

Article

Implementing a Sociotechnical Module on Conflict Minerals in a Large “Introduction to Circuits” Course

Karen E. Nortz ¹, Lea K. Marlor ¹, Musabbiha Zaheer ², Cynthia J. Finelli ^{2,*} and Susan M. Lord ³

¹ Engineering Education Research, University of Michigan, Ann Arbor, MI 48109, USA; knortz@umich.edu (K.E.N.); lmarlor@umich.edu (L.K.M.)

² Electrical and Computer Engineering, University of Michigan, Ann Arbor, MI 48109, USA; mzaheer@umich.edu

³ Integrated Engineering, University of San Diego, San Diego, CA 92110, USA; slord@sandiego.edu

* Correspondence: cfinelli@umich.edu

Abstract

Engineers are often faced with complex problems that require both technical and social expertise. However, typical engineering curricula teach technical skills in isolation, without introducing social issues. To address this gap, we implemented a sociotechnical module that linked the circuits topic of capacitors with the social issue of conflict minerals in a single class session of a large “Introduction to Circuits” course. Using a midterm student feedback survey and student group interviews, we explored students’ responses to the module, their takeaways, and their general attitudes towards sociotechnical content in technical engineering courses. Overall, students found the module to be valuable and relevant, with many noting that it helped them understand real-world engineering practice. While some expressed concern about adding new material to an already content-heavy course, more than half agreed that this type of content is important and that they would like to see more sociotechnical topics in their engineering courses.

Keywords: sociotechnical thinking; social responsibility; electrical engineering



Academic Editor: Carla C. Johnson

Received: 8 August 2025

Revised: 5 September 2025

Accepted: 11 September 2025

Published: 18 September 2025

Citation: Nortz, K. E., Marlor, L. K., Zaheer, M., Finelli, C. J., & Lord, S. M. (2025). Implementing a Sociotechnical Module on Conflict Minerals in a Large “Introduction to Circuits” Course. *Education Sciences*, 15(9), 1243. <https://doi.org/10.3390/educsci15091243>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Engineering education is critical for preparing future engineers to tackle complex global challenges (Erickson et al., 2020; Leydens & Lucena, 2017). However, many undergraduate curricula isolate technical skills from social issues. The National Academy of Engineering emphasizes the inherently sociotechnical nature of many engineering problems (National Academy of Engineering, 1991), highlighting the need to integrate ethics and social responsibility in engineering education (National Academy of Engineering, 2016). This aligns with ABET accreditation criteria, which require engineering programs to demonstrate that students have achieved outcomes addressing ethical, global, cultural, social, environmental, and economic impacts (ABET, 2024).

Beyond these institutional calls for greater sociotechnical integration, research highlights the importance of incorporating social issues into engineering practice and education. Professional engineers must consider public welfare and ethics in engineering (Cech & Finelli, 2024; Colby & Sullivan, 2008; Haws, 2001; Herkert, 2000, 2001), understand the sociotechnical impacts of engineered solutions on society (Conlon, 2008; Jesiek et al., 2019; Riley, 2008), and challenge normative cultural beliefs in engineering (Cech, 2014; Erickson et al., 2020; Faulkner, 2007; Niles et al., 2020). Engineering leaders advocate for undergraduate education that equips students to address sociotechnical issues, thereby

better preparing them for future professional practice (Leydens & Lucena, 2017; Nieuwsma, 2013; Riley, 2008). Providing social context within engineering coursework has also been shown to improve learning (Guloy et al., 2017) and increase student interest (Amelink & Creamer, 2010). Furthermore, Ozkan and Andrews (2022) found that minoritized students value sociotechnical discussions, which foster a broader view of engineering and enhance their sense of belonging. Incorporating sociotechnical topics in engineering curricula is, therefore, crucial for preparing engineering students for the workforce and improving undergraduate education.

1.1. Challenges Integrating Sociotechnical Content

Despite the need for sociotechnical integration, studies have found a lack of sociotechnical content in most engineering classrooms (Bielefeldt, 2018; Colby & Sullivan, 2008; Jesiek et al., 2019; Riley, 2008). Typical engineering courses often emphasize technical skills while neglecting social issues, resulting in the devaluation of nontechnical skills (Claussen et al., 2019). This approach promotes a culture of disengagement (Cech, 2014) by reinforcing the normative cultural belief that engineering is “objective” and by emphasizing the ideologies of both depoliticization (the belief that political and cultural factors should be excluded from the field (Cech, 2013)) and technical/social dualism (the belief that technology-focused skills should take precedence over socially-focused ones (Faulkner, 2000, 2007)). Prioritizing technical skills over social issues has been shown to undermine the confidence and engineering identity of students who value sociotechnical thinking (Hwang et al., 2022) and to create challenges regarding ambiguity and open-ended problems (Blacklock et al., 2021).

Another common approach in many engineering curricula is to isolate nontechnical content (e.g., social issues and ethical considerations) into low-credit, stand-alone courses. This approach also minimizes the perceived relevance of social content, and research suggests that systematically embedding nontechnical content throughout the engineering curriculum can emphasize its centrality to professional practice and foster more meaningful student engagement (Martin et al., 2021). Integrating social issues into traditional engineering courses could help instill a sense of social responsibility in students and challenge normative cultural beliefs in engineering (Cech & Sherick, 2015; Costello, 2006).

Social responsibility refers to a foundational disposition shaping professional skills in ethics and social impact (Canney & Bielefeldt, 2015). Research indicates that students’ sense of social responsibility often declines throughout their undergraduate education (Bielefeldt, 2017; Cech, 2014; Claussen et al., 2021; Leydens et al., 2018; Niles et al., 2020), potentially due to unmet expectations in engineering opportunities to “help” the public. Bielefeldt (2017) and colleagues showed that students initially believed they could help others by applying engineering knowledge; however, this was not typically studied in the undergraduate curriculum. This disconnect is particularly relevant for minoritized students, including women and students of color (Amelink & Creamer, 2010; Bielefeldt, 2021; Klotz et al., 2014). Some researchers (e.g., Riley, 2008; Vanasupa et al., 2009) have proposed leveraging public service narratives to attract and retain a more diverse cohort of engineers. Thus, integrating social issues may also promote a more diverse workforce.

1.2. Approaches to Sociotechnical Integration in Engineering Education

Efforts to integrate social issues can occur at both the curriculum and module levels (Haws, 2001; Hess & Fore, 2018). While curriculum-level changes require broad institutional support and extensive modifications to multiple courses (Chen et al., 2020; Czerwionka et al., 2025; Hoople et al., 2020; Zandvoort, 2008), module-level integration can be a more feasible approach. Defined as micro-insertions by Davis (2006), sociotechnical modules introduce relevant content in small, manageable units without displacing core technical ma-

terial, making the modules appealing to students, instructors, and administrators (Polmear et al., 2021). Modules have been successfully implemented in engineering courses in many disciplines, including electrical engineering, mechanical engineering, and materials science (Gelles & Lord, 2021; Huang & Reddy, 2019; Leydens et al., 2021; Lord et al., 2019).

1.3. Our Sociotechnical Integration Project for Introduction to Circuits

We have developed several sociotechnical modules for the “Introduction to Circuits” course (Finelli & Lord, 2023; Nortz et al., 2025). Circuits is a core course in nearly every electrical engineering (EE) program worldwide, and it is required for students in EE and several other engineering majors. The course typically does not feature sociotechnical content; therefore, introducing social issues in this foundational course can influence how students perceive the potential impact of their work. However, although engineering instructors may recognize the importance of integrating social issues into the course, they may face challenges such as having a primarily technical education and a lack of comfort with more open-ended social issues. Therefore, to make it easier for instructors to use our sociotechnical modules, we also provide comprehensive teaching guides.

In this paper, we explore students’ responses to one of those modules, Conflict Minerals, when it was implemented in a large circuits course at a public, research-intensive university in the Midwestern United States. Our research questions are as follows: (1) How did students respond to the incorporation of sociotechnical content in “Introduction to Circuits?”; (2) What was their perception of the value of this sociotechnical content?; and (3) What were the students’ takeaways from the sociotechnical module? We present data from a midterm student survey and from student group interviews to address our research questions.

2. The Conflict Minerals Module

The Conflict Minerals Module is a one-hour sociotechnical module that explores minerals commonly used in the production of capacitors, typical sources for these minerals, and the way mining them contributes to funding war and conflict. Students focus specifically on the Democratic Republic of the Congo (DRC) and discover that addressing the issues related to conflict minerals is complex.

The Conflict Minerals Module was initially developed by an interdisciplinary team of researchers with backgrounds in EE, biomedical engineering, and anthropology. It has been successfully implemented in a small course at a small private school (Lord et al., 2019). Using backward course design (Wiggins & McTighe, 2005), the module was developed to include technical and social learning objectives and to align those objectives with the instructional activities and assessments of the course. The following learning objectives relate to the social content for the module:

- Define conflict minerals and describe at least two issues surrounding them.
- Describe potential options for engineers concerned with the use of conflict minerals.
- Describe at least two things that might be part of a company’s strategy to reduce reliance on conflict minerals.

The module consists of several components, including a pre-class assignment, in-class activities, and lecture slides with a script for a one-hour class session. In addition to the lecture content, the module includes optional homework and exam questions as well as a group project that involves researching a tech company’s conflict minerals policy.

Before the session, students complete a pre-class assignment. They calculate the amount of tantalum (a conflict mineral) in one cell phone and estimate the total amount of tantalum in all smartphones globally. Then, they search the internet to identify the three nations that mine the most tantalum.

During the class session, the instructor reviews the pre-class assignment and discusses how it illustrates the large impact of the tantalum mined for the global cell phone market. Then the instructor provides a context for the complex conflict by presenting some background and history of the DRC. Towards the end of the class session, students form small groups, reflect on the big ideas they have learned in class, and brainstorm ways they can address these issues as engineers.

Besides homework and exam problems assigned by the instructor, students have the option to complete a project in which they select a company from Samsung, Apple, Intel, or IBM, and describe the products the company manufactures, the way the company uses conflict minerals, and the company's published strategy for reducing its reliance on conflict minerals. (Following the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 ([Securities and Exchange Commission, 2012](#)), companies in the United States are required by law to have a responsible minerals policy.) Students then evaluate the completeness and reliability of the data and critique at least one aspect of the company's strategy. After completing their research, students connect with a classmate who researched a different company, and the group compares how the two companies are reducing their reliance on conflict minerals.

3. Materials and Methods

Here, we examine how the Conflict Minerals Module was used in a large "Introduction to Circuits" course at a research-intensive university in the Midwestern United States during Fall 2023. The course includes two 90-minute class sessions per week, a one-hour discussion section, and a two-hour laboratory section. At this university, the course is a requirement for majors in EE and computer engineering, and it is also taken by students from other engineering majors as one of several options to fulfill a circuits requirement for their degrees. The five most enrolled majors in this course are EE (25%), computer engineering (25%), aerospace engineering (11%), mechanical engineering (11%), and computer science (8%). During the semester under study, 308 students enrolled in two sections of the circuits course: 164 students in Section 1 and 144 students in Section 2. Of the 210 students who consented to using their data for our study, 55% identified as white, 30% as Asian, 4% as Black or African American, 4% as Middle Eastern or North African, and 7% as Bi- or Multi-racial. Additionally, 6% of the students identified as Hispanic or Latino/a/x. Regarding gender identity, 31% identified as women, 65% as men, and 3% as non-binary or gender queer. Because these data reflect only those students who provided consent, they may not be representative of the class as a whole.

The Conflict Minerals Module was facilitated by a tenured full professor in EE with over thirty years of experience teaching EE courses. The course instructor did not help in developing the module content, but he met with our research team several times prior to facilitating the module to ensure his comfort with the content. He facilitated the module during week seven of the 15-week semester, just after the capacitor was introduced. The instructor asked students to complete the pre-class assignment, followed the script provided in the teaching guide, recorded the class session to allow students who missed it to view it later, and assigned the project as an optional, extra-credit assignment. Attendance was low on the day the module was facilitated, but was typical of other class sessions based on the instructor's observations. A total of 106 students were in attendance (54 for Section 1 and 52 for Section 2).

We collected various data before and after the module facilitation. For this paper, we analyze data from a tailored midterm student feedback survey that students completed in class immediately following the module and from group interviews conducted with students who participated in the session.

3.1. Midterm Student Feedback Survey

On the day of the module facilitation, the course instructor requested that a consultant from the university's teaching and learning center conduct a midterm student feedback (MSF) session (Finelli et al., 2011). The consultant (not associated with the instructor or the research team) observed the module facilitation, and then the instructor left the room while the consultant conducted the MSF session to collect feedback about the Conflict Minerals Module. The MSF session consisted of small group discussions, a report-out session, and a brief MSF survey. The MSF survey asked students to rate their level of agreement, using a Likert-scale, with six statements about the module and to explain any of their answers by responding to an open-ended item. All 106 students completed the MSF survey, and 85 (80%) offered explanations in the open-ended item, while 21 (20%) provided no comment. We calculated descriptive statistics (mean and standard deviation) for the six Likert-scale items, as well as the percentage of students indicating "agree" or "strongly agree" with each (see Table 1).

Table 1. MSF survey results.

Please Rate Your Agreement with the Following Statements, Using the Scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = Strongly Agree		Mean (M)	Standard Deviation (SD)	Percent Who Agree or Strongly Agree
1.	The conflict minerals case study added value to the course.	3.8	1.1	69%
2.	The pre-course assignment provided adequate background for me to engage in the class discussion.	3.9	0.84	83%
3.	After this class, I can define conflict minerals and describe at least two issues surrounding them.	4.3	0.91	93%
4.	After this class, I can describe at least two things that might be part of a company's strategy to reduce its reliance on conflict minerals.	4.1	0.96	86%
5.	I have a deeper understanding of the sociotechnical aspects of engineering because of the conflict minerals case study.	4.2	0.89	90%
6.	I would like to have more opportunities to learn about sociotechnical aspects of engineering in this course.	3.5	1.2	57%

3.2. Student Group Interviews

Students who attended one of the two class sessions were invited to participate in a one-hour structured group interview about their general impressions of the Conflict Minerals Module and the inclusion of sociotechnical content in their technical courses. We conducted two in-person group interviews (G1 and G2, see Table 2) with a total of six participants and provided a gift card for their participation.

Table 2. Group interview participants.

Pseudonym (Group Number)	Gender	Race	Major	Year in School
Daniel (G1)	Male	White	Electrical Engineering	2
David (G1)	Male	White	Aerospace Engineering	4
Alec (G1)	Male	White	Aerospace Engineering	3
Eliza (G1)	Female	White	Electrical Engineering	2
Sarah (G2)	Female	White, Other	Electrical Engineering	2
Robert (G2)	Male	Black or African American	Electrical Engineering	2

We recorded the group interviews and transcribed them for analysis, utilizing inductive coding (Saldaña, 2021) to analyze the data. Researchers collaborated to develop a codebook through several rounds of analysis of G1, after which the final codebook was applied to both G1 and G2. Findings from the student group interviews clustered into three main categories: (1) student responses to the module; (2) student takeaways from the module; and (3) student thoughts about sociotechnical content in the engineering curriculum, and in each category two or three themes emerged.

4. Findings

Here, we use the categories and themes (Table 3) that emerged from the student group interviews to organize our results. In support of each theme, we include data from the Likert-scale items of the MSF survey (Table 1), sample responses from the open-ended MSF survey item, and representative quotes from the group interviews (note, we removed disfluencies, such as “like” and “um” to improve the clarity and readability of the quotes).

Table 3. Categories and themes for group interviews.

Category	Theme
Student responses to the module	Most students found the module valuable
	Students’ attitudes included empathy, detachment, and cynicism
	Most students found the module relevant to the course content
Student takeaways from the module	Students report meeting learning objectives
	Students saw connections to the engineering workplace
Student thoughts about sociotechnical content in the engineering curriculum	Many students expressed interest in more sociotechnical content
	Students were concerned about adding content to an already full course

4.1. Student Responses to the Module

4.1.1. Most Students Found the Module Valuable

Student responses to the module were generally positive, with many students expressing that they saw the value in the Conflict Minerals Module. Most students (69%) agreed or strongly agreed with the statement “The conflict minerals case study added value to the course” ($M = 3.8$, $SD = 1.1$). In the open-ended responses, students noted that they found the material valuable, stating, for instance, “*This was a valuable and new experience,*” and “*The case study was engaging and provided valuable insight into one of the many aspects of a product that engineers need to consider.*”

The group interviews provide further insight. All group interview participants expressed that they saw value in the content and thought it was interesting, new to them, and important to learn. For example, Eliza said,

“I thought it was interesting. It’s nothing I’d ever learned about before, and part of me was like: ‘Why are we doing this?’ But . . . it’s important to learn because it’s a real issue.”

This statement captures the initial mixed response that many students had when seeing the new sociotechnical material. While students found the content unfamiliar, they appreciated its relevance and real-world applications.

Some students struggled with the broadness of the conflict minerals issue and wished the lecture offered a clear-cut answer for solving the problem. Some stated that the problem

was so big and distant that they felt there was nothing that they could do to help the situation. For example, Sarah said,

“This is important. Someone needs to do something about it. . . .One person can’t make a difference, and so it has to be like a collective. . . .It’s not something that falls on an individual alone, because it can’t be something that could be solved for an individual.”

Additionally, participation in the optional extra-credit assignment suggests that students valued the module. Out of the 308 students enrolled, 206 students (approximately 67%) opted to complete the extra-credit assignment. This high participation rate could be interpreted as enthusiasm for the module content or as a more pragmatic desire to earn extra credit in a challenging course. Regardless, the fact that a large portion of the class engaged with the extra credit suggests that, at the very least, students recognized the potential benefits of exploring sociotechnical topics outside of the regular course material. Some students in the group interviews also discussed the optional extra-credit assignment, saying that they enjoyed it and appreciated the opportunity to learn more. For example, Robert said, *“The extra credit was more meaningful and actually made me learn more about it.”*

4.1.2. Students’ Attitudes Included Empathy, Detachment, and Cynicism

During the group interviews, student attitudes about the Conflict Minerals Module ranged from empathy to detachment to cynicism. Some students expressed empathy for the situation in the DRC. For instance, Sarah reflected on the broader implications of engineering work, saying,

“I guess for me personally, the conflict minerals kind of made me think of the broader spectrum of how some of the technologies we develop here affect the rest of the world.”

This sentiment was also echoed in some of the open-ended responses of the MSF survey, with one student saying, *“It was interesting to not only see how components work but how our decisions impact many people.”*

Some students in the group interviews expressed detachment, some of which was directed toward their perceived inability to affect real change. They felt powerless in the situation. For instance, Alec reflected on how the war in the DRC may impact him, saying,

“Why and how does this lecture affect me? Why and how does what’s going on in the Congo directly affect me? And because of that, I might have a lapse (and other people may have a lapse) of social feeling of responsibility to do something about it.”

In the open-ended responses in the MSF, one student also expressed a level of detachment when brainstorming potential solutions, saying,

“While this topic does give a brief look into the socioeconomic issues behind the materials we use, I feel as though it doesn’t equip us with ideas on how to really solve these issues in those contexts: as engineers, our solutions (even the ones we mostly came up with) were based on the material and not on the conflicts of the country that produces it.”

Other students in the group interviews expressed cynicism, particularly when completing the extra-credit assignment. They thought companies were disingenuous when stating they wanted to make improvements regarding conflict minerals. For example, when talking about how this module impacted his perspective on the social responsibilities of engineers, Alec said,

“For Intel, I feel like a lot of the reason why they were doing it was less because they actually cared, and more that it was just good to say they’ve done it,. . .like marketing and [saying]: ‘Oh well look at us. We get our semiconductors in a good way. Buy from us.’”

4.1.3. Most Students Found the Module Relevant to the Course Content

Overall, students thought the sociotechnical content was relevant when asked during the group interviews. Some students discussed how they thought the lecture and assignments were relevant to what they were learning in class and to being an engineer. They appreciated how the assignment helped them learn what it would be like to be an engineer. Alec said,

“It felt like an actual engineering problem that someone would email to you at a company where you have to understand the problem from a . . . technical background. To solve the problem, you’re gonna have to talk to people and you’re gonna have to comply with what other people want, so it felt more like an actual engineering problem.”

This comment highlights the value of the module in helping students understand how engineering problems involve navigating social and ethical concerns. It indicates that, for some students, the module helped bridge the gap between theoretical knowledge and practical, real-world problem-solving in engineering.

While most students saw relevance in the Conflict Minerals Module, there was a wide range of responses regarding the use of class time from positive to mixed to negative. For instance, *“This was honestly great to talk about, . . . very happy that we covered this subject”* and *“I thought it was beneficial to see how some of the concepts we learn about in class (like capacitors) impact the world in a real and social way”* to *“It was an interesting topic but kind of felt unnecessary with all the new content going on”* and *“I think it’s cool, but one class isn’t enough”* to *“This class period was useless,”* and *“I could have slept in instead.”* In the group interviews, only Robert questioned the module’s relevance, particularly the pre-class assignment. He described it as “busy work” and noted that while it provided some context, it did not seem directly applicable to class discussions. However, the rest of the class did not seem to share this sentiment, with the majority (83%) agreeing or strongly agreeing with the following statement: *“The pre-course assignment provided adequate background for me to engage in the class discussion”* ($M = 3.9$, $SD = 0.84$), and some commenting that they found the pre-class assignment useful. For example, one student said, *“The pre-class assignment was not overly challenging, but it provided a good background to why the mineral in question (Tantalum) is so valuable and helped a lot in the lecture.”*

Some of the mixed reactions may stem from the way the module was facilitated in the course. Some students expressed feeling unprepared for a different type of lecture. However, Sarah mentioned that she appreciated the instructor’s care for the material, which helped her become more invested in the content, saying, *“I think he did a pretty good job putting emotion into it, ‘cause you could tell he cared about what was going on.”* Nevertheless, she found the sudden shift to new content jarring, going on to say,

“Yeah, I don’t know if he told us that we were gonna be doing that in class. . . I didn’t really understand what the goal was with the assignment, I thought it was just an extra credit opportunity and then I didn’t even know it was gonna go any further, so I guess a better introduction to what was coming probably would’ve been helpful to take it more seriously.”

This sentiment was also reflected in some of the open responses of the MSF survey, where one student commented, *“I would have preferred a warning as to what this class was about. I was thrown off on what this lecture would be about and thought it would be more content based.”* Another wrote, *“The material was really interesting, but I don’t know if now was the right time to talk about it. It might have been better at the beginning or end of the term, just not right in the middle of learning confusing technical content.”* This sentiment signals a sense of disconnection from the typical content presented in the course. Together, these responses

suggest that while many students recognized the module's relevance, some struggled with the shift from typical course content.

4.2. Student Takeaways from the Module

4.2.1. Students Report Meeting Learning Objectives

From the MSF survey and group interviews, students reported achieving the learning objectives for the social content of the Conflict Minerals Module. Most students (93%) agreed or strongly agreed with the statement "After this class, I can define conflict minerals and describe at least two issues surrounding them" ($M = 4.3$, $SD = 0.91$). Additionally, most (86%) agreed or strongly agreed with the statement "After this class, I can describe at least two things that might be part of a company's strategy to reduce its reliance on conflict minerals" ($M = 4.1$, $SD = 0.96$). Furthermore, 90% agreed or strongly agreed with the statement "I have a deeper understanding of the sociotechnical aspects of engineering because of the conflict minerals case study" ($M = 4.2$, $SD = 0.89$). These results suggest that students not only retained key concepts but also recognized the broader implications of their work as engineers.

Students in the group interviews also demonstrated that they had achieved the module's learning objectives. All of them described the different things they learned from the module at various points, all were able to define conflict minerals in their own words, and many discussed specifics that were covered in the lecture. For example, Robert described conflict minerals as *"minerals that are used in semiconductors and a lot of technology that are currently and . . . have a history of being sourced unethically."*

4.2.2. Students Saw Connections to the Engineering Workplace

A common theme from both the group interviews and open-ended MSF survey is that students appreciated seeing how the concepts they learned in class connect to the "real world." For example, one student in the survey said, *"I really enjoy this type of lecture because I am able to connect the technical concepts that I learn with real world issues."* Students also appreciated gaining a broader understanding of what they might need to consider when making decisions as an engineer. Another student in the survey wrote,

"I believe the issues brought up in the discussion greatly impact our views as engineers and encourage [us] to consider more than just the direct outcomes of our work. We should be able to identify other world problems that arise from things we build."

In the group interview, Alec said,

"A lot of people going through school don't realize that you can't just be an engineer and blindly just work away at a circuit board or something. You actually have to think, 'What's going on this circuit board? Where is it coming from?' . . . You have to think about the supply chain and where things are coming from, which you don't normally think about but you have to keep in mind. . . So I feel like this lecture did a good job of describing how these things affect an engineer's life."

Additionally, students felt that engineers should be aware of the different consequences that can arise when making these decisions. Daniel said,

" . . . understanding that the decisions you make as an engineer can have consequences, whether that be the material you use, the design you create, or anything else, [is important]. Anything that you do is gonna have a consequence, and I think it's important to weigh those consequences against what you're doing and what you're creating. I think that's the main takeaway I got."

While students completed the MSF survey immediately following the module facilitation, the group interviews took place more than a month after that class session. Thus,

the group interviews represent students' longer-term memories and understandings of the course material. The Conflict Minerals Module clearly made a lasting impression on the students we interviewed; they were able to recall specific details about it and understood how it could relate to their work as engineers.

4.3. Student Thoughts About Sociotechnical Content in the Engineering Curriculum

4.3.1. Many Students Expressed Interest in More Sociotechnical Content

Although faculty may expect students to resist sociotechnical content in engineering courses, we observed more positive responses. Most students (59%) agreed or strongly agreed with the statement "I would like to have more opportunities to learn about sociotechnical aspects of engineering in this course" ($M = 3.5$, $SD = 1.2$). Some open-ended comments also shared this sentiment, with one student saying,

"I would like more opportunities to learn about sociotechnical aspects of engineering. I think it's a quite underused presentation topic in classes, but whenever it is used, I find a lot of value in it. I feel understanding sociotechnical issues in engineering will help me to become a more effective and empathetic engineer, and will allow me to truly make a difference in the world in my design work."

Another student in the survey also wished there were more opportunities for sociotechnical content in their courses, saying,

"I feel this class was great overall. It really showed the societal impacts of engineering. It also allowed us to brainstorm how we as engineers can play a role in preventing some of these humanitarian crises within conflict areas. All in all, I really enjoyed the structure of this lecture and hope to see more lectures of this type in the future."

In group interviews, students were also positive about incorporating sociotechnical content into their course. They appreciated that the material was connected to social issues and that their work as engineers could truly impact people. For example, Eliza said,

"I think it's important, because you're relating the material you're learning to a real issue, which I guess in some cases can help you remember it better. But it's also like you can get funneled into the technical aspect and not realize that it's a real thing that you have to experience."

Daniel further supported this perspective, advocating for the inclusion of sociotechnical discussions in engineering curricula. He said,

"It almost should be required to have at least one class session that goes over the social issues of the topic of the field or whatever. . . I think you need to be able to relate what you are doing to how it affects the population in mass instead of just the small group in the classroom."

4.3.2. Students Were Concerned About Adding Content to an Already Content-Heavy Course

Despite having generally positive attitudes toward the module, some students noted that the course already had a full workload and were concerned about the addition of more content. Some discussed the possibility of including social content as an add-on discussion section to avoid detracting from the material they deemed important. Robert said,

"You could have a separate discussion that's only half a semester instead of a whole semester. . . Maybe you do assignments in there and it's just extra credit, so it's an incentive to go and learn about the impacts instead of just having one day in class."

In the open-ended MSF survey responses, several students expressed a similar idea, stating that content such as the Conflict Minerals Module should be taught in different courses. For example, one student said, *"... maybe this shouldn't be done in a circuits class."*

Another said, “I understand why these topics should be covered, but it feels like something that could be a 1-credit engineering ethics class instead.” One student thoughtfully commented on the balance of technical and social content in the class, saying,

“I agree that this lecture was incredibly informative and important. As future engineers, it is our responsibility to understand the socioeconomic impacts of our work and try to develop products and processes that reduce harm to humanity. However, I picked undecided [on the survey] on having more opportunities for this type of lecture as I don’t want to compromise our coverage of the traditional . . . material. I think this is something we could probably do 1–2 more times throughout the semester, but I would like to avoid having to speed through content to allow for this.”

Other students in the group interviews expressed concern that the instructor was adding social issues to the course without removing any content, noting that they lacked the time and mental capacity to thoroughly consider different issues. David said,

“You can’t expect us to do everything at once . . . If [the faculty] want . . . talk about social issues then we need to make the space for people to be able to take that seriously.”

Some students in the open-ended MSF survey responses also questioned whether class times should be used for sociotechnical content. While many recognized the importance of the topic, several responses expressed concern about adding more content when they could be focusing on the difficult concepts of the course. One student remarked, “I think this is a good topic, but it is hard to pay attention when more time could be spent on course material.” Another response echoed this sentiment, stating, “I agree that the issue is important, but I feel we would have been better off using the time to review difficult course material.” While students generally recognized the value of the module, some viewed the material as secondary to the technical aspects of the course.

5. Discussion

Overall, students valued the Conflict Minerals Module in their “Introduction to Circuits” course, and they reported achieving the learning objectives related to the sociotechnical content for the module. They also demonstrated an increased understanding of the social and ethical dimensions of engineering, indicating that the module successfully broadened their perspectives, introduced them to social aspects of engineering, and reinforced a sense of social responsibility. Students were able to articulate the ethical and social implications of engineering decisions and to describe how the module prompted them to reflect on the broader consequences of engineering work. Although there was some understandable variation, most students said that the module was relevant to the circuits’ content and that they would like to see more sociotechnical content in their technical classes. Students described how the module helped prepare them for the real world of engineering. These sentiments are all important for achieving several of the required student outcomes for ABET accreditation that are often challenging for instructors and supporting students in transitioning to the workforce.

There was some reluctance to add more material to an already content-heavy course. Two students in the group interviews indicated that they would have preferred the sociotechnical content to be an optional or supplementary part of the course or even a separate course. In the open-ended MSF survey responses, several students expressed that while they considered the content important, they did not view it as the best use of class time. This perspective is consistent with prior research, which suggests that engineering students often prioritize technical training over social content, especially when social content is not included in assessments (e.g., [Cech & Sherick, 2015](#)). These findings reflect the cultural bias in engineering education, where technical content often outweighs social issues and

further reinforce the technical/social dualism (Cech, 2013; Faulkner, 2000, 2007; Gelles et al., 2021; Gelles & Lord, 2021). This resistance also aligns with expectancy violation theory (Burgoon, 2015), which posits that discomfort might arise when expectations shaped by past experiences are disrupted. For many students, the module challenged past experiences and assumptions that engineering coursework should be objective, apolitical, and technical (Cech & Sherick, 2015). This may have led some students to feel uncertain about its place in the curriculum. In doing so, these students not only expressed concerns about the workload but also contributed to reproducing the cultural norms of the field by framing ethical and social engagement as optional, also reinforcing the technical/social dualism (Costello, 2006).

This study also emphasized the importance of students' perceptions regarding their instructor's attitude toward sociotechnical content. As Sarah said in the group interview, she appreciated that the instructor cared enough to introduce the module and felt that students may be more likely to engage with sociotechnical topics if they perceive these topics as being supported and valued by their instructors. However, some students also voiced concerns about the delivery of the module, noting that the content felt disconnected from the rest of the class. These findings suggest that instructor framing plays a key role in shaping how students engage with and value sociotechnical content in their engineering classes. Since the way students perceive what is primary or secondary material is influenced by how instructors present and frame the content, the instructor's approach can significantly impact students' engagement and valuation of the material.

Students in both the group interviews and the midterm student feedback form provided recommendations on how to improve the facilitation of the module. One recommendation was to implement the module at either the beginning or end of the course. We chose not to adopt this recommendation as we feel it is important for students to see how the module directly connects to the technical course content. In this case, the module is connected to the topic of capacitors, and thus it should be situated after capacitors are introduced, rather than at the beginning of the course. Another recommendation was to provide a clearer introduction to help students transition from the traditional technical material to the sociotechnical content of the module, further emphasizing the importance of instructor framing. In response, we revised our instructor preparation plans to encourage instructors to preview the coming shift so students are better prepared. A third recommendation was to devote more time to discussing challenging sociotechnical topics. To address this concern, in future instructor preparation meetings, we will emphasize the importance of allotting sufficient class time for discussion. A fourth was to increase the weight of the module in the course grade to incentivize engagement. We will support this suggestion by encouraging instructors to include module-related questions on homework and exams, signaling to the students that this content is valued. Another recommendation by some students was to relegate this material to a low-credit, stand-alone ethics course. We intentionally reject this suggestion, as prior research indicates that students see these courses as secondary, and instead, ethics and sociotechnical issues should be integrated into core engineering courses (Martin et al., 2021), taught by regular course instructors, even if they are not "experts" in the area. As instructors grow more comfortable embedding sociotechnical material, student resistance may diminish, and students may eventually come to expect such integration. A final recommendation is to incorporate sociotechnical content more regularly throughout the semester, which we view as a promising direction for our work.

6. Limitations

This study has limitations that impact the interpretation of its findings. First, there was low attendance during the facilitation of the module. While 306 students were enrolled in the course, only 106 attended the session when the sociotechnical module was facilitated. However, this level of attendance was not unusual for the course—attendance was not required, the instructor did not take attendance, all sessions were recorded and posted to the class website, and the professor mentioned he had been experiencing attendance difficulties throughout the semester. Many students who did not attend the lecture but watched the video did participate in the extra-credit assignment; exploring their motivations could be interesting. Second, student learning objectives were self-reported, as we have not yet analyzed student work to directly assess whether students achieved the learning objectives. Future research could analyze student homework solutions and the optional extra-credit assignment to address this gap.

Third, the group interview data also has limitations. Only six students participated, and their voluntary involvement suggests that they may have particularly strong opinions. Additionally, their demographics may not be representative of the course overall. As a result, their views may not be generalizable to the entire class. Furthermore, the group interviews were conducted by the course teaching assistant, which may have influenced students' responses. Despite these limitations, this study provides valuable insights into the integration of sociotechnical content in engineering education.

7. Conclusions

In a large “Introduction to Circuits” course, we implemented a one-hour sociotechnical module on conflict minerals. Overall, students recognized the importance of the Conflict Minerals Module, acknowledging its relevance to real-world engineering practice and ethical decision-making. Students expressed appreciation for the opportunity to engage with broader social issues and demonstrated an increased awareness of the consequences of engineering decisions beyond technical problem-solving. Some students felt that, while the material is important to learn, it should not be added to a course that is already content-heavy.

Students reported achieving the module's learning objectives, stating that they could define conflict minerals. Given that most students in the group interviews reported not being aware of conflict minerals previously, this is an important result. Students reported that they gained a deeper understanding of the sociotechnical aspects of engineering because of this module, and 57% expressed a desire for more opportunities to learn about sociotechnical aspects of engineering.

We recognize that a single, one-hour module cannot fully address the need for sociotechnical education in engineering curricula, but it is an important step in the right direction. Providing students with opportunities to engage with these topics can help cultivate a mindset that considers the broader implications of engineering work, increase social responsibility, and challenge the normative cultural beliefs in engineering. By incorporating more sociotechnical topics in traditional engineering courses, engineering educators can foster a better understanding of the field, one that not only equips students with technical expertise but also prepares them to navigate the ethical and social dimensions of their work.

Author Contributions: Conceptualization, C.J.F. and S.M.L.; methodology, C.J.F. and S.M.L.; formal analysis, K.E.N., L.K.M., M.Z., C.J.F. and S.M.L.; data curation, L.K.M. and M.Z.; writing—original draft, K.E.N. and L.K.M.; writing—review & editing, K.E.N., L.K.M., M.Z., C.J.F. and S.M.L.; supervision, C.J.F. and S.M.L.; project administration, C.J.F. and S.M.L.; funding acquisition, C.J.F. and S.M.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the United States National Science Foundation (NSF), grant number 2235576 and 2233155. Any opinions, findings, conclusions, or recommendations expressed in this material do not necessarily reflect those of NSF.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (IRB) of University of Michigan (protocol code HUM00230337 and date of approval 1 February 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available due to privacy issues and to ensure the confidentiality of the participants.

Acknowledgments: The authors would like to thank the students who participated in and engaged with the conflict mineral module, particularly those who participated in group interviews.

Conflicts of Interest: The authors declare no conflicts of interest.

References

- ABET. (2024, October). *Criteria for accrediting engineering programs, 2025–2026*. Available online: <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2025-2026/> (accessed on 7 August 2025).
- Amelink, C. T., & Creamer, E. G. (2010). Gender differences in elements of the undergraduate experience that influence satisfaction with the engineering major and the intent to pursue engineering as a career. *Journal of Engineering Education*, 99(1), 81–92. [CrossRef]
- Bielefeldt, A. R. (2017, June 24–28). *Disengaging or disappearing? Losing the most socially motivated students from engineering?* 2017 ASEE Annual Conference & Exposition, Columbus, OH, USA. [CrossRef]
- Bielefeldt, A. R. (2018). Professional social responsibility in engineering. In I. Muenstermann (Ed.), *Social responsibility*. InTech. [CrossRef]
- Bielefeldt, A. R. (2021, July 19–26). *Intersectional complexities of race/ethnicity and gender in engineering students' professional social responsibility attitudes*. 2021 ASEE Annual Conference, Virtual. [CrossRef]
- Blacklock, J., Johnson, K. E., Cook, R., Plata, N. A., & Claussen, S. (2021, June 26–29). *Faculty interpretations of sociotechnical thinking in their classrooms: Techniques for integration*. 2021 ASEE Annual Conference, Virtual. [CrossRef]
- Burgoon, J. K. (2015). Expectancy violations theory. In *The international encyclopedia of interpersonal communication* (pp. 1–9). Wiley. [CrossRef]
- Canney, N., & Bielefeldt, A. (2015). A framework for the development of social responsibility in engineers. *International Journal of Engineering Education*, 31, 414–424.
- Cech, E. A. (2013). The (mis)framing of social justice: Why ideologies of depoliticization and meritocracy hinder engineers' ability to think about social injustices. In *Engineering education for social justice: Critical explorations and opportunities*. Springer. [CrossRef]
- Cech, E. A. (2014). Culture of disengagement in engineering education? *Science Technology and Human Values*, 39(1), 42–72. [CrossRef]
- Cech, E. A., & Finelli, C. J. (2024). Learning to prioritize the public good: Does training in classes, workplaces, and professional societies shape engineers' understanding of their public welfare responsibilities? *Journal of Engineering Education*, 113(2), 407–438. [CrossRef]
- Cech, E. A., & Sherick, H. M. (2015). Depoliticization and the structure of engineering education. In *International perspectives on engineering education* (pp. 203–216). Springer. [CrossRef]
- Chen, D. A., Chapman, M. A., & Mejia, J. A. (2020). Balancing complex social and technical aspects of design: Exposing engineering students to homelessness issues. *Sustainability*, 12(15), 5917. [CrossRef]
- Claussen, S., Jesiek, B. K., Zoltowski, C. B., & Howland, S. J. (2021, July 26–29). *Early career engineers' views of ethics and social responsibility: Study overview*. 2021 ASEE Annual Conference, Virtual. [CrossRef]
- Claussen, S., Tsai, J., Boll, A., Blacklock, J., & Johnson, K. E. (2019, June 15–19). *Pain and gain: Barriers and opportunities for integrating sociotechnical thinking into diverse engineering courses*. 2019 ASEE Annual Conference & Exposition, Tampa, FL, USA. [CrossRef]
- Colby, A., & Sullivan, W. M. (2008). Ethics teaching in undergraduate engineering education. *Journal of Engineering Education*, 97(3), 327–338. [CrossRef]
- Conlon, E. A. (2008). The new engineer: Between employability and social responsibility. *European Journal of Engineering Education*, 33(2), 151–159. [CrossRef]
- Costello, C. Y. (2006). *Professional identity crisis*. Vanderbilt University Press.
- Czerwionka, L., Joshi, S. S., Rios-Rojas, G. O., & Davis, K. A. (2025). Developing students' sociotechnical thinking in the humanities-engineering classroom: A treatment versus control study using a scenario-based assessment. *Journal of Engineering Education*, 114(3), e70004. [CrossRef]

- Davis, M. (2006). Integrating ethics into technical courses: Micro-insertion. *Science and Engineering Ethics*, 12, 717–730. [\[CrossRef\]](#) [\[PubMed\]](#)
- Erickson, J., Claussen, S., Leydens, J. A., Johnson, K. E., & Tsai, J. Y. (2020, June 21–24). *Real-world examples and sociotechnical integration: What's the connection?* 2020 ASEE Annual Conference & Exposition, Montréal, QC, Canada. [\[CrossRef\]](#)
- Faulkner, W. (2000). Dualisms, hierarchies and gender in engineering. *Social Studies of Science*, 30(5), 759–792. [\[CrossRef\]](#)
- Faulkner, W. (2007). 'Nuts and bolts and people': Gender-troubled engineering identities. *Social Studies of Science*, 37(3), 331–356. [\[CrossRef\]](#)
- Finelli, C. J., & Lord, S. M. (2023). Integrating sociotechnical issues into the Introduction to Circuits course. In *SEFI 2023—51st Annual Conference of the European Society for Engineering Education: Engineering Education for Sustainability, Proceedings* (pp. 2039–2044). European Society for Engineering Education (SEFI). [\[CrossRef\]](#)
- Finelli, C. J., Pinder-Grover, T., & Wright, M. C. (2011). Consultations on teaching: Using student feedback for instructional improvement. In C. E. Cook, & M. Kaplan (Eds.), *Advancing the culture of teaching on campus: How a teaching center can make a difference* (pp. 65–79). Stylus Publishing.
- Gelles, L. A., & Lord, S. M. (2021). Pedagogical considerations and challenges for sociotechnical integration within a materials science class. *International Journal of Engineering Education*, 37(5), 1244.
- Gelles, L. A., Mejia, J. A., Lord, S. M., Hoople, G. D., & Chen, D. A. (2021). Is it all about efficiency? Exploring students' conceptualizations of sustainability in an introductory energy course. *Sustainability*, 13(13), 7188. [\[CrossRef\]](#)
- Guloy, S., Salimi, F., Cukierman, D., & Thompson, D. M. (2017). Insights on supporting learning during computing science and engineering students' transition to university: A design-oriented, mixed methods exploration of instructor and student perspectives. *Higher Education*, 73(3), 479–497. [\[CrossRef\]](#)
- Haws, D. R. (2001). Ethics instruction in engineering education: A (mini) meta-analysis. *Journal of Engineering Education*, 90(2), 223–229. [\[CrossRef\]](#)
- Herkert, J. R. (2000). Engineering ethics education in the USA: Content, pedagogy and curriculum. *European Journal of Engineering Education*, 25(4), 303–313. [\[CrossRef\]](#)
- Herkert, J. R. (2001). Future directions in engineering ethics research: Microethics, macroethics and the role of professional societies. *Science and Engineering Ethics*, 7(3), 403–414. [\[CrossRef\]](#)
- Hess, J. L., & Fore, G. (2018). A systematic literature review of US engineering ethics interventions. *Science and Engineering Ethics*, 24(2), 551–583. [\[CrossRef\]](#)
- 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. [\[CrossRef\]](#)
- Huang, M., & Reddy, E. (2019, June 16–19). *Board 97: Robots at your service: An entrepreneurial and socio-technical ACL course module*. 2019 ASEE Annual Conference & Exposition, Tampa, FL, USA. [\[CrossRef\]](#)
- Hwang, M. H., Trueblood, E., & Claussen, S. A. (2022, October 8–11). *Engineering identity, Perceptions of sociotechnical education, and views of engineering practice in undergraduate students*. 2022 IEEE/ASEE Frontiers in Education Conference (FIE), Uppsala, Sweden. [\[CrossRef\]](#)
- Jesiek, B. K., Buswell, N. T., Mazzurco, A., & Zephirin, T. (2019, July 10–12). *Toward a typology of the sociotechnical in engineering practice*. 2019 Research in Engineering Education Symposium, Cape Town, South Africa. [\[CrossRef\]](#)
- Klotz, L., Potvin, G., Godwin, A., Cribbs, J., Hazari, Z., & Barclay, N. (2014). Sustainability as a route to broadening participation in engineering. *Journal of Engineering Education*, 103(1), 137–153. [\[CrossRef\]](#)
- Leydens, J. A., & Lucena, J. C. (2017). *Engineering justice: Transforming engineering education and practice*. John Wiley & Sons, Inc.
- Leydens, J. A., Johnson, K. E., & Moskal, B. M. (2021). Engineering student perceptions of social justice in a feedback control systems course. *Journal of Engineering Education*, 110(3), 718–749. [\[CrossRef\]](#)
- Leydens, J. A., Johnson, K. E., Claussen, S., Blacklock, J., Moskal, B. M., & Cordova, O. (2018, June 24–27). *Measuring change over time in sociotechnical thinking: A survey/validation model for sociotechnical habits of mind*. 2018 ASEE Annual Conference & Exposition, Salt Lake City, UT, USA. [\[CrossRef\]](#)
- Lord, S., Przestrzelski, B., & Reddy, E. (2019, June 16–19). *Teaching Social Responsibility in a Circuits Course*. ASEE Annual Conference & Exposition, Tampa, FL, USA. [\[CrossRef\]](#)
- 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. [\[CrossRef\]](#)
- National Academy of Engineering. (1991). *Engineering as a social enterprise*. National Academies Press.
- National Academy of Engineering. (2016). *Infusing ethics into the development of engineers*. National Academies Press.
- Nieusma, D. (2013). Engineering, social justice, and peace: Strategies for educational and professional reform. In J. C. Lucena (Ed.), *Philosophy of engineering and technology* (Vol. 10, pp. 19–40). Springer. [\[CrossRef\]](#)
- Niles, S., Contreras, S., Roudbari, S., Kaminsky, J., & Harrison, J. L. (2020). Resisting and assisting engagement with public welfare in engineering education. *Journal of Engineering Education*, 109(3), 491–507. [\[CrossRef\]](#)

- Nortz, K. E., Finelli, C. J., & Lord, S. M. (2025, November 2–5). *WIP: Piloting three new sociotechnical modules for an 'Introduction to Circuits' course*. 2025 IEEE/ASEE Frontiers in Education Conference (FIE), Nashville, Tennessee.
- Ozkan, D. S., & Andrews, C. (2022, June 26–29). *Perspectives of seven minoritized students in a first-year course redesign toward sociotechnical engineering education*. 2022 ASEE Annual Conference & Exposition, Minneapolis, MN, USA. [CrossRef]
- Polmear, M., Bielefeldt, A. R., Canney, N. E., Swan, C., & Knight, D. W. (2021, July 26–29). *Student perceptions of an ethics intervention—Exploration across three course types*. 2021 ASEE Annual Conference, Virtual. [CrossRef]
- Riley, D. (2008). Engineering and social justice: Synthesis lectures on engineers, technology, and society. In *Engineering and social justice: Synthesis lectures on engineers, technology, and society* (Issue 1). Morgan and Claypool.
- Saldaña, J. (2021). *The coding manual for qualitative researchers*. SAGE Publications Ltd.
- Securities and Exchange Commission. (2012). *Conflict minerals—Overview*. U.S. Securities and Exchange Commission. Available online: <https://www.sec.gov/rules-regulations/2012/08/conflict-minerals> (accessed on 7 August 2025).
- Vanasupa, L., Stolk, J., & Herter, R. J. (2009). The four-domain development diagram: A guide for holistic design of effective learning experiences for the twenty-first century engineer. *Journal of Engineering Education*, 98(1), 67–81. [CrossRef]
- Wiggins, G., & McTighe, J. (2005). *Understanding by design* (expanded second ed.). Association for Supervision and Curriculum Development.
- Zandvoort, H. (2008). Preparing engineers for social responsibility. *European Journal of Engineering Education*, 33(2), 133–140. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.