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Integrating Sociotechnical Issues In The Introduction To Circuits Course

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INTEGRATING SOCIOTECHNICAL ISSUES INTO THE INTRODUCTION TO CIRCUITS COURSE (RESEARCH-PRACTICE)

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ABSTRACT

Engineers frequently encounter sociotechnical issues in their work, so it is critical that they are prepared to address complex, real-world issues that require both technical and social expertise. Engineering accreditation criteria further underscore the importance of understanding sociotechnical issues by expecting engineering undergraduate programs to address ethical, global, cultural, social, environmental, and economic considerations in student outcomes. However, most engineering instructors were educated with a deep technical focus, have little experience outside of engineering, and feel ill-equipped to integrate non-technical topics. As a result, engineering is often taught in the undergraduate curricula from a purely technical perspective, with an emphasis on calculations and mathematical modelling, and without mention of social issues.

In this paper, we outline a new project to help engineering instructors integrate sociotechnical issues into their classrooms. Applying proven principles of backward course design and working with a team of electrical engineering graduate students, 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 each will emphasize a different social issue. We will prepare detailed

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teaching guides so instructors can easily use the modules in their own contexts, and we will assess the effectiveness of the modules.

1 INTRODUCTION

Engineering is often taught in undergraduate curricula with an emphasis on calculations and mathematical modelling and without mention of social issues. But real problems are broader – they are multidimensional and interdisciplinary, and they encompass complex sociotechnical issues [1]–[4]. To prepare graduates for the workforce, instructors must equip students with both technical and social expertise.

Engineering accreditation criteria (e.g., ABET [5] and the European Network for Accreditation of Engineering Education [6]) further underscore the importance of understanding sociotechnical issues by expecting engineering undergraduate programs to address ethical, global, cultural, social, environmental, and economic considerations in student outcomes. Despite these criteria, however, typical engineering undergraduate curricula focus on the technical domain and often exclude social issues [7]–[11]. This focus reinforces normative cultural beliefs about engineering by inherently valuing technical issues and devaluing social ones, supporting the status quo of engineering as “objective”, and obscuring that engineering is done by, for, and with people [12]–[14].

Introducing sociotechnical issues into the engineering classroom can be difficult. Most engineering instructors have been educated with a deep technical focus, and though they may see the value of integrating sociotechnical issues into their courses, they often have little experience outside of engineering and feel ill equipped to integrate non-technical topics. Through this project, we aim to make it easier for engineering instructors to integrate sociotechnical issues into their classrooms.

Specifically, we will apply proven principles of backward course design and work with a team of electrical engineering graduate students to develop and test several sociotechnical modules for the Introduction to Circuits course. Each module will leverage fundamental circuits’ topics and will emphasize a different sociotechnical issue such as conflict minerals used for electronics or issues related to electric vehicle (EV) battery life cycles. We will prepare detailed teaching guides so instructors can use the modules easily in their own contexts, and we will assess the effectiveness of the modules in reinforcing both technical and social content of the module and in promoting students’ sense of social responsibility.

2 THE MODULES

Our sociotechnical modules will each integrate a specific social issue with relevant circuits’ content to help students see engineering as a sociotechnical endeavour. To maximize the learning potential of the modules, we will employ the principles of backward course design – including Understanding by Design [15] and principles of constructive alignment [16]. Accordingly each module will include learning objectives that address both social and technical considerations, post-class assessments (problems for homework and exams), and instructional activities that are all aligned with each other (*Figure 1*).

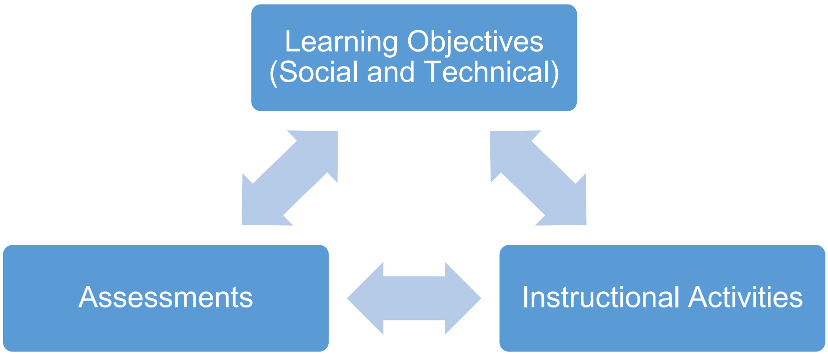

Figure 1. Backward course design

To make it as easy as possible for instructors to integrate the module into their courses, we will develop detailed teaching guides for each. The teaching guides will include sample slide decks, detailed lesson plans, and lecture notes. We will also provide assessment materials (e.g., sample homework problems and exam questions) as well as other resources to scaffold faculty in their use of the module.

2.1 Module 1: Conflict Minerals

As our first module, we will leverage an existing sociotechnical module that focuses on conflict minerals [17] and connects with basic circuits' principles of capacitors. It introduces students to social issues involved with mining of "conflict minerals" (e.g., tantalum, a material frequently used in fabricating the capacitors found in smart phones and other familiar consumer-electronic devices) in the Democratic Republic of the Congo. We outline learning objectives (which include both social and technical considerations), assessments, and instructional activities for this module in Table 1.

Students do some technical calculations related to capacitors, they discuss strategies and challenges faced by circuit designers in light of the social issues related to conflict minerals, and they research and present about different conflict minerals policies of several popular electronics companies. Finally, students make a critical comparison of the conflict mineral policies for various companies and reflect on their role as engineers. Homework for the module is integrated into regular class assignments, and technical calculations as well as oral presentations and discussion are included in the module.

Table 1. Learning objectives, assessments, and instructional activities for Module 1

Learning objectives	Assessments	Instructional activities
• Analyze capacitors as electrical devices • Define conflict minerals and describe at least two social issues surrounding them • Describe where conflict minerals are used • Describe potential options for engineers concerned with the social implications of conflict minerals	• Complete calculations and internet research about conflict minerals • Prepare presentation about conflict minerals policies and social implicatons	• Learn about and discuss conflict minerals and the social implications • Present research about conflict minerals policies

2.2 Module 2: EV batteries

Our second module focuses on issues related to life cycles of EV batteries [18], and it connects with basic circuits' principles of the voltage divider. It introduces students to issues involved with the growing number of end-of-life EV batteries and concerns related to recycling them by applying principles of the circular economy. We outline learning objectives (which include both social and technical considerations), assessments, and instructional activities for Module 2 in Table 2.

Table 2. Learning objectives, assessments, and instructional activities for Module 2

Learning objectives	Assessments	Instructional activities
• Design a voltage divider for a DC voltage source to illustrate repurposing EV battery packs • Estimate the energy available in end-of-life EV batteries • Describe social risks introduced by recycling EV batteries that could be alleviated by applying circular economy principles.	• List various social risks introduced by recycling EV batteries • Write about the principles of the circular economy and how it can be applied to repurposing EV batteries • Use a loaded voltage divider model to calculate voltage, resistance, and 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 some related questions • Estimate and discuss the future voltage capacity of existing EV batteries and the potential demand that could be met using them • Learn about the circular economy and how it relates to circuits concepts and EV batteries • Discuss ways to use the circular economy to repurpose batteries.

2.3 Additional modules

To develop additional modules, we will recruit a cohort of electrical engineering graduate students from across the U.S. We will design a workshop to introduce the cohort to both proven course design principles and the importance of integrating sociotechnical topics into traditional engineering courses. The cohort will then collaborate to propose a series of sociotechnical modules for the Introduction to Circuits course, and they will ultimately prepare detailed teaching guides for each.

We expect that establishing a cohort will introduce diverse perspectives into the module design and will create a sense of community among the graduate students as they tackle the challenging tasks related to developing the modules. Students in this cohort will be able to help recruit instructors to implement the modules at diverse institutions, and they will themselves be prepared to implement the modules in their own courses and to include sociotechnical content in their teaching when they become professors. Using a cohort approach in this way will hopefully increase the likelihood of changing the culture of electrical engineering teaching broadly.

3 ASSESSING THE IMPACT OF THE MODULES

As we introduce our modules, we will evaluate the extent to which they achieve both the social and technical learning objectives. Because we will have applied proven course design principles, we will do this by studying student responses on the assessments. Specifically, we will review student solutions to the relevant homework assignments and exam questions and will summarize student responses to open ended reflection prompts, thereby generating evidence about how well they achieve our learning objectives.

We will also assess the impact of the modules on students' social responsibility attitudes (i.e., their sense of social responsibility and their adherence to normative engineering cultural beliefs). To do so, we will conduct student interviews and focus groups, and we will develop and administer a student survey instrument as a pre- and post-course assessment measure. The survey will include a combination of pre-tested and previously validated survey items as well as demographics items (e.g., sex, race/ethnicity, class level, and field of study). Key components of our survey, include a subset of items from the Engineering Professional Responsibility Assessment instrument (EPRA, [19]) to assess students' social responsibility attitudes and items from a published survey about engineers' training in professional responsibilities [20] to assess students' adherence to normative cultural beliefs.

4 NEXT STEPS

We plan to test and deploy each of the modules using a four-stage process:

1. Pre-pilot the module in a small circuits course at a small, private institution taught by a member of the research team
2. Pilot the module in a large circuits course at a large, public university taught by another member of the research team
3. Launch the module in large circuits courses at the same large, public university taught by an instructor not part of the team
4. Deploy the module in at least four other courses at diverse institution types (including minority-serving institutions and specialty schools)

We will refine the modules at each stage using student and instructor feedback.

Our project is a work in progress. To date, we have developed and pre-piloted Modules 1 and 2. After developing our student survey, we will pilot those two modules and then launch them broadly. We have just begun to formulate our plans for the electrical engineering graduate student workshop, and we will start recruiting students soon. We expect to be able to broadly disseminate our project findings and share detailed teaching guides with instructors across the globe within a few years.

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