WIP: An instrument to assess students' perceptions about sociotechnical issues in engineering

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***Abstract*—This work-in-progress research paper describes the development and pilot administration of a survey to assess students' perceptions about sociotechnical issues in engineering. After refining the survey through iterative rounds of review, we piloted it in an "Introduction to Circuits" course at a large, public university in the Midwestern USA in which we deployed a short module addressing technical and social issues. In this paper we document our instrument development process and present descriptive statistics and results of paired t-tests used to analyze the pilot data. We also describe ways our instrument can be implemented by instructors and researchers in multiple contexts.**

Keywords—circuits, electrical engineering, engineering curriculum, socio-technical thinking, student perception, survey

I. Introduction

Introducing students to social issues in technically-focused engineering courses is an important way to prepare graduates for the complex, real-world problems they will encounter in their professional work [1]–[3]. Accreditation bodies (e.g., ABET, European Network for Accreditation of Engineering Education) underscore the need to infuse sociotechnical issues throughout the undergraduate curricula, and licensing regulations (e.g., National Society of Professional Engineers, Engineers Europe) require professional engineers be attentive to social issues in their work. Research also calls for more consideration of sociotechnical issues, as studies have shown that professional engineers need to be able to enact to their public welfare responsibilities [4]–[7] and to understand the sociotechnical impacts of their solutions [8]–[11].

Traditional undergraduate engineering curricula, however, focus on the technical domain without emphasizing engineers' social responsibilities. The curricula prioritize calculations and mathematical modeling while excluding social issues; hence promoting a culture of disengagement [12]. By inherently valuing technical issues and devaluing social ones, traditional approaches promote technical/social dualism [13], [14]; and by supporting the status quo of engineering as "objective," they emphasizes the depoliticization of engineering [15].

Integrating sociotechnical issues into traditional engineering courses may be one way to instill in students a sense of social responsibility and disrupt normative cultural beliefs in engineering – there have been multiple initiatives to do so. Successful efforts at the curriculum level have integrated sociotechnical issues into a single course, into multiple courses, or throughout the engineering undergraduate curriculum [16]–[20]. Smaller units of instruction have also been successfully integrated as modules into typical engineering courses in various engineering disciplines [21]–[25].

There is no widely-accepted instrument to assess the extent to which such efforts influence students' perceptions about sociotechnical issues in engineering. To fill this gap, we developed a student survey that includes a combination of pre-tested and previously validated survey items to assess perceptions about sociotechnical issues in engineering (i.e., their social responsibility attitudes and their adherence to normative engineering cultural beliefs).

A. Social Responsibility

Canney and Bielefeldt [26], [27] conceptualize social responsibility as "a foundational disposition that informs how engineers relate to many professional skills valued in engineering including ethics and the impacts of engineering on society." They describe how the process of professional socialization influences the development of an individual's perceptions of their social responsibilities, and they propose a framework for exploring social responsibility in engineering – the Professional Social Responsibility Development Model (PSRDM). The PSRDM [26] describes the development of social responsibility using three realms: personal social awareness, which describes how an individual develops a desire to help others; professional development, which describes how an individual develops professional skills and how those skills are related to social considerations; and professional connectedness, which relates to how an individual's views about social responsibility and their own professional skills are connected.

B. Normative Cultural Beliefs

Engineering has a unique professional culture; "a set of beliefs, myths, and rituals that give meaning to the intellectual content and practices of the profession" [15]. The normative cultural of engineering is the set of values, beliefs, and norms that characterize the engineering profession. Cech [15] notes that this normative culture emphasizes the ideologies of both technical/social dualism (the belief that technology-focused skills are more valuable in engineering than people-focused activities; [13], [14]) and depoliticization (the belief that political and cultural concerns like social responsibility should be kept out of engineering to maintain its objectivity; [28], [29]).

Funding provided by the USA National Science Foundation through Award #2233155 and 2235576.

Thus, normative cultural beliefs frame social justice issues as separate from traditional engineering, and they can shape the curricula that are used to instruct engineering students, the skills that are emphasized in the workplace, and the traits an individual engineer values in their professional identities [29].

II. Our survey

We designed a survey to assess students' perceptions about sociotechnical issues in engineering (i.e., social responsibility attitudes and adherence to normative engineering cultural beliefs). The survey includes both pre-tested and previously validated survey items as well as demographics items (e.g., sex, race/ethnicity, class level, and field of study).

To assess students' social responsibility attitudes, we leverage the Engineering Professional Responsibility Assessment instrument (EPRA) developed by Canney and Bielefeldt [30] to operationalize their PSRDM. The EPRA includes 50 items to measure the three realms of the PRSDM. We focus on items within two of those realms: professional development and professional connectedness.

We leverage an instrument developed by Cech and Finelli [31][32] to assess students' adherence to normative cultural beliefs. Among other constructs, the survey includes several items to probe an individual's perceptions about sociotechnical dualism (broadly in the field of engineering, related to the professional responsibilities of engineers, and for their own career) and about the ideology of depoliticization.

We considered items from both instruments for inclusion on our survey, eliminating several from the original instruments and including only three to five primary items within five key categories: the field of engineering, the professional responsibilities of engineers, the students' discipline/instructor, their career decisions, and their personal identity. We mixed relevant items from both instruments and we edited items for several reasons: to better balance the social and technical questions (e.g., we added an item "Community engagement should be disconnected from engineering work" to the items in the field of engineering category to balance the two existing technical-focused questions); to result in greater response variability (e.g., we changed the item "Engineers should use their skills to solve social problems" to "All engineers should use their skills to help solve social problems" to build in a stronger comparison); to avoid "leading" language and potentially double-barreled items (e.g., we reworded the item "Becoming wealthy has no effect on my choice to pursue engineering as a career" because students could disagree that pursuing a career in engineering could result in wealth or they could disagree that becoming wealthy has no bearing on their decision); and to improve flow and keep our survey short. We refined the survey through several rounds of iteration, including consultations with the developers of each original instrument and pilot administration with graduate students to establish the instrument's content and face validity.

Ultimately, our survey includes 15 items with a total of 32 questions. Eight items assess demographics, including year in school, major, gender, race, and ethnicity. Consistent with recommendations [33], we place items that could potentially induce stereotype threat at the end of the survey.

Five multipart items, comprising 22 questions, measure students' perceptions about sociotechnical issues in engineering (i.e., their social responsibility attitudes and their adherence to normative engineering cultural beliefs). Specifically, using a 7-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neither agree nor disagree, 5 = somewhat agree, 6 = agree, and 7 = strongly agree to 7 = strongly agree) as recommended [34], [35], students indicate the extent to which they agree with statements related the broad field of engineering, the professional responsibilities of engineers, their college discipline and instructor, their career decisions, their personal identity. One item allows students to write their definition of "social responsibility of engineers", and a final item gives students the opportunity to provide other comments.

III. Pilot Data

After refining the survey through iterative rounds of review, we piloted it in an "Introduction to Circuits" course at a large, public university in the Midwestern USA. Students from all engineering disciplines enroll in the course, typically in the second year of their undergraduate studies, and it is required for several majors, including electrical engineering. Typical course enrollment exceeds 250 each semester.

As part of a larger project to help engineering instructors integrate sociotechnical issues into their classrooms [36], the course instructor introduced a one-hour module [22] about conflict minerals that was connected with the technical course content of capacitors. During the module, students learned about minerals used in typical capacitors and discussed social implications of using conflict minerals (materials that are mined in areas of conflict such as the Democratic Republic of the Congo where profits finance armed groups and fuel forced labor and other human rights abuses [37]). The instructor also assigned a homework problem about conflict minerals and offered extra credit for students to research conflict minerals policies developed by various companies.

We administered our survey instrument at the beginning and end of the "Introduction to Circuits" course to explore students' perceptions about sociotechnical issues in engineering. A total of 170 students completed the survey both times and consented to allow their responses to be used for our research. To assess changes in their perceptions from the pre- to post-test administration, we conducted a series of paired t-tests.

IV. Results and Discussion

Based on credits, most students who completed the survey were sophomores or juniors (76 and 74 students, respectively, out of 170 total students), while a few were seniors (19). One did not report their class level. Of the 170 students, 107 identified as men, 56 as women, and 6 as non-binary or gender queer. One did not report their gender. Most students were majoring in either electrical or computer engineering (45 and 44 each, respectively), with other common majors including mechanical engineering, aerospace engineering, computer science, and robotics engineering (21, 20, 13, and 11 respectively). Fewer than five students were majoring in each of several other areas (biomedical engineering, engineering physics, material science and engineering, sound engineering, environmental engineering, industrial engineering, or undeclared).

In Table 1, we present the survey items, pre-test and post-test descriptives (means, *M*, and standard deviations, *SD*), and results of paired t-tests (*t*-statistics and *p*-values) used to identify statistically significant differences in pre- and post-test responses of the pilot survey data. At both the beginning and end of the course, students' responses about the field of engineering suggest that they agreed about the value of sociotechnical issues. They somewhat agreed that "all engineers should use their skills to help solve social problems" ($M = 5.27$ at the beginning of the course and 5.32 at the end) and disagreed that "community engagement should be disconnected from engineering work" ($M = 2.33$ and 2.58 at the beginning and end, respectively).

Regarding professional responsibilities, students agreed that all the job aspects we presented are integral parts of engineers' responsibilities. However, they responded more strongly about technical aspects than societal ones at both survey administrations (e.g., for "testing and evaluating potential solutions," $M = 6.23$ and 6.22 at the beginning and end of the course, respectively; while for "accounting for the cultural contexts in which their projects are embedded", $M = 5.55$ and 5.63 at the beginning and end).

Generally speaking, students agreed that both the discipline of electrical engineering and their course instructor "emphasized technological advances" ($M = 5.82$ and 5.79 at the beginning and end for the discipline and $M = 5.75$ and 5.78 at the beginning and end for their instructor). They were neutral about whether the discipline and their instructor "emphasized the social responsibility of engineers" ($M = 4.11$ and 4.44 at the beginning and end for the discipline, and $M = 4.42$ and 5.18 at the beginning and end for their instructor).

In terms of students' career decisions, at both survey administrations, students somewhat agreed that "having a career that helps people" was important to them personally ($M = 5.49$ and 5.50 at the beginning and end of the course) and that their "desire to help society was a driving factor in their choice of career" ($M = 5.07$ and 4.95 at the beginning and end). Balancing the scale, students also somewhat agreed that "gaining financial security was the most important factor in their career" ($M = 5.21$ and 4.98 at the beginning and end of the course).

Regarding students' personal identities, students somewhat agreed that they "valued learning technical skills more than learning about social issues" ($M = 4.69$ at the beginning of the course and 4.85 at the end of the course). They also somewhat agreed that "raising concerns about social issues enhances their credibility amongst peers" ($M = 4.76$ and 4.88 at the beginning and end of the course) and that "it is important to integrate social issues like social responsibility into their work as engineering students" ($M = 5.35$ and 5.36 at the beginning and end).

From the beginning to the end of the course, there was generally little change in students' perceptions about sociotechnical issues in engineering, as most t-tests comparing those data not yield statistically-significant differences at the $p < 0.05$ level. Some t-tests, though, did indicate a positive impact of our course module.

Encouragingly, at the end of the term, there was a *statistically significant increase* in students' agreement that the discipline of electrical engineering "emphasized the social responsibility of engineers" ($p = 0.005$). There was a similar *statistically significant increase* in their agreement that their course instructor "emphasized the social responsibility of engineers" ($p = 0.000$).

Students' agreement that "gaining financial security is the most important factor in their career decision" had a *statistically significant decrease* ($p = 0.032$), suggesting that other factors became more important to students. And there was a *marginally significant increase* ($p = 0.082$) increase in student agreement that "seeking out the expertise of non-engineers to solve problems" is part of the professional responsibilities of engineers.

On the flip side, however, students' agreement that "community engagement should be disconnected from engineering work" had a *marginally significant increase* ($p = 0.054$) as did their agreement that "they prioritize stable employment above all other job considerations" ($p = 0.068$).

V. Conclusion

In this paper, we described the development of a survey instrument to assess students' perceptions about sociotechnical issues in engineering (i.e., their social responsibility attitudes and their adherence to normative engineering cultural beliefs). The instrument is short (15 items with a total of 32 questions), and can be administered in multiple contexts. We used the instrument as a pre-/post-course assessment measure to evaluate the impact of a one-hour module for the "Introduction to Circuits" course that addressed sociotechnical issues related to mining conflict minerals. Though the module is modest and unlikely to result in significant changes in students' perceptions, we did find some encouraging trends.

Looking to the future, we plan further refinements to the survey instrument based on our pilot data. For instance, we will include additional options in our list of potential majors, add "Middle Eastern" or "Middle Eastern and North African" as an option for race, and reword items about the professional responsibilities of engineers to yield a greater comparison between social and technical responsibilities by inquiring about "the most important" responsibilities. In addition, we will better adhere to guidelines about collecting demographic data which recommend structuring questions as "select all that apply" items and providing open-ended "write-in" responses [33]. Then, we will use the survey instrument to continue assessing the impact of our sociotechnical modules.

As we describe in this paper, our survey can be used to assess students' perceptions about sociotechnical issues in engineering in general. As well, when administered as a pre- and post-course assessment measure, the instrument can identify changes in students' perceptions. Although we administered the instrument in a single course, we expect that is can be applied in multiple contexts, including courses with large and small enrollment, first year courses and those at the senior year, courses across all engineering disciplines and courses at various institution types. Future testing of our instrument will confirm this expectation and will identify other next steps.

Table 1. Descriptive statistics and results of two-tailed, paired t-tests. (df = 169, M = mean, SD = standard deviation).

	Pre-test		Post-test			
	M	*SD*	*M*	*SD*	*t-statistic*	*p-value*
The field of engineering						
The most important thing engineers can use their skills for is creating new technology.	4.70	1.33	4.88	1.40	1.54	0.126
All engineers should use their skills to help solve social problems.	5.27	1.39	5.32	1.28	0.49	0.627
Community engagement should be disconnected from engineering work.	2.33	1.20	2.58	1.47	1.94	0.054^
The professional responsibilities of engineers						
Testing and evaluating potential solutions	6.23	0.85	6.22	0.86	–0.08	0.939
Advancing basic engineering and technical knowledge	5.94	0.96	5.96	0.85	0.30	0.765
Accounting for the cultural contexts in which their projects are embedded	5.55	1.32	5.63	1.22	0.83	0.410
Seeking out the expertise of non-engineers to solve problems	5.53	1.28	5.67	0.94	1.75	0.082^
Prioritizing technological objects and systems that make society more equitable	5.49	1.26	5.54	1.17	0.35	0.725
The discipline and instructor						
The discipline of electrical engineering emphasizes technological advancements.	5.82	0.96	5.79	1.08	–0.64	0.525
My circuits course instructor emphasizes technological advancements.	5.75	1.02	5.78	1.10	0.00	1.000
The discipline of electrical engineering emphasizes the social responsibility of engineers.	4.11	1.37	4.44	1.42	2.82	0.005***
My circuits course instructor emphasizes the social responsibility of engineers.	4.42	1.41	5.18	1.32	5.70	0.000***
The student's career decisions						
Gaining financial security is the most important factor in my career decision.	5.21	1.43	4.98	1.49	–2.16	0.032*
Being able to make new technology is the most important factor in my career decision	4.60	1.41	4.54	1.40	–0.68	0.498
I prioritize stable employment above all other job considerations.	4.50	1.47	4.71	1.43	1.84	0.068^
It is important to me personally to have a career that helps people.	5.49	1.21	5.50	1.12	0.15	0.885
My desire to help society is the driving factor in my choice of a career.	5.07	1.46	4.95	1.41	–0.92	0.357
The student's personal identity						
As an engineering student, I value learning technical skills more than learning about social issues.	4.69	1.66	4.85	1.57	1.21	0.226
If I follow mathematical and scientific principles as an engineering student, I will always find an objective solution.	3.78	1.55	3.96	1.50	1.33	0.186
If I raise concerns about social issues in my work, I am less objective as an engineering student.	3.23	1.46	3.38	1.62	1.35	0.178
Raising concerns about social issues as an engineering student enhances my credibility amongst my peers.	4.76	1.31	4.88	1.37	1.10	0.275
I think it is important for me to integrate social issues like social responsibility into my work as an engineering student.	5.35	1.31	5.36	1.28	0.15	0.890

Note: The *t-statistic* is used to determine if there is a mean difference between pre- and post-tests measures. A *t-statistic* that is positive indicates a pre- to post-test increase and one that is negative indicates a pre- to post-test decrease. A larger *t-statistic* indicates a more significant difference, and the *p-value* describes the level of significance. We mark *p-values* that suggest *marginally significant* (^ $p < 0.1$) and *statistically significant differences* (* $p < 0.05$; *** $p < 0.001$.)

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