Board 321: Integrating Sociotechnical Issues in Electrical Engineering Starting with Circuits: Year 1

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Abstract

This NSF-funded Division of Undergraduate Education (DUE) Improving Undergraduate STEM Education (IUSE) project aims to integrate sociotechnical issues in electrical engineering (EE) curricula beginning with the Introduction to Circuits class. To prepare graduates for the workforce, instructors must help students address the sociotechnical nature of engineering. Most engineering instructors have been educated with a deep technical focus, have little experience outside of engineering, and feel ill-equipped to integrate sociotechnical issues. In this project, we aim to make it easier for engineering instructors to include sociotechnical issues in their courses by developing modules (with detailed teaching guides and instructional resources) for the introduction to circuits course.

In year 1, we developed and refined modules on (1) conflict minerals and (2) the circular economy and electric vehicle (EV) batteries. We piloted both modules in one of the principal investigator's (PI's) classes at the University of San Diego (USD) a small private institution with about 20 students and one module at the other PI's large public institution (University of Michigan) with over 150 students. We developed a survey which we administer at the beginning and end of the semester to assess students' attitudes toward social responsibility and engineering. We will use student feedback to refine the modules and explore the experiences of the engineering instructors and students who engage with them. Further, we will assess the effectiveness of the modules at reinforcing technical content, promoting students' sense of social responsibility, and disrupting students' adherence to normative cultural beliefs.

We are recruiting a cohort of EE graduate students to assist in developing additional modules. After pre-piloting each new module at a small private institution and piloting it at a large public research institution, we will scale it to other large circuits courses across the country.

This project will provide a model for developing sociotechnical modules to be used in traditional engineering classes that can be adapted by other instructors. Including such content in a fundamental course like circuits sends a powerful message about what is valued by the field, and that message can have a significant impact on students.

Motivation

This NSF-funded Division of Undergraduate Education (DUE) Improving Undergraduate STEM Education (IUSE) project aims to integrate sociotechnical issues in electrical engineering (EE) curricula beginning with the Introduction to Circuits class. In the undergraduate curricula, engineering is often taught from a purely technical perspective. However, real-world problems are interdisciplinary and involve complex social impacts. To prepare graduates for the workforce, instructors must help students address the sociotechnical nature of engineering. Accrediting organizations such as ABET stress the importance of sociotechnical issues and require undergraduate programs to consider global, cultural, social, environmental, and economic

factors in student outcomes [1], as do licensing agencies such as the National Society of Professional Engineers (NSPE) [2] and profession societies such as IEEE [3].

Most engineering instructors have been educated with a deep technical focus, and though many see the value of addressing sociotechnical issues, they have little experience outside of engineering and feel ill-equipped to integrate these topics in the curriculum. In this project, we aim to make it easier for engineering instructors to include sociotechnical issues in their courses by developing modules (with detailed teaching guides and instructional resources) for the introduction to circuits course, each emphasizing a different sociotechnical issue, leveraging fundamental circuits topics, and introducing students to potential subdisciplines in their field.

Research Plan

With a cohort of graduate students, we will develop a series of new modules. We will pre-pilot each module at a small private institution (University of San Diego), pilot it at a large public research institution (University of Michigan), and then scale it to other large circuits courses.

Our research questions include

#1 How can graduate students apply proven course design practices to effectively integrate sociotechnical issues into an introduction to circuits course?

#2 What is the impact of the modules on students' sense of social responsibility and their adherence to normative cultural beliefs? How do these impacts vary by race and sex?

#3 To what extent do our course materials assist engineering instructors in implementing sociotechnical modules into their introduction to circuits courses?

To address these research questions, we developed a survey that we will administer at the beginning and end of each semester in which a module is facilitated to assess students' attitudes toward social responsibility and engineering. We will use student feedback to refine the modules and explore the experiences of the engineering instructors and students who engage with them. Further, we will assess the effectiveness of the modules at reinforcing technical content, promoting students' sense of social responsibility, and disrupting students' adherence to normative cultural beliefs.

Activities

Modules

Official funding for this grant began in May 2023. Prior to that, one member of the research team (SML) had developed a module on conflict minerals (Module 1) and implemented it in her class of about 20 students [4, 5]. In addition, the research team had begun to develop a second module about EV batteries and the circular economy (Module 2) [6]. Details on the learning objectives, assessments, and instructional activities are shown in Table 1 for Module 1 and Table 2 for Module 2.

Table 1 Details on Module 1 on Conflict Minerals

Learning objectives	Assessments	Instructional activities
Analyze capacitors as electrical devices Define conflict minerals and describe at least 2 social issues surrounding them Describe where conflict minerals are used Describe potential options for engineers concerned with societal implications of conflict minerals	Complete calculations and internet research about conflict minerals List concerns about companies' strategies for reducing reliance on conflict minerals Prepare and deliver presentation about conflict minerals policies and societal implications	Learn about and discuss conflict minerals and their societal implications Investigate strategies used by several common companies to reduce reliance on conflict minerals Present research about conflict minerals' policies

Table 2 Details on Module 2 on Electric Vehicle (EV) Batteries

Learning objectives	Assessments	Instructional activities
Design a voltage divider for a DC source to illustrate repurposing EV battery packs Estimate energy available in end-of-life EV batteries Describe societal risks introduced by recycling EV batteries that could be alleviated by applying circular economy principles	List various societal risks introduced by recycling EV batteries Write about how principles of the circular economy can be applied to repurposing EV batteries Use a voltage divider to calculate power of a second life EV battery pack Estimate the effect of energy degradation on EV battery repurposing	Listen to a podcast about the circular economy and answer questions Estimate energy demand that could be met by existing end-of-life EV batteries Learn how the circular economy relates to circuits' concepts and EV batteries Discuss ways to use the circular economy to repurpose batteries

In Spring 2023, a graduate student from the University of Michigan presented the first version of Module 2 to a small group of student volunteers at the University of San Diego. Overall, the students found the module interesting and informative, and their feedback was incorporated into the module before it was presented to a class of 20 students on the following day. During the module facilitation, students were actively engaged in the discussions. They recorded their impressions about the module at the end of the sessions by listing one thing they like about the module and one suggestion for improvement.

Students liked the discussions, the calculations, and consideration of the circular economy as a current issue, and thought the presenter did a good job. They also provided several suggestions for improving the module including considering the pacing and topics to add. Sample comments from students are included in Table 3.

Table 3 Feedback from students after EV module

Things students liked about the module	**Suggestions students had for improving the module**
• The discussions and activities went really well. • Group discussions were helpful. • Enjoyed calculations and real applications so we could see it wasn't as theoretical. • The pictograph of the circular economy • Very good flow, I liked the issue arrow potential solution arrow issue with potential situation, all bases covered. • Second life to batteries and more use out of them • Considerations of current issues • I liked it • You did a very good job, the presentation was very well paced. • Detailed sociotechnical considerations.	• Felt frantic at end? • Maybe add a little overview of how EV batteries are made and how they work etc. • I'd be interested to hear about different batteries and how they are used and recycled. • A couple more details about how remanufacturing works/video • Current industry demands? But I think that's outside the scope. • info on current state of the power grid with such an increase in EVs • (add) more discussion over how much longer the EV battery will run, how efficient, distances etc. • (add) More into where exactly parts of the batteries go in second life stages and disposal. • (add) Manufacturing processes, battery engineering, what is the importance of state of charge etc. • Changes to the infrastructure needed. How much? • I want to see a big map showing where certain minerals came from

Two students also participated in interviews after the module to discuss their reactions to it. These students found the module interesting and impactful. For example,

- "I think if more people knew about [topics like this EV module] and it was brought to the attention of more people, especially like our generation of engineers, it would be really helpful towards the future."
- "… [the EV module] definitely made me consider going into something that does more with like sustainability and stuff like that."
- "... I came in hating electrical engineering, like it was just not for me. So I think like actually doing the voltage divider and using that for like sustainability purposes and the

circular economy was really cool to like actually be like, okay, the stuff we're learning is like being used for something …. I liked that part of it."

- "… we are a part of the issue if we don't decide to fix it."

We have also conducted the first module at the University of Michigan with over 150 students. We administered our student survey at the beginning and end of the semester, conducted a midterm student feedback session to identify strengths and areas for improvement, and several students participated in focus groups after the module. These results are still being analyzed.

Recruiting a Cohort of Sociotechnical Electrical Engineering Stars (SEES)

We are recruiting a cohort of EE graduate students, *Sociotechnical Electrical Engineering Stars (SEES),* from across the USA to assist in developing new modules. We sent out information on how to apply to the SEES cohort in Fall 2023 to multiple divisions of ASEE, the IEEE Education Society, our Advisory Board, and other individuals in our network. Interest in the SEES cohort is high, as we received more than 40 eligible applicants by the deadline. Our next steps involve selecting the cohort (we had originally planned for four students in the SEES cohort, but we are hoping to be able to accommodate more than that). We aim to recruit a diverse group of students for our SEES cohort, and since our project team is currently comprised of White women, we are particularly interested in recruiting students of color.

The SEES cohort will learn about proven course design practices (e.g., backward course design [7, 8]) and sociotechnical topics, will collaborate to propose a series of possible sociotechnical modules for the *Introduction to Circuits* course, and will prepare several modules, including learning objectives, instructional activities, and post-class assessments with homework and exam questions for each module. We expect that the SEES cohort will establish a sense of shared community as the graduate students tackle the challenging tasks related to developing the modules.

The cohort of graduate students will participate in an in-person SEES Summit in May 2024 to learn about the project, course design, and sociotechnical issues. They will collaborate virtually to develop the modules throughout the summer and will attend an online showcase in August 2024 to present details about and further refine the modules. Throughout the process of developing the modules, students will receive coaching and feedback from the research team to help them refine their proposed modules.

External Advisory Board (EAB)

Throughout our project, we will also engage an External Advisory Board (EAB) to supplement the expertise of the project team.

1. Angela Bielefeldt, PhD, Civil Engineering, University of Colorado at Boulder, is an engineering education scholar with expertise in social responsibility and assessing it. She has

developed instruments we plan to draw from in this work [9, 10, 11].Dr. Bielefeldt helped with our survey development and will provide insights on data analysis. She has helped distribute our call for the SEES cohort.

2. John Booske, PhD, ECE, University of Wisconsin-Madison, has been chair of a large EE department and has taught introduction to circuits. He has a demonstrated interest in motivating faculty to implement effective pedagogies, and he is well-connected to other EE departments across the USA. He has helped distribute our call for the SEES cohort and will help identify EE faculty to launch our modules.
3. Denise Simmons, PhD, Civil Engineering, University of Florida, is an engineering education scholar with expertise in preparing graduate students for faculty positions and the workforce, particularly those from historically marginalized groups [12, 13, 14]. She has helped distribute our call for the SEES cohort and will help develop strategies to mentor them.

Our EAB will ensure that our project is meeting its research and dissemination goals in a timely and useful manner. The EAB meets annually to evaluate and advise the team about the progress of the project. At the first meeting of our board in January 2024, we summarized progress of the grant to date, reviewed our plans for the agenda for the May 2024 SEES Summit, discussed the current survey and focus group results to date, and brainstormed strategies for mentoring the graduate student cohort.

Dissemination and Products

In year 1, we have shared our work with the larger international engineering education community at the 2023 European Society for Engineering Education (SEFI) Conference in Dublin, Ireland [15] and the 2023 Frontiers in Education conference in Texas, USA [16]. Our work was enthusiastically received at both of these venues with several people indicating an desire to receive updates about our modules and stay informed through an electronic interest form (tinyurl.com/circuits-modules).

Conclusions

Successfully implementing these sociotechnical modules in a range of different contexts will enhance the likelihood of widespread adoption. This project will provide a model for development of sociotechnical modules in traditional engineering classes which can be adapted by other instructors. Circuits is typically the first course in the electrical engineering curriculum and enrolls students from many disciplines. Thus, inspiring other engineering instructors to implement these modules has the potential for far-reaching influence on the field. We believe that including such curricula in a fundamental course such as circuits sends a powerful message about what is valued by the field, and that message can have a significant impact on students.

Acknowledgments

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