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Teaching Social Responsibility in a Circuits Course

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Teaching social responsibility in a Circuits course

Abstract

In an entry-level *Electrical Circuits* course, we designed a series of modules to help engineering students consider the social and ethical implications of electrical engineering. Such implications are particularly evident when we consider the origin of materials that electrical engineers use, the products that they develop, and the lifecycle of those products. Engaging with issues related to social context can seem disconnected from technical course content by both students and faculty because doing so challenges students to engage productively beyond the technical and requires faculty to devote class time to these themes. In this paper, we describe the design and implementation of three modules that integrate technical and social content to enhance student learning: one dealing with conflict minerals in capacitors, a second with design considerations for an innovative solar power source for use in developing nations, and a third with recycling of electronics. Modules included student homework, guest lectures, in-class discussions, and student presentations. Students recognized this material as not deviating from the technical content of the class but rather contributing to their efforts to understand the implications of this technical content. We describe sociotechnical learning modules as well as student response to them and lessons learned by the instructors. For example, one student commented, “I thought it was a really interesting topic that has larger social consequences. It was cool to get away from the stigma of engineers only worrying about math and showing that engineering is able to have effect in other disciplines.” Overall, students felt that these modules enhanced their learning of circuits’ content and was relevant to their training as engineers.

Introduction

ABET accreditation includes requirements to consider social and global impact [1]. Such an awareness is cited by engineering leaders as critical for students’ future professional practice and long-term success with trans-disciplinary problems, as well as their ability to participate in diverse communities, act as informed community members, pursue intellectual and personal development, and engage in work related to social justice [2-7]. In fact, as Vanasupa, Slivovsky, and Chen point out citing the National Society of Professional Engineers’ creed, “social responsibility is at the heart of the Engineer’s Creed embodied in the pledge that we will ‘dedicate [our] professional knowledge and skill to the advancement and betterment of human welfare…[placing] public welfare above all other considerations.’” [8, p. 373] Many of the problems facing humanity today have technical, social, and global aspects. Thus, it is important for engineering educators to help prepare students to be successful in tackling such problems by helping students to see how technical challenges are intertwined with social and global considerations.

There are notable efforts throughout engineering education to help students develop social responsibility. Many curricular efforts throughout Europe are discussed in a section of an issue of the *European Journal of Engineering Education* in 2008 focused on preparing engineers for social responsibility [9] and a special issue of *Science and Engineering Ethics* in 2013 focused on perspectives on teaching social responsibility to science and engineering majors [10]. Canney and Bielefeldt developed a framework for the development of social responsibility for engineers including the development of personal social awareness, the development of professional skills and how they relate to social considerations, and the connection between personal and professional views of obligation or responsibility [11]. Using global challenges as an inspiration, Vanasupa, Slivovsky, and Chen suggest a framework for use in engineering classes [8]. This framework includes five principles: 1) everything is connected, 2) earth is a closed thermodynamic system, 3) make responsible choices early in the design phase, 4) the sun is the earth's energy source, and 5) optimize rather than maximize.

At the University of San Diego (USD), we have undertaken a project with support from NSF Revolutionizing Engineering and Computer Science Departments (RED) funding called "Developing Changemaking Engineers." Our efforts are designed to help students innovate engineering solutions in light of an awareness of how their work relates to peace, sustainability, and social justice. We have begun to reimagine the "engineering canon" across a number of classes by framing engineering as a sociotechnical endeavor rather than a purely technical one. These classes include materials science and engineering, heat transfer, user-centered design, engineering and social justice, and an elective on using drones for peace [12-18].

How can engineering instructors, whose expertise and education has focused on technical topics, incorporate this material into their already full technical classes, particularly courses in the critical middle years of the engineering curriculum such as *Electrical Circuits* [19]? In electrical engineering (EE), *Electrical Circuits*, typically focuses on many technical topics and lacks larger societal or global context. One of the authors, the primary instructor for the course, has taught circuits for many years and has wanted to make the class more relevant for students, particularly those who are not EE majors, and to highlight its implications for social responsibility. This paper describes the design and implementation of three modules that begin to do this. Student and instructor responses are also included.

Course Logistics

At USD, *Electrical Circuits* is a required class for EE, Integrated Engineering, and Mechanical Engineering (ME) majors. It is the first class focused on EE in the curriculum, is typically taken by students in the fourth semester, and includes a separate 3-hour weekly laboratory. In Spring 2018, three modules were implemented in one lecture section of this course with 16 students. Testing in one section offered an opportunity to develop modules before they could be implemented more broadly or the effects of their use evaluated in participating and nonparticipating sections. The instructors were an interdisciplinary team of educators including the instructor for the class, a tenured engineering professor with expertise in EE and Materials Science and two postdoctoral scholars, one with expertise in anthropology and the other in bioengineering. All were familiar with active learning techniques. The modules were designed to creatively integrate social context and responsibility into the classroom while complementing development of engineering technical skillsets. Throughout this course, students worked in semester-long cooperative learning homework teams to complete weekly assignments, and the modules made use of these already formed homework teams. The module activities were part of the required elements of the class, and informed consent was obtained for participation in surveys and interviews. Students who participated in interviews were given a $25 gift card after the interview.

Learning objectives for this course as listed on the syllabus were that students should be able to:

- Apply appropriate mathematics to solve simple electric circuit problems.
- Design circuits and systems that are consistent with stated specifications.
- Design and analyze circuits that are excited by DC, AC, and pulsed signals.
- Apply circuit analysis methods to models of complex systems such as operational amplifiers.
- Use circuit analysis to determine the transient response for first-order and second-order circuits.
- Use and interpret results obtained from circuit analysis software.
- Describe and evaluate their own solutions and those of others with sufficient detail that non-electrical engineers can comprehend.
- Work effectively as a member of a small team.
- Provide and explain how two examples of electrical circuits relate to their everyday lives.

The last objective listed above was added for this section of the course during this offering. In addition, the following specific learning objectives were added relating to Module 1:

- Define conflict minerals and describe at least 2 issues surrounding them
- Describe where conflict minerals are used
- Describe potential options for engineers concerned with the use of conflict minerals

In designing these modules, the instructors wanted to ensure that the social context and technical content fit together to help students see engineering as a sociotechnical endeavor, not as social and technical appreciated separately. We wanted the homework assignments to be integrated into the students' weekly homework rather than something that seemed extraneous, and we wanted to include technical calculations as well as oral presentations and discussion. Another important consideration was that we wanted to help students begin to appreciate the complexity of these social issues without overwhelming them with guilt. We wanted to help them connect these topics to their everyday lives as consumers of electrical circuits.

Module 1: Conflict Minerals

The "Conflict Minerals" module was incorporated in weeks eight and nine of a 15-week semester. It included a homework, interactive classroom experience, group presentations, and discussion. Before the first class, students completed a homework problem where they estimated the amount of Tantalum (Ta) used globally in capacitors within smart phones and identified several countries where Ta is mined. During the discussion in class, the multidisciplinary instructor team introduced students to the definition of conflict minerals, conflicts in the Democratic Republic of the Congo (DRC) including maps of conflict zones and mineral sites where Ta is mined [20, 21, 22], and the connection to capacitors, which were a topic in class. Discussions that connected the price surge for Tantalum to the demand for Sony's PS2 in 2000, as well as contrasting the situation in the DRC with the fictional country of Wakanda from the movie *Black Panther* were used to make these topics relatable to students. Students were then encouraged to consider how they could minimize the use of conflict minerals as engineers. Ideas included recycling, reuse, optimizing designs, synthetic production, and researching alternative materials. For homework, each of the five student teams were assigned a different company's conflict materials policies to research. To help students connect this module to their everyday lives, we chose companies that the students were likely to be familiar with: Apple, IBM, Mitsubishi, Intel, and Samsung. The next week, students presented their findings by describing products made by the company, where they use conflict minerals, their strategy for dealing with conflict minerals, and the students' critique of these strategies. This module is described in more detail in [23].

Student Response: Homework and Midterm Exam

All groups correctly answered the homework problem estimating the amount of Ta used in smart phones around the world and identifying countries where Ta is mined. Overall, the student presentations were informational and showed advanced critical thinking for an introductory circuits class. Although not required in the assignment, every group made sure to have each group member speak.

The second midterm exam was held about one week after this module's implementation in class. The learning objectives for the module were included on the study guide for the students. On the exam, students did well in answering three short questions about conflict minerals related to those objectives. For the first question, students defined conflict minerals. For the second question, students stated a specific conflict mineral and an application of such mineral in electronics. The most common answers given were Tantalum in capacitors or Tin in soldering electronic components or Gold in electronic interconnects. For the third question, students described two potential options for engineers concerned with the use of conflict minerals. Student responses included researching alternative materials (8 responses), advocating for recycling and/or reusing (7), changing design (6), and investigating sourcing (6).

Student Response: Survey Comments

Students were surveyed anonymously about their experiences directly after the "Conflict Minerals" module. In this electronic survey, 12 of the 16 students responded to questions about this module. The last question was open-ended. "Before you go, can you leave us with a short comment about how we addressed the topic of Conflict Minerals?" Students' engagement with this question about their experience was encouraging.

Student comments allowed us to better understand their perception of the module, and suggest that the module integrated social topics into the technically-focused engineering course in ways that students appreciated and understood to be pertinent to their training. One shared *"I think it was addressed well, and I'm really glad you did, it really sparked my interest in issues like that and how we can affect them from an engineering standpoint!"*

Another student reported *"I thought it was a really interesting topic that has larger social consequences. It was cool to get away from the stigma of engineers only worrying about math and showing that engineering is able to have effect in other disciplines."*

Two students went out of their way to thank the instructors outside of class. One wrote an email indicating his enjoyment of the module, and another made the same type of comments in person. This was not, in the instructors' experience, a common way for this population of students to engage outside of the classroom.

Module 2: Electronics Recycling Center (ERC) Tour

To continue the discussion about recycling electronic materials such as Ta, we decided to take the students on a tour of an Electronics Recycling Center (ERC) located on our campus as our second module. This would allow them to explore further what recycling and reuse of electronics involves. In week 11, students participated in a tour of the ERC on campus. We conducted a survey using Google forms to determine times when students could go for a one-hour tour. Despite having only 16 students, we had to take three different groups to accommodate everyone's schedule. All students attended the tour.

ERC staff showed us around and told us about the history of the ERC, its role, and provided insights into the local and global electronics waste problem. The staff described and showed their store-front where they sell items that are in working order, their storage area for items that are sold over the internet, and their area where they determine if items are working and fix if possible. They also showed us the area where they take apart computers by hand and put the components (e.g. motherboards, power supplies etc.) into large Gaylord boxes for distribution to other partners who will recycle them. The ERC partners with a local organization for people with mental disabilities to have them help with taking apart the computers. The ERC staff emphasized that the ERC is really a materials collection center rather than recycling center since they do not have the facilities to process toxic chemicals such as those in cathode ray tubes (CRTs) but then described the numerous partners with whom they work to actually conduct the recycling process. As an added benefit, two of the students in the class got summer internships at the ERC.

Student Response/Assessment

As part of their weekly homework assignment, students completed a memo responding to several prompts that required them to use information from and reflect on their experience. They described the process their TV would go through at the center and after that. In response to the prompt "What stood out to you about your time at the USD Electronics Recycling Center? Describe how this learning can impact you both personally and professionally as a future engineer," about half of the students commented that what stood out to them was the large amount of electronic waste generated in the USA. Several mentioned that they had never been to such a center and never considered "*what has happened to all of my old electronics*."

Some found it inspirational that students from our university had started the ERC.

"It really inspires me knowing that I can still make a difference being a student."

"This was inspiring for me to learn because it illustrates that a group of people just like me can start something that makes a big difference, not just [at USD], but in the entire [city] community and the world as a whole."

When reflecting on the personal aspect of the experience, most students described an interest in considering their habits as consumers more carefully in the future. Envisioning their future careers in engineering, several students mentioned an interest in environmental and social consequences of their designs and attempting to reduce e-waste including investigating ways to improve the overall electronics recycling process.

"This field trip was a much needed experience. I think sometimes as engineers we get so hung up on the bookwork and the hypothetical problems that we forget that these are real processes. We forget that every device we make and material we purchase has an impact on the surrounding community if not the world."

"As engineers we have to think about waste because the environment is just as important as technological advancement."

One student reflected on the responsibility of engineers widening it to be sociotechnical rather than purely technical moving beyond design and into consumer education and end of product life cycle.

"This impacts us as engineers because not only is it our job to design and build these electronics, but it is also our job to make sure people know how to use and dispose of them properly."

Several students were struck by the need to address the problem of e-waste at the design stage, combatting planned obsolescence.

"Over all going there and seeing all of the electronic waste just makes me want to be an engineer who is good at future proofing technology."

"As an engineer I should be developing electronics that can adapt to the growing demands of society instead of designing electronics that are meant to be replaced as soon as they come out to stores because they are already obsolete."

"Professionally, this makes me want to look into ways to improve the recycling process. If a process was able to be created that could recycle e-waste faster than it was produced then instead of just managing the e- waste produced every year there could be efforts to eliminate it completely."

We were pleased that two students explicitly connected this ERC module to the first module on conflict minerals, seeing connectedness in their learning.

"Now that we have learned about conflict minerals in class, the awareness has made me much more conscientious about electronics and the materials in them. Conflict minerals are a huge deal in the electronics world, and major companies may in fact be deceiving consumers about their "conflict free initiatives". ... Are substantial efforts actually being made? I am skeptical as a consumer. From what I could tell from my experience at the electronics recycling center, old electronics materials are being recycled, however it is fairly difficult to extract and reuse conflict materials."

"This lead [sic] me to wonder if as an engineer I could potential[ly] design an electronic component in which if it was to be recycled the process of completely recycling/reusing this component would be more efficient. Also design this component in a way of not needing to use conflict minerals so this process wouldn't be as needed."

This experience also helped some students see connections between their personal values and professional goals as engineers. Since engineering is sometimes seen as conflicting with social responsibility, it is encouraging that students believe these can be connected, *"As a future engineer, this experience provided me with the inspiration to use my knowledge and skills to create a sustainable system to deal with huge issues. It encouraged me to pursue my interests and passions in a manner that benefits society as a whole, and that I do not have to do it alone, I can use the resources of my community and fellow engineers to implement it."*

"As an engineer I want to be consistent with my values of being socially responsible within both my professional and personal life."

Module 3: Responsible Social Innovation

A third module titled "Responsible Social Innovation" was incorporated into the class near the end of the semester. This module centered on the Sunshine Box [24], a product of 17°73° Innovation Company that aims to provide safe and reliable solar power charging for cell phones in countries that do not have stable electrical grids. Connor Hazelrigg, founder of the company, graciously shared practical circuit diagrams with us. For their last homework assignment, students worked in their homework teams and applied what they had learned in the *Circuits* class to calculate some key values for these circuits. This assignment was also an opportunity for students to learn how to find information on data sheets. This is an important skill for the workplace but not always incorporated into this first EE class. In this homework assignment, students calculated the voltage for two voltage divider circuits, calculated the current in an LED given voltage and resistance of items in series with the LED, identified the color of an LED from its datasheet, and predicted if a MOSFET would turn on based on the calculation of voltage at the gate. They compared capacitor values in a part of the Sunshine Box circuit to those in a sample circuit provided on the datasheet and speculated why they might be different. Note that the students had previously learned about voltage dividers but not transistors or LEDs.

For the second to last class period of the semester, the founder came to class and shared her experiences. She began by introducing herself and the Sunshine Box. Then she reviewed the students' responses to their homework questions and clearing up some confusion. The Sunshine Box uses Aluminum capacitors that do not rely on conflict minerals. Then she prompted students to think critically about responsible design considerations for engineered products. Students first brainstormed and then she discussed their responses and how some of those considerations had impacted her own design process of the Sunshine Box. Issues considered included having the box be waterproof, weighing reparability vs. replaceability, handling phone batteries with no charge so customer can't send text to pay, and durability. Students were particularly interested as she described the need for considering theft as part of deciding on an appropriate weight; box should be light enough to carry on a motorcycle but heavy enough not to be stolen easily. Throughout the process, she emphasized the need to be a seeker, displaying empathy for users, rather than purely a solver, providing a solution. This is based on the work of Easterly [25].

The 17°73° Innovation Company founder also gave a talk cosponsored by IEEE and Engineering Global Brigades for the campus on the day before this class period where she described her company and her experiences with social innovation. Some of the students from this class attended this talk along with other engineering students, faculty, and people from across the campus.

Assessment/Homework

Student teams did well on these homework problems that comprised four points on a twelve-point assignment. Students struggled to suggest reasons why the capacitors on the Sunshine Box were larger than those in the datasheet's example circuit. The founder explained that these larger values were chosen to minimize noise and interference in the circuit. This is not a topic that was discussed in the class so it is understandable that students struggled given their lack of practical experience designing circuits. The best answers came from two groups who mentioned the larger values helping to "smooth out the wave." Others mentioned needing larger capacitors to account for the +/- 20% accuracy of the capacitors. They likely thought that the previous question about tolerance was related to this question. On the second problem, two groups calculated all correct answers. Two groups misunderstood the concept of threshold voltage and thought the circuit must be at that value to turn on rather than above that value. One of those groups incorrectly calculated the current in the LED. Another group did not recognize the voltage divider in part a and identified the wrong color for the LED wavelength. The threshold voltage was explained in the assignment but that was the students' only exposure to this concept that can be challenging so it is reasonable that some were confused. This suggests that a more detailed introduction to transistors might be helpful in subsequent implementations of this module.

Assessment/Student Response

Students felt the experience was beneficial. Ten students responded to an electronic survey after class. In response to "The way we learned about the Sunshine Box (and its circuits) that was most valuable for me was," six students chose the classroom activity and discussion, three chose the talk on the day before class, and one student chose the homework problems.

The last question on the survey was open-ended: "Before you go, please leave us with a short comment about how we addressed the topics of (1) the Sunshine Box circuit itself and (2) how electrical design decisions are made?"

Responses were all positive. Several students commented on enjoying the module. Students appreciated the connection of the homework and course content to the class discussion and the value of a real world application.

"It was interesting to see the circuit board used for the box after we had completed problems about it for the homework. It was also helpful to discuss why certain materials were made and how the capacitors came into play."

Other student comments addressed the topic of how electrical design decisions are made, emphasizing the value of this module. Given our focus on engineering as sociotechnical, it was encouraging that some students specifically mentioned the importance of considering users in addition to technical constraints.

"The process of making electrical design decisions highlighted the importance of working with both the constraints and the users for effective and useful designs."

Overall Assessment

Relevance to Me as an Engineer and Emotional Response
Two questions relating to relevance and emotional response were asked on the electronic surveys following Modules 1 and 3. This data is not available for Module 2. For Module 1, 12 out of 16 students (75%) responded to these questions. For Module 3, ten out of 16 students responded to these questions (62.5%). Table 1 summarizes student response to the question of how this topic matters to them as engineers on a scale of "1 - does not matter at all" to "5 - a lot." Note that all students who responded on both surveys said these topics mattered to them as engineers.

Table 1 Student Responses to "this topic matters to me as an engineer"

	Not at all (1)	**2**	**3**	**4**	**A Lot (5)**
Module 1 Conflict Minerals	0	0	2 (17%)	6 (50%)	4 (33%)
Module 3 Responsible Social Innovation	0	0	0	7 (70%)	3 (30%)

Table 2 summarizes students' response to the question "When we addressed (the Conflict Minerals for Module 1 or the Sunshine Box for Module 3) in class, I felt (click all that apply)." Note that "curious" and "excited" were the most common responses. This data is not available for Module 2. Some students chose more than one emotion. For Module 1, five students chose "curious," another five chose "curious" and "excited," one student chose "excited and curious," and one chose "empowered, depressed, angry, excited, and curious." For Module 3, six students chose "empowered, excited, and curious,", one chose "excited and curious", two chose "curious," and one chose "excited." No one chose "depressed, bored, angry, or drained."

Table 2 Student Responses to "when we talked about this topic in class, I felt (click all that apply)"

	Module 1 Conflict Minerals	**Module 3 Responsible Social Innovation**
Empowered	2	6
Depressed	1	0
Bored	0	0
Angry	1	0
Drained	0	0
Excited	7	8
Curious	12	8

Final Exam
About half the students recalled content from the modules on the final exam where one question came directly from the learning objectives. "Provide two examples of activities or concepts from [this course] that relate to your everyday life. Please be specific and explain your reasoning for your choices." Students did a good job on this. The most common response referred to AC power usually with respect to its importance since it is delivered to their homes. Ten students

mentioned this often including a reference to paying for and using electricity with some mentioning different types of power including converting between AC and DC power and calculating complex power. Complex power was the last topic covered in class which may have contributed to its prominence in students' minds.

Seven students referred to something from the modules: three students specifically mentioned the tour of the ERC, two mentioned electronics recycling, two mentioned conflict minerals, and two cited the Sunshine Box.

"Prior to this class, I did not even know what conflict minerals were or where they were used. The in-class group presentations on this topic were especially relevant because I researched on Samsung, while having a Samsung phone. I learned that non-conflict tantalum and tin are used in the circuitry of my cellphone. In the future, I can apply this knowledge as an engineer (in design) and as a consumer (in purchasing from companies that have specific procedures for dealing with conflict minerals.)"

"This class showed that it isn't safe to improperly dispose of old electronics because of the harm it causes to the environment. There is a long process for which recycling old electronics goes through, and now everyday I will be able to spread the word to close friends and family on how to recycle their old electronics properly and what will happen if they don't."

"I came into engineering so I can make a difference in the world. After seeing/hearing more about the Sunshine Box, I've realized that I don't need to make a complex designed object to make a difference. Becausae of this circuitry I realized that even basic engineering practice can make a difference."

"By attending to the Sunshine Box designs, I learned to be a seeker instead of a solver. W e need to seek for problems in our daily life or design, not just waiting [sic] to solve problem people provide. In addition, I learned that we need to look at the problems in many different ways because the actual world is complex, not as simple as the problems in our test."

Final Course Evaluations

Several students commented about the modules on the standard final course evaluations. These are summarized in Table 3. No one commented negatively about the modules or mentioned them in "aspects of the class that detracted from your learning."

Table 3 Final Course Evaluation Comments

Question	*Student Responses Related to Modules*
Do you find this class to be intellectually challenging?	*-The outside design aspects stretched my thinking.* *-Helped expand my view on electronics.*
What aspects of this class contributed most to your learning?	*-I also liked that we did so much social justice stuff, super interesting!* *-Lectures from other people*
What suggestions do you have for improving the class?	*-Keep the field trips*

Interviews
Semi-structured interviews were conducted with three students: one Integrated Engineer and one ME who were interviewed together and one EE who was interviewed separately [26]. All students in the class were invited to participate. These interviews were done at the end of the semester, which is a busy time for students and likely contributed to the small number of participants. Students were asked to respond to questions regarding the course itself, about engineering, and about sociotechnical implications of engineering. These students indicated that they found modules to be well-integrated into the class. They explained that conflict minerals and the Sunshine Box were just “real world” applications of circuits. In fact, when asked about engineering, every student brought up the modules to suggest that they saw the social context pieces as important for developing their sense of engineering in the real world.

“Well, I think all the things we did, including conflict minerals, and especially going to the recycling center, and having the Sunshine Box, you know, circuits in front of us was like, ‘This is the real world.’”

One student wrestled with how the topics of the modules fit into the scope of engineering.

“obviously we looked at a lot of stuff that wasn’t engineering including the conflict minerals, and the Sunshine Box which I thought was really cool. And that was very clearly…I mean it was engineering but at the same time it was very clearly like looking at it from different angles.”

While they commented that they liked to see “big picture” and “real world” applications and indicated that this course impacted them and helped broaden or “open up” their idea of engineering, students also struggled to respond to questions about what exactly that meant for them. Conceptual questions such as “Do you think you learned anything about the social ramifications of circuits in this class? If yes, what and why? If no, why?” prompted students to work through and reflect on their thoughts on each module.

“I mean … the conflict minerals thing was huge ‘cause …that was one thing I had never realized was how it was like all the, I guess how much one little electric component that’s so important can affect like everyone…or can affect those people in underdeveloped nations. And then also with the Sunshine Box, that was kind of a cool way to see like what an EE can do like on a positive note. I mean how much you could help or start to help with just circuits basically.”

“The Sunshine Box, yes, I would say more of kind of what a circuit can do for a community. The conflict minerals kind of made me think differently of just on the design side, when you’re designing something, that you need to take more into…it opened my mind to thinking of what you take into account when you’re doing it. You’re not just thinking of the circuit itself, but what’s making up that circuit really including the materials and what that means.”

The two students interviewed together had different interests, but both agreed that the course had a good “balance” or “mix” of technical and social material.

“I’m more of a technical person but I still do like to have the non-technical side of things; thought it was a really good balance of the two.”

"I'm like a non-technical person but I really liked how the technical things fit in. Like, I love the math and it's interesting when it works out and so yeah, this was a really cool mix of them and I didn't really expect that out of circuits"

One measure of the success of these modules is that a student specifically recommended keeping them and even expanding them because they were beneficial for learning.

"I'd want to repeat like the stuff we did with the recycling center. Definitely the Sunshine Box, I really liked that one. And then even the conflict minerals … – I really liked all three of those, maybe like another one even. Because … for me they helped like further my learning a lot with just real examples of how the things worked."

Lessons Learned/Instructor Response

Highlights of the experience for the instruction team included the enthusiasm of the students for engaging with the topics of these modules, insights of the students, and the opportunity to design modules in ways that students felt enhanced their learning of circuits.

Having an interdisciplinary team was valuable for blending technical and social material in these modules. The instructor with expertise in EE was able to develop relevant homework assignments while the instructor with expertise in sociocultural anthropology was able to prepare a presentation on conflict in the DRC. Active learning techniques were also helpful here.

The instruction team did find developing and executing these modules challenging, however. Decisions regarding how to describe violence related to conflict minerals in the DRC, logistics of arranging for the tour outside of class time, and finding aspects of the social innovation electronic circuit design that students in this introductory circuits class could understand well enough to perform calculations were not easy.

Conclusions

Three modules emphasizing social relevance were successfully incorporated into a required second-year Electrical Circuits class. Students explored conflict minerals building on their introductory knowledge of capacitors. They took a tour of the Electronics Recycling Center on campus to learn about what happens to electrical and electronic devices including capacitors at the end of their life cycle. Finally, students examined circuit diagrams for a socially responsible electrical system and then worked with a social entrepreneur to consider responsible design criteria including technical and social features. Student response to the modules was positive with students believing that these modules provided real world applications of the course content and were relevant to their training as engineers.

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