engineering has a distinct White patriarchal disciplinary culture that amplifies issues of race and oppression that are pre-existing in higher education [192], [198]. As such, not only do engineering students of color persist the same issues of discrimination, but they must also persist the lack of support and sense of belonging due to being the only person of their race or ethnicity in the classroom [199], harmful racial stereotypes about their predisposition for or not for the field [200], [201], and depoliticized nature of curriculum which ignores the social and political climate that impacts these students livelihood [2].

4.2.4 Asset Based Teaching Approaches

A response to violences and harms caused by deficit-based research and teaching models are asset-based models. Asset-based teaching models "see the outcome of learning as additive rather than subtractive, as remaining whole rather than framed as broken, as critically enriching

strengths rather than replacing deficits.” [44]. Broadly speaking, asset-based teaching models posit students as having existing strengths through *cultural knowledge* they bring with them into the classroom and suggests that instructors with *critical awareness*, an understanding of the social and historical structural barriers to marginalized students’ success, can integrate students’ cultural knowledge into pedagogy to promote inclusive teaching [202]. Several asset based teaching approaches to resist deficit based teaching have emerged over the past several decades. These include resource pedagogies grounded in concepts such as funds of knowledge, community cultural wealth, and third spaces. From these concepts came approaches such as culturally appropriate, culturally responsive, and culturally relevant pedagogy all of which we discuss and critique further in this paper.

4.2.5 Culturally Sustaining Pedagogy

Out of a variety of asset-based pedagogies, this work specifically engages Culturally sustaining pedagogy (CSP). CSP is a teaching approach that emerged from a greater tradition of pedagogies that grappled with the dissonance between students of color’s home culture and language such as culturally appropriate [203], culturally compatible [204], and funds of knowledge [205]. Believing that the struggles of students of color was more complex than culture and language mismatch, Ladson-Billings proposed culturally relevant pedagogy, key features of which are that “students must experience academic success, students must develop and maintain cultural competence, and students must develop a critical consciousness through which they challenge the status quo of the current social order” (p.160) [202]. Similar to culturally relevant pedagogy is culturally responsive teaching (CRT) which also emphasizes cultural awareness, student assets, cultural expression, student empowerment, and education transformation [206]. However, Alim and Paris the contemporary scholars of this school of

thought, noticed that culturally relevant pedagogy (CRP) (as well as CRT) assumed that cultural practices remained fixed and therefore proposed two contemporary critiques of CRP which are that current asset based pedagogies take into account long standing community of color practices without considering contemporary enactments of communities, and that asset pedagogies do not address some problematic cultural practices of young people of color [207]. Furthermore, Paris and Alim state that CSP and other asset-based pedagogies advocate for students to succeed educational goals under white and other dominant gazes.

The purpose of CSP goes beyond bridging the achievement gap between Black and Brown students and White students. Rather, CSP helps students survive social systems and structures of power as they are, and that through centering students' culture, ways of knowing and being of communities of color we can achieve a more socially just and pluralistic society [208]. Thus, instead of focusing on ways for students of color to meet hegemonic educational expectations, CSP pushes educators toward a movement of social justice-based teaching and learning liberated from how well a student can imitate dominant norms. Grounded in this attitude, Paris bolsters Ladson-Billing's element of critical consciousness by exploring, honoring, extending and problematizing student/community culture and practices toward "love and life" [207]. Ultimately, CSP demands an alternative to accepting the pre-existing standards set by White cisheteromale as the ideal all students should aim to achieve.

4.2.6 Challenges to CSP in Engineering Education

Paris and Alim center their writings on mostly examples of CSP in K-12 non-STEM contexts (high school English class) but they were clear that CSP does and should apply across teaching and learning in all disciplines and levels of schooling. However, besides ideological conflicts between engineering as White supremacist and CSP as decentering the White gaze,

there are several pragmatic challenges unique to engineering education that impede direct implementation. The first is that engineering education was created by the White gaze, for the white gaze, and upholds the white gaze. Therefore implementing CSP would mean significant transformation and cultural shift that would create discomfort in primarily White male tenured faculty who hold the most institutional power, benefit the most from the status quo, and already struggle with racialized classrooms [181]. We would expect a significant level of resistance because of this discomfort in which these faculty would wield their power to maintain a possessive investment in Whiteness [209]. From a logistical perspective, engineering education in general is relatively resistant to changes in traditional teaching methods, as much of the foundational technical knowledge that students learn today (e.g. calculus, solid mechanics, organic chemistry etc.) remains the same [210]. Therefore there is little incentive to adapt pedagogical approaches because often even when an instructor does prioritize “diversity, equity, and inclusion,” they interpret it as all students should be treated the same [211] which can be done by teaching the same way every year. Furthermore, there are some potential conflicts with assessment and evaluation of ABET learning goals [212]. Though many ABET requirements are knowledge and skill-based, the ways in which an institution and the accreditation board measures these outcomes are along the same White cisheteromale criteria that is inherently oppressive to students of color. Thus, full implementation of CSP at an institutional and cultural level in engineering education may ultimately require a degree of educational abolition and transformation which comes with its own barriers of power, organizing, and resources. However, this does not mean that CSP cannot be implemented in individual classrooms by individual instructors within the scope of their agency to control classroom environment, course learning outcomes, assessment and metrics for meeting course goals, and course content.

4.2.7 Research and Implementation of Asset-Based Pedagogies and CSP in Engineering Education

Despite multiple challenges to teaching approaches that advance equity and justice in engineering education, there is a wide body of research that focuses broadly on asset-based pedagogy as well as specific approaches such as culturally relevant pedagogy. For example, as a response to issues of diversity in the field, Castaneda and Mejia applied culturally relevant pedagogy to fostering critical consciousness in civil engineering students through curricular implementation [213]. Other scholars have identified culturally relevant pedagogy as an opportunity for instructors to think critically about the connections between cultural and engineering identity with the purpose of growing student cultural capital [214]. With regard to culturally responsive pedagogy, researchers have investigated ways to create culturally responsive curriculum for Navajo students [182], using culturally responsive teaching to prepare teachers to engage rural students in computational thinking [215], and the efficacy of integrating culturally responsive pedagogy and engineering design process for improved K-12 engineering engagement and academic achievement [216].

While centering culture knowledge as these existing research studies in engineering education do, does disrupt dominant ideologies, the same critiques that Paris makes about CRP exist in engineering education as well. Thus, it is critical that we also extend CRP and prioritize adoption and integration of CSP as its contemporary sibling. Other scholars in engineering education have sought to study and implement culturally sustaining pedagogies in the classroom. However, many of these efforts are either theoretical [217], in K-12 STEM contexts, or focus on evaluating assignments or interventions. These studies also often center instructor perspectives and student performance outcomes. Additionally, while the struggles, persistence, and

experiences of students of color have been well researched in engineering education, little has been done to link student experiences to principles of culturally sustaining pedagogy such that students' needs can be directly addressed through transformative teaching practices.

4.2.8 Challenging Deficit-Based Research Methods

It is intuitive that engineering education researchers apply deficit framings to their work as that is simply the status quo of approaching problem-solving within an engineering epistemology. Like deficit-based teaching approaches, deficit-based research methods challenge *what* information students should know, not *how* students should be taught or learn. Even studies that use a framework [218] positioning the learner as a cultural-historical individual, rarely go so far as to explore the implications of identity on learning and instead focus on the decontextualized learner. Although deficit research approaches may be beneficial for researching pedagogical approaches to technical knowledge, they are not necessarily appropriate for researching issues where the intersections between sociopolitical identity and learning/practice are so crucial.

With deficit research framing, students are implicated in not having enough information or understanding to see engineering design as a social discipline, which prevents them from developing as socially responsible practitioners. Engineering education research studies with deficit framing have been designed to *prime* participants to elicit specific one-dimensional responses that highlight how engineering education shapes students to not see the social dimensions of design [177], [219], [220]. This approach is insufficient to transformative change because it centers whiteness as the context that is “missing” curriculum content, types of classes, or even diversity, equity, and inclusion interventions. It operates on the assumption that if this deficit of content is met, students will connect the dots and become more equity-minded

practitioners. It is infrequent that research approaches to addressing the lack of social dimensions of engineering design education work toward imagining an alternative pedagogical reality that centers students of color. This is demonstrated by the normalized research method of only treating student participants as uniform novice designers and where demographic data is collected as a best practice rather than a valuable attribute that can lead to more insight. In reality, these students are whole, complex individuals with personal identities, social issues they are passionate about, formal and informal civic engagement, and the communities and cultures they are from. Rarely are student participants asked to explore, identify, and share these aspects about themselves *before* being asked to connect engineering to society.

Therefore, because asset-based pedagogies have fundamentally different assumptions about learners compared to deficit approaches, a matching asset-based research approach which embraces the same values is necessary. This work proposes an asset-based research approach that conceptualizes inquiry and knowledge discovery with the same ideological underpinnings of asset-based teaching. Enacted, asset-based research methods treat student participants as whole people whose experiences intersect the research topic in nuanced complex ways that we may not anticipate. Each participant can have varying perspectives on the research topic, and it is important not to make assumptions about their knowledge, values, and beliefs. Asset-based research emphasizes an element of trust between the participants and researcher, with the researcher transparent with sharing their authentic selves such that the research is to build a relationship of exchange instead of a one-directional pursuit of knowledge extraction.

4.2.9 Influences of My Positionality

Who I am, what I have experienced, and how I see the world are all attributes that shape my research paradigm which informed this work. My experiences of violences and harm as a

biracial woman of color in engineering school motivated me to consider CSP as a means to prevent future students from experiencing the same thing. Additionally, now as an engineering educator, my identity and experiences informed my desire to do this research in a way that was humanizing and asset-based. I saw how my students cared about social and political issues and wanted engineering to be a way to enact their values. However, as a scholar, there is a common theme in engineering education research that identifies students as not caring about social issues [221], divorcing their values from their work [222], and not connecting their social identities to their engineering identity [223]. My students led me to believe that student participants in existing research studies were often not being given the chance to authentically show up in research conversations. Thus, as I designed this study, I wanted to find ways for students who share my identities to be sustained in their engineering education through CSP to persist through violences and harm, while also holding restorative space for students as a part of the research purpose itself. Ultimately, because of my shared identities with my participants, I was able to connect deeply with them, share my own experiences as a response of solidarity to their experiences, and was entrusted with the privilege to share their narratives in this paper.

4.3 Methods

To investigate the needs and opportunities for CSP in engineering education, we used the five principles of CSP outlined by Wong to design a qualitative research study. This study sought to interview 14 undergraduate engineering students of color about their cultural assets as well as their experiences in and critiques of their engineering education. Transcripts were then analyzed in accordance with the following conceptual framework and research questions.

4.3.1 Research Questions

This project will use an asset-based research approach to ask the following research questions:

- 1) What violences and harms do students experience that could be alleviated or addressed by each principle of culturally sustaining pedagogy?
- 2) What recommendations to their engineering education do students suggest that show opportunities for instructors to integrate CSP in engineering classrooms?

4.3.2 Conceptual Framework: Principles of Culturally Sustaining Pedagogy

For the research design and analysis of the data, I used the five principles of Culturally Sustaining Pedagogy (CSP) distilled by Wong as a conceptual framework. In **Figure 8**, the principles are all linked to this concept of decentering the White gaze. In alignment with Paris and Alim (2017), Wong describes the White gaze as the way Whiteness and White Supremacy operationalize to systematically force Eurocentric ways of knowing and being to be the only “right” way of making sense of our world and our place in it. The White gaze does not only apply to hegemonic ideas of racial oppression but also includes other dominant gazes -ways of seeing and being- such as White settler colonial, nationalist, racial capitalist, kindred cisheteropatriarchal, English-monolingual, ableist, xenophobic, Judeo-Christian, and more. While decentering the White gaze can be a practice within and of itself, Wong argues that the four principles shown as outer on **Figure 8** are all specific ways that CSP seeks to decenter the White gaze. Each principle is defined below **Figure 8**.

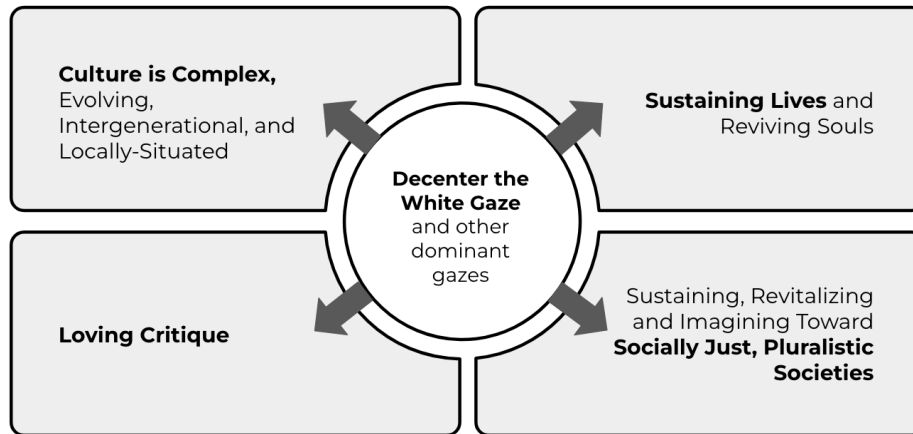


Figure 8: Five Principles of Culturally Sustaining Pedagogy (Wong 2019)

Decentering the White Gaze means teaching and learning outside of dominant ways of knowing and being with the prior ideologies listed above being challenged through alternative perspectives. In my study, I conceptualized data related to decentering the White gaze as any instance where a student was harmed because of dominant ideologies manifesting as oppressive, and suggestions to decenter the White gaze were ones that sought to question or combat these dominant ideologies, particularly the ones that show up the most in engineering such as cis-heteropatriarchy, capitalism, and racism.

Sustaining, revitalizing, and imagining toward socially just, pluralistic societies mean teaching to revive and maintain the hope students have for a better world where diverse types of people like them are humanized, celebrated, and where social justice can be achieved. Sustaining students means helping students dream of liberation, where they no longer have to see assimilation as necessary, where they do not have to continue to witness and be impacted by the inequities and injustices affecting their communities, and where they can see their values align with their identity and work as engineers.

Culture is complex, evolving, intergenerational, and locally situated means combatting the regular practice of treating cultural groups' characteristics as ubiquitous such that stereotypes

about the inherent nature of certain cultural groups are assumed and therefore apply to all students from those cultures. For example, students may also have different relationships to their racialized identities even if they are the same race or culture. Instead, it is imperative to understand each student as independent individuals who have different cultural practices that may be unique to their situations, change over time, are family specific, or from their close communities.

Sustaining lives and reviving souls means to “complicate, sustain, and extend what is important to students and their lives” p. 19 [208] as an instructor’s priority in addition to learning goals and course outcomes. This means supporting students to pursue the interests and goals they seek to accomplish in and outside of the classroom. Sustaining lives means humanizing students, making them feel cared for, cultivating their wellbeing, and encouraging their holistic success.

Loving critique is a response to how not all cultural practices and beliefs that students of color have are liberative in nature and can reproduce oppression. Sometimes these anti-liberative cultural practices are the values and beliefs that students are raised in (ie. one participant discussed his home as patriarchal which he had to unlearn). Through loving critique, educators can help students identify and change behaviors that are embedded with hegemonic ideologies such as cis-heteropatriarchy, capitalism, or nationalism.

4.3.3 Data Collection

I recruited 14 undergraduate engineering students who were either juniors, seniors, or very recently graduated to each participate in 90 minute interviews. I sought to build a participant pool that was as diverse as possible along the lines of race, gender, ethnicity, and engineering discipline as shown on **Table 2**. The students were recruited through a screening survey that was distributed through department email listservs, identity based organization

newsletters, and word of mouth between students. The screening survey consisted of 14 questions aimed at collecting demographic information, ability/willingness to engage in the types of vulnerable conversations required by the interviews, and strength of relationship to family culture, heritage, and values. I was informed by Bonilla-Silva and Zuberi critiques of traditional approaches to racial and ethnic categorizations [224] so I invited students to self-describe their own race and ethnicity as free response answers; the race and ethnicity shown in **Table 2.** are exactly the way each student described themselves in the screening survey. Because I did not want to assume all students would have the same conceptualization of what “culture” means, I used proxy questions. One such proxy question was “what is your favorite food and why?” to assess students’ relationship to culture, as students close to their heritage and cultural identity often name a food out of nostalgia related to their ethnicity or family (i.e.. “A sticky rice dish my grandma makes me because it reminds me of my childhood”). 114 students responded to the screening survey, and from those students I selected 14 that had already experienced at least three years of engineering school, fit our selection criteria, created a diverse participant pool, and responded to emails to schedule an interview. The 14 students consisted of seven in mechanical, two in aerospace, two in industrial operations, one material science, and one in biomedical engineering.

Table 7: Participant demographic data

Pseudonym	Gender	Race	Ethnicity
Sola	Non-binary	Black	Nigerian-American
Sareena	Women	MENA	Lebanese
Andrea	Women	Southeast Asian	Filipino
Tahir	Man	South Asian	Pakistani and Burmese
Mia	Woman	Latina	Mexican

Victoria	Woman	Mixed Latina	Mexican/Swedish
Robin	Woman	Latinx	Ecuadorian/Colombian
Devani	Woman	South Asian	Indian
Zain	Man	Black	African American, Iranian
Jasmin	Woman	Black	Black
Rebecca	Woman	Latinx	Argentinian/Mexican
Carlos	Man	Latinx/Indigenous	Ecuadorian/Quechua
Lili	Woman	East Asian	Chinese
Logan	Man	Native American	Native American

The interview was semi-structured with a protocol that had three main parts and followed recommended practices by several methods scholars [87], [90]. The first was rapport building through exploring the students' family, community, interests, culture, beliefs, and values without discussing engineering at all (e.g., “What are some stories or values your family taught you that you still follow today?”). The second portion included questions about the relationship between students' culture, values, and identity to their experiences in engineering education. Lastly, students discussed critiques about their engineering education experiences and made suggestions for what could have been improved. While the interview was semi-structured and had general goals per the protocol sections, we allowed the participants to have control over the direction of the conversation and allowed them to talk about the things they felt were relevant to share.

I approached the interviews as research partnerships, which meant the conversations were two-sided, I shared some of my own related experiences, and the students were not pushed to answer any question in a specific way. As a result, the interviews became much more narrative and open-ended than they were originally expected to be. Despite this, I felt like this research approach best aligned with my asset-based research philosophy and yielded rich narratives with

many participants noting the conversation in and of itself had value to them, meaning they left feeling restored, seen, or encouraged. The research study originally sought to explore students' cultural assets that could be leveraged by instructors to implement CSP. However, because I gave the students agency to direct the conversation, many students shared the harms and struggles they experienced without prompting, which as a result, informed our first research question. No students were asked about whether they experienced harm or were requested to talk about traumatic experiences. Many students seemed to need an opportunity to be heard and to vent and it was mutually restorative for the researcher and research participant to hold that space for them. Interviews were recorded and transcribed through Rev.com, with member checking occurring by having the participants review the transcripts and communicate whether they would like any of the data to be redacted. We received consent from all participants to use pieces of their stories in this work.

4.3.4 Data Analysis

I leveraged thematic analysis to identify instances of epistemic, affect, and ontological violences and harm in the experiences of our participants in alignment the definitions in **Table 6**. These instances of harms were then sorted into groupings that were associated with the principle of CSP that best fit as a way to address or have prevented that harm from occurring in the first place. The analysis was performed by a single coder and was done in three rounds: 1) identifying all violences, harms, suggestions, and critiques, 2) categorizing the violences and harms as epistemic, affect, and ontological, and 3) to determine according to the definitions for each principle of CSP, which principle could best address each violence and harm. While there were more instances of harms, violences, suggestions, and critiques than what is presented in the following findings, what *is* shared are examples with excerpts that best represent answering the

two research questions. After each harm, we make recommendations for potential applications for CSP grounded in existing examples and ethnographic narratives of implementing CSP [44], [208], [225].

4.4 Findings

4.4.1 RQ1: What harms do students experience that could be alleviated or addressed by each principle of culturally sustaining pedagogy?

There are many ways to address or heal a harm. Similarly, the harms that our student participants experienced can be addressed by more than one principle of CSP particularly because of the complexities of their specific contexts. I present students' experiences of harms and violences grouped under the principle that they most directly align with. However, these harms could easily be alleviated by the other CSP principles as well. The ways in which I describe responses to these violences and harms are theoretical interventions or pedagogical choices to demonstrate opportunity for CSP implementation.

Decentering the White Gaze: The White gaze influenced multiple ways in which our student participants' self efficacy, confidence, and sense of belonging were impacted. One shared sentiment across multiple participants was feeling inadequate because the way they communicated, processed knowledge, and even spoke did not align with the way the White gaze influenced assignments and assessments. For example, Carlos described how he struggled because his class relied on reading large portions of textbooks on a weekly basis as the only form of digesting information:

"I literally hate reading. A lot of Quechua Ecuadorians, like what my mom said, talk singingly. When you sing a song, you remember it way harder than you would if you just

spoke it. But the other people are making the system skewed because they're able to just walk in, and then they have so much book knowledge from tutors, from professors, from really, really high education places. I'm over here like I'm dumb as a shit ton of bricks. But I will not be outworked by anyone ever.” - Carlos

The course's enforcement of Eurocentric approaches to speaking, reading, and writing did not acknowledge the validity of alternative ways of information transfer [226], and as such, acted as an affective violence, forcing Carlos to do additional labor to conform to dominant norms. This caused the affective harm of emphasizing his otherness and eroded the confidence he had in his intellect. Under the White gaze, Carlos's worth is only measured by his ability to conform to idealized standards of Whiteness instead of his aptitude to actually learn and apply technical skills. To counter this outcome, an instructor willing to implement CSP through decentering the White gaze, might identify textbooks as forced assimilation, celebrate and center Carlos's connection to his culture, and offer multiple mediums (e.g. verbal, visual, audio etc.) for learning content, assignments, and assessments.

Other students experienced harm under the White gaze in different ways, such as Sola, who shared how during conversations with their peers in class, they were subjected to the epistemic violence of their knowledge and capacity being discounted due to the White centric notion of meritocracy that is particularly prevalent in engineering culture [2]:

“A lot of assumptions people make are based on that whole, “you have to earn where you are” and the false meritocracy that is a result of growing up in America. Because people see you and they'll either assume you earned your place or assume that you've gotten

here for something else. So I'm like, yeah, I'm a Scholarship Fellow. They'd be like, oh is that a Black scholarship? And I'm like, no, it's a scholarship because I got a 33 on the ACT I got a 1460 on the SAT. This isn't easy, it's just different.” - Sola

Even though Sola’s accomplishments were quantified by the same White metrics for success as their White peers, their classmates’ assumptions about how they earned an equal place were based on racist assumptions about Black students only being in engineering because of affirmative action [227]. A White gaze assumes that students must earn their place through White methods to belong, whereas if an instructor were to apply CSP and challenge the White gaze, combatting meritocracy could include shifting learning outcomes to reduce competitiveness and instead, focus on growth. Furthermore, emphasizing the existence of multiple experiences that coexist can validate students like Sola, and forge a classroom cultural shift that does not prioritize one pathway to engineering school over another.

Another violence (affective) carried out by the White gaze is the default neoliberalism of engineering culture due to depoliticization where engineering is taught as value neutral and separate from social and political contexts [228]. Tahir recounts how the violent eviction of Palestinians from East Jerusalem and ensuing Israel-Palestine crisis in 2021 caused harms to his mental health and degradation of his support system:

“So just seeing that getting carried out in the month of Ramadan, which is one of the holiest months, just completely crashed on me. I was just mentally deteriorating completely. And there were some of my friends that actually took the other side [Israel]

and I just lost people. It was just very difficult seeing some of my close friends [in engineering] just not care about me.” - Tahir

It is not necessarily that Tahir’s engineering school environment was outright anti-Muslim. But rather, by not having conversations about a pro-Palestine position, the dominant White Judeo-Christian gaze embedded in neoliberalism meant that anti-Muslim sentiment was a latent norm revealed by Tahir during conversations with his friends. To combat neoliberal ideologies in engineering an instructor interested in decentering the White gaze through CSP might include conversations about non-dominant global perspectives and take explicit political stances in alignment with social justice and liberation. This would displace Judeo-Christian ideologies as the default and promote cultural and political pluralism.

Sustaining, revitalizing, and imagining toward socially just, pluralistic societies:

Because of the dominant neoliberal gaze in engineering Tahir did not know about the anti-Muslimism beliefs his friends had until he discussed current events with them. This in part was also a result of the lack of supporting students like Tahir in sustaining, revitalizing, and imagining toward socially just, pluralistic societies. Another student, Victoria, also experienced the ontological violence of depoliticization which led to her experiencing the harm of self-suppression.

“In engineering, I feel like I never know exactly what the community feels about certain topics. So then I just don't talk about those topics with engineering students. It's also never really touched on within classrooms or communities. So then it feels like ‘well does anyone really care?’” - Victoria

Victoria experienced a sense of isolation in engineering due to not knowing whether her peers humanize her by recognizing the validity of the political and social issues related to her personhood. Responding to this through CSP would be similar to supporting Tahir's experience, in that conversations beyond focusing on only technical topics normalizes the idea that engineering can be a tool for social justice, and that multiple perspectives aside from the dominant one are necessary for engaging in equitable engineering practice. Victoria continues to describe the mixed messaging on an institutional level that trickles into the classroom:

"The college will say, "We really care about everyone," or something. And then they do stuff that is supposedly to care for everyone. But then it feels very like this is the one day we'll talk about it, and then we're never going to talk about it until next year. The same thing happens in my engineering classes like when we learn about ethics and stuff."

- Victoria

Victoria noted that just like how the college of engineering celebrated single events (e.g. Black history month, AAPI month etc.) but did not make meaningful changes that would express an authentic commitment to equity and inclusion, conversations even just about ethics or the social implications of engineering, were only reserved for one or two class sessions a semester. A possible approach for an instructor implementing CSP would be to incorporate social justice content into technical content instead of treating it as separate or secondary.

Adjacent to how Victoria felt a lack of care and commitment to social justice and equity, Jasmin described why she became disengaged with the political and social issues that she cared about because of the oppressive nature of engineering spaces:

“Prior to me going to college and undergrad, I had more of an awareness of social issues going on. But me as an undergrad engineer, not having that access or space to talk about those things or be incorporated into my actual curriculum, limited my ability to care for those issues or want to do things that were not related to engineering.” - Jasmin

In addition to the overwhelming amount of work that engineering school requires (a sentiment multiple participants shared), the ontological violence of not creating spaces for conversations that make students like Jasmin feel seen, forces assimilation. The harm Jasmin experienced was not only giving up on the things she believed in, but also her desire to do anything outside of engineering at all. If an instructor wanted to implement CSP through sustaining, revitalizing, and imagining toward socially just, pluralistic societies, an opportunity for this would be to identify the values and interests of students like Jasmin and leverage them in course content.

Culture is complex, evolving, intergenerational, and locally situated: Several students expressed frustration with the cultural assumptions in content that was presented as representing diversity, equity, and inclusion. CSP emphasizes that culture is specific to students themselves and their particular contexts. However, nuance and plurality of cultural experience is frequently not recognized. One example of this is Logan, who while Native, describes himself as White passing to non-Natives. Because Logan’s classes are mostly with other White students, the

assumed stereotypes of what a Native person looks like are dissimilar to the way he presents.

Logan explains the harms he experienced not only as a Native person, but one who cannot show up as his authentic self:

“My experience of being one of the only Native people in engineering school is, being alone, which I wouldn't mind so much If I could present more as Native because then I could be like, "Yeah, I'm here. What are you going to do?" Deal with it. Right? It is defiance, So it's defiance for me right now simply because of the sheer number of native people who don't go to college, but it doesn't feel like defiance that affects anything else.” - Logan

Logan finds internal validation, but because of the erasure of his identity, the significance of his presence and representation is negated and results in isolation. Instructors interested in CSP could allow students like Logan to show up authentically by being open and honest about their own identities, and model discussions about the contextual nuances of their culture. This might create a class community that focuses on students seeing each other as whole people rather than reducing each other to their stereotypes, or like Logan, be erased for not fitting a stereotype.

Another harmful assumption that ignores how culture is complex, evolving, and locally situated is the fact that a significant portion of diversity, equity, and inclusion (DEI) content in the participants' engineering education, strictly focused on cultural tensions in the United States. It was primarily focused on anti-blackness due to the rise in visibility from the Black Lives Matter movement. While DEI content was intended to improve inclusion, assumptions about

who needed to feel included caused unintended exclusion [229]. Lili, an international student described her experience with a DEI assignment:

“We have an open-source database of all the police shootings happening in the states and we made an analysis on it to determine if the data really showcase some racist trends. It was interesting but I don't know, it's strange. international students usually avoid talking about politics and things that happen in the States 'cause we're not the citizens, we don't have the right to say anything, we just hold our opinion inside ourselves.” - Lili

While Lili understood the cultural relevance of the assignment for students in the United States and the validation it might have for American students of color, assumptions about the universal applicability of DEI content further emphasized her lack of belonging. Lili's experiences also reflect the fact that the high number of Asians in STEM often causes invalidation of their experiences of marginalization such that they are effectively treated as invisible [230], [231]. More cultural assumptions about the audience for DEI material also presented as exclusionary to Sola, a student from a Nigerian immigrant family. Sola describes her classmate's ignorance about the cultural characteristics of the Black cultural experience:

“People forget I'm African. They'd be like, oh what do you think about this popular Black culture thing? And I'm like, I don't know about that, I'm African, I grew up on P-Square, I didn't grow up on these things and it's very generalizing too because even in the data sets

and everything, they'd be like, oh, Black people. And I'm like, okay, what type of Black people?" - Sola

Sola expressed frustration about the erasure of her identity as African, an ontological violence that implies the impossibility of being Black but not American. Sola, as a result, experiences the harm of feeling an invalidation of her culture and the erasure of her sense of self. To combat this, an instructor interested in implementing CSP through emphasizing that culture is complex, evolving, intergenerational, and locally situated could take the time to get to know their students and their cultural practices/preferences and also encourage students to forge similar relationships with their peers. Instead of applying DEI as content fit for all types of students, adapting content to validate and sustain the specific students in the class could communicate an authentic commitment to their sense of belonging.

Sustaining lives and reviving souls: Many students in higher education are subject to a number of affective violences such as microaggressions and discrimination leading to psychological harm through isolation and self-censorship [232]. This has major implications on student mental health, joy, persistence, and ability to pursue their interests and the goals they envision for themselves. Jasmin described her isolation and silencing:

"I was the only black woman in my cohort. So me talking a lot in these engineering spaces was not something that I was too keen on. I'm not going to say anything too crazy because who am I? I'm a tatted black woman that gets stared at every time I walk into the classroom. The semester's 14 weeks long and I was the ugly black mark in the room."

- *Jasmin*

Jasmin noted that being subject to dehumanization as the only Black woman in her cohort made her want to blend in and assimilate. She explained feeling the need for assimilation caused her to want to stop doing the things she loved (long nails, style, covering her tattoos) because she did not want to stand out and face more exclusion that would last an entire semester. However, she realized that dressing and looking the way she wanted to was one of the only restorative things she had, and assimilating would not make a difference in the way her peers treated her. To sustain her life and revive her soul, an instructor teaching students like Jasmin could prevent the harm she experienced by creating a classroom culture that explicitly does not tolerate anti-Blackness, judgment, and racism. Additionally, an instructor taking the time to check in on and support the things that were restorative to Jasmin could contribute to her survival.

Other students experienced ontological violences such as not being given the space and opportunity to be a young person that grapples with trying to discover their true passions and interests. One student, Zain, discussed his values being at odds with engineering and how he still was not sure if he wanted to stay in engineering but could not spend time figuring that out because of harmful stereotypes about Black men:

“You feel like you have to represent your race and I feel like that's true for me, sometimes, especially because of my mixed feelings about being an engineer... It reflects badly on how much interest or effort I put in, which is in conflict with me not wanting to be a stereotypical Black guy who doesn't put in the work and that doesn't pull the weight

of their end of whatever the project is even when I'm struggling to stay interested.” -

Zain

Zain experiences the harm of not being able to be someone who struggles with staying engaged and has reduced agency because being labeled lazy means feeding anti-Black stereotypes. As the Token Black student in his class, Zain feels the weight of an undue burden of representing the reputation of all Black men instead of being able to focus on his own hopes, dreams, and identity formation. Another student, Robin also discussed undue weight and responsibility of being the epistemic representative of women of color in engineering. Robin described her frustration with the pressure of not being able to simply be herself:

“I don't think it's a compliment when people say to me “you're so brave for being a woman in STEM” or stupid shit like that. Oh you're a trailblazer. There's going to be so many people after you. And it's like, I don't want to be a trailblazer sometimes I just want to be a student and cruise by and worry about stupid shit like dating.” - Robin

The assumed and unrecognized burden of women of color to act as sacrifices for the diversity of the field is frequent in higher education [233]. An instructor interested in using CSP to remove the burden of being token representatives of their race and gender from Zain and Robin would allow for them the agency to just be students; nothing more than they themselves want to be. To be explicit in this unburdening might include focusing on ways to dismantle and challenge the oppressive systems and structures of power that create the significance of Zain and

Robin's presence within engineering, rather than putting the burden of doing the work to make change on students of color.

Andrea, a Filipino student hoping to unlearn the cultural assimilation she went through growing up, experienced an ontological violence that was less obvious. Because of the pressures of engineering, she was forced to choose between prioritizing rediscovering her culture or supplementing her engineering course material through a co-curricular design team. Andrea describes how choosing her culture had adverse consequences:

"They were just throwing all these concepts at me, and they were using vocab words I had never even heard of. But all my classmates were like, "Oh yes, the load of the motor." I didn't know what that meant for half the semester, and it threw me off so bad. I should have just joined a project team my freshman year and I would've been fine, but I chose to do cultural stuff but I still feel like I should have done more. I wish I was smarter."

- Andrea

Not only did Andrea feel behind in classes, but it impacted the way she saw herself as a knower on par with her peers. Andrea expressed mixed feelings about the outcomes of choosing extracurriculars that were restorative and brought her joy, noting that feeling inadequate as a student did impact her mental health. If an instructor interested in CSP wanted to support Andrea holistically to sustain her life and revive her soul, they could integrate her culture, interests, and extracurriculars as part of engineering content. Additionally, it could be helpful for an instructor to check-in on each student in the class, so students like Andrea do not fall behind and can receive additional learning support without supplementation outside the classroom.

Loving Critique: Not all cultural practices and beliefs held by students of color align with liberation and social justice. Some students discussed unlearning sexism that they were socialized with at home or struggling to participate in self-care because of notions of competitiveness and exceptionalism impressed on them by their parents. Two students in particular, Tahir and Carlos held complex anti-liberative beliefs about success which acted as end goals to help motivate their persistence in engineering. Informed by his experience being a first gen student from a low-income immigrant household, Carlos explained his logical response to oppressive systems and structures of power:

“When the system fails, what happens? It's a jury of your peers. And what are your peers? A lot of them are racist at the end of the day. And even if they're not racist, they're purely capitalistic and looking out for their own. And that's literally what America is, is it not? Trying to make the most money, trying to do whatever to get the best in your own life. I respect that. At the end of the day, I'm also trying to do that as well, for my family and those around me.” - Carlos

Carlos was hyper aware of capitalism, how harmful it is to the freedom of people like him and his family, and expressed his displeasure in the degree to which it is embedded in engineering. Despite this awareness, he did not believe that it was realistic for him to try to change or dismantle the system. Thus, to cope under capitalism, Carlos believes buying into is the only way to achieve his life goals. Tahir describes a similar awareness and response where he

wanted to contribute to helping his community but saw no other avenue than through accumulation of wealth:

“I really wanted things to happen for infrastructures. I really wanted to aim towards hospitals, making libraries, stuff like that in very difficult areas. So if you don't have political power, how are you even going to make it happen? So the other route is to become filthy rich and become a philanthropist of some sort. That's a hard route, and that's the route I'm looking at.” - Tahir

Tahir and Carlos’s beliefs about capitalism, power, and impact align with dominant American cultural ideologies about meritocracy. At the same time, capitalism has been an economic system and ideology extremely harmful and oppressive to the communities Carlos and Tahir want to impact, leading to cognitive dissonance. An instructor embodying CSP could engage in loving critique by showing students like Tahir and Carlos alternatives to achieve the same impact they desire through approaches such as collective action, advocacy, and mutual aid, instead of assimilating to capitalism.

4.4.2 RQ 2: What recommendations to their engineering education do students suggest that show opportunities for instructors to integrate CSP in engineering classrooms?

The student participants provided several types of recommendations for ways their engineering education could have supported their holistic success. These suggestions were distilled into four types: supporting engineering-cultural identity co-development, adjustments to design projects, equity and justice curriculum, fostering class community, and care from instructors.

For engineering identity development, several students pushed back on the fact that engineering and their culture inherently conflicted but that there was also mutual development. Rebecca talked about how she later in her educational career, came to the conclusion that being Hispanic woman, inspired by the women in her family strengthened her engineering identity:

“I do see myself as a strong woman, and I don't think that the role or like the expectation of what a woman should be in a Hispanic household kind of negates my engineering identity at all but I think that now my compassion and everything kind of makes my engineering identity stronger. Like I always kind of believed it, but I wish it was encouraged.” - Rebecca

Rebecca expressed that she would have gained more confidence and it would have carried her through her engineering career if engineering and cultural identity had convergence in the classroom. She suggested that instructors be less prescriptive about what it means to be a good engineer, and more invested in supporting students as their unique whole selves.

For adjustments to design projects, multiple student participants suggested that having more freedom to pursue projects in their design courses that aligned with their interests and values would be more restorative than ranking options from a prescribed list which was all of their experiences. However, Lili took a different perspective and wanted professors to help her find her values within the work that she was given:

“If the instructors can help us find our values in the questions and trigger that sparkle of interest, that is more important to me compared to just digging and finding only the questions that we think are interesting because industry isn’t like that.” - Lili

Lili was concerned that while pursuing projects that she innately cared about more would not appropriately prepare her for the lack of agency she would have in industry, and consequently suggested that if there were more conversations about values and value conflicts in relation to engineering work, she would gain the skills to persist in industry more effectively.

Other students like Lili, wanted values to become a larger part of conversations in class. One such student, Victoria described how she felt that being open about diverse beliefs, interests, experiences, and values would reduce isolation it felt to be a student who was often the only woman or specific ethnicity in the class:

“Having these kinds of discussions about similarities or differences in our values and really exploring those, really helps bond a community more. Engineering feels more like you're an individual, and you only get together when you have to work on a project. While in my history classes, we never had a group project. But you felt like a community, you felt easier to reach out to people or continue to talk to someone after class about the topic. Because you've built this community based off of all your conversations that you had in class.” - Victoria

An instructor that emphasizes exploring difference in a classroom could support students in imagining a pluralistic society, and reduce stereotyping by showing the complexities of

culture. Additionally, when students become comfortable with each other through authentic peer relationships, it could address individualism, an engineering cultural characteristic rooted in the White gaze [211].

With regard to equity and justice in curriculum, as addressed by student experiences described in the RQ1 section of the findings, existing efforts to include DEI content into coursework was more invalidating than validating. However, some students like Zain suggested that integrating equity and justice into technical problem sets or assignments to contextualize engineering would sustain his desire for a more just world:

“ Including equity and justice would be great but engineering education right now, it's just teaching you how it works and you don't need to know the system that it's working under, all that other stuff that's not under the umbrella of engineering. I feel like it makes me feel empowered, just that I know that it's an issue and it's a problem, and the fact that I'm aware of it.” - Zain

Zain’s feelings of empowerment based on learning about the systems and structures of power underpinning engineering demonstrate a possibility for an instructor to cultivate critical consciousness. This also would also sustain Zain’s life and soul as integrating the things he cares about into class would demonstrate the instructor cares about him.

Care from instructors was by far the most prevalent recommendation from students. Students described how impactful a good, bad, or indifferent professor was on their engagement, performance, and attitude they had about the class topic. Carlos in particular emphasized how

impactful it was to have one teacher remember his name and ask how he was doing regularly, and why it would be so meaningful for professors to simply care about their students:

“Give professors space to show their hearts, because I feel like if the professors talked a little bit more about themselves, or embedded their history ... I don't know anything about my professors. That's kind of sad because I come from this very family, tribalistic view, where it's like, you introduce yourself, I'm So-and-so, daughter of So-and-so, and with professors it's like, I'm a professor, I got this degree from this place. I'd try way more harder, because then I wouldn't see it as this obstacle that only these smart, smart people can achieve, but this obstacle that quite anybody can achieve.” - Carlos

Carlos described how his cultural views on interpersonal relationships conflicted with dominant practices of how professors usually acted with students. Having a professor break this dominant practice would humanize them, and as a result, make engineering expertise seem attainable by diverse kinds of people.

4.5 Discussion

The harms and violences that our student participants of color experienced align with existing research on student experiences with regard to trauma and persistence [180], [192], [234], [235]. As such, findings from RQ1 revealed a variety of violences and harms our participants experienced included having their capabilities questioned and confidence weakened, microaggressions and impacts to mental health and wellbeing, the erasure of their needs and voices, and a lack of space to be their whole selves. However, when matched with principles of CSP, there were clear opportunities for instructor intervention to address, prevent, or alleviate

these harms and violences. For example, for decentering the White gaze an instructor could allow multiple communication mediums for content delivery and assessment; for sustaining, revitalizing, and imagining toward socially just, pluralistic societies an instructor could integrate the political and social issues that students care about into engineering curriculum; for culture is complex, evolving, intergenerational, and locally situated, instructors can take the time to individually get to know their students to avoid stereotyping and tokenization; for sustaining lives and reviving souls, instructors can establish classroom norms where discrimination is not tolerated to invite students of color to show up as their authentic selves; for loving critique, instructors can combat anti-liberative ideologies such as capitalism with guidance toward critical consciousness development. These proposed opportunities were the primary way I discussed the significance of the findings, as it is more impactful to see the opportunities directly associated with real experiences instead of broad recommendations that are disjointed from student needs.

The findings from RQ1 affirm how similar the way principles of CSP are implemented are to other asset-based teaching approaches like culturally relevant pedagogy and inclusive teaching. What makes opportunities for CSP as described in the findings different from these other approaches, is the spirit or purpose held by the instructor related to decentering the White gaze. For example, meeting students where they are is one element of inclusive teaching that improves a sense of belonging and academic performance [236]. For CSP, meeting a student where they are is one way to enact decentering the White gaze through not determining students' progress by how well they achieve White metrics for success. Implementing CSP is not only *what* an instructor does, but *how* and *why* the instructor uses a certain teaching or mentoring practice. This may be a useful perspective in engineering education, as CSP does not demand that we no longer teach the technical knowledge and skills necessary to prepare students for

engineering practice, but rather the ways in which we choose to convey and assess this knowledge.

Findings from RQ2 revealed that the students recommendations for improving their engineering education through CSP consisted of four themes, supporting engineering-cultural identity co-development, adjustments to design projects, integrating equity and justice into technical engineering curriculum, fostering a class community, and care from instructors. It is clear that the findings for RQ1 are much more substantive than for RQ2. The reason for this might be that when collecting data to answer RQ2, we directly ask students for suggestions for making their education more restorative, and center their values and interests more. These are the recommendations described in our paper. At first glance, this seems like a straightforward question. Yet many students said that it was difficult to imagine a more restorative education because they were unconvinced that change could feasibly happen. Other students struggled to imagine changes would not just increase the amount of work that they already struggled to complete. Robin aptly described this tension between wanting equity in the classroom (to center her experiences) but having a hard time thinking about what it would look like in practice without being disjointed due to technical nature of engineering curriculum:

“I would say that equity belongs in the classroom because the material that we're taught is already through a specific lens. Research, science, it all already has a background that's racially biased. But I don't think like, ‘Oh, here's a problem for dynamics and controls. Also, by the way, did you watch the new Will Smith movie Emancipated where he's a slave?’ I don't see that happening.” - Robin

Consequently, the suggestions that students *did* make were fewer than the harms they described, simply because it was easier to speak about their own experiences than to dream about something they had not necessarily thought about before.

4.5.1 Implications

The findings from this work do suggest that implementing CSP in engineering is possible despite epistemological and logistical challenges specific to engineering education. Thus, this study can inform an instructor's own practice, teacher training and curriculum development. By looking at the principles of CSP alongside with the violences and harms students experience, instructors can draw parallels between the participants in the study, and the students in their own classrooms. Instructors who have never heard of CSP can also be guided by this work to consider new perspectives on teaching. Because there are few examples of CSP in engineering classrooms, the findings from this work can help individual instructors remove the initial barrier of imagining possibilities which in turn, can help spur creativity. Administrators or leaders in pedagogy training (e.g. centers for teaching and learning) can use the findings from this paper to add CSP to their repertoire of approaches to helping instructors support students of color. Universities are increasingly trying to educate engineering students that consider equity and social impact in their work. CSP can address this through curriculum development, where instructors or departments can implement elements of CSP into standard course material to support the imagining for socially just pluralistic societies alongside technical knowledge. Broader implications of this work are that more research is needed to identify the outcomes of CSP in engineering education. This study demonstrates possibility, but future work needs to confirm and demonstrate the impact of CSP in actual classrooms.

4.5.2 Limitations

One limitation of this study is that it is exploratory, which means that the findings are initial and meant to be transferable in the sense of supporting the reader to reflect on their own relationship to violence, trauma, and the need for education for love and life. Because of the nature of small n qualitative work, this study does not seek to declare statistical significance, or prove a claim about the measurable efficacy of CSP. Further research needs to be conducted to assess these questions.

Additionally, this work was conducted by one researcher, which means there was not interrater reliability, or collaboration on the research design. Adding an additional researcher could have allowed the analysis to be more cohesive. However, because the study was broad and meant to assess a theoretical possibility, the lack of a second coder or researcher does not compromise the validity of the work as the claims are relatively broad.

Lastly, ideally, CSP should be adapted to fit the students and institutional context relevant to the instructor interested in implementing it. Thus, the harms and associated ways that each principle can address them shown in our findings are specific to our students and the departmental, class, and interpersonal contexts they are in. The way we conceptualize how CSP can meet the needs of our student participants are examples to demonstrate an overall need for CSP in engineering education.

4.6 Conclusion

This study sought to explore the needs and possibilities for culturally sustaining pedagogy in engineering education and found that there are both a plethora of needs, and many actionable approaches to address them. Engineering remains a White, male, dominated field and minoritized students continue to be harmed on their path to becoming engineers, making equity and justice imperative objectives. Equity and justice as objectives can often feel like a nebulous

responsibility for task forces, deans, or department heads. Yet the student participants in our study were adamant in how instructors can make a significant impact on their success, engagement, persistence, and excitement for learning. While there are certainly challenges instructors may face to implementing CSP in engineering education, the benefits of trying to implement even single principles in the classroom could be the difference between a student staying or leaving the field. This paper describes different possibilities for using CSP to respond to the participants' experiences, but these possibilities are by no means exhaustive or even appropriate for every context. The purpose of this work was to inspire instructors to seek opportunities for CSP in their own classrooms and believe that tangible immediate change is possible. Ultimately, CSP calls for the total transformation of education by disrupting the White gaze's grasp on preparing and measuring students to achieve their goals. This call may be daunting, but even small changes in the classroom can contribute to collective action towards love and life as the purpose of education.

Chapter 5 Discussion, Implications, and Conclusions

5.1 Summary of Findings and Contributions

This dissertation consists of three studies that explore how equity-minded practitioners and students address equity through design and experience barriers to the equity outcomes they hope to achieve. Chapter 2 established that 59 transportation practitioners in the public, private, non-profit, and academic sectors were able to address equity directly or indirectly. They addressed equity by engaging in 12 different approaches with the most frequently described approaches being collaborating with other organizations and sectors, integrating non-transportation related data, and considering vulnerable communities' contextual needs. Aside from approaches, these practitioners also experienced nine different barriers to addressing equity, the most frequently described being that more or better is needed than available, challenges with accessing or collecting data, and no standards or clear metrics for equity outcomes. Experiences describing these approaches and barriers varied across sectors. For example, private sector practitioners were more able to directly address equity because they had more available resources, and no constituents or laws to be mindful of. Furthermore, multiple barriers demonstrated that barriers were often embedded in systems and structures that continue to perpetuate inequities regardless of the efforts or desires of practitioners.

What makes the findings in Chapter 2 a contribution to design practice is that while research has been conducted to identify approaches to addressing equity in design contexts besides infrastructure (e.g. product design [237], user experience design [238], architecture

[239]), designers in these contexts face different barriers than our participants because of differences in scale of impact, diversity and size of stakeholder groups, and relation to laws and regulations. For example, one design approach practitioners have used to address equity is community-based participatory design (CBPD). CBPD, in a United States context, is a design approach that takes into account the historical injustices affecting a stakeholder group, and emphasizes the equal involvement and sharing of power between community stakeholders and designers during the design/decision-making processes [20]. While CBPD can be effective in design contexts where a designer is able to work closely with a specific community to focus their efforts on, infrastructure design requires considering the needs of entire cities full of multiple communities and types of stakeholders. Furthermore, often CBPD is employed in the private and non-profit sectors where distribution of resources is not determined by legislation or government grants which pose unique challenges to public sector practitioners. Thus, the contribution of Chapter 2 is highlighting how existing practitioners are able to engage in equitable design practices despite the complex barriers related to infrastructure projects that are not always taken into consideration in existing equity oriented design approaches.

Chapter 3 describes a data-driven semi-fictional narrative to demonstrate the limited agency students have during curricular and co-curricular community engaged design projects to pursue the equitable community outcomes they intend to. Using a wide range of data including but not limited to autoethnographic reflections, artifacts from student teams, course materials, and interviews, this study uncovered the way external factors outside of students' control mediated agency in four different domains of power (interpersonal, curricular, institutional, and hegemonic). For example, one external factor in the interpersonal domain is student-stakeholder relationships where in the case of Ash, the narrative's main character, fixed power dynamics

embedded in the global reputation of the American education system meant community stakeholders meant that students were perceived and treated as experts. We described the way Ash's ability to work towards equitable outcomes is controlled by external factors through a visual model representing the amalgamation of the conceptual frameworks of agency and domains of power. The model can be used by instructors, students, and other researchers to advance understanding of how power operates within engineering higher education.

Findings in Chapter 3 extends existing understanding about intersections of design and equity in engineering education. Several of the external factors in Ash's story in relation to their agency have been documented in other research studies, such as the influence of mentor-student relationships [240], team dynamics on design teams [241], neo-colonialism in community engaged design projects [242], and the broad social implications of design [243]. However, few studies illustrate what these external factors look like together within the lived experiences of an engineering student. Aside from creating a model for evaluating agency and power in the academy, Chapter 3 contextualizes the intersecting problematic aspects of engineering higher education through a cohesive narrative. Lastly, Chapter 3 fills a research gap where agency has been studied amongst faculty [176], but not significantly so amongst students.

Chapter 4 describes potential opportunities for instructors to implement culturally sustaining pedagogy (CSP) through examining students of colors' experiences of violences and harms, and suggestions for ways for instructors to have improved their engineering education. The study explored the use of an asset-based research approach that invited 14 student participants to have greater control over the direction of the semi-structured interview topics, and building trust and solidarity in the relationships between the researcher and participant. Findings proposed opportunities to implement teaching strategies in alignment with the five principles of

CSP in alignment with Wong [208]: 1) decentering the White gaze, 2) sustaining lives and reviving souls, 3) culture is complex, evolving, intergenerational, and locally-situated 4) sustaining, revitalizing and imagining toward socially just, pluralistic societies, and 5) loving critique. Opportunities were matched with the violences and harms shared by the student participants as ways they could be alleviated. Findings suggest explicit ways instructors can implement CSP, as well as guide reflection on how to adapt the principles to their own classroom contexts.

Chapter 4 contributes to a greater understanding about how to support the holistic success of students of color who are interested in implementing social justice through engineering and design. Similar to how Chapter 3 contextualized problems in engineering higher education that have already been researched in a cohesive way, Chapters 4 also contextualizes prior research on the violences and harms students of color, reinforced by the experiences shared by our research participants. For example, our student participants explained their experiences with being tokenized [244], isolated due to their racial identity [245], and feeling a significant lack of sense-of-belonging [199]. Pedagogical strategies have been suggested by existing literature as well, such as building mentoring networks [246], alternative assessment methods [247], and leveraging students' funds of knowledge to increase inclusivity in engineering classrooms [248]. Thus, the research contribution of Chapter 4 is directly connecting experiences with opportunities for CSP interventions in the classroom.

5.2 Discussing Findings Across Chapters

One shared attribute across the chapters is that the barriers students and practitioners faced in both industry and academia are structural in nature and control the amount of agency these individuals must behave authentically in alignment with their values. Structural barriers are

rules, policies, norms, and practices that present as obstacles to achieving equitable outcomes and maintain disparities between majority and minoritized groups. For example, in Chapter 1, the transportation practitioners faced barriers such as lack of allocated funding, lack of legislative support, and little to no broader systemic support. Initially these barriers seem logistical however the underlying reason why they are significant enough for participants to discuss them are because they are symptoms of *structural* barriers. Lack of allocated funding to address equity is often because of policies that maintain a racialized, classist status quo; in the case of transportation, funding highways used by middle class-wealthy individuals who own personal vehicles. Lack of legislative support for addressing equity is a structural barrier because policymakers are primarily White men who create policies to maintain their own power and comfort; policies to support equity would divert resources away from this toward communities of color.

In Chapter 3, many of the external factors that students like Ash experience are also structural in nature outlined by the power analysis of these factors. For example, in the curricular and institutional domains of power, university *policies* such as the length of spring break prevented Ash's co-curricular team from having more time in the village to properly engage stakeholders and execute a more detailed design plan. Similarly, in the curricular domain of power, ABET requirements which institutions need to maintain accreditation encourage stakeholder engagement as an element of design projects, which leads to exploitive relationships with vulnerable populations such as the unhoused stakeholder who was not compensated for their time helping Ash's first year engineering class. Like Chapter 2, motivations for enforcing these policies and metrics align with other theories about the pervasiveness of underlying structural barriers such as racism as defined by Critical Race Theory. Critical race theory

describes how race is socially constructed and is an endemic part of our society that maintains racial inequalities. As such, legislative (e.g. transportation funding allocation) and education (e.g. grading) policies are both grounded in upholding White supremacy if not explicitly intended to do otherwise.

Both Chapter 2 and 3 primarily discuss the way structural barriers inhibit the outcomes of designer/student decisions whereas Chapter 4 investigates the way structural barriers directly impact students themselves. Chapter 3 uses domains of power as a conceptual framework to understanding structural barriers, while Chapter 4 leverages decentering the White gaze and other dominant gazes to disrupt structural barriers that impact the lives and success of students of color. White and other dominant gazes are grounded in oppressive ideologies such as ci-heteropatriarchy, capitalism, english-monolingual etc. all of which are levied through systems and structures of power as illustrated through the student participants. Though structural barriers impacted the findings of all three body paragraphs, Chapter 4 is the only chapter that centers examining structural barriers explicitly. This could be because of variation in the audiences for each chapter. The audience for Chapter 2 was for practitioners to improve their approaches to equity in industry; many practitioners do not find theories (on structural barriers) that are helpful in improving their every-day tasks versus specific actions. The audience for Chapter 3 was intended to be students, instructors, administrators, and researchers, a much broader audience so structural barriers were a background explanation for the paper's significance. Conversely, Chapter 4 is specifically meant to inform instructors teaching practices and how structural barriers *directly* impact their students versus act as a backdrop to generally explain why inequities happen.

Findings in and the study design of Chapter 3 centered how power operates in different ways at different levels in engineering education. Though Chapter 3 is about student agency in engaged design projects, the way the external factors are organized into four context-specific domains (*interpersonal, curricular, institutional, hegemonic*, adapted from Hill-Collins original domains, *interpersonal, disciplinary, structural, hegemonic* [249]) can also be extended to understand how power is organized in Chapter 4. One example of this is how Carlos describes his struggles with reading as the only way knowledge was communicated in his class leading to him experiencing harm to his confidence and self-efficacy. This violence was levied through the *curricular* domain of power, as rules for course communication style are a curricular choice by instructors or department units. Another example is how Victoria described a violence in the *institutional* domain of power, where the university making performative pledges to supporting minoritized students once a year with no other authentic efforts. Additionally, some of the approaches in Chapter 2 also demonstrate how power operates at different levels. Two examples include the *interpersonal* approach addressing equity through “engaging stakeholders” which involves talking and soliciting information directly from community members, versus the approach “considering vulnerable communities contextual needs” which involves keeping in mind oppressive *hegemonic* beliefs that have led to racially motivated transportation plans (e.g. redlining, dividing Black neighborhoods to build freeways etc.).

Lastly, the Chapters all grapple with the influence of capitalism in design and engineering practice, and the ability for both students and practitioners to act on their equity-mindedness. For example, in Chapter 2, capitalism and the free market creates tensions amongst private sector participants whose fundamental obligation as employees is to reduce the bottom line of the corporations they work for, even if they are assigned to equity related projects. For students,

learning outcomes of their engaged design projects are to supplement their preparation to be good workers in industry, where a significant portion of engineering jobs are in industries that rely on capitalism to persist (defense, natural resource (oil, gas), manufacturing, IT). Thus, students must negotiate their equity-minded values with the career options their education leads to because there is no direct pathway to design equity work under capitalism. Students of color experience the influence of capitalism in unique ways, especially students from immigrant families, where labor compensation, citizenship, and xenophobia heavily influence their motivations for pursuing engineering degrees. While they are passionate about equity and liberation, because their engineering education does not show them alternative opportunities for liberation outside of wealth accumulation to lift their families and communities out of poverty. Consequently, the chapters in the dissertation demonstrate that capitalism as a characteristic of engineering culture is not simply a background belief, but an ideology about power that influences everything from the agency of practitioners to the career trajectories of students.

5.3 Implications for Practice, Pedagogy, and Future Research

This work has several implications for design practitioners, engineering education instructors, engineering undergraduate students, and researchers. Currently, many changes to engineering education come from adapting aspects of professional design practice to better prepare students for industry jobs. However, this dissertation could suggest that some approaches to address equity and create more equitable environments can be drawn from education research and applied to practitioner contexts. Chapter 3 proposes a conceptual model to understand and better navigate the ways in which students doing design practice are limited in agency. This model is an adaptation of Domains of Power to an engineering education context, and there may be benefits to assessing the transferability of the model to design practice, as Chapters 2

demonstrates that practitioners also struggle with agency based on some of the barriers they discussed. Additionally, though engineering education primarily happens in academia, professional development aims to extend it in industry practice. Chapter 4 presents suggestions for improving the experiences of undergraduate engineering students of color. These same implications could be carried into professional development contexts to further sustain the persistence of engineers of color in industry. Lastly, revisiting the core concept of the equity-mindedness framework (in Chapter 1) which comes from higher education, there are implications for the power engineering practitioners who must influence social change even when they are not making design decisions. This is because often, when engineers are uninvolved in work that is directly related to equitable outcomes, they still remain in community with those who might be. Engineers are often positioned as experts and leaders. Thus, if engineers always embody equity-mindedness, there may be opportunities for their leadership to indirectly lead to equitable outcomes.

There are also implications for the importance and power instructors have in shaping student experiences. As pedagogical approaches that center equity continue to gain in popularity across disciplines, it is necessary for these approaches to be tailored to engineering education specifically. Findings from the dissertation can support this tailoring by revealing the way engineering has disciplinary characteristics that are at odds with liberation (e.g., meritocracy, capitalism, depoliticization), and offering alternative ways to achieve the same learning goals. This work can also offer guidance to instructors in using their relative agency to decenter the White gaze in their teaching, evaluate the way they benefit from dominant gazes, and be explicit in how they define success outside traditional academic metrics. Decentering the White gaze may seem like a foreign concept in engineering pedagogy; however the dissertation suggests that

small actions have large impacts. One example of a low-resource strategy for decentering the White gaze is building supportive, restorative interpersonal relationships with students as the absence of this in engineering education significantly contributes to the formation of equity-minded engineers. Additionally, to bridge the gap between practice and education, engineering instructors can integrate the approaches to addressing equity that design practitioners implemented in their work into the course curriculum. This would allow students to practice tangible skills to address equity and expose them to barriers they might anticipate as practitioners.

There are also implications for how students could benefit from the work in this dissertation. Much of the dissertation involves students sharing narratives about their own experiences and can facilitate students' critical consciousness and self actualization. Many students of color feel like they struggle in isolation because they are often the only students with their identities in the classroom. Knowing other students experience the same things they do could feel empowering, and help students see that their experiences happen because of oppressive systems and structures of power not because of their lack of competence. This could be facilitated by extending the model for critical agency described in Chapter 3 to scaffold understandings about the structure of engineering higher education. Another implication for students is that, like previously stated, few opportunities to directly address equity exist in traditional engineering industry jobs. Despite this, Chapter 2 does share the ways that practitioners can integrate ways to address equity in their work, even when the work is not equity centered. Students could take these approaches with them into industry and find ways to apply them to their own work to converge their values with their engineering practice.

Findings in this dissertation suggest opportunities for future research in advancing equity in design practice and engineering education. The approaches and barriers found in Chapter 2, as well as the power analysis model in Chapter 3 could advance existing design for equity frameworks such as community-based participatory design [20], design justice [6], and Equity Meets Design [250] to be applicable beyond human centered design to more traditional design contexts (e.g. mechanical engineering). For example, the design justice framework is high level guidance for collaborative practices and addressing needs of historically underserved communities. A potential addition to the design justice framework could be data focused as many of the practitioners in Chapter 2 discussed data collection, access, and usage as having direct ties to their ability to address equity.

Many of the theories, topics, and perspectives in this dissertation come from non-engineering or education disciplines demonstrating possibilities for further interdisciplinary research on engineering design practice and education. To explore the transferability of some of the findings of this work, researchers can consider how domains of power as discussed in Chapter 3 can be used to pursue other research projects in different contexts outside engineering design education. From a methodological standpoint, researchers can assess the efficacy of asset-based research approaches in future studies on engineering students to humanize participants and reduce the power differential between researchers and participants. There may also be opportunities to use asset-based research approaches while studying the experiences of practitioners as well.

5.4 Conclusion

This dissertation explored how designers and students seek opportunities to address equity through their work and must persist through structural barriers to act on their equity-

mindedness. In Chapter 2 we explored how transportation industry practitioners engaged in design activities to identify approaches and barriers they experienced when addressing equity in their every-day practices. We found that most practitioners across the public, private, non-profit, and academic sectors address equity through efforts to improve the quality of life for historically underserved communities, and that barriers are primarily related to the ability to use and access relevant data. Based on our findings, we recommend that practitioners consider the barriers we revealed to anticipate and plan to overcome similar obstacles to equity in their work. In Chapter 3 we sought to use data to provide a greater understanding about how students' agency to achieve the equity outcomes they intend to in engaged design projects is limited due to external factors beyond their control. We found that these external factors are located in and manifest differently in four nested domains of power which also explain where power is located in higher education. Based on our findings, we suggest that future efforts to support equitable engaged design opportunities should target dismantling systemic and institutional barriers instead of more pedagogy that only focuses on individual students' skills. Chapter 4 explores the experiences of undergraduate students of color in engineering to identify the ways in which the harm they experience can be addressed through culturally sustaining pedagogy. Findings suggested multiple opportunities for instructors to implement principles of culturally sustaining pedagogy to improve the holistic success of students of color while decentering dominant gazes. Broadly, this dissertation underscores the need for greater attention to equity in engineering design practice and education and demonstrates ways to support equity-minded practitioners and students. By examining the ways in which design and education practices can perpetuate inequities, we can begin to identify ways to achieve more liberative learning and just design outcomes. Through this work, we hope to motivate others to imagine a radical future for the role

of engineers and designers in society, and to rethink what preparation to be an engineer can look like with a focus on achieving equity through social justice.

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