WIP: Developing a Framework for Equity-Centered Engineering Curriculum and Instruction

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Introduction and motivation

In this work-in-progress (WIP) paper, we report on initial stages of ongoing work to develop a framework to support the design and delivery of equity-centered engineering curriculum and instruction within undergraduate courses. This paper presents high-level learning from (1) our synthesis of relevant literature on how instructors teach equity-centered content – how they integrate equity considerations into engineering content – and (2) a summary of interviews with equity-oriented instructors. Our literature review and interviews aim to identify course design components that instructors and staff consider essential for equity-centered engineering education, including pedagogy, content, and the interplay between them. For this research, we defined equity-centered engineering curriculum and instruction as courses or sequences of courses that both integrate equity considerations into technical content and support students' engagement through pedagogical attention to equitable classroom environments.

Students, particularly Black and Latinx students (e.g., [1]) and women (e.g., [2]), are often interested in learning how they can support equity through work in STEM [3] - [12], but this is still slow to be addressed in courses. Educators have identified dimensions of engineering culture that impede attention to equity in engineering courses. These barriers include a culture of competition over collaboration [9], [13], [14]; whiteness, masculinity, and heteronormativity [10]; the belief that engineering is neutral and meritocratic [3], [7], [10], [15], [16]; and prioritization of technical knowledge over social understanding [3], [7], [10], [13], [14]. To challenge these conceptualizations, educators have suggested interventions that refute narrow understandings of engineering practice, including guidance on how to introduce social justice and equity into course content and practice (e.g., [7], [11], [13], [17] - [21]), and recommendations for inclusive teaching practices (e.g., [5], [6], [10], [14], [20], [22], [23]). Yet, our ongoing review of the literature and our interviews with instructors reveal the need for a more holistic approach to curricular and instructional change that includes ongoing support for instructors as they learn to design and implement courses that center equity. This will involve implementing both equity-centered *content* and *pedagogy* (e.g., [20], [24]) in a range of courses.

We describe the first phase of research to build a curricular and instructional change framework to support educators who seek to revise or develop engineering courses to center equity. Our emerging framework acknowledges that instructors – including tenure-track, contract faculty, and graduate teaching assistants – will typically require professional development to support them as they design and teach these courses. We also acknowledge that for engineering to move beyond siloed discussions of equity, academic programs need to revise multiple required courses, including technical/ engineering science courses. In the following sections, we provide a project overview and a sample of initial findings categorizing equity-centered content.

Project overview

The goal of the NSF Broadening Participation in Engineering (BPE) grant that includes this effort is the development of a Teaching Engineering Equity (TEE) Center at the University of Michigan. The Center will support existing and new efforts aligned with the College of Engineering's Diversity, Equity, and Inclusion (DEI) strategic mission and share initiatives with leaders similarly committed to equity-centered engineering education. Currently, the TEE Center

has three main objectives: (1) designing and validating an evidence-based framework for creating an equity-centered engineering curriculum; (2) generating and evaluating a collection of DEI learning activities within specific engineering contexts; and (3) developing a replicable and adaptive training infrastructure to enable instructors to use the learning activities. The work described in this paper relates to Objective 1 and engages an interdisciplinary team of faculty, administrators, and graduate students from the fields of engineering, education, and sociology in research efforts to inform the development, implementation, and study of the framework. The early phases of the team's work have focused on the development of the framework. Subsequent phases will focus on researching its implementation. As the project has evolved, the three TEE Center objectives have become more interconnected and mutually supportive.

To date, Objective 1 work has involved literature review and individual interviews with engineering educators. There is more literature on equitable *pedagogy* (e.g., [2], [5], [6], [10], [14], [22], [23], [25] - [28]) than on equity-centered engineering *content* (e.g., [7], [8], [11], [13], [17] - [21], [29] - [31]), though we argue that both are necessary in order to prepare students to be equity-oriented in their engineering practice. Additionally, there are different approaches to centering equity in engineering courses, e.g., sociotechnical content (e.g., [7], [9], [12]), Diversity, Equity, Inclusion, and Justice (DEIJ) curricula (e.g., [19], [31]), macro-ethics (e.g., [18]), universal design (e.g., [17]), engineering for social justice (e.g., [8], [13], [15], [34]), etc. Given the variety of terms and approaches, we first sought to define our goals for equity-centered engineering curriculum and instruction. To challenge conceptualizations of engineering that reproduce and maintain inequitable processes and outcomes, educators must interrogate what counts as engineering and support such reflection in their students. Educators must teach that engineering is sociotechnical in nature [7]; authentic engineering problem-solving is contextual [13], [23]; and engineering is part of justice movements [1], [20]. Such teaching requires both equitable pedagogy – to model equitable practices and create environments in which students can learn to be equity-minded engineers – as well as equity-centered content – in which the sociotechnical nature of engineering is integrated throughout engineering courses.

To develop our shared understanding of equity-centered engineering education, our team engaged in an iterative process of group reflection and discussion on these ideas and our own experiences and commitments. Currently, we contend that, in principle, an equity-centered engineering course or program (1) integrates a sociotechnical view of engineering practice that consistently counters views of engineering as neutral, objective, or decontextualized; (2) encourages ongoing personal reflection on instructors' and students' biases and positionality; (3) critically examines the intersections of identity, power, and privilege in society and thus their influence on processes and outcomes of engineering practice; (4) develops students' ongoing capacity to identify, address, and reflect on inequities and students' role and positionality in engineering practice; (5) models equity-oriented engineering practices using content, activities, and teaching approaches; (6) assesses students' developing understanding and capacity to engage in equity-centered engineering practice; and (7) intentionally cultivates equitable social interactions that support students' and instructors' co-learning. These principles both emerged from and continue to inform the literature review and interview analysis. Some principles focus on instructional moves while others focus on the content with which students directly engage. For practical use by instructors, it is convenient to separate instructional and curricular practices, but we later discuss the reciprocal relationship between pedagogy and content.

Alongside literature review, we also conducted interviews. Through both literature review and interviews we sought to identify course components that engineering instructors and instructional staff consider essential for equity-centered engineering education, considering both pedagogy and content and the interplay between them. Our interview guide thus prompts interviewees to develop their idea of the essential components. We conducted seven pilot interviews to refine the guide, and then drafted a list of engineering faculty known to be focusing on equity in their courses and used snowball sampling to identify additional participants. The interview collected information about the courses participants teach and about how their institutional and departmental contexts shape their experience of teaching these courses and engaging in equity-centered work. We also asked about the kinds of departmental support that would be useful. To date, we have interviewed 25 instructors and three teaching center staff. Faculty participants come from all ranks and include non-tenure line instructors. They represent seven engineering disciplines and three adjacent programs (i.e., technical communication; general engineering; and STEM education), and come from a variety of private, public, and minority-serving universities across the US, with one in the UK. Ten participants had significant experience in engineering education research.

Partway into this data collection effort, we began data analysis. To build a codebook, we began with a list of codes aligned with our interview topics (e.g., motivations, learning objectives, etc.). Each transcript was individually coded by at least two team members, and then discussed to resolve coding discrepancies and synthesize new categories and definitions. To deepen our analyses, the team wrote reflective memos that examine codes and build categories.

In the next section, we focus on one of the six major categories in our data analysis: *course content*. This code captures types of course activities that interview participants used to teach equity considerations in engineering content. Table 1 provides examples of approaches that would be coded with different *course content* codes, paired with similar ideas found in literature.

Preliminary findings: Learning from the technical course context

While our work has been informed by descriptions of courses, workshops, and modules that integrate equity into engineering curricula (e.g., [7], [17] - [19], [32] - [34]), the limited number of empirical studies on equity-centered course content shifted our focus to mapping recommended teaching approaches and practices in the literature. This effort has supported us in identification of connections between literature and our interview data. Many of our interviews and much of the literature we reviewed focused on incorporating equity into design courses, but our framework needs to be applicable in a range of engineering courses. Scholars have argued that students will best receive the message that engineering inherently involves equity considerations when topics of equity and justice are integrated into and throughout engineering curricula [3], [7], [11], [18]. Leydens and Lucena, who described engineering sciences (ES) as "the sacred cow of the engineering curriculum" wrote, "Perhaps more than any other element of the engineering curriculum, the ES play important definitional and normative roles in what an engineer is and what engineering education should be" [13]. Thus, integrating content about equity into engineering *science* courses is uniquely important. It is also uniquely difficult to do.

Leydens and Lucena acknowledge that some of their engineering for social justice (E4SJ) criteria are easier to implement in design than ES courses, but they also write, "Whereas listening contextually is greatly facilitated by design projects that feature a client…, such listening is more abstract in the absence of clients… However, students can identify the kind of

listening they would do with hypothetical clients" [13]. This quote suggests both that it is difficult to integrate an equity focus into science courses, but also that similar approaches can be used in ES and design courses, though the connections to real-world impacts might be more abstract or hypothetical in the former. Although we specifically sought interview participants who teach engineering science courses, we found participants primarily discussed design courses when asked to describe a course in which they focused on DEIJ. In some cases, they particularly noted the difficulty of teaching equity-centered content in their fields. For example, an assistant professor of aerospace engineering said,

> We have good guidelines on how to [use equitable pedagogy]… I want to think about, how can the content of these courses be connected to social justice or equity? *That's a lot more challenging, especially in aerospace because we never talk about people in general, let alone ethics or equity.* We are starting to have conversations around sustainable aviation or things like that, but lots of engineering fields never talk about equity. I think in aerospace it's particularly bad. …We never talk about harms. (italics added)

Table 1: Content Category: Code descriptions, example data, and connections to literature

Code description	*Examples from interviews*	*Examples from literature review*
Course content about nature, culture, history, and *context of engineering*	Discuss student and faculty demographics in engineering and the reasons these numbers are the way they are	Discuss the nature of science and inequitable participation; use the subjectivity of science to interrogate inequitable STEM culture [35] Challenge statistical objectivity in data science by discussing eugenics [36]
Student reflexivity about their identities, positionality, influences, and biases in general and as engineers	Have students take implicit bias tests and reflect on them Have students break into groups based on their alignment with Pew's top 10 national priorities and reflect on experiences impacting priorities	Students should "express and critically reflect on how [their] identities, background, experiences, biases, privileges and disadvantages influence [their] engineering education, practice, and teamwork" [3] Assign readings and activities about implicit bias [35]
Sociotechnical impact of existing designs, solutions, and applications	Assign case readings, e.g., exclusionary NYC bridge design Share examples, e.g., how sensors don't always respond to dark-skinned hands	Discuss impacts of single-use plastic straws, considering sustainability and accessibility; examine and reflect on one's own contribution to global waste [7] Discuss racial bias of pulse oximeter [19]
Interpersonal skills and values, ethics, and sustainability	Teach engineering students to have empathy as engineers Integrate ethics throughout courses, rather than isolating it	Tie social justice to sustainability [7], [8] and engineering ethics [13] Discuss ethics and avoiding catastrophes [18], [19], [21]
Consider diverse human *users*' needs in students' designs	Have students design playgrounds for disabled users or users in a cold location	Design playground equipment for children with disabilities [17] Teach students to ask questions, like, "Who benefits?"; "Who suffers?" [13]

This instructor is actively thinking about and trying to center equity, but finds that difficult to do because of the culture of aerospace engineering. His point that it is easier to use equitable *pedagogy* than to teach equity-centered *content* is reflected in engineering education

literature, which presents many more equity-oriented pedagogical frameworks than curricular ones, suggesting the need for a framework that addresses both.

Another assistant professor described the ways caring pedagogical practices open opportunities for sociotechnical discussions in technical courses, stating:

> I want students to know that I care about them and that we should care about each other. I want a cooperative environment [not competitive]. What that looks like in a technical space is I put up discussion questions about how we're doing, I create space for us to talk about these things as part of class. *We end up having the sociotechnical discussions* because that environment is established from the beginning. …it creates an environment where later that person can speak up and they're not scared to. (italics added)

This participant suggests equitable pedagogical practices create the conditions needed for equity-centered and sociotechnical discussions of technical content. However, our findings to date suggest that most instructors teaching equity-centered content view it as more difficult in "technical" courses than in design courses – a view aligned with publications on teaching about equity in engineering (e.g., [13]). We are currently seeking to interview instructors who center equity in engineering science courses to ensure that our framework will be broadly applicable.

Discussion and future work

Our work to date benefits from our review of frameworks for equitable pedagogy in STEM; literature-based examples of equity-centered engineering courses, workshops, and modules; and interviews with engineering instructors teaching about equity. The categories in Table 1 include some elements of an equity-centered engineering course that instructors identify as opportunities to integrate equity content and that map to recommendations in the literature. We will continue to identify elements of equity-centered engineering courses through further analysis of our data corpus, additional interviews with engineers teaching about equity in technical courses, and continued mapping of ideas in the literature to our findings.

In addition, through discussions with the full TEE Center team, we are identifying ways to integrate the three "objectives" (above) into a curricular and instructional change framework that recognizes the need for 1) initial and ongoing professional development for engineering instructors who seek to create and teach equity-centered courses, and 2) a collective effort by department leaders and teams of faculty that receive ongoing support for their efforts from conception and design of equity-centered courses and through implementation and evaluation of these curricular reform efforts. This holistic approach faces an important challenge, which is to accommodate different users in different contexts while providing concrete, practical guidance. We plan to address this challenge by partnering with early adopters (departments and individuals) to study the framework. We will study their experiences as department leaders and instructors engaging in equity-focused curricular and instructional change efforts, as well as the impact of newly designed courses on students' and instructors' experiences and learning. This comprehensive effort will be needed to support refinement of the framework before we engage additional partners beyond our home institution to further study and refine the framework in different institutional and disciplinary contexts.

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