Opportunities and Challenges in Teaching Equitable Design in Engineering Education: A Scoping Literature Review

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Abstract

This paper presents the results from a scoping literature review (ScLR) conducted to elucidate the current landscape, trends, methods, and potential gaps in the literature surrounding equitable design pedagogy in engineering education. The ScLR follows the methodology presented by Arksey and O'Malley (2005), which breaks the process into five stages: (1) identifying the research questions, (2) identifying the relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting the results. These stages were performed iteratively, which allowed for reflection and study team collaboration along each stage. The study was grounded in four central inclusion criteria: (1) equitable design, (2) engineering education, (3) engineering course, and (4) secondary education. These criteria were used to search the existing literature in online databases. The database search was conducted in August 2023 and resulted in 476 publications. After removing duplicates, 460 publications remained for analysis and 15 publications remained after completing the three screening cycles. Our ScLR revealed the current landscape of engineering and design education in regards to teaching equitable design across three main themes: Level of Intervention, Approach, and Challenges with Intervention. Educators, institutions, and legislators must overcome these challenges to ensure that students are not only technically proficient but also possess the skills, knowledge, and values necessary to meet the constantly changing needs of the 21st century. By addressing these issues, we help foster an educational environment that produces engineers and designers who are socially conscious, creative, and advance positive change in the world.

Keywords: engineering design process, human-centered design, scoping literature review, social justice, equitable design

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Introduction

> *"Design is essential to inclusive growth. It closes the gaps in the interactions between people and the world around them. We need solutions for human environments that adapt to fit individual needs, diverse bodies, and diverse minds" (Holmes, 2018, p. 140).*

Learning how to design solutions to real-world problems is one of the cornerstones of an engineering student's formation. From the industrial to the everyday settings, engineers play an influential role in how the tools, objects, and systems we interact with daily are designed. Yet, during their engineering education, quite often students experience a disconnection between the socio-technical aspects of engineering design and the more technical courses in their curriculum, which can lead students to favor a view of engineering as a neutral discipline and put less importance on the human-centered aspects of design (Loweth et al., 2021; Miska et al., 2022). In turn, when applying their knowledge to create a solution, current practices in the engineering design process can unintentionally lead young designers to exclude users from traditionally marginalized populations (e.g., those who are disabled or who live in different socio-economic contexts from their own), thus ingraining and perpetuating societal barriers within their solutions (Burleson et al., 2023; Rodriguez et al., 2023).

Equitable design practices seek to break this cycle, increasing accessibility and usability by guiding designers towards the inclusion of voices and experiences that have traditionally been excluded from the engineering design process, leading to solutions that are more adaptable, usable, and human (Costanza-Chock, 2020; Figard & Carberry, 2023; Holmes, 2018; Wong Lau et al., 2016). But while most approaches in engineering education have consisted of one-time interventions or additions to existing curricula, it has been suggested that the shift towards the teaching of equitable design would require a systemic change that includes faculty and student perspectives, institutional leadership, as well as external stakeholder influence from accreditation boards and industry partners (Figard & Mercado Rivera, 2023). However, such systematic change requires that the current state of equitable design pedagogy in engineering education be established and contextualized so that potential gaps and areas for growth can be highlighted. Currently, it is unclear how to guarantee curricular alignment across the board because there is little consensus on how socio-technical design goals can be applied in engineering design instruction, or on the instructional strategies used (Martin et al., 2021). The purpose of this study is to identify current trends in the pedagogical approaches used by engineering faculty to teach equitable design concepts. This paper is guided by the following question:

What are the current trends and findings in academic literature regarding the applications of equitable design in engineering courses?

Methods

Methodological Overview

This paper uses a Scoping Literature Review (ScLR) to explore the current literature related to the teaching of equitable design concepts at the high school and post-secondary levels. The goals of this study are to shed light on the pedagogical practices used to introduce equitable

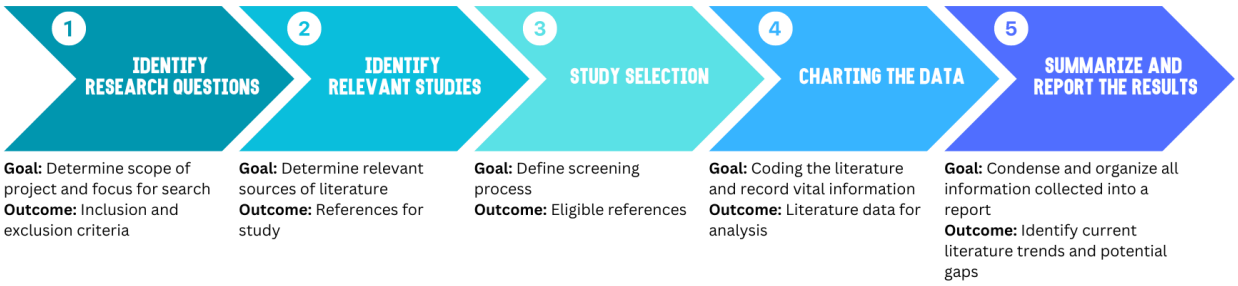
design concepts in engineering courses, understand the challenges faced by faculty and practitioners during their implementation, and understand the implications of adding these concepts to existing engineering curricula.

Scoping Literature Review (ScLR) Protocol

Scoping Literature Reviews (ScLRs) are conducted to understand the research landscape of a particular content area. This literature review method is defined by a broader research question and differs from systematic literature reviews in that its goal is to summarize and synthesize literature with greater specificity without the formalized structure required by a systematic review (Arksey & O'Malley, 2005; Borrego et al., 2014; Grant & Booth, 2009; Samnani et al., 2017). ScLRs are particularly useful for quickly mapping out key concepts, existing literature, and evidence to identify gaps in current research defined by a specific research question (Arksey & O'Malley, 2005; Samnani et al., 2017). Our study used Arksey and O'Malley's (2005) ScLR framework (Figure 1), which recommends a five-stage protocol for conducting a scoping review: (1) identify research question(s), (2) identify relevant studies, (3) select relevant studies, (4) chart the data, and (5) summarize and report the results. Figure 1 further details the process used in our study.

Figure 1

Five-Stage Protocol for Conducting Scoping Reviews



In the following subsections we detail our team's outcomes for each of the first three phases of this protocol.

Stage 1. Identify Research Questions

The purpose of this study was to engage with current engineering education literature to shed light on the pedagogical approaches or methods that are currently being used when teaching equitable design concepts. Thus, the research question guiding this ScLR is the following:

What are the current trends and findings in academic literature regarding the applications of equitable design in engineering courses?

This study operationalized "trends" as the means for implementing equitable design pedagogy within an engineering design course.

Stage 2: Identify Relevant Studies

To further guide our ScLRs, we utilized this study's research question and goals of this study to outline four main inclusion criteria to find relevant studies:

1. The literature must discuss both pedagogy and practices related to teaching equitable design concepts
2. The literature must include the teaching of equitable design concepts in an engineering course
3. The discussions of the pedagogical and practical application must describe challenges faced in the application
4. The literature must emphasize the implications of teaching equitable design to engineering students

Additional inclusion and exclusion criteria related to publication specifics (e.g., publication type, publication date, language published in) are summarized in Tables 1 and 2. These criteria guided our search for existing literature in the following online databases: Engineering Village (Compendex, INSPEC) and ProQuest (ERIC, Education Database). The research team created a generalized search query (Figure 2) for the databases to ensure consistency in the searches across databases. Databases were searched individually, and results were exported to a spreadsheet application (Google Sheets) to prepare for study selection. The database search was conducted in August 2023 and resulted in 476 publications. After removing duplicates, 460 publications remained for study selection and analysis.

Table 1
Central Inclusion Criteria

Central Inclusion Criteria	Working Definition	Synonyms
Equitable design	Design processes that include the needs and realities of marginalized populations	Socio-technical design, socio-cultural design, inclusive design, empathy-led design, socio-technical thinking, socio-cultural thinking, human-centered design
Engineering education	Teaching carried out mainly by faculty with expertise in engineering disciplines; this may be done as part of an undergraduate or graduate engineering curriculum, or engineering preparation programs at the pre-college level	Computer science education, CS education, design education
Engineering course	A formal course or workshop where engineering design is taught to students as a method to create solutions (in the form of physical products or otherwise) to existing engineering problems	Design workshop, engineering class, design course, design class, engineering seminar, design seminar, course, class, workshop, seminar
Education level	Education from secondary (high school) to graduate level	College, university, post-secondary school/ education, postsecondary, higher education, graduate, graduate school/ education, tertiary school, pre-college, secondary level/ school/ education, high school

Table 2
Additional Criteria

Additional Criteria	Working Definition	Implementation
Publication type	Journal article or conference publication	Database search restriction
Written in English	Publication written and available in the English language	Database search restriction
Publication year	Dates ranging from January 1, 2013 to August 1, 2023	Publication date was determined by authors during screening
U.S. institutions	Institutions of secondary (high school) or higher education (college, university, etc.) located in the United States	Location was determined by authors during screening

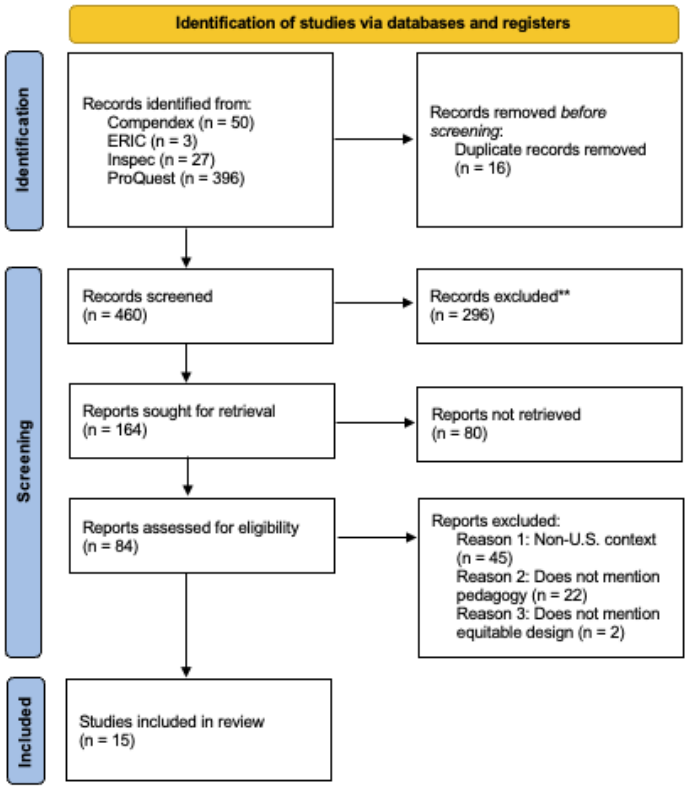
Figure 2
Search Query Criteria

"equitable design" OR "socio-technical design" OR "sociotechnical design" OR "socio technical design" OR "socio-cultural design" OR "sociocultural design" OR "socio cultural design" OR "inclusive design" OR "empathy led design" OR "empathy-led design" OR "human-centered design" OR "human centered design" OR "socio-technical thinking" OR "sociotechnical thinking" OR "socio technical thinking" OR "socio-cultural thinking" OR "sociocultural thinking" OR "socio cultural thinking"
AND
"engineering education" OR "computer science education" OR "CS education" OR (("engineering" OR "computer science" or "cs") AND education)
AND
"engineering course" OR "engineering class" OR "engineering seminar" OR "design workshop" OR "design course" or "design class" OR "design seminar" OR "course" OR "class" OR "workshop" OR "seminar"
AND
"college" OR "university" OR "post-secondary" OR "postsecondary" OR "post secondary" OR "higher education" OR "graduate" OR "graduate education" OR "graduate school" OR "tertiary education" OR "pre-college" OR "precollege" OR "pre college" OR "secondary level" OR "secondary school" OR "secondary education"OR "high school"

Stage 3: Study Selection

We employed a three-screening cycle structure to select the studies: (1) title screening, (2) abstract screening, and (3) full-text screening. The research team reviewed, revised, and reached agreement on the inclusion and exclusion criteria before each screening cycle. The reviewers' conclusions were guided by iterative and critical reflection at each level of the screening process. A screening tool was created to standardize study selection within the research team using the inclusion and exclusion criteria. Members of the study team were then randomly assigned publications to review. During the review, team members noted if the study would be included in the next screening cycle and, if not, the reasons why (defined by the inclusion criteria that were not met). 15 publications remained after completing the three screening cycles. Figure 3 further details the identification process for studies.

Figure 3
PRISMA Flow Diagram for Reporting Scoping Reviews (Page et al., 2021)



Results

This section describes the themes that emerged from the analysis of the fifteen papers included. The research team identified three main themes among the selected papers: *Level of Intervention, Intervention Challenges,* and *Approach*. This paper focuses on the themes of *Level of Intervention* and *Intervention Challenges*. Both themes are further discussed below.

Level of Intervention

The Level of Intervention refers to the level at which the intervention was implemented and reported. This literature review classified the intervention levels in the classroom, curriculum, or external. Table 3 presents the papers sorted by type of intervention. The classroom level consisted of changes, updates, or new approaches that aimed to improve a single course. Ten of the fifteen papers included focused on describing a classroom intervention. The classroom level offers information that can support other instructors in ideating and designing changes in the teaching approach of a course, strategies to assess students' socio-technical skills, or new courses. On top of that, the classroom-level intervention papers added to the discussion descriptively, having in common the development of students' interdisciplinary skills, criticality, and understanding of engineering political and social impact.

Although they are presented as case studies and semi-guides for other instructors interested in the topic, classroom-level intervention reports do not address the necessary systemic change in engineering. For example, Hoople et al. (2020) discussed the importance of reorienting

their course to a culturally relevant approach and highlighted the need for an integrated, holistic effort to change engineering education from a technocratic model to a socio-technical paradigm. They call attention to the hyperfocus engineering puts on traditional scientific discourse, which thereby excludes the alternative discourse of inclusivity through the myth of neutrality (Holly & Masta, 2021).

Two of the selected papers described interventions at the curricular level. The curriculum-level intervention consisted of papers that described and discussed the creation of new programs or changes in an existing engineering curriculum. Curriculum interventions allow learners to engage with equitable design pedagogy over time and in different approaches. The over-time experience allows students to understand that equitable design is not a single concept in a one-time course. It is embedded in engineers' professional life and is reflected in multiple aspects of engineers' social roles. Moreover, equity and social justice engineering curricula may foment a culture that welcomes differences, as Rossmann et al. (2020) reported. The authors identified that their program, designed to develop engineering socio-technical skills, had more gender and ethnic diversity in the student population than other engineering programs in the same institution.

The third intervention category was external, which encompasses papers that describe the implementation of workshops, external project grants, and external professional development to help students, faculty, or staff apply equitable design. Similarly to classroom intervention, external intervention is offered on a one-time basis. Still, they play an introductory role to faculty and practitioners who were never exposed to the idea of integrating social justice thinking in the design process.

Table 3
Level of Interventions Included in ScLR

Level of Intervention	Articles Cited
Classroom	Brinkley, 2020; Brinkley et al., 2021; Claussen et al., 2019; D'Souza, 2017; Forbes et al., 2022; Hoople et al., 2020; Leydens et al., 2018; Motti & Dura, 2023; Murdock et al., 2023; Oleson et al., 2023
Curriculum	Reynante, 2022; Rossmann et al., 2020
External	Gale, 2022; Kang et al., 2022; Letaw et al., 2022

Challenges with Intervention

Throughout the articles, authors discussed seven main challenges when integrating equitable design concepts into their workshops, courses, or programs: (1) curriculum integration, (2) faculty development, (3) assessment and evaluation, (4) student engagement and motivation, (5) prior experience, (6) long-term impact, and (7) addressing societal challenges (Table 4). During curriculum integration, faculty encountered challenges incorporating new, interdisciplinary concepts into their existing curricula, namely topics on ethics, social justice, accessibility, and sustainability (Forbes et al., 2022; Hoople et al., 2020; Letaw et al., 2022; Motti & Dura, 2021; Rossmann et al., 2020). Engineering education has continued to face difficulty in striking a balance between technical and non-technical components. While the significance of sociotechnical factors is becoming more widely acknowledged, faculty still noted

their challenges in figuring out how to successfully infuse these aspects without diluting engineering's core technical components (Claussen et al., 2019; Forbes et al., 2022; Gale, 2022; Hoople et al., 2020).

Relatedly, articles also spoke about obstacles faced in preparing and empowering faculty to effectively teach equitable design concepts (Claussen et al., 2019; Letaw et al., 2022; Motti & Dura, 2021). This includes the need to equip faculty with the necessary knowledge about equitable design and teaching strategies to support such learning. A recurring theme was the need to motivate and prepare instructors to teach relatively new concepts like ethics, accessibility, inclusive design, and sociotechnical thinking (Claussen et al., 2019; Letaw et al., 2022; Motti & Dura, 2021). Faculty development programs are essential in supporting faculty to confidently and effectively teach equitable design (Huerta et al., 2022; Tinnell et al., 2019). There was a recognition that faculty may face resistance within established engineering education programs when challenging the status quo. Challenging personal and institutional biases are and will continue to be a significant barrier (Hoople et al., 2020; Letaw et al., 2022).

Table 4
Challenges Faced During Intervention Integration

Challenges Faced		**Articles Cited**
Curriculum Integration	*Integration of new concepts*	Forbes et al., 2022; Hoople et al., 2020; Letaw et al., 2022; Motti & Dura, 2021; Rossmann et al., 2020
	Balancing between technical and non-technical aspects	Claussen et al., 2019; Forbes et al., 2022; Gale, 2022; Hoople et al., 2020
Student Engagement and Motivation	*Relevance and engagement*	Claussen et al., 2019; D'Souza, 2017; Forbes et al., 2022; Kang et al., 2021; Letaw et al., 2022; Motti & Dura, 2021; Murdock et al., 2023; Reynante, 2022; Rossmann et al., 2020
	Shifting student motivations	Brinkley et al., 2021; D'Souza, 2017; Gale, 2022; Kang et al., 2021; Murdock et al., 2023; Oleson et al., 2023
Faculty Development	*Preparing faculty*	Claussen et al., 2019; Letaw et al., 2022; Motti & Dura, 2021
	Overcoming resistance	Hoople et al., 2020; Letaw et al., 2022
Assessment and Evaluation		Hoople et al., 2020; Letaw et al., 2022; Reynante, 2022
Prior Experience		D'Souza, 2017; Gale, 2022; Kang et al., 2021; Motti & Dura, 2021
Long-term Impact		Forbes et al., 2022; Hoople et al., 2020; Motti & Dura, 2021; Murdock et al., 2023; Oleson et al., 2023; Reynante, 2022; Rossmann et al., 2020
Addressing Societal Challenges		Claussen et al., 2019; Hoople et al., 2020; Motti & Dura, 2021; Murdock et al., 2023; Rossmann et al., 2020

From a curricular perspective, there is a growing need to assess and evaluate the effectiveness of educational interventions, teaching methods, and curriculum changes around teaching equitable design (Hoople et al., 2020; Letaw et al., 2022; Reynante, 2022). This includes measuring student outcomes, understanding the impact of educational initiatives, and developing suitable assessment tools. Several articles discuss the challenge of assessing and evaluating the effectiveness of educational interventions, including developing appropriate assessment methods for topics like ethics and inclusive design (Hoople et al., 2020; Letaw et al., 2022; Reynante, 2022), as well as measuring long-term impact (e.g., Murdock et al., 2023; Oleson et al., 2023). Additionally, some articles mentioned the potential sustainability of their initiatives (e.g., Letaw et al., 2022; Reynante, 2022). Many of the courses or workshops were small-scale, thus raising concerns about the feasibility of implementing their interventional approach on larger scales (e.g., program-wide) (e.g., Forbes et al., 2022; Gale, 2022; Hoople et al., 2020).

The articles voiced challenges related to maintaining and enhancing student engagement and motivation throughout the learning process (Brinkley et al., 2021; Claussen et al., 2019; D'Souza, 2017; Forbes et al., 2022; Gale, 2022; Kang et al., 2021; Letaw et al., 2022; Motti & Dura, 2021; Murdock et al., 2023; Oleson et al., 2023; Reynante, 2022; Rossmann et al., 2020). These articles addressed factors that may have contributed to students' boosted or lessened enthusiasm for the subject matter. Across several articles, authors expressed challenges around keeping students engaged and motivated, particularly when teaching abstract or seemingly less relevant topics like ethics and socio-technical aspects of engineering (Claussen et al., 2019; D'Souza, 2017; Forbes et al., 2022; Kang et al., 2021; Letaw et al., 2022; Motti & Dura, 2021; Murdock et al., 2023; Reynante, 2022; Rossmann et al., 2020). Including real-world applications, team projects with students across disciplines, hands-on experiences, and structured discussions related to current societal issues in a course were noted as strategies that enhanced student motivation around learning equitable design concepts (e.g., Gale, 2022). Other articles mentioned a recognized challenge around managing students' changing motivations. Initially, students may be motivated by societal impact, but they can shift their focus to technical challenges, assignment completion, deadlines, and grades in the course (Brinkley et al., 2021; D'Souza, 2017; Gale, 2022; Kang et al., 2021; Murdock et al., 2023; Oleson et al., 2023). Relatedly, there was a recognized need to acknowledge and accommodate the educational backgrounds of engineering students. Students from backgrounds such as computer science, human factors, human systems engineering, industrial engineering, or ergonomics may have more prior knowledge of equitable design concepts (D'Souza, 2017). Articles highlight the criticality of creating inclusive learning environments that accommodate students from varying levels of prior knowledge, different educational backgrounds, and confidence in the subject matter (e.g., Claussen et al., 2019, D'Souza, 2017; Motti & Dura, 2021).

Many of these articles were one-time interventions (e.g., workshop, course) (e.g., Gale, 2022; Motti & Dura, 2021; Murdock et al., 2023). A noted challenge with these interventions was ensuring lasting influence on students' perspectives, values, and behaviors around equitable design throughout their academic and professional careers. Articles emphasize the challenge of fostering long-term impact on students regarding their care for, knowledge of, and applications of equitable design (Forbes et al., 2022; Hoople et al., 2020; Motti & Dura, 2021; Murdock et al., 2023; Oleson et al., 2023; Reynante, 2022; Rossmann et al., 2020). Understanding how engineering education shapes students' professional identities and ethical practices over time is a critical challenge. On a meta-level, there were recognized challenges in adapting engineering

education to align with the evolving needs and expectations of society. This includes addressing contemporary global challenges, such as sustainability, social justice, accessibility, and ethical considerations, within educational curricula (Claussen et al., 2019; Hoople et al., 2020; Motti & Dura, 2021; Murdock et al., 2023; Rossmann et al., 2020). Aligning engineering education with pressing societal needs and expectations is a common concern (Claussen et al., 2019; Hoople et al., 2020; Motti & Dura, 2021; Murdock et al., 2023; Rossmann et al., 2020).

Limitations

In being a preliminary exploration of our research question, this study has its limitations. First and foremost, the decisions taken during the second and third phases of the ScLR protocol served to filter literature that might have been relevant to our research question. Decisions such as keeping to literature and associated interventions grounded in a U.S. context (and written in the English language) might have filtered out successful pedagogical trends in use in other countries. Another limitation is found in one of the central problems surrounding the teaching of equitable design, i.e., the lack of a golden standard of equitable design practices in the engineering discipline. This gave our ScLR an added level of difficulty when searching for equitable design practices, as not all programs or faculty define these practices in the same manner. While this was overcome through a thorough search query that included various terms related to equitable design (see Figure 2), some studies might have escaped our search due to a difference in terminology. Finally, the lack of documentation of effective and efficient teaching practices to teach human-centered design poses a problem for a study of this kind. While faculty and practitioners may be creating curricula, course modules, and spaces that enable students to learn and practice equitable design, it is possible that they are not documenting these processes due to their institutional views on what constitutes research in engineering, ironically harking back to the preference for more technical problem-solving in engineering.

Implications and Future Work

Teaching equitable design in engineering challenges the historical paradigm of engineering as a neutral discipline. As Morgan et al. (2020) discussed, topics such as politics and social issues are situated on the periphery of engineering. Engineering curriculum traditionally offers socio-technical thinking development as specific courses instead of as a component integrated into the curriculum. Such a structure delegitimizes the technocentric approach of engineering education and thus hinders the development of diverse and inclusive engineering solutions. The papers selected for this ScLR illustrate the efforts that educators and groups of researchers are performing to support a future of engineers equipped with critical thinking and socio-technical skills. A small body of research currently exists regarding the long-term impacts of these interventions, which offers the opportunity for future projects to investigate and understand the impact of student participation in equitable design interventions.

Our ScLR revealed that engineering faculty may have challenges when planning and implementing equitable design teaching interventions. As higher education institutions seek to diversify their population and graduate professionals able to address the changing landscape of global issues, they must equip their faculty with the tools to continually integrate critical social reflection into their teaching. Faculty must also be supported in the process of implementing those innovations in their courses and curricula. Since students may not be used to integrating social reflection in the design process, course evaluations can be impacted negatively. Further investigation into ways to reduce potential students' resistance to equitable design teaching

should be developed. An example is provided by Tharayil et al. (2018), who compiled classroom strategies to mitigate students' resistance to active learning. Future work should address ways of assessing and evaluating equitable design implementation.

Teaching equitable design requires clear and specific learning objectives to help students and faculty assess the desired skills development. One of the challenges reported by the papers was the lack of validated instruments to assess the competencies related to equitable design. In this regard, future work should address what core competencies and skills engineering students should acquire with equitable design interventions. Relatedly, future work may seek to understand how to effectively assess those competencies and skills (i.e., formatively and summatively). Such a set of instruments will help orient the future development and integration of socio-technical perspectives into engineering curricula.

Conclusion

This paper elucidated the growing number of faculty and practitioners working to integrate equitable design concepts into their engineering courses. Through such integration, they are helping students break away from the traditional engineering design process and obtain a more holistic view of their role as engineers and designers of the world surrounding them. The results of this study can help inform faculty, practitioners, and students who are considering or are in the process of adding equitable design practices to their courses or seeking to impact their engineering curriculum. Similarly, directions for future work include researching the long-term impact of students' participation in equitable design interventions, defining and outlining equitable design core competencies, and developing assessment methods to guide the integration of equitable design perspectives in engineering curricula.

References

Arksey, H. & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, *1*(8), 19-32.

Borrego, M., Foster, M.J., &. Froyd, J.E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*, *1*(103), 45–76.

Brinkley, J. (2020). Participation at What Cost? Teaching Accessibility Using Participatory Design: An Experience Report. *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, 114–120. https://doi.org/10.1145/3328778.3366931

Brinkley, J., Huff, E. W., & Boateng, K. (2021). Tough but Effective: Exploring the Use of Remote Participatory Design in an Inclusive Design Course Through Student Reflections. *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, 170–176. https://doi.org/10.1145/3408877.3432527

Burleson, G., Herrera, S. V. S., Toyama, K., & Sienko, K. H. (2023). Incorporating Contextual Factors Into Engineering Design Processes: An Analysis of Novice Practice. *Journal of Mechanical Design*, *145*(2), 021401. https://doi.org/10.1115/1.4055780

Claussen, S., Tsai, J., Boll, A., Blacklock, J., & Johnson, K. (2019). Pain and Gain: Barriers and Opportunities for Integrating Sociotechnical Thinking into Diverse Engineering Courses. *2019 ASEE Annual Conference & Exposition Proceedings*, 33151. https://doi.org/10.18260/1-2--33151

Costanza-Chock, S. (2020). *Design Justice: Community-Led Practices to Build the Worlds We Need*. The MIT Press.

D'Souza, C. (2017). Topics in Inclusive Design for the Graduate Human Factors Engineering Curriculum. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *61*(1), 403–406. https://doi.org/10.1177/1541931213601583

Figard, R. & Carberry, A. (2023). A Law of Diminishing Returns: Quantifying Online Accessibility for Engineering Students with Disabilities in the Wake of the COVID-19 Pandemic. *IEEE Transactions on Education*, 1-9. https://doi.org/10.1109/TE.2023.3326760

Figard, R. & Mercado Rivera, A. (2023). STEM Education's Misalignment to Proactive Accessible Design: Policy Recommendations for Realignment. *United Nations Multi-stakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals*.

Forbes, M., Lord, S., Hoople, G., Chen, D., & Mejia, J. (2022). What Is Engineering and Who Are Engineers? Student Reflections from a Sustainability-Focused Energy Course. *Sustainability*, *14*(6), 3499. https://doi.org/10.3390/su14063499

Gale, J. (2022). Inventing the Baby Saver: An Activity Systems Analysis of Applied Engineering at the High School Level. *Journal of Pre-College Engineering Education Research (J-PEER)*, *12*(1). https://doi.org/10.7771/2157-9288.1312

Genaro Motti, V., & Dura, E. (2023). Evaluating an accessibility intervention based on persona cards with diverse needs to teach accessibility to undergraduate students. *Universal Access in the Information Society*, *22*(2), 369–385. https://doi.org/10.1007/s10209-021-00853-9

Grant, M. & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, *2*(26), 91- 108.

Holly, J., & Masta, S. (2021). Making whiteness visible: The promise of critical race theory in engineering education. *Journal of Engineering Education*, *110*(4), 798–802. https://doi.org/10.1002/jee.20432

Holmes, K., & Maeda, J. (2018). *Mismatch: How inclusion shapes design*. The MIT Press.

Hoople, G. D., Chen, D. A., Lord, S. M., Gelles, L. A., Bilow, F., & Mejia, J. A. (2020). An Integrated Approach to Energy Education in Engineering. *Sustainability*, *12*(21), 9145. https://doi.org/10.3390/su12219145

Huerta, M., London, J., & Mckenna, A. F. (2022). Engineering Deans' Perspectives on the Current State of Faculty Development Programs in Engineering Education. *International Journal of Engineering Education*, *38*(4), 1073–1091.

Kang, S. P., Chen, Y., Svihla, V., Gallup, A., Ferris, K., & Datye, A. K. (2022). Guiding change in higher education: An emergent, iterative application of Kotter's change model. *Studies in Higher Education*, *47*(2), 270–289. https://doi.org/10.1080/03075079.2020.1741540

Letaw, L., Garcia, R., & Morreale, P. (2022). Educating Educators to Integrate Inclusive Design Across a 4-Year CS Degree Program. *arXiv*. https://doi.org/10.48550/arXiv.2209.02748

Leydens, J., Johnson, K., Claussen, S., Blacklock, J., Moskal, B., & Cordova, O. (2018). Measuring Change over Time in Sociotechnical Thinking: A Survey/Validation Model for Sociotechnical Habits of Mind. *2018 ASEE Annual Conference & Exposition Proceedings*, 30794. https://doi.org/10.18260/1-2--30794

Loweth, R., Daly, S., Paborsky, L., Hoffman, S., & Skerlos, S. (2021). "You Could Take 'Social' Out of Engineering and Be Just Fine": An Exploration of Engineering Students' Beliefs About the Social Aspects of Engineering Work. *2021 ASEE Virtual Annual Conference Content Access Proceedings*, 36539. https://doi.org/10.18260/1-2--36539

Martin, D. A., Conlon, E., & Bowe, B. (2021). A Multi-level Review of Engineering Ethics Education: Towards a Socio-technical Orientation of Engineering Education for Ethics. *Science and Engineering Ethics*, *27*(5), 60. https://doi.org/10.1007/s11948-021-00333-6

Miska, J. W., Mathews, L., Driscoll, J., Hoffenson, S., Crimmins, S., Espera, A., & Pitterson, N. (2022). How do undergraduate engineering students conceptualize product design? An analysis of two third‐year design courses. *Journal of Engineering Education*, *111*(3), 616–641. https://doi.org/10.1002/jee.20468

Morgan, D. L., Davis, K. B., & López, N. (2020). Engineering political fluency: Identifying tensions in the political identity development of engineering majors. *Journal of Engineering Education*, *109*(1), 107–124. https://doi.org/10.1002/jee.20300

Murdock, L., Osgood, L. (Elizabeth), & McCarvill, L. (2023). Embracing Co-Design: A Case Study Examining How Community Partners Became Co-Creators. *Education Sciences*, *13*(5), 492. https://doi.org/10.3390/educsci13050492

Oleson, A., Solomon, M., Perdriau, C., & Ko, A. (2023). Teaching Inclusive Design Skills with the CIDER Assumption Elicitation Technique. *ACM Transactions on Computer-Human Interaction*, *30*(1), 1–49. https://doi.org/10.1145/3549074

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *International Journal of Surgery*, *88*, 105906.

Reynante, B. (2022). Learning to design for social justice in community‐engaged engineering. *Journal of Engineering Education*, *111*(2), 338–356. https://doi.org/10.1002/jee.20444

Rossmann, J., Sanford, K., Nicodemus, J., & Cohen, B. (2020). The Sociotechnical Core Curriculum: An Interdisciplinary Engineering Studies Degree Program. *2020 ASEE Virtual Annual Conference Content Access Proceedings*, 35373. https://doi.org/10.18260/1-2--35373

Rodriguez, N. M., Burleson, G., Linnes, J. C., & Sienko, K. H. (2023). Thinking Beyond the Device: An Overview of Human- and Equity-Centered Approaches for Health Technology Design. *Annual Review of Biomedical Engineering*, *25*(1), 257–280. https://doi.org/10.1146/annurev-bioeng-081922-024834

Samnani, S., Vaska, M., Ahmed, S., & Turin, T. (2017). Review Typology: The Basic Types of Reviews for Synthesizing Evidence for the Purpose of Knowledge Translation. *Journal of the College of Physicians and Surgeon*s, *10*(27), 635-641.

Tharayil, S., Borrego, M., Prince, M., Nguyen, K. A., Shekhar, P., Finelli, C. J., & Waters, C. (2018). Strategies to mitigate student resistance to active learning. *International Journal of STEM Education*, *5*(1), 7. https://doi.org/10.1186/s40594-018-0102-y

Tinnell, T. L., Ralston, P. A. S., Tretter, T. R., & Mills, M. E. (2019). Sustaining pedagogical change via faculty learning community. *International Journal of STEM Education*, *6*(1), 26. https://doi.org/10.1186/s40594-019-0180-5

Wong Lau, K., Norris, R. L., Siddique, Z., Altan, M. C., Baldwin, J., & Merchan-Merchan, W. (2016). Cognitive Empathy in Design Course for a More Inclusive Mechanical Engineering. *Volume 3: 18th International Conference on Advanced Vehicle Technologies; 13th International Conference on Design Education; 9th Frontiers in Biomedical Devices*, V003T04A005. https://doi.org/10.1115/DETC2016-60382