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# Toward Sociotechnical Engineering Practice: Lessons from a Course Integration Model (IUSE: DUE)

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## Introduction

Engineering work is inherently sociotechnical, with the technologies and processes developed by engineers shaping the world around us and influencing countless facets of daily life. To ensure that engineering innovations benefit, rather than harm, our society and world, engineers must go beyond technical expertise, thoughtfully engaging with the social factors that impact and are impacted by their work. Recognizing this imperative, there is a growing movement to enrich engineering education with sociotechnical knowledge and skills, which include accounting for cultural, economic, environmental, and political contexts, ethical considerations, and human perspectives associated with a given engineering problem [1], [2]. While there have been some noteworthy efforts to promote sociotechnical engineering education (e.g., [3]-[5]), social and contextual aspects of the field still remain underemphasized in the curriculum and often isolated from much of the technical coursework [6]. There is an ongoing need for innovative approaches and resources that help students develop the ability and awareness to practice truly integrative sociotechnical engineering—balancing technical prowess with a keen understanding of the social contexts in which their work is implemented—critical for responsible professional practice.

In one effort to support future engineers' development of sociotechnical engineering knowledge and skills, the Center for Socially Engaged Engineering and Design (C-SED) partners with instructors to develop, adapt, and integrate sociotechnical content in a wide variety of engineering courses. Since its founding in 2015, C-SED has built an extensive collection of research-based sociotechnical content and teaching resources intended to support students' development of understandings of the importance and application of integrative sociotechnical engineering practice. Motivated by the need to gain greater insight into if and how students perceive sociotechnical course content to be relevant and transferable to their future academic and professional work, the present study draws on focus group interviews with undergraduate students who participated in one or more class sessions in which C-SED content was integrated. We leverage these data to answer the following research question: *What do students report gaining from sociotechnical engineering sessions and how, if at all, do they characterize the relevance of this to their future academic and professional work?* Findings from this study also offer transferable insights to other engineering educators engaged in the work of supporting engineering students' development of sociotechnical knowledge and skills that can be translated into their professional practice.

## Background

For many years, educators and researchers (e.g. [7]-[9]), have identified the need for engineering education to better prepare students for the sociotechnical complexity of engineering work, necessitating an ability to account for the ways in which technical aspects of engineering problems both shape and are shaped by various dimensions of the social context in which the problems are situated [1], [2], [10]. Sociotechnical engineering practice necessitates engineers develop both extensive technical know-how while also being able to identify and meaningfully account for social factors such as the perspectives of multiple interested parties, characteristics of contexts and systems in which solutions could be implemented, cultural norms, economic dynamics, environmental considerations and impacts, institutional or governmental policies and regulations, and potential long-term implications of a given decision [2], [11].

Currently, the field of engineering is undergoing substantial change, driven by advances in artificial intelligence and other social and technological forces that are reshaping both employment opportunities for engineering graduates and the wider contexts in which technological solutions are implemented [12], [13]. Scholars contend that, more than ever before, success in engineering professions demands that students acquire not just technological proficiency, but also the ability to recognize and address the social and contextual factors that shape engineering processes and the design and impact of technological systems [14]-[17]. Failure to consider both technical and social and contextual dimensions in engineering work can result in considerable harm, or, at the very least, lead to wasted time and resources when solutions fail to deliver intended outcomes or benefits to users and the broader environment [18]-[20]. Furthermore, a sociotechnical approach to engineering not only increases the likelihood that engineering outcomes positively affect people, communities, and ecosystems – it can also help expand and sustain the engineering workforce [21], [22]. Recent research also indicates that students found lessons highlighting the societal and human impacts of engineering as particularly memorable, deepening their engagement with course content and supporting its perceived relevance to their future careers [3].

While fostering sociotechnical skills and knowledge among engineering students is crucial, significant hurdles remain. Undergraduate engineering education continues to center technical skills and knowledge, perpetuating the long-standing technical/social divide within the discipline, in which social and contextual aspects of engineering work are undervalued and often marginalized relative to technical expertise [20], [23]-[25]. Prior research suggests that students' sense of social responsibility and prioritization of public welfare can actually diminish when engaging with a heavily technocentric engineering curriculum [26]. When social and contextual dimensions are integrated into engineering programs, they are typically confined to a stand-alone course or module [6], [27], [28], and rarely touched upon in the core engineering science courses that play an outsized role in shaping students' views on what engineering work entails [29]. Additionally, many faculty members lack formal preparation for teaching sociotechnical topics [4] and face further obstacles such as the substantial time and energy required to develop lessons that link technical content with relevant social dimensions, as well as institutional reward structures that may not favor investing time in teaching efforts [30]-[33]. Compounding these issues, research indicates that instructors' understanding of the nature and expectations of the professional roles that students are likely to pursue after graduation can be limited, making it difficult to effectively connect sociotechnical learning to the real-world situations students will face [34]. Understanding how students perceive sociotechnical engineering education initiatives and their relevance to their future work is an essential foundation for assessing current strategies to support sociotechnical awareness and identifying new strategies to most effectively prepare students for the sociotechnical complexities of engineering practice.

## Methods

In order to understand if and how students perceive sociotechnical course content to be relevant and transferable to their future academic and professional work, our team conducted a series of five focus group interviews with 16 undergraduate engineering students who participated in one or more class sessions integrating sociotechnical content as part one of their undergraduate engineering courses. Our research is guided by the following research question: *What do students report gaining from sociotechnical engineering sessions and how, if at all, do they characterize the relevance of this to their future academic and professional work?*

The sociotechnical sessions explored in the present study were developed and facilitated by the Center for Socially Engaged Engineering and Design (C-SED) [35]. C-SED has an extensive collection of sociotechnical education resources to support engineers' development of the awareness and skills necessary to account for social and contextual considerations throughout engineering or design problem solving processes. C-SED sessions emphasize the use of real-world examples and are designed to be adapted to the particular goals and content of a given course. C-SED partners with faculty in a variety of ways, including working with instructors to integrate one or more sociotechnical sessions led by C-SED facilitators (the approach highlighted in the present study), offering asynchronous lessons that students can complete independently or supported with coaching and feedback, and sharing resources with faculty to facilitate a C-SED-developed sociotechnical session on their own. C-SED's resources and approaches have and continue to be assessed in multiple ways to ensure their effectiveness and inform continued refinement [36]-[39].

Our team developed a focus group protocol that built on questions from previous research and evaluation efforts and new questions tailored to our present research goals. We sought feedback on an initial draft of the protocol from several colleagues with experience in sociotechnical education initiatives. We used enrollment lists from the undergraduate courses that partnered with C-SED to integrate sociotechnical content to send a recruitment email asking interested students to complete a brief interest form with basic background information and availability. Our team followed up with students based on their availability, inviting them to participate in the focus group. Of the 32 students who completed the interest form, we contacted 26 and a total of 16 students responded and were able to participate. Participants included seven 1st year students, two 2nd years, five 3rd years, and two 4th years whose majors or intended majors (in the case of several 1st year students) included biomedical engineering, computer science, civil or environmental engineering, computer engineering, mechanical engineering, aerospace engineering, industrial engineering, and chemical engineering. Focus groups averaged 36 minutes in length. Recordings of these focus groups were automatically transcribed and checked for accuracy by the author who conducted them. She then used an inductive thematic analysis approach to identify emergent themes related to what students reported learning from sociotechnical training sessions and how they thought about the sessions and sociotechnical skills and knowledge more broadly (including social and contextual dimensions of engineering work) in relation to their future academic and professional work. These themes were then discussed by both authors. This study was approved as exempt by our institution's IRB and students received $40 for their time.

**Findings**

Focus group participants reported the sessions as advancing their understanding of sociotechnical engineering work, particularly as it relates to societal influences on and impacts of problem solving, topics which many students noted were often not stressed in their other courses. As one student articulated, *"For me, the biggest takeaway was that when you think of engineering, you think almost purely technical—you're just building something. But [the sessions] really emphasized that actually building the product is just half the work."* Many students spoke of the way C-SED sessions supported their learning about why and how to consider a broad range of interested parties, including those beyond the end user or investor. One student explained, *"The biggest thing I took away was to not make assumptions about your user... instead use more evidence-based and interview-based practices."* Relatedly, several students spoke of gaining a new awareness of how engineering work may differently consider and benefit different parties and strategies they could leverage to better account for these potential disparate impacts, such as *"engaging in the community and understanding your different potential markets."* Other students explicitly named the C-SED sessions as helping them learn to understand and balance social, contextual, technical, and business considerations. One student described this lesson in the context of material selection, stating: *"You're not just making a technical choice when you're choosing this material. You can see the context that will surround it."* Finally, several students also spoke about how the C-SED sessions prompted them to reflect on their own experiences and role as engineers – including how their own experiences can shape what they attend to and how their actions may influence others. As one student described, *"We were kind of taking the reason that we were engineering for granted... But then kind of taking a step back and realizing… is it actually benefiting the community before we just start doing something randomly out of nowhere."*

Overall, students described the content of the sociotechnical sessions as highly relevant to their engineering work. They appreciated examples of real-world applications of sociotechnical skills and many described C-SED content as aligned with their desires to have a positive social impact in their own future work. One student, explaining a transportation and city planning-related session's alignment with their interests shared, *"We talked about different stakeholder meetings and meetings that have happened. I think that was interesting to think about because you're not getting those experiences in the classroom, and that's a pretty real-world experience."* Another student articulated the session *"felt pretty relevant to something I might do in the future, because I know I want to do something socially engaged."* Several students felt sociotechnical skill sessions might be most relevant once they had the chance to assume leadership positions in their organizations. As one student explained: "*It would definitely help as you move up in industry. At the beginning, you don't have much control over projects, but as a head engineer, you really have to consider whether to allocate the team's energy somewhere. That's when moral considerations become really important."* Several other students felt the sociotechnical sessions gave them greater insight into what professional work might look like. One participant expressed that *"C-SED teaches us what's easy to neglect when thinking about engineering traditionally… They were very informative: 'Here's what your life would look like when you are an engineer, here's what the process looks like.' It felt like a real-world glimpse into what we'll be doing."*

While nearly all participants described gaining useful understandings and skills from the C-SED sessions and many felt such skills would be relevant to their future work, several students also expressed how these sessions felt like a "one-off" within their courses and described ways in which greater integration of sociotechnical content could support deeper learning and application. As one student explained *"I feel it was kind of a one-and-done thing: [C-SED] came in, and then professors just said, 'Okay, keep that in mind as we work forward.'"* Students suggested several ways sociotechnical content could be integrated more deeply, including *"classwork revolving around it or further discussion"* of session topics or support making explicit linkages to students' specific course projects. One student elaborated, stating *"Sometimes it helps if you can say, 'This would be an impactful thing for your project.' Overall,* *the general message - be conscious when you design for people and the environment - was effectively conveyed. But a little personalization might help some students."* Other students expressed an interest in more in-depth connections between C-SED sessions and the particular technical content of their course, with one student explaining *"It'd be cool to see more closely how technical and human-centered content intertwine.*" Finally, students expressed that multiple opportunities to engage with sociotechnical content in the span of a course or even throughout their undergraduate curriculum would be beneficial in shaping their understanding of the sociotechnical nature of their field. One student concluded *"I think the earlier and more consistent we see C-SED is helpful…It's important to have it early on in your engineering as you're like defining your scope and your view as an engineer."* Students suggested that more consistent exposure to sociotechnical topics would help reinforce the relevance of accounting for both technical and social and contextual dimensions in engineering practice.

**Discussion and Implications**

Our findings highlight the ways in which the C-SED sessions advanced or reinforced students' understanding of the sociotechnical nature of engineering work and the skills required to engage in comprehensive problem solving. Often citing the integration of authentic examples and context, many participants characterized the sociotechnical sessions as offering insights into "real-world" engineering practice. Generally, students also noted the sessions' relevance to their future engineering work, though some students articulated that sociotechnical skills felt particularly aligned with the work of engineering leaders and expressed some uncertainty about how entry-level roles might allow them to engage with social and contextual dimensions alongside technical demands. Consistent with well-documented challenges in fully integrating social and contextual considerations in otherwise technically focused curricula [6],[29], some students characterized C-SED sessions as feeling different or disconnected from other content in their individual course and/or throughout their engineering coursework. While sociotechnical content introduced in a single session or course is unlikely to significantly shift students' understanding of what engineering work entails [4], [40], [41], the challenges associated with a content-dense curriculum and limited time and resources for instructors to significantly rework curricula can pose daunting barriers to sociotechnical content integration [30]-[33], [42]. However, integrating even brief interventions that connect technical concepts with relevant social and contextual dimensions—such as a short discussion, homework question, or relevant real-world example—could help reinforce the relevance of sociotechnical skills and knowledge while reducing the burden on any single course or instructor.

Our findings suggest that C-SED's approach to integrating sociotechnical content into existing engineering courses shows promise for supporting students' development of the comprehensive skills needed for their future professional work. At the same time, we recognize that translating attention to social and contextual dimensions into professional practice— particularly in early-career roles that students anticipate will emphasize technical work—remains a challenge. Efforts to support the future engineering workforce in developing and applying sociotechnical skills at the scale required would benefit from structures and resources to connect across individual initiatives and institutions to share knowledge and evidence-based strategies among engineering educators and scholars engaged in this work.

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