

Work-in-progress: Sociotechnical modules for the Introduction to Circuits Course

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Abstract—In this work-in-progress, we outline a new National Science Foundation-funded project to help engineering instructors integrate sociotechnical issues into their circuits' classrooms. Inspiring electrical engineering (EE) instructors to implement our sociotechnical modules has the potential to achieve far-reaching influence on the field. The modules address the need for sociotechnical curricula in the middle years, when students are forming their engineering identities, and can be used to help students achieve key ABET outcomes related to ethical, global, cultural, social, environmental, and economic considerations that are often challenging for faculty to address. Working with a team of EE graduate students and applying proven principles of backward course design, we aim to develop and test several sociotechnical modules for the Introduction to Circuits course. Each module will be linked to technical topics addressed in the course and emphasize a different sociotechnical issue such as conflict minerals used for electronics components or recycling electric vehicle batteries. We will assess the effectiveness of the modules at reinforcing the technical content of the course and at promoting students' sense of social responsibility and we will prepare detailed teaching guides that will allow instructors to easily use the modules in their own contexts.

Keywords—circuits, sociotechnical, electrical engineering

I. INTRODUCTION AND BACKGROUND

The U.S.'s National Academy of Engineering asserts that many of today's Grand Challenges are inherently sociotechnical [1] and calls for engineering educators to integrate a sense of ethics and social responsibility throughout the undergraduate curricula to better prepare students to solve those challenges [2]. ABET accreditation criteria further stress the importance of addressing sociotechnical issues and require engineering undergraduate programs to include learning outcomes that address ethical, global, cultural, social, environmental, and economic impacts [3]. The National Society of Professional Engineers also stresses the preparation of engineering graduates to address sociotechnical issues in their work [4].

In addition to these calls for more attention to sociotechnical issues, research has demonstrated its importance. For instance, research has shown the need for professional engineers to be able to address public welfare and ethics in engineering [5] – [9], to understand the sociotechnical impacts of engineered solutions on society [10] – [13], and to

recognize the need to disrupt normative cultural beliefs in engineering [9], [11], [14] – [16]. Further, engineering leaders argue that, to better prepare students for future professional practice, engineering undergraduate education should integrate the abilities to address sociotechnical issues, solve multidimensional and interdisciplinary problems, and serve diverse communities [13], [17] – [19].

Despite the need to integrate sociotechnical issues, typical engineering undergraduate curricula prioritize calculations and mathematical modeling, focus on the technical domain, and often exclude social issues. Studies about perceptions of and methods for integrating sociotechnical topics in engineering education curricula (e.g., [5], [12], [13], [20] – [23]) have identified social issues as missing from most traditional engineering classrooms.

Integrating sociotechnical issues into engineering undergraduate education can occur at both the curriculum and module level [6], [7], [24] – [26]. We believe that, when deployed early in the undergraduate curriculum (i.e., in an introduction to circuits course for electrical engineering (EE) majors), sociotechnical modules will promote student's sense of social responsibility while also disrupting their adherence to normative cultural beliefs. In this work-in-progress, we introduce our project.

II. THIS PROJECT

A. Modules

Our project aims to help engineering instructors integrate sociotechnical issues into their already full technical courses, particularly those courses in the critical middle years of the engineering curriculum when students are forming their identities as engineers [27]. We specifically focus on *Introduction to Circuits*, a course that addresses many technical topics but typically disregards the larger social context. *Introduction to Circuits* is a required course for EE students across the U.S. and is often required for other engineering majors. It is the first course focused on EE in the curriculum, and students typically enroll during their second year. Owing to its highly analytical, mathematical, and abstract nature, the course is often unpopular, particularly for students who are not majoring in EE [28] – [30].

Drawing from lessons learned in our previous work, we will adapt a Conflict Minerals module [31] for large courses (it was previously used in small courses). Then we will develop, pilot, and test three other modules. Each module will emphasize a different sociotechnical issue (e.g., social considerations in recycling electric vehicle (EV) batteries) and each will leverage fundamental circuits topics (e.g., capacitors or voltage dividers). We expect that the modules will reinforce the technical content of the course, promote students' sense of social responsibility and disrupt their adherence to normative cultural beliefs. By preparing detailed teaching guides including lecture notes, homework problems, and exam problems, we aim to make it easy for engineering instructors to adopt the sociotechnical modules in their own circuits course.

B. Research Questions

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?

C. Project Plan

We will recruit a cohort of EE graduate students to assist in developing and testing the modules, and we will deploy each of the modules using a four stage process: (1) pre-pilot the module in a small circuits course (15-20 students enrolled) taught by one of the researchers at a small private school, (University of San Diego) (2) pilot the module in one section (80-120 students enrolled) of a large circuits course taught by one of the researchers at a large public school (University of Michigan), (3) launch the module in other sections of the large circuits course at University of Michigan taught by other instructors, and (4) launch the modules in at least four other courses outside of the researchers home institutions. Demonstrating that these modules are effective in a variety of college settings will provide evidence that they can be used in others.

Materials for each module will include learning objectives, instructional activities (pre-class and in-class materials), and post-class assessments (problems for homework and exams). We will employ proven course design practices (e.g., [32], [33]), refine the modules using feedback from students and instructors, and assess the effectiveness of the modules at reinforcing the technical content of the course, promoting students' sense of social responsibility, and disrupting students' adherence to normative cultural beliefs. With all these materials, we hope that other instructors will be able to continue

to incorporate these modules into their courses after the grant funding has ended.

D. Graduate Student Cohort

To assist in developing the sociotechnical modules, we will recruit a cohort of EE graduate students from across the U.S. The cohort will learn about proven course design practices and sociotechnical topics, will collaborate to propose a series of possible sociotechnical modules for the *Introduction to Circuits* course, and will ultimately prepare several modules. Establishing a cohort will create a sense of community as the graduate students tackle the challenging tasks related to developing the modules and will allow us to incorporate more perspectives. Since our project team is currently comprised of White women, we are particularly interested in recruiting students of color, so we will issue a broad application call, especially targeting minority-serving institutions. To aid in selecting participants for the cohort, we will administer a diagnostic survey to collect applicants' demographic information and to assess their baseline knowledge about social issues in engineering, familiarity with social responsibility, and level of preparedness for teaching EE.

The cohort of graduate students will participate in an in-person meeting at the beginning of the Summer of 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 a second meeting at the end of Summer 2024 to present details about and further refine the modules. Throughout the process, students will receive coaching and feedback from the research team to help them refine their proposed modules. We plan for the graduate students to present a paper about their modules engineering education conferences and will assist in facilitating a workshop for other instructors to teach these modules at an upcoming ASEE Annual Conference & Exposition.

E. Module Impact

We will study student responses on the post-class assessments (homework and exam questions) to assess the effectiveness of the modules at reinforcing the technical content of the course and achieving the course learning objectives. Specifically, we will review student solutions to the relevant homework assignments and exam questions and will summarize student responses to open ended reflection prompts. This will allow us to refine the modules to be more effective and to generate evidence that they are (or are not) achieving our goals.

To evaluate the impact of our sociotechnical modules on students' social responsibility attitudes and their adherence to normative cultural beliefs, we will develop and administer a student survey instrument as a pre- and post-course assessment measure. The survey will include a combination of validated survey items as well as demographics items. We will draw from the Engineering Professional Responsibility Assessment (PSRDM) instrument (EPRA; [34]) and a survey that explores engineers' training in professional responsibilities [35].

III. PROGRESS AND NEXT STEPS

We have begun working on this National Science foundation-funded project to help engineering instructors integrate sociotechnical issues into their circuits' classrooms. A graduate student from one of our institutions has developed a module to address sustainability and elective vehicle (EV) batteries [36]. In May 2023, the student piloted a module on sustainability and electric vehicle (EV) batteries in one of the researcher's classes at USD with 20 students. Students were enthusiastic about the module, particularly appreciating how it incorporated the concept of voltage dividers, included interactive components, and was relevant to current topics.

In Fall 2023, we will pilot one module (Conflict Minerals) at the University of Michigan with 80-100 students. Feedback from this offering will be used to improve the module for future offerings. In 2023-2024, we will be recruiting our graduate student cohort. Their work will begin in Summer 2024. We will be recruiting EE instructors outside of our institutions to implement the modules in 2025-2026.

We look forward to the continuation of this project and hope it will contribute to changing the culture of electrical engineering education.

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REFERENCES

- [1] National Academy of Engineering, *Engineering as a Social Enterprise*. Washington, D.C.: National Academies Press, 1991.
- [2] National Academy of Engineering, *Infusing Ethics into the Development of Engineers*. Washington, D.C.: National Academies Press, 2016.
- [3] ABET, "Criteria for Accrediting Engineering Programs, 2021-2022," Oct-2020. [Online]. Available: <https://www.abet.org/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/>
- [4] L. Vanasupa, K. C. Chen, and L. Slivovsky, "Global Challenges as Inspiration: A Classroom Strategy to Foster Social Responsibility," *Sci. Eng. Ethics*, vol. 12, no. 2, pp. 373–380, 2006.
- [5] A. Colby and W. M. Sullivan, "Ethics Teaching in Undergraduate Engineering Education," *J. Eng. Educ.*, vol. 97, no. 3, pp. 327–338, 2008.
- [6] R. Foley and B. Gibbs, "Connecting Engineering Processes and Responsible Innovation: A Response to Macro-Ethical Challenges," *Eng. Stud.*, vol. 11, no. 1, pp. 9–33, 2019.
- [7] D. R. Haws, "Ethics Instruction in Engineering Education: A (Mini) Meta-Analysis," *J. Eng. Educ.*, vol. 90, no. 2, pp. 223–229, 2001.
- [8] J. L. Hess and G. Fore, "A Systematic Literature Review of US Engineering Ethics Interventions," *Sci. Eng. Ethics*, vol. 24, no. 2, pp. 551–583, 2018.
- [9] S. Niles, S. Contreras, S. Roudbari, J. Kaminsky, and J. L. Harrison, "Resisting and Assisting Engagement with Public Welfare in Engineering Education," *J. Eng. Educ.*, vol. 109, no. 3, pp. 491–507, 2020.
- [10] E. Conlon, "The New Engineer: Between Employability and Social Responsibility," *Eur. J. Eng. Educ.*, vol. 33, no. 2, pp. 151–159, 2008.
- [11] J. Erickson, S. Claussen, J. A. Leydens, K. E. Johnson, and J. Y. Tsai, "Real-world Examples and Sociotechnical Integration: What's the Connection?," in *ASEE Annual Conference & Exposition*, 2020.
- [12] B. K. Jesiek, N. T. Buswell, A. Mazzurco, and T. Zephirin, "Toward a Typology of the Sociotechnical in Engineering Practice," in *Research in Engineering Education Symposium*, pp. 597–606, 2019.
- [13] D. Riley, "Engineering and Social Justice," *Synth. Lect. Eng. Technol. Soc.*, vol. 3, no. 1, pp. 1–152, 2008.
- [14] E. A. Cech and H. M. Sherick, "Depoliticization as a Mechanism of Gender Inequality among Engineering Faculty," in *ASEE Annual Conference & Exposition*, 2019.
- [15] G. L. Downey, J. C. Lucena, and C. Mitcham, "Engineering Ethics and Identity: Emerging Initiatives in Comparative Perspective," *Sci. Eng. Ethics*, vol. 13, no. 4, pp. 463–487, 2007.
- [16] W. Faulkner, "Dualisms, Hierarchies and Gender in Engineering," *Soc. Stud. Sci.*, vol. 30, no. 5, pp. 759–792, 2000.
- [17] C. Baillie, A. L. Pawley, and D. Riley, Eds., *Engineering and Social Justice*. Purdue University Press, 2012.
- [18] J. A. Leydens and J. C. Lucena, *Engineering Justice: Transforming Engineering Education and Practice*. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2017.
- [19] D. Nieuwsma, "Conducting the Instrumentalists: a Framework for Engineering Liberal Education," *Eng. Stud.*, vol. 7, no. 2–3, pp. 159–163, 2015.
- [20] A. R. Bielefeldt, "Professional Social Responsibility in Engineering," in *Social Responsibility*, I. Muenstermann, Ed. InTech, 2018, pp. 1–21.
- [21] T. Børsen, Y. Serreau, K. Reifschneider, A. Baier, R. Pinkelman, T. Smetanina, and H. Zandvoort, "Initiatives, Experiences and Best Practices for Teaching Social and Ecological Responsibility in Ethics Education for Science and Engineering Students," *Eur. J. Eng. Educ.*, vol. 46, no. 2, pp. 186–209, 2021.
- [22] M. Forbes, O. Dalrymple, S. M. Lord, C. Baillie, G. D. Hoople, and J. A. Mejia, "The Engineering Exchange for Social Justice (ExSJ): Advancing Justice through Sociotechnical Engineering and Equitable Partnership Exchanges," in *ASEE Annual Conference & Exposition*, 2021.
- [23] B. Williams and J. Trevelyan, *Engineering Practice in a Global Context*. CRC Press, 2013.
- [24] D. A. Chen, M. A. Chapman, and J. A. Mejia, "Balancing Complex Social and Technical Aspects of Design: Exposing Engineering Students to Homelessness Issues," *Sustainability*, vol. 12, no. 15, p. 5917, 2020.
- [25] G. D. Hoople and A. Choi-Fitzpatrick, "Drones for Good: How to Bring Sociotechnical Thinking into the Classroom," in *Synthesis Lectures on Engineers, Technology, and Society*, vol. 9, Morgan & Claypool Publishers, pp. i–148, 2020.
- [26] H. Zandvoort, "Preparing Engineers for Social Responsibility," *Eur. J. Eng. Educ.*, vol. 33, no. 2, pp. 133–140, 2008.
- [27] S. M. Lord and J. C. Chen, "Curriculum Design in the Middle Years," in *Cambridge Handbook of Engineering Education Research*, Cambridge University Press, pp. 181–200, 2014.
- [28] S. Bell and M. Horowitz, "Rethinking Non-major Circuits Pedagogy for Improved Motivation," in *ASEE Annual Conference & Exposition*, 2018.
- [29] Q. Malik, P. Mishra, and M. Shanblatt, "Learning Barriers In Service Courses A Mixed Methods Study," in *ASEE Annual Conference & Exposition*, 2010.
- [30] J. Song and D. Dow, "Project-Based Learning for Electrical Engineering Lower-Level Courses," in *ASEE Annual Conference & Exposition*, 2016.
- [31] S. M. Lord, B. Przestrzelski, and E. A. Reddy, "Teaching Social Responsibility in a Circuits Course," in *ASEE Annual Conference & Exposition*, 2019.
- [32] G. Wiggins and J. McTighe, *Understanding by Design*, Expanded 2. Alexandria, VA: Association for Supervision and Curriculum Development, 2005.
- [33] J. Biggs, "Enhancing Teaching Through Constructive Alignment," *High. Educ.*, vol. 32, no. 3, pp. 347–364, 1996.
- [34] N. E. Canney and A. R. Bielefeldt, "Validity and Reliability Evidence of the Engineering Professional Responsibility Assessment Tool," *J. Eng. Educ.*, vol. 105, no. 3, pp. 452–477, 2016.
- [35] E. A. Cech, C. J. Finelli, E. Goldenkoff, and T. Davis, "Does Public Welfare Responsibility Training in Engineering Education Shape Engineering Professionals' Reasoning about Ethical Issues?," in *ASEE Annual Conference & Exposition*, 2022. <https://peer.asee.org/40494>
- [36] M. G. Judge, S. M. Lord, and C. J. Finelli, "Development of a Sociotechnical Module Exploring Electric Vehicle Batteries for a Circuits Course," in *ASEE Annual Conference & Exposition*, 2022. <https://peer.asee.org/40831>