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Integrating Technical and Social Issues in Engineering Education: A Justice Oriented Mindset

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Abstract

The problem-solving skills of engineers are necessary to address modern, global, sociotechnical issues (e.g., accessibility, climate change, health/pandemic, racism). Undergraduate engineering students, particularly women, people of color, and individuals with disabilities, are often motivated by these sociotechnical challenges to pursue engineering. However, technical learning and social issues are frequently separated in current forms of undergraduate engineering education, and engineering students may learn to devalue social aspects of engineering as a result. Integrating social issues, such as issues of equity, diversity, inclusion, and justice, into an engineering education may privilege the experiential knowledge of a wider set of students and empower a new generation of engineers to address pressing sociotechnical issues. In this study, we synthesize examples of such integration from prior literature through a narrative literature review, beginning with seminal works and using a snowballing method to include other articles. We consider themes across the prior literature that address our research questions: How might social and technical aspects of engineering be effectively integrated in undergraduate engineering education and what are the benefits of such integration? Our synthesis may support engineering educators and engineering institutions to better integrate sociotechnical issues into their coursework. Particularly, our work provides insight into methods for addressing the misconception that engineering is purely technical. The larger goal of the work is to empower more students to respond to global, sociotechnical issues through engineering and to increase representation and inclusion in engineering.

Introduction

Modern global issues (e.g., accessibility, climate change, health/pandemic, racism) are complex, systemic, sociotechnical problems, and the problem-solving skills of engineers are necessary to address these issues. Further, because engineering occurs within systems of social inequalities, politics, and social hierarchies, engineering students must have opportunities to consider these social aspects of engineering [1]. Without exposure to unpacking inequalities, engineers may perpetuate oppression, marginalization, and other forms of social inequalities [2]. Undergraduate engineering education then needs to train and empower engineering students to be aware of the social implications of their engineering designs and to find ways that they can justly apply their problem-solving skills to global, sociotechnical issues.

Undergraduate engineering students, particularly women, people of color, and individuals with disabilities, are often motivated by sociotechnical challenges to pursue engineering [3]–[5]. However, technical and social aspects of engineering are frequently separated in current forms of undergraduate engineering education, and engineering students may learn to devalue social aspects of engineering (e.g., [6]–[8]). This devaluing happens because technical skills are often placed at the forefront of engineering education while sociotechnical skills may be de-emphasized [9]–[11]. As a result, faculty and students tend to place higher value on technical skills in engineering [9], [12]. This valuing of technical aspects of engineering over social aspects may decrease the motivation of engineering students to address sociotechnical problems,

and may turn people away from the field, particularly women, people of color, and individuals with disabilities. Thus, in this work, we examine examples of the successful integration of social and technical aspects of engineering through a social justice frame as a mechanism for increasing student retention and motivation to address sociotechnical problems.

Integrating social issues, such as issues of equity, diversity, inclusion, and justice, into a technical engineering education may privilege the experiential knowledge of a wider set of students and empower engineering students to address sociotechnical issues (e.g., [13], [14]). Prior literature rarely includes empirical examination of engineering courses which integrate social justice, although theory behind this integration has been explored (e.g., [15]–[17]). Starting with several relevant, well-cited articles that were known to us (e.g., [8], [13]), we used a snowballing approach to review prior work that documents engineering courses which integrate social justice. Our research questions are: **How might social and technical aspects of engineering be effectively integrated in undergraduate engineering education through a lens of social justice and what are the benefits of such integration?** The goal of this work is to empower more students to justly respond to global, sociotechnical issues through engineering, and to make the field of engineering more diverse.

Background

Engineers must be technically proficient and also aware of the sociotechnical nature of engineering and the social contexts in which they are developing engineering solutions [10]. Recognizing sociotechnical aspects of engineering and the societal context of engineering work is an important element of student outcomes specified by ABET, the organization that accredits university engineering programs [18]. Specifically, ABET requires that engineering students are able to produce solutions with consideration for "global, cultural, social, [and] environmental" factors, amongst others, and that engineering students are able to "consider the impact of engineering solutions" in "societal contexts," amongst others [18].

However, engineering students are not often given opportunities to generate an understanding of social issues or the importance of social contexts to engineering. Instead, social issues are often viewed as tangential to technical problems [8], as engineering is often defined through the application of mathematics and science towards problem solving and design [19] and seen as objective and apolitical [6], [7]. Additionally, within engineering curriculum, many faculty value technical problem solving knowledge most highly, then engineering design, and value social sciences and humanities as the least important [20]. These faculty then may teach their engineering students to do the same [9], [20]. Further, engineering students are often exposed to closed-ended problems that are decontextualized, extending the gap between social and technical aspects of engineering. The result is that engineers may be unprepared to understand the larger contexts and implications of their work [17], [21]. Thus, social aspects of engineering are both overlooked and undervalued in engineering education.

Yet, engineering inherently has social outcomes. Engineering artifacts are innately sociotechnical as some individuals benefit, some are overlooked, and some have power to negotiate change [20]. Further, the definitions of engineering shape who becomes an engineer, which problems are solved by engineers, who benefits from engineering, and, thus, the relationship of engineering to

society and social justice [20], [22]. It is then necessary that engineers recognize their own positionality and the social impacts of their engineering work [8], [23].

Integrating social issues into engineering education necessarily bring equity and social justice to the forefront of engineering. Turner et al. [1] argue that current engineering curricula contribute to a culture of engineering that does not center equity or justice and, as a result, engineering is inequitable in society and perpetuates systemic oppression and historic inequalities. Engineering educators are working to address injustice by bringing focus to benefiting underserved populations rather than the traditional focus on profit and efficiency [1], [24]. Thus, in order to continue to improve engineering education and increase the equity of engineering in society, scholars must consider the ways that social issues are being integrated into engineering and the ways that engineering students are being taught to consider justice and equity in engineering.

Engineering for Social Justice

Engineering education scholars argue that social justice dimensions are present but currently rendered invisible in technical engineering courses [17]. In an engineering context, "social justice involves engineering practices that strive to enhance human capabilities through an equitable distribution of opportunities and resources while reducing imposed risks and harms among agentic citizens of a specific community" [17, p. 73]. To engage in social justice and consider social issues through engineering, engineering students must be challenged to overcome the depoliticization and meritocracy present in engineering [6], [25]. Because positivism and objectivity are often emphasized in engineering education [6], [25], it can be a challenge for engineers to understand justice and systemic oppression [26].

While there is currently no tool for implementing or recognizing components of social justice within an engineering curriculum, Lucena and Leydens [17], [20] put forth six Engineering for Social Justice (E4SJ) criteria for guiding engineers to center social justice in their designs. These criteria might similarly be used in engineering education to help center justice in the integration of social issues into engineering courses, and we expect that many of these criteria are present in the effective integration of social and technical aspects of engineering in undergraduate education. As such, we provide a brief overview of the E4SJ criteria.

The first criterion is *listening contextually*, which means listening to, and empathizing with, the goals and challenges of different peoples' stories in a variety of contexts without being shaped by prior assumptions. The second criterion is *identifying structural conditions* or recognizing the variety of factors that shape the goals and challenges of the people who may be impacted by engineering work. The third criteria, *acknowledging political agency/mobilizing power*, refers to an engineer acknowledging the political agency of themselves and of the communities that they serve in order to organize and rally resources. The final three criteria come directly from the definition of social justice. *Increasing opportunities and resources* refers to assessing increased opportunities and resources that are needed in partnership with members of the community being served. Similarly, *reducing imposed risks and harms* refers to assessing risk and harms and how they are distributed and tolerated in partnership with the community. The final criteria, *enhancing human capabilities*, highlights the overall goal of E4SJ, towards which all the other criteria contribute. The relationship between community members and the designers is essential

to E4SJ, as listening to community members is a strategy for improved understanding of the local context and structural conditions that lead to inequalities [27]. Additionally, developing an awareness of one's own privilege and biases is essential to E4SJ. This is done through reflecting on power and privilege, the ways in which privilege or disadvantage may be determined due to intersecting social identities of race, class, and gender [17], and how privilege is connected to the power of social institutions, such as universities or government agencies [27]. We expect that aspects of these E4SJ criteria are present in the effective integration of social and technical aspects of engineering, as considering social issues necessitates attention to equity and social justice.

Literature review approach

Literature examining courses that integrate social and technical aspects of engineering with a focus on social justice has started to expand in the past ten years. As a result, we searched for literature that focused on the implementation of such courses in undergraduate engineering contexts from 2012 through 2022. Our objective in reviewing this literature was to gain a fundamental understanding of the types of courses that have been offered previously and what, if any, empirical evidence there may be of benefits to students. We then used this prior literature to begin to characterize the successful implementation of such a course.

We started with relevant articles that were known to us and searched through the works cited by these initial articles, and later work that cited those initial articles, to find additional, relevant articles. We then reviewed those articles for relevance and, in reviewing the articles, further expanded our sample through searching through additional articles that were cited by relevant work. Articles were deemed relevant if they documented an *empirical study* of the *implementation* of the integration of social justice in *undergraduate engineering education* from *2012 to 2022.* The first two articles we searched were [8], [13], and other articles were included in the works cited or later work cited by these two articles, such that these two articles could be a starting point for replicating our search.

Our search resulted in many articles about theory and recommendations for integrating social justice issues into engineering education (e.g., [2], [6], [16], [17], [25]), but few articles that described empirical studies of the implementation of social justice-oriented engineering in the classroom. While the theory and recommendations provided useful information to motivate this study and to begin to understand the goals of such curricula, these articles were outside the scope of our review. In this review, we focus on 11 empirical studies of the implementation of the integration of social issues into engineering education through the lens of social justice (Table 1). In the following, we present themes that we identified from across these 11 papers.

Limitations

There are several limitations to our literature review approach. Most notably, there are likely other papers detailing social justice applications within engineering courses that we did not find using this non-systematic approach. While this review may not include all examples of social justice applications, the themes revealed from this review of well-cited, relevant articles do provide a useful overview of the type of work being done in this space. Additionally, we chose to

focus narrowly on the concept of social justice in this review. Many other scholars are engaging in similar work but may not explicitly tie their work to "social justice," instead using terms like "empathy," or "active learning." We chose to limit the scope of this review to studies that specifically focus on social justice, but want to recognize that additional empirical work is being done, and, although not included in this review, that work also informs the implementation of social justice work in our engineering classrooms.

Literature examining courses that integrate social and technical aspects of engineering

Most of the papers we reviewed did not mention the use of a framework in the design of the course or in the evaluation of student outcomes (e.g., [1], [28]–[30]). Those that did used a variety of different frameworks. Specifically, Chen et al. [31] used Problem-Based and Project-Based Learning (e.g., [32]), Leydens et al. [13] and Reynante [33] used Engineering for Social Justice [17], and Reynante [33] also created and used a framework of four key mind shifts in design-for-charity to design-for-justice.

In the following, we give a brief overview of the courses described in the papers we reviewed and note that several courses were described across multiple papers.

Introduction to Feedback Control Systems course

A seminal example of a course that integrated social and technical aspects of engineering is an Introduction to Feedback Control Systems course that intentionally integrated social justice considerations [13], [28], [29]. Three iterations of this course were studied. Third and fourth year electrical or mechanical engineering students took one of two sections of the course. One section of the course was augmented with social justice interventions, including readings, guest lectures, examples, homework problems, and final project design constraints related to social justice concerns. Additionally, students in this augmented section were introduced to the E4SJ criteria (all six criteria in the first two iterations, and only two criteria in the third iteration) [13], [29]. The other section did not include these interventions.

Johnson et al. [28], [29] examined the first iteration of the Introduction to Feedback Control Systems course. While students expressed that they were initially uncomfortable with the social justice integration, student focus group data demonstrated that the students had an interest in social justice being integrated into engineering courses; students indicated that integrating this content earlier and throughout the course would increase their comfort with the social justice content and would make the content more valuable to them [29]. Further, the students reported difficulty switching between social and technical aspects of engineering. They expressed a desire for more real-world examples of social justice in engineering to make the social justice content less abstract [28]. Finally, analysis of students' revisions to homework problems demonstrated that the first iteration of the course did not have the desired outcome, as students did not demonstrate a strong ability to apply the six E4SJ criteria taught in the course [28].

Through qualitative case study of all three iterations of the course, Leydens et al. identified three interrelated themes in students' perceptions of social justice: 1) a continuum of simple to detailed descriptions of social justice, 2) a continuum of technical-social dualism to sociotechnical

integration, and 3) diverse conceptions of engineers as agents of change [13]. Students who expressed a simple description of social justice tended to also express the perspective of technical-social dualism, while more detailed descriptions of social justice were associated with descriptions of sociotechnical integration. The goal of this course, and others, that integrate social and technical aspects of engineering is to shift student perceptions towards more detailed descriptions of social justice, towards a view of sociotechnical integration, and towards a deeper understanding of engineers as agents of social change. There was evidence of small shifts in students' perceptions by the implementation of the third iteration of the course. A limitation to the examination of the implementation of this course is that the student participants were fairly homogeneous in terms of race, gender, and class; most demographic data were not tracked due to the small sample size, so comparisons based on race and gender were not made [13].

User-Centered Design course and Engineering and Social Justice course

Mejia et al. described the development of a curriculum that contextualizes engineering through two courses that address social justice in engineering [23]. One course was an Engineering and Social Justice course required for third-year students that challenged students to analyze and write about the historical and societal impacts of engineering in marginalized communities. The other was a User-Centered Design course for first- and second-year engineering students that challenged students to generate an engineering design to meet the needs of the local population of individuals experiencing homelessness. The outcomes or transformative nature of these courses were not explored in the descriptive 2018 manuscript [23], but outcomes and student perspectives of the User-Centered Design course were explored in later papers [8], [31].

The User-Centered Design course focused on the social justice issue of homelessness in partnership with a local homelessness advocacy group. Students in the course were required to participate in awareness events for homelessness and food insecurity before the project began [8], [23], [31]. The issue of homelessness was made relevant to students because of the local nature of the issue around their campus. The first time the course was offered, students were tasked with designing a solar water heater for mobile showers for people experiencing homelessness. In the second iteration of the course, students were tasked with identifying a need related to the COVID pandemic that affected people experiencing homelessness and then generating a design to address that need. Pre- and post-responses to four open-ended questions were collected from 105 students across both iterations, along with students' final projects and written reflections on the awareness events [8].

There was some shift in students' perceptions of the issue of homelessness. Pre- and post-responses revealed that the deficit perspective that homelessness is the result of inherent individual characteristics was mostly present in pre-surveys and decreased but did not disappear after the project [8]. Students' written reflections demonstrated their surprise that their previous notions of the causes of homelessness and the demographics of individuals experiencing homelessness were inaccurate or incomplete [31]. However, several students did present a critical and systemic view of social injustices, mostly in their post-responses [8]. Finally, in the final projects, students were mostly able to describe accurate causes of homelessness rather than perpetuating their previous misconceptions [31]. Although the course challenged students to wrestle with the idea that engineering alone could not solve the problem of homelessness, as

there were non-technical factors that contribute to the problem, both pre- and post-responses contained the perspective that engineering was technical and not social. Together, these findings demonstrate that the course began to demonstrate the sociotechnical nature of engineering through exploring the ways that engineering alone cannot solve the issue of homelessness.

Other courses designed to integrate social issues

Hendricks and Flores [34] described the design and implementation of a course that explored social justice in engineering through class discussions and written reflections examining race, gender, sexuality, and disability. Students examined cultural and scientific theories of race, gender, sexuality, and disability, and how engineering has perpetuated oppression. Students reflected that, because of the course, they felt more confident in their ability to communicate about social justice, advocate for themselves and others, and account for social justice concerns in engineering designs. Student feedback throughout the course led to several changes in the ways that the course was taught, including not cold-calling on students, allowing a larger number of students to speak in class debates, and giving students more autonomy in choosing topics for debate and their final papers [34]. The authors describe how these changes helped students feel more comfortable addressing the uncomfortable or challenging topics required by the course.

Most recently, in 2022, Reynante [33] described an introductory and laboratory course aimed at engaging engineering students in projects with community partners to shift students' mindsets from uncritical, deficit-based, design-for-charity mindsets towards a critical, asset-based design-for justice mindset. In this project, students were challenged to address the issue of affordable lighting in a rural village in the Philippines. Students' experiences in the course were analyzed in alignment with the Engineering for Social Justice framework. While coursework supported students' shift in mindset, the authors note that coursework alone was insufficient. Students also needed active experimentation with the social justice concepts, which they were learning at an abstract level in their courses, to develop empathy with community members [33].

Other modules designed to integrate social issues into existing technical engineering courses

Several papers described modules designed to integrate social justice into existing technical engineering courses, such as a Heat Transfer course or an Electrical Circuits course. In 2018, Reddy et al. [30] examined their Social Relevance and Global Context Module that incorporated contextual details into technical material in a Heat Transfer course. In this study, 28 senior undergraduate engineering students were presented with a quantitative problem related to the length of a pipe in a water heater and given context for the problem that created additional design considerations. Students wrote memos to present their final solutions and describe additional considerations for solar water heating. Classroom observations and student memos demonstrated that students were able to consider contexts to their heat transfer content that went beyond traditional, technical considerations; however, most of the considerations that students brainstormed were environmental, rather than economic or social [30].

Similarly, in 2019, Lord et al. [35] described the design and implementation of three modules that integrated social responsibility and consideration for social context into the development of technical skills in one section of an electrical circuits course. These modules included a mixture

of homework, guest lectures, and student discussions and presentations. Through these modules, students considered the origins of materials, products developed, and lifecycle of products relevant to electrical engineering, specifically through examining conflict minerals used in capacitors, solar power design for use in developing nations, and the recycling of electronics. Survey and interview data collected from students indicated that students felt like the modules were providing real-world application of what they were learning and that the content would be relevant to future work as engineers [35].

Most recently, Turner et al. [1] examined students' perceptions of social justice through the implementation of a learning module incorporated into an undergraduate civil engineering course. The module, a fictional transportation revitalization case study, led students through the design process, taught historic context of highway construction, and exposed students to socially just design principles. Students discussed the themes of the project and learned from each other in discussion groups of 8-10 students, followed by whole-class discussion. Pre- and post-surveys from 59 students who took the course demonstrated that students held positive perceptions towards social justice before the implementation and that their perceptions of the likelihood of encountering social justice issues, opportunities to address social justice issues, relevance of social justice to engineering, and knowledge about social justice all increased after the implementation. Several students expressed that the activity increased their interest in becoming an engineer [1]. However, students also gave feedback that the integration of such content throughout a course and across multiple courses would be more beneficial.

Discussion

We discuss themes from across the described papers related to pedagogy and course design that were demonstrated to be effective for integrating social and technical aspects of engineering through a lens of social justice in undergraduate engineering education. We also discuss evidence of the benefits of integrating social justice in undergraduate engineering education. Finally, we discuss the necessity of additional work in integrating social and technical aspects of engineering in undergraduate engineering and potential directions for future research in this area.

How might social and technical aspects of engineering be effectively integrated in undergraduate engineering education through a lens of social justice?

Findings from the papers we reviewed highlight the **need for engineering students to be exposed to social justice or social aspects of engineering throughout an engineering education, rather than through a single module or a single course** (e.g., [1], [13], [29], [30]). Through distributing the teaching of social justice criteria and the larger importance of social justice in engineering across an engineering curriculum instead of delivering them all in a single course, engineering educators might better demonstrate for students how social justice considerations are inherent in engineering problems [13]. Further, undergraduate engineering students were shown to be initially uncomfortable with social justice topics and integrating these topics throughout an engineering education may make students more comfortable, as evidenced by student feedback [29]. Similarly, when social aspects of engineering were concentrated in a single module, the relevance of social concerns to the larger course was not as apparent to

students (as in [1], [30]). Therefore Reddy et al. and Turner et al. suggest integrating such content throughout a course [1], [30].

Findings from the included studies also indicate the **importance of using real-world examples to contextualize technical aspects of engineering and make the social aspects of engineering less abstract** (e.g., [28], [30], [31], [33]). Coursework alone was insufficient at teaching students to consider social concerns as students also needed active experimentation with the social justice concepts [33]. For example, to emphasize the real-world context of their engineering design challenge, Chen et al. worked with a local homelessness advocacy group to educate students about the social issue they were considering [31]. This contextualized learning and the local nature of the issue of homelessness for the students made the social aspects of the design project more relevant and less abstract. This finding is aligned with the suggestion that **students are more likely to value social justice when the content is presented in the context of engineering problem solving** [13]. There is evidence that students expect that they would need to consider social factors more often in addressing real-world problems in their engineering professions than they do in their engineering education [28]. Further, when considering non-technical concerns, engineering students may need additional support to consider economic or social contexts [30]. Additional real-world examples of social concerns in engineering design would support engineering students to consider these contexts in their future problem solving.

Other pedagogical lessons for teaching social justice in engineering included **not cold-calling on students**, **allowing a larger number of students to speak**, and **giving students more autonomy in choosing topics** [34]. These recommendations may help in **creating safe spaces for students to learn** and **creating collaborative learning experiences within these safe spaces** [1]. It can be productive for an engineering educator to f**ocus on becoming an expert in allowing for and encouraging conversations about social justice, rather than becoming an expert on social justice itself** [1].

What are the benefits of integrating social and technical aspects of engineering?

Overall, **students expressed interest in addressing social issues and learning about social justice in engineering** (e.g., [1], [29]). Turner et al., [1] found that their undergraduate engineering students held positive perceptions towards social justice before the implementation of a social justice intervention. Further, Johnson et al. [29] found that most undergraduate engineering students had been exposed to social justice in a prior course, but few had learned about social justice outside of coursework and engineering. Despite being interested, **many students held deficit perspectives based on meritocracy** and **viewed social issues as separate from engineering** before intentional interventions (e.g., [8], [31], [33]). The collective evidence of students' 'before-intervention' beliefs and knowledge point to the **necessity of continuing to include social justice in engineering courses.**

Further, the papers we reviewed provide initial evidence that **the integration of social and technical aspects of engineering in undergraduate engineering courses may shift students' attitudes towards addressing social issues through engineering and change their definitions of engineering** (e.g., [1], [8], [30]). Such integration of social and technical aspects of engineering may, more specifically, *begin* to shift students' deficit perspectives and meritocracy

beliefs towards more critical and systemic views of social injustices. For example, while there was some shift in the deficit perspectives of students through the User-Centered design course, the attitudes of some students remained unchanged [8]. Although there was evidence of some shift in the perspectives of students through the course, the ideology of meritocracy was still prevalent after the project, demonstrating the **need for continued and improved integration of social and technical aspects of engineering in undergraduate engineering courses.** Additionally, while there is evidence that teaching social justice in engineering benefits undergraduate engineering students, this evidence is rather limited, highlighting the **necessity of more robust future research**.

Where is the work going next?

Together, these studies demonstrate the need for continued work with engineering educators to integrate social and technical aspects of engineering in undergraduate engineering through a social justice lens. Future work needs to continue to investigate the challenges and benefits to such integration from the perspectives of the students and the instructors, which we plan to pursue through future empirical work. The papers that we focused on in this review contain thorough descriptions of the development and implementation of curriculum that integrate social and technical aspects of engineering through a social justice lens, which is an essential first step in working towards this goal. For example, Mejia et al. [23] describe in detail the development and implementation of two courses, and Hendricks and Flores' [34] described in detail the curricular materials that they used. While Mejia et al. did not explore outcomes for students in that paper, follow-up papers (e.g., [8], [31]) begin to investigate these outcomes. Hendricks and Flores gave a preliminary examination of instructor observations and student feedback, which was overwhelmingly positive [34]. Many of the studies included a similar initial exploration of the student outcomes, but **a deep analysis of what components of a curriculum impact student outcomes is missing from the literature.** Future work might work to clearly connect aspects of their curriculum to specific student outcomes such that those aspects might be replicated in other curricula to benefit additional undergraduate engineering students.

Many studies investigated preliminary student outcomes via examining students' work in the intervention (e.g., [28], [30], [31], [33]), exploring their reflections immediately after the intervention (e.g., [13], [29], [35]) or comparing their pre- and post-surveys (e.g., [1], [8]). While these are important methods for considering the impact of integrating social and technical aspects of engineering, there is a **need to investigate lasting impacts of such interventions**. Longitudinal or cross-sectional studies of students' perceptions of social justice in engineering within a course and in semesters after the course is over are important for the future of this work and might help demonstrate lasting impacts of social justice interventions on engineering careers.

Additionally, the studies included in this review do not address differences in student outcomes by social identities. While differences in student outcomes based on gender and race of participants is expected based on prior literature (e.g., [3]–[5]), limited numbers of students in the implementation and/or homogeneous student populations (e.g., [13]) may have prevented such an empirical analysis in prior work. Considering social issues in engineering presents an alternative way for students who identify less strongly with technical aspects of engineering to engage in engineering. For example, Reddy et al. consider that their Social Relevance module

could be an alternative way for students to engage with the course and suggest that this alternate form of engagement may especially benefit students with lower grades in the course, but this study does not have data to support this argument [30]. Future research will need to continue to investigate the benefits of the integration of social and technical aspects of engineering, particularly for minoritized students in engineering and for students who may struggle with traditional, technical approaches to engineering education.

Finally, there was limited use of frameworks in the design or evaluation of undergraduate engineering curricula that integrate social and technical aspects of engineering, and the frameworks that were used were not consistent. This points to the **need for the development of a framework for motivating and empowering undergraduate engineering students to engage in sociotechnical problem solving through engineering.**

In our own future work, we hope to implement the effective strategies revealed by prior work into our own engineering classrooms and engage in our own empirical work in this space.

Researcher positionality

We are motivated to better understand the integration of social justice and engineering education due to the belief that an understanding of social justice and civic responsibility are relevant and essential in the practices of engineering. We recognize the multitude of ways in which engineering shapes our society and the ways that engineering and the products of engineering perpetuate systemic inequalities. The authors of this work are white women, and we recognize that, while our womanhood may be marginalized in engineering spaces, our whiteness gives us certain privileges in those same spaces. It is our goal that, through this work, we contribute to a more equitable engineering education for marginalized students and an improved engineering education for all students.

Conclusions

It is the goal of this work to encourage an integration of social and technical aspects of engineering through a lens of social justice to broaden the scope of who is empowered to become an engineer. Engineering educators and programs aligning their coursework to include a focus on social challenges might empower a more diverse group of engineering students to generate designs for more diverse users and address diversity in the field more broadly. Thus, this type of work may make engineering itself more just and diverse.

Additionally, the integration of social and technical aspects of engineering creates a shift towards making engineering more interdisciplinary through the consideration of societal, cultural, historical, political, economic, and environmental implications of design. Engineering alone cannot solve large sociotechnical problems but can contribute towards solutions [8], [31]. Similarly, the integration of social and technical aspects of engineering may lead to a shift towards a more justice-oriented mindset of what it means to be an engineer. Namely, engineering is not just about solving problems of efficiency for profit but is about solving problems for people in ways that bring about equity and improve quality of life.

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Table 1: List of Articles

Full Citation	What they did	Scope / Students	Methods	Outcome	Frameworks
D. A. Chen, M. A. Chapman, and J. A. Mejia, "Balancing complex social and technical aspects of design: Exposing engineering students to homelessness issues," Sustainability, vol. 12, no. 15, pp. 1–12, Jul. 2020, doi: 10.3390/su12155917.	Engineering design project in a User-Centered Design course. Students participated in Homelessness & Food Insecurity Awareness Week. Tasked with designing a solar water heater for mobile showers for people experiencing homelessness.	One project in a User-Design course Lower-division Undergraduate Students	Open Coding of students' written reflections on Homelessness Awareness Week activities & final projects	Students surprised that their previous notions of the causes & demographics of homelessness were incorrect or incomplete. Homelessness was relevant to students because of the local nature of the issue.	Problem-Based and Project-Based Learning with Communities
D. G. Hendricks and Y. Flores, "Teaching social justice to engineering students," presented at the 2021 American Society of Engineering Education Annual Conference & Exposition, Virtual Conference, 2021.	Examined cultural/scientific theories of race, gender, sexuality, & disability, & how engineering perpetuated oppression through class discussions & written reflections.	One course focused on race, gender, sexuality, & disability	Analysis of students' reflections	Students felt more confident in their ability to communicate about social justice, advocate for themselves & others, & account for social justice concerns in engineering.	
K. Johnson, J. Leydens, B. Moskal, and S. Kianbakht, "Gear switching: From 'technical vs. social' to 'sociotechnical' in an introductory control systems course," in 2016 American Control Conference (ACC), Boston, MA, USA, Jul. 2016. doi: 10.1109/ACC.2016.7526716.	One section of the course contained social justice interventions (readings, guest lectures, examples, homework problems, & final project design constraints related to social justice concerns). The other section did not include these interventions.	One augmented & one traditional class section Undergraduate students, mostly electrical or mechanical engineering	Qualitative analysis of survey, focus groups, homework problems, and final projects	Students desired more real-world examples of social justice & expected that in their engineering professions they would consider social factors more often. Students did not demonstrate strong ability to apply the E4SJ criteria & reported difficulty switching between social and technical aspects.	

Full Citation	What they did	Scope / Students	Methods	Outcome	Frameworks
K. Johnson, J. Leydens, B. Moskal, D. Silva, and J. Fantasky, "Social justice in control systems engineering," in 2015 American Society of Engineering Education Annual Conference Proceedings, Seattle, Washington, Jun. 2015. doi: 10.18260/p.24715.	One section of the course contained social justice interventions (readings, guest lectures, examples, homework problems, & final project design constraints related to social justice concerns). The other section did not include these interventions.	One augmented & one traditional class section Undergraduate students, mostly electrical or mechanical engineering	Survey & Focus groups	Students were initially uncomfortable with the social justice integration & said that integrating this content earlier/throughout the course would make them more comfortable & make the content more valuable.	
J. A. Leydens, K. E. Johnson, and B. M. Moskal, "Engineering student perceptions of social justice in a feedback control systems course," J. Eng. Educ., Jul. 2021, doi: 10.1002/jee.20412.	In one section, social justice considerations were made visible (introduced some/all of the E4SJ criteria & reading). The other section was traditionally taught.	One augmented & one traditional class section over three years Undergraduate students	Qualitative case study; Interviews & focus groups	Three domains: 1) simple to detailed descriptions of social justice, 2) technical-social dualism to sociotechnical integration, 3) diverse conceptions of engineering students & practitioners.	Engineering For Social Justice (E4SJ)
S. Lord, B. Przestrzelski, and E. Reddy, "Teaching social responsibility in a circuits course," in 2019 American Society of Engineering Education Annual Conference Proceedings, Tampa, Florida, Jun. 2019. doi: 10.18260/1-2--33354.	Three sociotechnical modules throughout an electrical circuits course.	One class section Second-year electrical, mechanical, & integrated engineering students	Survey & interviews about student experience	Students felt like the modules were providing real-world application of their learning & that the content would be relevant to future work as engineers	Development of social responsibility in engineers (Canney & Bielefeldt, 2015); Fostering social responsibility in engineering classes (Vanasupa, et al., 2008)

Full Citation	What they did	Scope / Students	Methods	Outcome	Frameworks
J. A. Mejia, D. Chen, M. Chapman, and B. Fledderman, "'Drugs, alcohol, joblessness, and lifestyle': Engineering students' perceptions of homelessness and implications for social justice education," in 2021 American Society of Engineering Education Virtual Annual Conference Content Access Proceedings, Virtual Conference, Jul. 2021. doi: 10.18260/1-2--36531.	Engineering design project in a User-Centered Design course. All students participated in Homelessness & Food Insecurity Awareness Week. First iteration: students tasked with designing a solar water heater for mobile showers for people experiencing homelessness. Second iteration: students tasked with identifying a need related to COVID that affected people experiencing homelessness.	One project in a User-Design course (2 semesters of data) Lower-division Undergraduate Students	Pre-post, open-ended questions	Some shift in the deficit perspectives of students through the course, but the attitudes of some students remained unchanged. Ideology of meritocracy was still prevalent after the project.	
J. A. Mejia, D. Chen, O. Dalrymple, and S. Lord, "Revealing the invisible: Conversations about -isms and power relations in engineering courses," in 2018 American Society of Engineering Education Annual Conference Proceedings, Salt Lake City, Utah, Jun. 2018. doi: 10.18260/1-2--30937.	User-Centered Design course challenged students to generate an engineering design that met the identified needs of a local user. Engineering & Social Justice course challenged students to use writing to analyze historical & societal impacts of engineering in marginalized communities.	Two courses First- or Second- and Third-year undergraduate students	Description of curriculum	N/A	None stated, but courses were designed with a critical pedagogical approach and a transformative agenda
E. Reddy, B. Przestrzelski, S. Lord, and I. Khalil, "Introducing social relevance and global context into the introduction to heat transfer course," in 2018 American Society of Engineering Education Annual Conference Proceedings, Salt Lake City, Utah, Jun. 2018, doi: 10.18260/1-2--29640.	One module considering environmental, economic, social, and bodily contexts in the design of a solar water heater.	One module within a heat transfer course Undergraduate (Senior-level heat transfer course)	Qualitative (observations, student memos, & students' grades)	Students considered contexts to their heat transfer content beyond traditional considerations; most were environmental, rather than economic or social.	

Full Citation	What they did	Scope / Students	Methods	Outcome	Frameworks
B. Reynante, “Learning to design for social justice in community-engaged engineering,” J of Engineering Edu, vol. 111, no. 2, pp. 338–356, Apr. 2022, doi: 10.1002/jee.20444.	Introductory course, laboratory course, field practicum: addressing the issue of affordable lighting in a rural village in the Philippines.	One project from one Community-engaged engineering course Undergraduate	Observations & interviews	Shift in students’ mindset from Design-for-Charity towards Design-for Justice.	Sociotechnical Thinking, Design-For-Justice, 4 key mind shifts in design-for-charity to design-for-justice
S. Turner, P. Hancock, B. Gordon, T. Carroll, and K. Stenger, “Scaffolding social justice in the engineering classroom: Constructing a more restorative, inclusive, engineering practice,” presented at the 2022 American Society of Engineering Education Annual Conference & Exposition, Minneapolis, MN, 2022.	Online learning module & in-class workshop on intersection of social justice & construction design process.	One workshop & online module in a civil engineering course Undergraduate (civil engineering)	Pre-post surveys	Student perceptions of the likelihood of encountering social justice issues, opportunities to address social justice issues, relevance of social justice to engineering, & knowledge about social justice all increased.	No stated framework, but used Social Justice Scale (Torres-Harding et al., 2011)