Leveraging Sustainability to Teach About Social Justice in Civil Engineering Curricula

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Abstract

Sustainability is a vital interdisciplinary concept to address within engineering education. Furthermore, the natural connections that exist between sustainability and social justice provide an optimal opportunity to integrate both into curricula. We argue that engineering curricula ought to include sustainability and social justice so future engineers are trained to understand both societal and technical implications of their work, while acknowledging the challenges engineering faculty may face in conceptualizing social justice or social sustainability. We then highlight how new sustainable design rating systems, such as Envision and The Living Building Challenge, embed inclusion and social justice into their ratings and how these sustainability rating systems can help engineering faculty bring social justice into their classrooms in ways that meaningfully link to engineering content. Finally, we present two examples of how sustainability and social justice can be incorporated into the civil engineering curriculum through inclusive pedagogy and new curricula: 1) a semester-long effort to document, design, and improve the inclusive pedagogical practices in a first-year engineering course that included the theme of sustainability throughout much of the class meetings; and 2) a new assignment about the Envision rating system and the societal implications of rebuilding a major component of regional infrastructure. We conclude with recommendations that other instructors can use to begin incorporating social justice in their courses.

Keywords: Diversity and Inclusion in Engineering Education; Good practices; methodologies and tools for including the principles of Ethics; Social Responsibility; and Sustainability in Engineering Education

1 Introduction

Sustainability has become one of the most important and interdisciplinary [1] concepts that needs to be addressed in engineering education. While there are many definitions and approaches to sustainability, we use the concept of strong sustainability [2], rather than weak sustainability, such as the concept of sustainable development. While there are several definitions of weak versus strong sustainability, we build our understandings from these authors [2] who indicate strong sustainability does not allow tradeoffs between the three pillars of sustainability (environmental, economic and social), while weak sustainability does. Therefore, strong sustainability is a more demanding concept to realize in engineering design.

A distinguishing characteristic of sustainability is its inclusive nature. By this we are referring to the fact that sustainable approaches demand a more inclusive view of the impacts of the work of engineers as well as the involvement of many other disciplines to understand and reduce those impacts. It is clear that the convergence of engineering, sustainability, inclusion, and social justice form the future context for the engineering profession. Therefore, engineering education practices must acknowledge these intersections and address their impacts in engineering curricula. This requires both inclusive pedagogy (*how* professors teach) and inclusive content (*what* information professors teach) that supports future engineers in addressing sustainability and justice issues in their work.

A key element in all discussions of sustainability is the need for greater collaboration between disciplines, and across project lifespans from problem formulation through construction and use. Communities that are marginalized by society are often ignored in the design process, such as Black, Indigenous and other People of Color in the United States (BIPOC) and low-income individuals. For interdisciplinary approaches to be effective, it is critical to be more inclusive of who participates in the design process, which consequently requires more inclusive pedagogies as part of engineering preparation; if inclusion is to become a standard part of engineering design, then our pedagogy needs to match that philosophy. To help facilitate the process of future engineers embracing more inclusive design, faculty must demonstrate inclusive behavior in their teaching [3].

Beyond inclusive teaching practices there is also a need for direct engagement with content related to justice, equity, diversity, and inclusion (JEDI), arguably a natural component of strong sustainability. A sustainable society is one in which there is greater social justice: injustice tends to destroy societies, not sustain them. We build on a conceptualization of JEDI that considers the dignity of every human being, “individuals’ intellectual, social, emotional, and expressive capacities”, and understands and values human rights [7]. Unfortunately, there are too many examples where engineering has contributed to social injustice, whether it is purposeful or not. Future engineers need to be made more aware of the potential for injustice to result from their work. Designs that strive for being sustainable will also need to strive to increase justice. This idea is well illustrated by the United Nations Sustainable Development Goals (UNSDGs) which heighten awareness of social justice issues such as eliminating poverty and increasing gender equity [4].

Joining the conversation about sustainability and social justice, especially in Civil Engineering and related fields, there are several new rating systems in use that encourage more sustainable approaches to design. Two of the concepts shared by these new rating systems are: 1) the idea of more inclusive design as expressed by the breadth of considerations in the rating systems, and 2) a push for greater social justice through design, such as local employment development. To illustrate these points, we describe the inclusion and social justice content of three rating systems in some detail, while also acknowledging there are many other rating systems available. Through two examples, we also explore how these rating systems can contribute to advancing both sustainability and social justice content in different types of courses within civil engineering curricula.

The examples we discuss are curricular materials developed as part of a larger JEDI initiative in engineering and computer science. The authors are all members of the Partnership for Equity (P4E) project, a multi-institutional, multi-year, multi-disciplinary initiative funded by the U.S. National Science Foundation (NSF) to create inclusive engineering and computer science curricula. Both examples describe ways in which The Project has helped faculty create JEDI-related changes in their courses.

The first example provides insight into how JEDI content was integrated throughout an introductory civil engineering course. For the past seven years, the first author has taught first-year introductory courses to both undeclared engineering students and later, civil and environmental engineering students, all of whom participated in the P4E project. During the fall 2020 semester, 46 students took the class within the context of the COVID-19 pandemic, racial reckonings, and political divisiveness. Throughout the semester, sustainability was a prominent component in the course content. In parallel, the first and fourth authors met weekly to discuss the efforts taken to use more inclusive pedagogy and integrate more inclusive content. These meetings took place through the framework of design narratives [8] to illustrate how new designs can be "systematically adapted...during a period of social upheaval and political change" [9]. As part of the design narratives, the first author (Siller) wrote and shared his cognitive ethnographies, or research journal reflections, with a co-author (Paguyo). They then became the basis for ongoing conversations with the aim of strengthening inclusive pedagogies in the classroom sessions.

The second example focuses on how JEDI content was brought into one specific assignment in an upper-division civil engineering course. During the 2017-2018 and 2018-2019 academic years, the remaining pair of authors (Atadero and Casper) designed and implemented a new assignment in a third-year civil engineering materials course to bring topics of sustainability and social justice directly into the technical civil engineering curricula. The authors picked a regional highway reconstruction project taking place in a low-income, predominantly Hispanic/Latinx community that had long lived with the detrimental impacts of close proximity to the major viaduct. The state department of transportation had made significant social justice-oriented commitments to the neighborhood as part of the construction project, but concern among local residents remained. Students in the class read websites and articles about the project and analyzed the situation using specific quality of life and social justice credits in the Envision rating system.

In the background section of this paper we first provide information about sustainability, prior efforts to teach engineering students about sustainability, and the sustainability rating systems. We then elaborate on inclusive pedagogy as a theoretical framework through which we consider two examples of incorporating sustainability and social justice into civil engineering courses. Section 3 provides examples of course implementation and includes course descriptions, implications and lessons learned in our effort to promote greater adoption of inclusive pedagogy, sustainability and social justice into (civil) engineering courses. Taken together, our examples illuminate how professors bolstered inclusive teaching practices and inclusive content in the classroom—without diluting technical content, but in fact, strengthening students' understanding of engineering—by connecting the dots between sustainability, social justice, and ratings systems. In the discussion section we locate our examples in the broader context of engineering curricula. Finally, we provide a brief conclusion section where we highlight the importance of the type of efforts presented herein.

2 Background

This section provides the context for incorporating JEDI concepts into engineering curricula through a focus on sustainability. The UNSDGs represent international goals that combine sustainability and justice issues. The goals lay out a framework for what engineering should be working on in the coming decades. Next, we present a brief discussion on how engineering is addressing sustainability concepts in the curriculum and the difficulties of teaching sustainability concepts. Sustainability rating systems are growing in number and becoming tools for engineers to develop more sustainable designs. Herein we discuss the following rating systems: The Living Building Challenge (LBC), Envision, and LEED. This is not an exhaustive list of systems, rather we have chosen to describe these specific systems based on our experiences using these systems in courses. The LBC represents an ambitious and aspirational rating system that has requirements that are difficult to meet. The other two are well-established US-based rating systems used around the world. We show how each of the rating systems incorporate JEDI aspects into the design process. This section concludes with a presentation of how inclusive pedagogical approaches can be used to connect engineering content, as represented by the rating systems, with JEDI concepts.

2.1 United Nations Sustainability Goals

As sustainability grows in importance, engineering is finding ways to acknowledge the impact of climate change and resource depletion and prepare future engineers for careers shaped by the need for a more sustainable world. There are a couple of ways that both engineering and engineering education can and should be influenced by this trend. First, the great global context associated with sustainability provides an important lens for the future of engineering. This is exemplified by the UNSDGs [4]. These goals were promulgated in 2015 and have a timeline for many objectives to be accomplished by 2030. As these goals represent a vision of the future of the planet, and their focus on development being a mechanism for attainment, they represent important foci for future engineers. Upon reviewing these goals, it might be easy to think they are not that relevant to engineering. For example, goal 10 is focused on reducing inequality within and between countries. Goal 5 refers to gender equality, and Goal 16 refers to peace and justice. As pointed out in Leach, et al [5], Goals 5 and 10 explicitly mention equity and equality. In addition to these two goals, equity and equality are mentioned in "... around 18 of the 169 SDG targets ..." spanning every goal except goals 11-14. All of these topics are interrelated to the sustainability of the planet and all are connected to the future of engineering, and consequently to engineering education.

As engineering educators, there is much to be gained by using the UNSDGs as a context for framing the work of engineering. By doing this, we extend the worldview of engineering from local to global, and to push our boundaries from a reductionist view of engineering being an instrumentalist profession that just does what is asked of us. Engineers must become a more integral component of the larger system of society striving for a sustainable present and future. This does not imply that engineers must be experts in topics such as social justice, but they must be able to collaborate with JEDI experts because engineers without JEDI training may reduce social justice into trivial or formulaic design changes that do not center human dignity and fail to meet the needs or opportunities of a specific context. Further, it is important that engineers are involved in the ideation stage of developing solutions for people [6], because engineers have an understanding of what is (or could be) technically possible, whereas people without engineering training might have to fall back on well-known existing technologies or may suggest ideas that are not viable. Fundamentally, the UNSDGs provide the "why" for future engineering activities. They provide little guidance about how to do things differently, that is more related to rating systems discussed subsequently. But they do provide greater motivation for sustainability efforts.

2.2 Teaching Sustainability

Moving from the specific UNSDGs to sustainability in a broader sense, and ultimately to education and practice, requires further refining the meaning of sustainability. Sustainability is often conceptualized as consisting of three pillars: environmental, economic, and social, and in bringing sustainability into engineering curricula, it is common to consider the pillars independently and to different degrees, or to emphasize only one pillar, rather than exploring the interactions between the pillars [1]. Considering pillars in isolation does not prepare students to engage with strong sustainability, and in fact may obscure connections between justice and sustainability. There is unfortunate history [7] where engineering projects have considered issues of justice as being something that can be 'traded-off' in the interest of efficiency, for example. While trade-offs cannot be eliminated in engineering work, we portray JEDI issues as being critical components that are important components of strong sustainability. Therefore, as trade-offs are considered, justice issues must remain visible and explicit in the decision-making process. The rating systems described herein accomplish this by the inclusion of justice-related issues in the scoring systems. Therefore, points are lost when justice issues are ignored or minimized.

In some ways, the economic aspects of design have always been part of the civil engineering curriculum as engineering students are taught to create designs using the least amount of material, or to use repeated sizes/processes because repetition often leads to cost efficiency [8]. However, sustainability requires a more sophisticated and nuanced approach to economic concerns. As a starting point, we can advance sustainability with respect to the economic consequences of design by considering the whole life of the project (i.e. operation and maintenance phases) rather than just initial construction costs using techniques such as Life Cycle Cost Analysis (LCCA). LCCA fits well into existing curricula on engineering economics, making using of concepts such as the time value of money. When the economic pillar of sustainability is considered alone, we can use more advanced techniques to consider economics (such as LCCA) while remaining within a monetary/low-cost paradigm familiar to engineering. However, when interactions between the economic and social pillars are considered, larger questions about economic inequality and access to technology or engineering enhancements are raised.

The environmental pillar of sustainability is a newer addition to engineering curricula, yet is found to be the most common aspect of sustainability discussed in journal publications since 2003 about engineering education and sustainability [9, 10]. Procedures for environmental analysis such as Lifecycle Assessment (LCA), which rely on quantifying inputs and outputs and expressing impact in numerical terms align with the technocratic paradigm common to engineering education [11]. Similar to the economic pillar, when the environmental demands of sustainability are considered in connection with the social pillar, we encounter questions about environmental justice that require a shift from traditional engineering thinking.

The third pillar of sustainability, the implications of design for society, perhaps aligns most directly with JEDI concepts, and has typically received less attention in engineering curricula. One of the factors limiting the incorporation of social lessons is the difficulty in establishing conceptual understanding of social sustainability [10] and translating those concepts into things such as sustainability indicators that can be practically applied [1]. Valdes-Vasquez and Klotz [8] give an example about how the social aspects of sustainability can be conceptualized in the context of construction engineering through four primary dimensions: 1) community involvement, 2) corporate responsibility, 3) project safety, and 4) impact on end users; and they provide guidance for an in-class activity to teach students about these four dimensions, but recommend that faculty in other fields would need to develop their own conceptualizations. Other barriers to incorporating social sustainability include faculty attitudes about engineering. Social topics may be outside faculty comfort zones [12] and dealing with subjective and normative topics requires different instructor skill sets from teaching computational problem solving [10], suggesting the need for institutions to provide faculty development opportunities [13]. Despite these difficulties, other authors assert that students must be taught more about the social and economic aspects of sustainability (especially economic markets and policies that affect adoption of sustainable technology) because technical solutions alone (i.e. technology to reduce environmental emissions) are not enough to ensure sustainability [12]. The adoption of new technology or innovative designs is a social process and innovation is not just about creating something new, it is about changing the existing paradigms and systems [11].

Clearly, preparing students to contribute to sustainable development and leverage that knowledge for justice requires not only an understanding of the basic concepts associated with each pillar of sustainability, but also preparation to consider connections between pillars in a holistic way. The complexity of teaching about these connections and sustainability is evidenced by the sustainability competencies identified by [14], including systemic thinking, problem solving including integrative solutions, interdisciplinary collaboration and critical thinking. Stated another way, students need their sustainability learning to go beyond basic awareness and knowledge to applicability ([1], drawing on Heart, Head, Hands learning model [15]). Although existing sustainability rating systems may not include all of the potential interactions between sustainability pillars, these systems can help overcome conceptual difficulties to provide applicability for students in relevant fields. Furthermore, the structured format and broad scope of sustainability rating systems can serve to scaffold the learning of civil engineering faculty as they learn more about sustainability itself, particularly social sustainability and relationships to justice, and how to teach concepts of sustainability and justice to students.

2.3 Sustainability Rating Systems

New sustainable construction-related rating systems provide guidance on *how* sustainability can be incorporated into civil engineering design. These systems move engineering towards the 'how' of creating a more sustainable planet. While rating systems are currently optional, it is reasonable to assume they will be elevated to the status of codes in the future. Currently, it is common to use design codes in the teaching and practice of engineering design. These codes act as constraints to design and provide pathways to safe and acceptable design. Rating systems, on the other hand, play a different role. An important goal of these rating systems is to encourage more sustainable design by providing metrics for gauging sustainable design [16-18]. Taken together, codes and rating systems provide a larger context for engineering design. Herein, we will show how rating systems provide new pathways towards both safe, economical, and more sustainable design and at the same time promote social justice and equity. For our purpose we limit the discussion to three systems. There are many more systems available, and new ones continue to be developed. Our goal is not to provide an exhaustive review of rating systems, instead we focus on ones we have been considering or using in our teaching, providing a background for our subsequent examples of using sustainability to introduce students to social justice in our courses.

2.3.1 Living Building Challenge

As a starting point, let's look at the Living Building Challenge [18]. This is a recent rating system that encourages the creation of more self-contained built environments. The International Living Future Institute created this system as part of their mission to "lead the transformation toward a civilization that is socially just, culturally rich, and ecologically restorative." [19] The system draws heavily from the concept of self-sustaining ecosystems. For example, there are metrics that encourage buildings to be entirely self-sufficient for water use, including wastewater treatment and energy use, with 100% of generation from on-site renewable approaches. These concepts have important consequences for how we design the built environment, which make them a natural addition to engineering education. For our purposes, this rating system in particular states: "All project teams must assess cultural and social equity factors and needs in the community and consider those identified needs to inform design and process decisions" (p. 5). One of the eight major categories in this system is Equity. Within this category there are two subcategories: Universal Access and Inclusion. This represents a significant step forward on the path towards contextualizing JEDI concepts formally into a sustainable future. This rating system is well aligned with the discussion above concerning the UNSDGs that also focus on equity. It also forms a bridge between traditional engineering, and the way it is taught, with the future of engineering, and the way it should be taught. Example metrics used for the equity-related categories include:

- Universal Access: All non-building infrastructure must be: "… equally accessible to all members of the public regardless of background, age and socioeconomic class—including the homeless—with reasonable steps taken to ensure that all people can benefit from the project's creation."
- Inclusion: "… all projects must either: Include diverse stakeholders from vulnerable or disadvantaged populations in the design, construction and operations and maintenance phases …" or: "donate 0.1% of total project cost to a regional, community-based nonprofit organization focused on equity and inclusion.".

These metrics touch on both the design of the access to physical facilities, such as non-building infrastructure, and on equity through inclusion related to designers and contractors.

2.3.2 Envision

In 2010, the Institute for Sustainable Infrastructure was established as a non-profit educational organization to develop and manage the Envision sustainable infrastructure framework, by founding organizations the American Public Works Association, the American Society of Civil Engineers, and the American Council of Engineering Companies in collaboration with the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design [20]. The Envision framework recognizes that individual buildings and community infrastructure projects are distinct from each other in the number of agencies involved during planning, design, and construction as well as the wide-ranging impact of infrastructure on the broader community. Envision was specifically designed for infrastructure to enhance the sustainability of communities. Envision is applicable to a wide variety on infrastructure projects in sectors including energy, water, waste, transportation, landscape and information [17].

Envision assesses sustainability through a framework of 64 sustainability and resilience indicators, referred to as credits. These credits are grouped into five different categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience. Within each credit the Envision framework specifies different levels of project performance (improved, enhanced, superior, conserving, and restorative) and evidence required from the design and construction team to verify performance. The Envision framework can be used by a project to facilitate thinking and communication about sustainability, whether or not the project team decides to apply for project certification. Certification levels depend on the percent of points collected relative to the number of points available to the project.

Numerous credits within Envision address social sustainability and social justice. The Quality of Life category comprises 14 credits that consider the social impact of the project during and after construction. Credit categories include: Improve Community Quality of Life, Improve Community Mobility, Advance Equity and Social Justice, Improve Construction Safety and Minimize Construction Impacts. The Leadership category includes additional credits such as: Provide for Stakeholder Involvement and Improve Local Skills and Capabilities.

2.3.3 LEED

LEED [21] is a well-established rating system with a traditional focus on buildings, similar to the EU's Level(s) [16] system. Because of LEED's focus on buildings, its use is similar to the Living Building Challenge system and is narrower in its application than Envision. However, LEED offers a collection of different rating systems to cover different types of buildings (e.g. schools, healthcare, retail, single and multifamily homes), and different phases of a building's lifecycle (e.g. Building Design and Construction, Interior Design and Construction, and Buildings Operation and Maintenance). The newer Cities and Communities rating system extends beyond individual buildings to consider the sustainability performance of a broader urban area and can be applied to existing cities and communities or to large new developments.

With the variety of LEED systems, there is variation across the systems with respect to how JEDI topics are incorporated. For example, LEED BD+C for the design and construction of new buildings appears to have little relevance to JEDI principles, but does embed JEDI concerns in other criteria, for example, under the Location and Transportation Category, one of the credits is High Priority Site and Equitable Development which encourages development in disadvantaged locations or development of affordable housing. In contrast, the Cities and Communities rating system includes a Quality of Life Category with credits including: Distributional Equity, Environmental Justice, Housing and Transportation Affordability, and Civil and Human and Rights.

2.4 Theoretical Framework

We use Inclusive Pedagogy [22] as the theoretical framework for our paper and as a way to meaningfully integrate the JEDI concepts embodied in the sustainability rating systems into courses. When updating coursework to reflect JEDI concepts and sustainability, those concepts will be much less meaningful and potentially hypocritical if instructors do not consider JEDI approaches: in other words *how* we teach (inclusive pedagogies) is just as important as *what* we teach (inclusive content). Furthermore, inclusive teaching practices can help model effective and inclusive engagement of people impacted by our design, which is an important component of sustainable design. The following characteristics are prevalent among educators who enact inclusive pedagogical practices: increasing appreciation for how social identities, positionalities, and experiences impact student learning [22]; and growing awareness that students are not empty vessels who absorb information [23]. Rather, each student is a unique composite and expression of intellect, biology, and spirit who collaborate with the professor and peers to co-create the learning environment [24].

We use five empirically-supported principles from the University of Michigan Center for Research on Learning and Teaching (CRLT) [28] to bring JEDI from theory to praxis through inclusive pedagogy in the classroom. First, **academic belonging** is the practice of intentionally connecting students with course content, the academic discipline or profession affiliated with their majors, and community. Second, **critical engagement of difference** means recognizing and valuing how the classroom is not a neutral space due to heterogeneity of social identities and contexts in which classrooms are situated. Third, **transparency** reminds faculty to clearly communicate expectations, outcomes, and rationales for why students are asked to engage in learning activities and what learning goals we hope to achieve. Fourth, **structured interactions** ask faculty to purposefully choreograph connections between students in ways that amplify equity and voices that have historically been silenced or muted. Fifth, **flexibility** means that faculty "hold lightly onto our designs" [25, p. 26] so we can improvise and pivot in response to emergent needs. Throughout the course implementation examples, we highlight how we enacted these principles from inclusive pedagogy to holistically integrate sustainability into the courses.

3 Course Implementation Examples

In this section we describe two course implementations connecting sustainability and JEDI-related instruction. Both courses are required in our civil engineering curriculum and represent students in the same program but at different levels. This allows us to illustrate how these topics can be integrated across the curriculum. These two courses also represent two very different pedagogical approaches: the first-year course is an exploratory course to help students understand the civil engineering profession and is described first. There is less required technical content, instead students are exposed to the careers of civil engineers. The technical course, subsequently discussed, is a traditional materials course with significant required technical content.

3.1 Social Justice and Sustainability in the First Year Engineering Course

At Colorado State University, students gain exposure to sustainability concepts early by enrolling in the requisite Introduction to Civil Engineering course during their first semester in college. This 3-credit course is offered over a 15-week semester and meets twice a week for a one-hour lecture. An associated lab meets for 1 hour and 40 minutes on a weekly basis and focuses on developing student competencies in engineering tools, such as spreadsheets and computer-aided drafting. The lecture component focuses on using contemporary design examples to illustrate the various aspects of the civil engineering profession. Similar to the upper division course described in the next section, the lectures are taught by a senior faculty member while the labs are taught by graduate students. When the COVID-19 pandemic invaded the world in 2020, like all educators across the globe, the first author taught this course within the context of teaching and learning during the pandemic. To maintain the safety of all participants during the fall 2020 semester, guidelines required that 100% of students, instructors, and guest speakers wear masks during classroom lectures that were delivered in-person for the first 13 weeks of the semester. Students met in a large room spacious enough to accommodate appropriate physical distance between all 46 registered students who chose to attend in-classroom lectures. Two students chose to attend the entire semester using remote technologies. As required by the university, the professor delivered lectures virtually during the final two weeks of the semester using modern video-conferencing software.

The learning outcomes of this course are as follows:

1. identify the major job functions of civil and environmental engineering careers
2. formulate models for engineering design related problems
3. analyze simple engineering models using modern computer tools
4. design simple solutions to engineering-related problems both in teams and as individuals

During this course, sustainability concepts are introduced and discussed throughout the semester as sustainability has become a major component of the civil engineering profession. During the fall 2020 semester a total of nine class sessions addressed sustainability in some manner. Five of these sessions dealt with either the UNSDGs [4] or sustainability rating systems, including: Envision [26], LEED [21], and Living Building Challenge [18]. One lecture focused on the book Just Technology [27], while the other three dealt with water issues around the world. The three rating systems provide a framework to examine projects presented in class in terms of their addressing both traditional sustainability, such as the three pillars discussed earlier, and the justice issues which now play a prominent role in the ratings. Students are provided access to the rating system guidelines so as to be able to connect the systems to the projects under discussion.

To study the use of inclusive pedagogy during this course, the course instructor wrote cognitive ethnographies after each lecture session to reflect on how JEDI and learning theories emerged in his teaching [28]. He then discussed his cognitive ethnographies with the fourth author every week. During these weekly conversations, they engaged in dialogue about classroom experiences and developed experimental designs for enacting inclusive pedagogy more explicitly. The contours of this process purposefully folded in reflective practices through multiple timepoints and layers, iteratively spanning from individual reflection through cognitive ethnographies to joint meaning-making through the weekly dialogues to meta-reflection through co-authored manuscripts. The discussion below is largely extracted from these cognitive ethnographies and weekly dialogues.

The UNSDGs provide an important context for the future efforts of engineers. As mentioned above, these goals have an explicit and substantive connection to justice issues. The UNSDGs lecture included a review of the progress being tracked on them [29]. The following observations concerning this session were documented in a cognitive ethnography dated 10 September 2020:

> *"While reviewing the world data there was [sic] a couple of points that caused me to pause and be intentional about my presentation. Since we were reviewing topics such as mortality related to access to clean drinking water and sewage treatment, the reality is some of the lowest ranking countries are in Africa and also include India."*
>
> *"A good opportunity did present itself as one of the metrics, energy efficiency, showed a significant difference between lower and higher economic status populations. This allowed me to point out these discrepancies without any connection to any region or racial/ethnic groups."*

These observations demonstrate the explicit connection between the UNSDGs and JEDI concepts. The UNSDGs provide an excellent opportunity to promote the future of engineering and the fact that a more sustainable world needs to be a more just world. Existing data highlight the lack of equity on a world scale related to sustainable concepts such as clean drinking water and renewable energy. As this course depends heavily on a discussion-based, interactive pedagogy, the value of these examples comes in the quality of the in-class discussions.

Introducing the sustainable rating systems, specifically LEED, Envision, and The Living Building challenge, provides another layer to the conceptualization of the connection between future engineering and JEDI concepts. Each of these three systems incorporate JEDI aspects in their rating and are also easily connected to students' current state of knowledge. For example, on our campus all new buildings are required to meet a minimal rating level through the LEED system. This provides students the opportunity to connect the buildings around them to sustainability concepts and JEDI aspects.

We draw on the Envision system, which provided a rich set of examples regarding JEDI in engineering, to illustrate a long history of highway infrastructure imparting injustices on communities throughout the United States [30] and in the United Kingdom [31] as highlighted by the following cognitive ethnography dated 10 November 2020:

> *"This then led to discussing the types of criteria in the Envision system, where I focused on two criteria: 1) improve community mobility and 2) ensure equity and social justice are considerations in the design."*

Table 1 provides a list of inclusive teaching principles that frame this effort in the course. Principle 2 deals with making connections for students. The lecture related to the above quote was aimed at connecting social justice issues that are now important in infrastructure design with the students' future careers as engineers. During another session, as students were working on short team design projects that they identified and choose, principles 1 and 2, the concept of transportation on our campus arose. Recently, the local bus authority implemented a bus route that is limited to rides on the campus itself and does not venture into the surrounding community. This led to the following excerpt from the cognitive ethnography dated 27 October 2020 about the class interaction after one team indicated they wanted to improve campus transportation:

> *"This provided an opportunity to discussion [sic] inclusion in design as the student idea related to transportation on campus. I shared that my first reaction to having a bus on campus that went from one end to the other seemed crazy as the campus is not very big. Then I shared that this was the wrong way to look at things. Basically I was projecting my mobility onto others -feelings everyone should enjoy walking across campus as much as I do and as I can. This led to me discussing people differently abled and how in our design we are not designing for ourselves but for the broader community."*

Returning to the historical injustices related to infrastructure, two examples were discussed: the Big Dig project in Boston, Massachusetts and a current project in Denver, Colorado, approximately an hour drive from our campus. The Boston project highlights how highways were unjustly located in communities of mostly marginalized people [30]. The Big Dig project was implemented to correct these historic injustices. The Denver project has similar issues and provided lively discussion in the class as once again it is proximal to the students lived experiences. Additionally, this project provided for a rich assignment exploring injustice in the third-year course discussed in the following section.

A main benefit drawn from these topics is exposing students to the concept of sustainability and JEDI and the relationship between the two. While the course does not include many formal homework assignments, these topics amplify the in-class discussions and provide a foundation for students as they prepare for their future careers.

As a result of these reflections, this course has grown to integrate sustainability and JEDI concepts as foundational to the future of the engineering profession. Students are learning that the engineering profession is broadening, as exemplified by the three pillars of sustainability, environment, economic, and especially social concerns.

In contrast to this course, the next section looks at a more traditional, third-year course in the civil engineering curriculum.

3.2 Social Justice and Sustainability in a Technical Course

Evaluation of Civil Engineering Materials is a required course in Colorado State University's civil engineering degree program. The course is usually taken by students in the fall of their third year in the program. Civil engineering materials is a 3-credit course that meets for two 50-minute lectures each week plus a laboratory section of up to 3 hours. In most weeks, labs include testing of materials and analysis of resulting data (e.g., tension and shear tests of metals, compressive tests of concrete, flexural tests of wood). Course enrollment is typically in the range of 80-100 students in the lecture with students divided into lab sections of about 20 students. The lecture portion is taught by the faculty member, while the lab sections are taught by graduate teaching assistants. The course structure incorporates inclusive teaching principles through intentional efforts to develop accessible examples and metaphors for students (e.g., relating concrete mixes to baking); communicating an expectation of inclusion; openness to accommodations and concern for student well-being through syllabus statements and in-person interactions; providing rubrics and clear guidance on grading practices; and allowing students to choose project topics for the semester writing project.

The course learning objectives for students are:

1. Describe the basic properties of a variety of civil engineering materials including metals, concrete, aggregates, asphalt, wood and FRP composites.
2. Explain the importance of standards in the context of civil engineering materials and know how to locate and use relevant standards.
3. Follow standards to conduct tests of material properties and perform the calculations necessary to interpret test results.
4. Express the results of tests in the form of a letter report.
5. Define sustainability and explain the role of material selection in sustainable design.
6. Locate, interpret and evaluate information about materials that can be used for design and decision making.
7. Identify and explain significant considerations in choosing a material for a specific application and discuss design trade-offs.
8. Communicate effectively in writing.

Sustainability was first added to the course content with a single lecture when the current instructor took the course over about 10 years ago. This portion of the course has slowly expanded each year since. In the first few years a definition of sustainability including the three pillars was offered, but the emphasis was on the materials specific credits in LEED and how different types of materials (and their industries) sought to meet LEED credits. As Envision matured, emphasis switched to the Envision rating system as the focus on infrastructure made the topic more accessible to students not interested in structural engineering. In the first offering of the course by the current instructor, fall 2011, LCA and LCCA were defined and the differences between the two were explained. Over time the course instructor began to take the time for more intentional instruction on the environmental pillar of sustainability with examples of LCA for materials and discussion of Environmental Product Declarations. Most recently the course has evolved to address the other two pillars of sustainability: a lab assignment using a concrete deterioration modeling software, LIFE 365 [32] is used to teach students about Lifecycle Cost Analysis to offer further depth on the economic pillar and an assignment leveraging the Quality of Life credit category in Envision has been developed to address the social pillar. Both of these pillars of sustainability help incorporate JEDI through the inclusive teaching principle of Critical Engagement of Difference.

In an approach contrasting the one described above, the other two authors focused on one assignment for the civil engineering materials course. This assignment was included in the portion of the semester devoted to sustainability. The Envision assignment draws on a regional infrastructure project. The Central I-70 project in Denver, Colorado broke ground in 2018 after a lengthy planning period. The project provides for the reconstruction of a 10-mile stretch of I-70 including removing an aging viaduct and moving a portion of the highway below ground level. A portion of the project travels through the Elyria Swansea and Globeville neighborhoods in Denver. A 2014 report from the Denver Department of Environmental Health provides the following description of the neighborhoods:

> *"Globeville and Elyria Swansea are two of Denver's oldest neighborhoods, settled in the 1880s by Central and Eastern European ethnic communities who came for jobs in the railroad yards and heavy industries such as metals smelting. Over time, the neighborhoods continued to attract large industrial operations, which provided jobs but also produced decades of negative environmental impacts on air quality, water, and soil. The construction of Interstates 70 and 25 in the 1960s restricted physical access to the neighborhoods and produced more vehicular air pollution. At the time, little consideration was given to the health problems associated with such development. Today, the community of 10,000 residents regularly experiences noise, odors, and periodic poor air quality from industrial operations, heavy truck traffic, freight trains and highways. The residents, the majority of whom are Hispanic families with young children, suffer from some of the highest rates of cardiovascular disease, diabetes, obesity, and asthma in the City."*

As part of the project the Colorado Department of Transportation made a number of Community Commitments to the Elyria Swansea and Globeville neighborhoods to help address community concerns about the project. Example commitments include construction of a 4-acre park over a portion of the highway that will be constructed below grade, a 20% local hiring requirement including on-the-job training, improvements to Swansea Elementary, and home improvements to mitigate construction noise and particulate pollution.

For the assignment, students were introduced to the topic with a short reading about the socially situated nature of STEM written by the third author. Students were then asked to read project description materials on the CDOT website, as well as media articles about neighborhood views on the project. Finally, students were provided with pages describing Envision credit 3.1 Advance Equity and Social Justice, and asked to respond to the following questions.

1. Briefly explain a) the major problems the Central I-70 project is trying to alleviate, and b) the major problems the new project may create. Drawing from your readings, what can be done to look for a solution that avoids the problems you wrote about in part b?
2. Based on the articles, describe how the Central I-70 project addresses and doesn't address the Envision credits you read about.
3. What could have been done differently in the Central I-70 project to better meet the Envision credits you read about?
4. Name one other Envision credit that might apply to this case and explain why.
5. During the next class period you will be discussing these articles with students who may have read the same article(s) as you and other students who have read different article(s) about the Central I-70 project. What 3-5 topics do you think will be important to discuss in these groups?
6. How do your personal experiences affect how you read and interpret these articles?
7. What do you think might have been done differently in this project if it was located in an affluent predominantly white neighborhood?

In the first year of implementing this assignment, we used a structured jigsaw approach and had different groups of students read different articles. In class, students met first with others who had read the same article, and then with others who had read different articles for small group discussions. In the second year, we reduced the number of articles and had all students read the same articles. This year students were allowed to form their own groups. At the end of both classes we had a full class debrief.

We used the following set of questions (which were somewhat standard for the for the P4E project as a whole) to provide for some post assignment reflection. Since these questions were standardized for the larger research project, they are not as specifically probing as they could be.

1. What did you learn from this assignment?
2. Think about interacting with other engineering students, especially those who thought differently or had a different approach to the problem from you. How can you apply what you learned to your future interactions?
3. Did what you learned in this assignment change your views on how engineers' function or their roles? If so, how?
4. What did you like about this assignment?
5. What would you change about this assignment to make it more engaging for you?

In combination with the readings, the reading questions and post-assignment reflection questions engage students in all five of the Inclusive Teaching Principles (Table 1). When building this activity we specifically focused on integrating critical engagement of difference into the activity, particularly through selecting a current and local example to consider the relevance of course concepts to local communities and explicitly naming that individuals' experiences are informed by identity (e.g. race and class). We sought to do both of these through engaging students with local, current media (i.e. newspaper articles and the I-70 project information website) and pairing these with questions to help guide students in a critical analysis of the materials. In the first year of the assignment we designed the activity as more of a conventional jigsaw activity, in which each group of students were given different readings that portrayed different perspectives of the project; some students had readings that conveyed the success of the social engagement of the activity, while others had readings that pointed out the failures of engagement with the local communities and were critical of the social engagement. However, since most students in the class were already coming from a perspective where the social engagement of the I-70 project was effective, we changed the readings in the second year to focus on the materials critical of the project, to help draw critical engagement of difference more deeply into the activity.

While developing the activity we also drew from the four other Inclusive Teaching Principles to inform activity design (Table 1). For example, we gave students a chance to engage with materials and prompts in their pre-class work, so that they were able to read and work at their own pace, rather than facing the time pressure of trying to do this at the beginning of class. We also provided students with clear directions about how they would be using their pre-class work in class, and that they would be engaging with students who had read materials that provided different perspectives. We also framed the entire activity (pre-, in-, and post-class work) from a growth mindset perspective, and built norms around valuing each other's perspectives and that any graded parts of the assignment would be graded on effort put in, rather than on right or wrong answers.

Table 1: Inclusive teaching principles, definitions, and examples drawn from and informed by the University of Michigan Center for Research on Learning and Teaching [33] .

Principle	Examples
1) Critical Engagement of Difference: Acknowledging students' different identities, experiences, strengths, and needs; leveraging student diversity as an asset for learning	• Help students consider relevance of course concepts to local communities • Expose students to a range of social and cultural domains • Explicitly name that individuals' experiences are informed by identity (e.g. race and class) • Value a range of experiences and backgrounds
2) Academic Belonging: Cultivating students' sense of connection to and ability to feel included in your course, a broader community of scholars, or the discipline	• Review LEED status for buildings on campus to connect students' environment to the rating system requirements • Discussion of local bus routes and mobility on campus • Build rapport in the class through small group activities and collaborative thinking • Create intentional opportunities for students to provide feedback on their experiences of the learning environment and share ideas for improving it • Focus on a growth mindset, where grading emphasized effort rather than a right/wrong answer
3) Transparency: Clearly communicating about norms, expectations, evaluation criteria	• Explicitly communicate purpose, task, and assessment criteria for graded assignments • Invite student feedback on how assignments address inclusivity goals of the course
4) Structured Interactions: Using protocols or processes that support equitable access and contributions to interactive elements of the learning environment	• Give all students time to gather their thoughts in writing before sharing ideas with the whole group • Task students to work in pairs or small groups on brief, well-defined activities with a timeline and specific goals/outcomes • Give students regular opportunities to reflect on ways their learning has been enhanced by interaction with classmates
5) Flexibility: Responding and adapting to students' changing and diverse circumstances;	• Assess student understanding of key course concepts so you can provide relevant instruction or access to supplementary materials to fill common gaps

engaging empathetically with student needs; balancing intentional design and commitment to providing accommodations for equitable learning	

4 Discussion

In this paper, we describe how two different civil engineering courses used the context of sustainability and specifically sustainability rating systems to teach undergraduate students about the intersection of JEDI and technical engineering content. Although each professor approached the course learning outcomes, format, and assignments in different ways, the common denominator is the commitment to sustainability and JEDI in terms of content (what we taught in the class) and delivery (how we taught in ways to cultivate belonging and inclusion).

Integrating JEDI materials into engineering curricula may seem like a daunting task at first, in part due to the entrenched norms of 'depoliticizing' of engineering education [34]. But, by working to create a more integrative education experience through focusing on creating curricula that support those most commonly excluded from decision-making, we create a curriculum that better supports all students and that helps these students become better engineers. To help with this leap beyond the norm of a 'depolitical' engineering education we offer three practical tips to begin exploring how an emphasis on sustainability and JEDI can strengthen the engineering content in your class.

First, find collaborators with whom you can exchange ideas and begin building a repertoire of resources. Working with colleagues who are also integrating JEDI materials into their courses, either at your own institution or elsewhere, is helpful for generating ideas and solutions. Collaboration with colleagues can also help spread sustainability and JEDI content throughout the department curriculum, advancing the knowledge of students without placing the responsibility for all sustainability or JEDI content on just one or two classes. Your institution may also have a center for teaching and learning with colleagues who can help provide resources in course development, including integrating JEDI materials into your course.

Second, explore the "North Star" that guides your course and considers how to make JEDI explicit in your student learning outcomes and activities where relevant [27]. In the process of writing this paper, the first two authors realized that their own course learning objectives did not explicitly list JEDI content, even though both felt strongly about including this material in their course. This paper has explored how sustainability and social justice cannot be separated. As authors we ask ourselves, how can we list sustainability as a learning outcome without including JEDI content as a learning outcome of equal importance? By separating sustainability from JEDI, we create a false dichotomy. This also raises an important point regarding faculty being hesitant to be transparent (see principle 3 in Table 1) in sharing these goals with the students. It is now apparent to the course instructors that in the future that this transparency is critical and must be included in future course syllabi for these and other courses.

Third, make time to critically engage with new content, especially in relation to JEDI. In other words, be patient with how much time it takes to develop new materials and to learn new content such as JEDI. Remember that when developing new curricular materials, it takes time to fabricate and refine an activity. As we describe for the I-70 project, and as is often true for most course materials, it is common to refine and revise materials after teaching them for the first or second time. In fact, after creating one assignment to address both JEDI and Envision, the lead professor realized this was too much to cram into one assignment. In the future, JEDI and Envision will be addressed through a series of assignments. Also, if engaging with JEDI is new for you, it might be hard to anticipate how students will respond. Students in the classes showed a range of reactions: some students were happy to see this type of content in the class, others had personal experience with the project through a recent internship, or from living near the project and driving on I-70. Other students did not express hostility to the topic but may have questioned why justice was in a class about civil engineering materials. Be prepared to explain your views on a topic and how you came to those perspectives in a way that encourages students to reflect carefully and form their own opinions.

5 Conclusion

Engineering and engineering education is always about creating the future. As such, it has undergone many transformations in the past and will continue to be transformed in the future. Currently, an important transition is occurring in parallel with the transformation of society: a movement towards a more sustainable future. It is also clear that this transformation to a more sustainable society is inextricably connected to creating a more just society: one cannot exist without the other. The challenge for engineering educators is to find ways to educate future engineers to be prepared to engage in this societal transformation. In this manuscript, several examples that bring the sustainability and justice content together in the engineering curriculum have been illustrated. New sustainability rating systems provide a natural vehicle for incorporating these two important concepts. While the authors acknowledge that difficulties exist for engineering faculty to engage in this movement, this manuscript aims to show the possibilities. There are at least two main impediments to great adoption by faculty:

first, a perceived lack of knowledge about the concepts; and second, a concern that technical content will be diluted by including these JEDI concepts. To the first point, as with every new topic for a faculty member the best path is to gain the knowledge. This team of authors set out to do exactly that. We are an interdisciplinary team that have learned much together and from each other. To the second point, we believe that the examples presented above show that technical content and JEDI concepts are not as separate as one may believe and presenting them together enhances both.

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