BOARD # 272: NSF IUSE Integrating Sociotechnical Issues in Electrical Engineering Starting with Circuits: Year 2

Dr. Susan M Lord, University of San Diego

Susan Lord is Professor and Chair of Integrated Engineering at the University of San Diego. She received a BS from Cornell University in Materials Science and Electrical Engineering (EE) and MS and PhD in EE from Stanford University. Her research focuses on the study and promotion of equity in engineering including student pathways and inclusive teaching. She has won best paper awards from the Journal of Engineering Education, IEEE Transactions on Education, and Education Sciences. Dr. Lord is a Fellow of the IEEE and ASEE and received the 2018 IEEE Undergraduate Teaching Award. She is a coauthor of The Borderlands of Education: Latinas in Engineering. She is a co-Director of the National Effective Teaching Institute (NETI).

Dr. Cynthia J. Finelli, University of Michigan

Dr. Cynthia J. Finelli is the David J. Munson, Jr. Professor of Engineering, a professor of Electrical Engineering and Computer Science, a professor of Education, and and Director and Graduate Chair of Engineering Education Research at University of Michigan In her research she focuses on increasing faculty adoption of evidence-based instruction, identifying ways to better support students with neurodiversities, and promoting students" sense of social responsibility through engineering coursework.

Professor Finelli is a fellow of both the Institute for Electrical and Electronics Engineers (IEEE) and the American Society of Engineering Education (ASEE). She previously served as deputy editor for the Journal of Engineering Education, associate editor for the European Journal of Engineering Education, and associate editor for IEEE Transactions on Education. She founded the Center for Research on Learning and Teaching in Engineering at University of Michigan in 2003 and served as its Director for 12 years.

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This NSF-funded Division of Undergraduate Education (DUE) Improving Undergraduate STEM Education (IUSE) project aims to integrate sociotechnical issues into *Introduction to Circuits*, typically the first course in electrical engineering (EE) for undergraduate students. To prepare graduates for the real-world problems, which are interdisciplinary and involve complex social impacts, 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 professional societies such as IEEE [3].

However, many 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 *Introduction to Circuits* courses by developing modules with detailed teaching guides and instructional resources each emphasizing a different sociotechnical issue and leveraging fundamental circuits topics.

Methodology

Our research plan is to develop modules which integrate technical and social topics related to the *Introduction to Circuits* course. 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. To develop new modules, we worked with a cohort of graduate students.

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?

Successful implementation of these sociotechnical modules in a range of different contexts will enhance the likelihood of widespread adoption and potential for impacting the field of electrical engineering.

Results and Activities for Year 2 (2024)

In year 2 of this project, we implemented our first two modules at different institutions, developed and administered a survey assessing students' perceptions about sociotechnical issues in engineering, recruited and facilitated a cohort of graduate students from across the USA to develop more modules, and presented our work at several international venues.

Modules

Our first two modules explore conflict minerals and the circular economy and electric vehicle (EV) batteries, respectively [4, 5, 6]. In Fall 2023, an instructor who is not one of the principle investigators (PIs) implemented the conflict minerals module in a course of over 150 students at a large public institution. In Winter/Spring 2024, the two PIs each implemented both modules in their own courses: an interdisciplinary engineering course with about 20 students at a small private institution and a typical *Introduction to Circuits* course with over 150 students at a large public institution.

To help address our research questions, we are assessing the impact of these modules in multiple ways. We developed a survey about students' attitudes about sociotechnical issues in engineering which we administer at the beginning and **end** of the semester in courses that use a module. This is described in more detail in [7]. In those same courses we are also conducting focus groups and interviews of students after the semester, interviewing instructors about their reflections, and collecting student work. We are continuing to analyze this data and preparing journal publications.

Cohort of Sociotechnical Electrical Engineering Stars (SEES)

To develop more modules, we recruited a diverse cohort of graduate students from across the USA which we called the *Sociotechnical Electrical Engineering Stars* (SEES). From an enthusiastic response of over 70 applicants, we chose a cohort of 7 diverse graduate students: 3 men and 4 women, 3 in Electrical engineering and 4 in Engineering education research, 4 US Citizens and 4 from other countries.

The SEES cohort gathered in person in May 2024 to learn about the first two modules, typical circuits' learning objectives, the principles of backward course design, and the importance of aligning learning objectives, instructional activities, and assessments [8, 9]. They also brainstormed topics for new sociotechnical modules. They worked over the Summer of 2024 in pairs, with feedback from the PIs, to develop their own sociotechnical modules for the circuits course including detailed instructional guides with learning objectives, homework questions for before and after class, presentation materials (notes and slides), and exam questions. They all presented their modules online at a SEES Showcase in August 2024. Topics are shown in Table 1.

Piloting of three of the modules occurred at the PIs' institutions in Fall 2024 over Zoom with the module designers facilitating the module with volunteer groups of students. Feedback from these students was used to improve the modules. Implementation in the PIs' courses is planned for Winter/Spring 2025.

To address our first research question, we conducted a survey and interviews of the SEES cohort. More details about the experiences of the students in the cohort can be found in [10].

Table 1 Module ideas for SEES Cohort

Topic	Circuits Concepts	Social Concepts
Energy Efficiency	Power vs energy, calculating power	Sustainable Development Goals, efficiency, LED vs lightbulb
Energy Burden	Power vs Energy, calculating power	Energy insecurity, efficiency, LED vs lightbulb
Energy Priority	Open and short circuits, switches	Geographic variation in energy access and stability, determining priority
Real-world voltage sources	Ideal voltage sources, voltage sources in series	Hydrogen Fuel cells, Li-ion batteries, Applications
Lithium Sourcing	Batteries/voltage sources	Environmental and social impacts of Li mining
Power prioritization in Hospitals	Series and Parallel circuits, open and short circuits, calculating power	Red outlets, prioritizing redundant sections
CO_2 Emission in Power Generation	Power factor correction, Power triangle	Geographic variation in CO_2 Emission, Climate change

Dissemination

In year 2, we have shared our work with the larger international engineering education community at the 2024 ASEE Conference in Portland, Oregon, USA [11, 12], 2024 European Society for Engineering Education (SEFI) Conference in Lausanne, Switzerland [6] and the 2024 Frontiers in Education conference in Washington, DC, USA [7]. Our work was enthusiastically received at these venues with several people indicating a desire to receive updates about our modules and stay informed through an electronic interest form (tinyurl.com/circuits-modules). As of January 10, 2025, we have 67 people who have signed up on this form.

We plan to present our work at the EDUCON conference in London, United Kingdom in April 2025. At the 2025 ASEE Conference in Montreal, Canada, we will present in the NSF Grantees session, a paper about the SEES cohort, and facilitate a panel about the experiences of the SEES cohort. We will also facilitate a workshop, "Sociotechnical Modules for the Introduction to Circuits course," sponsored by the Electrical and Computer Engineering (ECE) Division to introduce others to our modules so that they can implement them in their own *Introduction to Circuits* courses in Fall 2025 and Spring 2026.

Acknowledgments

We are grateful for the support of the National Science Foundation through Grants 2235576 and 2233155. We would also like to thank the members of the SEES cohort for their enthusiastic participation. We acknowledge the contributions of Erin Cech, Lea Marlor, Karen Nortz, and Gracie Judge.

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