Just Add Context? Analyzing Student Perceptions of Decontextualized and Contextualized Engineering Problems and their Use of Storytelling to Create Context

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Abstract

Important scholarship in engineering education suggests that that the divide between social justice (SJ) concerns and technical knowledge in engineering curricula is an important reason that students with SJ concerns leave engineering [1, 2]. In their recent book, *Engineering Justice*, Leydens and Lucena [3] present criteria they hope “can be used to guide educators [to render] SJ visible within the engineering sciences without compromising valuable course content.” One approach is the so-called “Problem Re-write Assignment”: students write a context for a traditional “decontextualized” engineering science problem. We undertook this pilot study to understand how students frame their thinking about “contextualized/decontextualized” (Con/Decon) problems and what resources they would use to write a social context to an engineering science problem. Our goal is to better understand what it would take to successfully engage students around the social context of engineering science problems.

This paper draws on student responses to two assignments in two different semesters of an engineering ethics course. In this paper, we use open-coding to understand student attitudes toward contextualized and decontextualized problems and to get a better sense of how students articulate their thoughts about how context fits into engineering education. In addition, we analyze a storytelling assignment (students wrote context for a decontextualized problem) for the purpose of identifying strategies that students use to construct context and struggles they have doing so. We examine the way students choose scenarios, create relevant stakeholder maps in those scenarios, and the extent to which they integrate SJ issues into technical problems. In addition to evidence of four “engineering mindsets” previously outlined by Riley [4], we identify five themes in students’ perceptions of decontextualized problems and eight themes in their perceptions of contextualized problems. We also identify several strategies students employed for writing contextualized problems.

Introduction

Integrating social justice (SJ) into engineering education curriculum is a major challenge. For example, one of the driving questions in engineering ethics and SJ education is how to overcome technical-social dualism within undergraduate engineering education curriculum. This line of inquiry is relevant to issues of representation in engineering schools: the socio-technical divide impacts undergraduate engineering retention, especially students from historically underrepresented groups in engineering (e.g. women, students of color, LGBTQIA, indigenous
people, and low-income) [5]. A recurring justification for upholding the socio-technical divide (that we have heard voiced during discussions about engineering curricula and that we want to interrogate) is that technical content would have to be sacrificed in order to accommodate social justice issues. Therefore, a project in which students add context to traditional engineering science problems has the transformative potential of reaching students within their core engineering courses [6].

In *Engineering Justice*, Leydens and Lucena [3] present criteria to be used “to guide educators [to render] SJ visible within the engineering sciences without compromising valuable course content” and pedagogical tools designed to integrate SJ and engineering in the curriculum. We were intrigued by the “Problem Re-write Assignment” in which students are guided to write a social context for decontextualized engineering problems by specifying how “a system...might affect humans using it, including how it might enhance or curtail SJ criteria as opportunities and resources or the distribution of risks and harms” [3]. Lucena conducts this exercise in “Engineering and Social Justice,” an upper level course required of students in the Colorado School of Mines Humanitarian Engineering Major [3]. In that version, students are given context to a statics problem by watching a documentary. We wondered how our students would respond to this exercise, and whether we could take it in a different direction by asking students to create their own context for a decontextualized problem, a skill that could encourage socio-technical systems thinking and support the course’s emphasis on storytelling.

One of our motivations for having students write context that comes from their own experience is we have experienced negative student reaction when introducing students to issues concerning engineering and SJ. While students in “Humanitarian Engineering” self-identify to some extent with SJ concerns [3], we work with more technocratically oriented STEM majors. For this reason, we decided to start our research by inquiring into perceptions that students have about contextualized and decontextualized problems (Con/Decon), and what resources they would use to try to write contexts, in order to understand how we might successfully coach them to come up with context on their own.

Evidence suggests that the invisibility of SJ concerns in engineering curricula factors into a “culture of disengagement” [2], [5], [7]. This scholarship posits that the divide between technical knowledge and social concerns in engineering curricula impacts undergraduate engineering major retention — since students who are more driven by social/humanitarian concerns are more likely to come from historically underrepresented groups in engineering (e.g. women, students of color, LGBTQIA, indigenous people, and low-income) [5]. Bielefeldt [7] explores factors related to the loss of “socially motivated students” from engineering. She recommends engineering programs that wish to retain highly socially motivated students explore the infusion of social context into engineering courses beyond the first year, as well as the required balance of technical and non-technical coursework in their curriculum and opportunities for course choice.
Riley [8] argues that to counter the ideologies such as meritocracy, technical narrowness, and the myth of objectivity, what is needed is to challenge the status quo of current grading schemes and teaching evaluations, and build support for “other ways of knowing.” Such structures make it difficult for students to think past the ways they are graded and the most efficient way to get work done.

Our research aligns with other research that documents the challenges of integrating socio-technical systems thinking into engineering education [9-15]. Students arriving on college campuses often bring with them the technical-social dualism mindset [16] and instrumental thinking, which narrowly defines social relationships with technology in terms of efficiency and productivity outcomes [17]. This mindset is subsequently reinforced throughout their college engineering education [18]. Single ethical modules integrated into engineering courses or a single course focused on engineering ethics is not enough to give students knowledge about the broader macro-ethical effects of technology [11, 13].

Riley [4] identified four engineering mindsets that contribute to challenges of integrating socio-technical systems thinking and SJ into technical courses: Technical narrowness; Positivism and the myth of objectivity; Uncritical respect for authority; and Centrality of military and corporate organizations, and a fifth, Willingness to help, that might provide an ideal entry point for SJ thinking. Cech [19] argues that depoliticization of engineering and the emphasis on meritocratic advancement are two ideologies of engineering that create barriers to student engagement with social issues: Depoliticization renders engineering a politically neutral activity that discourages thinking about social responsibility on a micro-ethical level; and meritocracy gives advantages to already privileged students who have likely had superior educational experiences than less privileged students.

Our work is part of exploring, with students, ideas about engineering identity. For example, Downey, Lucena and Mitcham [20] posit the questions, “Who is an engineer? Or, what makes an engineer?” to follow how engineering ethics is constructed in a variety of cultures. Taylor et al. [16] suggest that critical pedagogies (deconstructing and critiquing knowledge and the source of its authority) might help shift thinking about engineering identity and the engineer’s role in society. Welling et al. [21] employ autoethnographic assignments in a summer bridge program to provoke “shifts in conceptions of engineering, including aspects of identity, values, and nature of engineering work.” Our storytelling work tends to the relevance of engineering identity by asking students to attend to their own understanding of objectivity. We are working towards understanding how engineering identity may connect with SJ concerns when we ask questions such as: How has a story been framed? Who does it leave out? How are the characters in this story complex/conflicted? And what forms of engineering identity does this story value and make visible?
Our research takes place in the context of other efforts to incorporate socio-technical systems thinking, ethics, social justice, and social responsibility (SR) into engineering education. For example, the problem rewrite assignment is a form of problem-based learning, a pedagogical strategy that others are using to teach SR and SJ [22]. Another promising strategy is using corporate social responsibility (CSR) as a tool in engineering ethics education, as a way of preparing students for “the CSR dimensions of their careers” and broadening students understanding of stakeholders, especially to include oppositional groups [23]. Nieusma and Cieminski [24] suggest “a shift to ethics knowledge as ‘skills that must be practiced in order to be learned’ [that] could fit nicely with the contemporary emphasis on active and problem-based learning approaches in engineering education. Similarly, storytelling for the purpose of constructing context for a decontextualized problem is a skill necessary to practice moral reasoning and dovetails with the goal of developing curriculum around real-world problems as well as students’ personal experiences.

To our knowledge no research has been conducted to assess the potential of the problem re-write to introduce socio-technical context into technical courses [25]. Many studies use the term context to refer to physical materials or environment but not necessarily humans or social structural factors. For example, Surovec [26] uses the term context in an assignment that asks students to “identify, photograph, model, idealize and analyze items or structures found locally (on campus or in town) that exhibit the mechanical behaviors described in class” and analyze and assess these items or material structures. There is also a line of research that develops metrics to assess engineering students’ contextual competence, defined in one case “as an engineer's ability to anticipate and understand the constraints and impacts of social, cultural, environmental, political, and other contexts on engineering solutions” [27]. This use of “context” aligns more closely to our meaning and it is in this spirit that we explore students’ perceptions of contextualized problems and strategies we could use to support them to write their own.

We were curious to take a closer look at the language students use to describe Con/Decon problems. Would student language reflect or challenge entrenched ideologies in the engineering curriculum? Do student’s perceptions of Con/Decon problems help us gain insight into how they prescribe a proper engineering education? What do students believe to be a complete education? In Cech’s [19] phrasing, what is supplementary and what is fundamental?

Our primary study questions are as follows:

R1: Given that students are conditioned to work with decontextualized problems, what is their attitude towards contextualized ones?

R2: What strategies are students using to create context?
Research Design and Methodology

In fall 2018, we adapted the Problem Rewrite Assignment (in an engineering ethics course, ENEE200) in order to better understand how students perceive contextualized and decontextualized problems in the first place. In January 2019, in the winter term of the same course, we presented a decontextualized problem from a first-semester course for all engineering majors and asked students to write a context for it.

ENEE200 is a general education class on engineering ethics. It is a large lecture class with approximately 80 students that meets three times a week: twice as a whole group lecture and once in smaller discussion sections of approximately 15 students. The course is open to any student, but approximately 65% are engineering students, as the course is based out of the Electrical and Computer Engineering Department. The remainder of students come from a wide variety of majors, including computer science, business, information studies, and biology. The semester is guided by a framework of storytelling -- students are taught to listen, tell and critique stories. This framework complements ethics training in many ways. First, student storytelling is used early on in the class to develop interpersonal relationships among students. Next and throughout the course, we use storytelling prompts to improve communication skills and give students practice at explicitly connecting their personal experiences to course content. In an ethics framework, storytelling helps demonstrate the situatedness and partial perspective of individuals [28], while building skills, habits and mindsets of empathy. Many active learning activities center around building a character and identifying overlapping and conflicting factors that constrain the behaviors of individuals (both macro and microethical factors). We supplement the course textbook, *The Ethical Engineer* by Robert McGinn [29], with readings in virtue ethics and care ethics as well as a contemporary case that students develop throughout the first part of the semester.

In fall 2018 we presented the decontextualized statics problem from *Engineering Justice* [3], showed a short documentary about window washers in Chicago [30], and the statics problem rewritten by a student [3]. To establish a baseline of student of student attitudes toward Con/Decon problems (R1 and R2, Table 1), we asked students (n = 69 responses) to free write their thoughts about Con/Decon problems and gave them time in small groups to discuss (See Table 1). We used the categories of physical and non-physical harms, which we had previously introduced [31].
Table 1 - A summary of the timing and nature of student activities for research questions.

<table>
<thead>
<tr>
<th>Timing/Student Activity</th>
<th>Research Questions</th>
<th>Student Prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2018:</td>
<td>R1: Given that students are conditioned to work with decontextualized problems, what is their attitude towards contextualized ones?</td>
<td>P1: How do you feel about decontextualized engineering problems?</td>
</tr>
<tr>
<td>Students receive examples of decontextualized and contextualized problems and discuss how they feel about them.</td>
<td>P2: How do you feel about contextualized engineering problems?</td>
<td></td>
</tr>
<tr>
<td>Winter 2019:</td>
<td>R2: What strategies are students using to create context?</td>
<td>P3: Discuss your stories (physical and non-physical)</td>
</tr>
<tr>
<td>Students create their own contextualized problems through storytelling exercise.</td>
<td>P4: Which type of story was most challenging to come up with? Why?</td>
<td></td>
</tr>
</tbody>
</table>

After ascertaining how students feel about Con/Decon problems, we created a storytelling exercise designed to help us understand what strategies students use to create context around a decontextualized problem (R3) and the challenges they have doing this (R4) (Table 1). In the 3-week winter-term of ENEE 200, we conducted this work in the context of discussing barriers and possibilities to implementing “ethics across the curriculum, which we had extensively discussed earlier in the course, and which is a topic in course textbook [29]. Similar to fall 2018, we showed the decontextualized statics problem and the video in class.

For homework, we gave students a decontextualized problem that represented a battery circuit (from a homework assignment for ENES100, a course for all engineering students), and asked students (n = 16) to write two stories: one based on physical harm, the other based on non-physical harm. In a class debrief, we gave small groups prompts 3-6 (Table 1) to discuss and then asked them to provide written answers to prompts 4-6 (Table 1). We designed these questions to get an understanding of criteria and stakeholders students used for creating questions and the challenges they had developing a context for potential physical and non-physical harms associated with battery power production. What challenges would they face? What resources would they use to create context? What strategies would they use (i.e., would they conduct additional research, rely on personal experience, invent scenarios, some
combination, or something completely different?) In class we solicited their feelings about decontextualized and contextualized problems but did not capture them for analysis.

Analysis

Open coding is the primary mode of analysis in this paper [32]. However, as a starting point, we conducted thematic coding [33] to identify the prevalence of engineering mindsets (Table 2: Uncritical Acceptance of Authority, Technical Narrowness, Positivism, Willingness to Help) [3-4] but soon realized that student characterizations of Con/Decon problems was more diverse. As a pilot study, the analytical goal of the paper is to identify, through open coding, the diverse ways that students perceive Con/Decon questions and the strategies they used to contextualize decontextualized problems. We focus our analysis on P1-P4 (Table 1). The coding themes identified here will help us develop hypotheses for future research.

For R1 we open coded student prompts 1 and 2. Beyond the four engineering mindsets identified above, we identified five themes for decontextualized problems (P1) and eight themes for contextualized problems (P2) (Tables 3 and 4). To understand student attitudes toward Con/Decon questions, we coded each student response for P1 and P2 as positive, negative, mixed or indeterminate. We are using this measure as a speculative proxy to gauge how Con/Decon questions motivate engineering students. We also broke this analysis down by major (engineering/non-engineering), as not all ENEE 200 students are engineering majors. We also open coded student stories (P3) to identify strategies they used to contextualize decontextualized problems and challenges they had writing them. To validate the coding process, the authors coded the student work separately and later compared notes on emerging themes and to finalize coding categories.

Results

Research Question 1: Given that students are conditioned to work with decontextualized problems, what is their attitude towards contextualized ones?

What follows is a taxonomy of ways students are thinking about Con/Decon problems. In general, the analysis reveals that students are highly ambivalent about contextualized problems, their role in engineering education, the timing of when they should be introduced, and their utility to engineering careers. Table 2 displays typical student references that align with Riley’s engineering mindsets. Students often articulated variations on the theme Technical narrowness in their defense of decontextualized problems and their critique of contextualized problems. Notions of Positivism showed up mainly through references about decontextualized problems as necessarily being generalizable to different situations. Less common were references that align
with the theme, *Uncritical acceptance of authority*. Student references to the theme *Willingness to help* typically were associated with contextualized problems.

**Table 2** - Thematic coding of student responses using engineering mindsets as themes.

<table>
<thead>
<tr>
<th>Coded Theme</th>
<th>Description</th>
<th>Student Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Narrowsness</td>
<td>The development of a narrow sense of the technical that leaves out social considerations.</td>
<td>“Primary job of problem is to teach engineering skills not to teach ethics which should still be done but in a different separate assignment.”</td>
</tr>
<tr>
<td>Positivism (Universalism)</td>
<td>A commitment to empirical data which engineering students see as the source of objectivity, which might prevent them from deploying other sources of knowledge or values.</td>
<td>“Decontextualized problems support the teaching of general theories, decontextualized just means generalized.”</td>
</tr>
<tr>
<td>Uncritical Acceptance of Authority</td>
<td>Students socialized via ingrained practices of problem solving wherein SJ and ethics is rendered invisible</td>
<td>“Adding too much extra information takes away from what is actually being taught and tested. Too much context wastes time and effort.”</td>
</tr>
<tr>
<td>Willingness to Help and Persistence</td>
<td>The desire to envision future imaginaries and use technical skills to help humanity.</td>
<td>“Engineering classes should prepare you to be a “good” engineer. This requires technical knowledge and contextual/ethical knowledge.”</td>
</tr>
</tbody>
</table>

Most student reflections defended decontextualized problems, referring to them as foundational to their learning and becoming better problem solvers. The below quote captures typical student response to P1 and many of the student themes presented in Tables 2 and 3 [noted in brackets]:

A decontextualized problem is meant to test the student’s knowledge and ability to solve the problem [*Technical Narrowsness, Easier to assess*]. It is the most crucial part of being an engineer [*Uncritical acceptance of authority, Foundational*], having the knowledge to solve problems. I believe it is all that is needed to test/teach student [*Simple*]. It has enough details that allow the student to know what they need to solve for.

This student believes that problem solving is a decontextualized process, suggesting that problem solving is merely a technical issue and that further information is unnecessary. This
student also expresses the idea that decontextualized knowledge is easier to assess, and at least closely associates teaching with testing.

Despite this common sentiment, many students supported the use of both Con/Decon problems. However, these students were ambivalent about the combined role of Con/Decon problems. Many students allowed for both to be taught during their engineering education, but noted that contextualized problems had a proper place. For instance, one student stated, “I don’t think contextualized problems would work well for exams where the extra information takes up time and space, but they would be ideal for projects so that students can understand what kinds of problems they will deal with in real life.”

**Table 3 - Open coded student themes associated with decontextualized problems.**

<table>
<thead>
<tr>
<th>Coded Theme</th>
<th>Description</th>
<th>Student Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundational/order</td>
<td>The belief that there is a proper order to learn engineering, with decontextualized problems representing a foundation.</td>
<td>“I think these problems are necessary to establish a foundation on the subject matter”</td>
</tr>
<tr>
<td>Simple</td>
<td>Students’ self-perception that decontextualized problems are simpler and have less distractions than contextualized problems.</td>
<td>“Engineering problems that are decontextualized are easier to interpret because the information that you need is presented clearly and concisely for you to then be tested on.”</td>
</tr>
<tr>
<td>Development of problem solving skills</td>
<td>Learning through decontextualized problems is fundamental to developing problem-solving skills.</td>
<td>“I think they do serve an intended purpose. That being problem solving and basic knowledge of material.”</td>
</tr>
<tr>
<td>Misleading</td>
<td>Decontextualized problems do not provide enough information to make informed decisions.</td>
<td>“I don’t think it gives us the full picture. It feels a bit misleading and unclear.”</td>
</tr>
<tr>
<td>Easier to assess</td>
<td>Student beliefs that decontextualized problems are easier and are a more efficient way to assess student knowledge.</td>
<td>“Adding too much extra information takes away from what is actually being taught and tested. Too much context wastes time and effort.”</td>
</tr>
</tbody>
</table>

Others considered prioritizing contextualized problems because they felt decontextualized problems lacked context and made problems harder to solve. This sentiment is represented by the Misleading theme in Table 3 and the Real World theme in Table 4. Students that endorsed the use of both types of problems seemed to have a limited notion of context.
[P]roviding a context for a problem can be useful. For example, I am more motivated and curious when a problem has a context. Some of my professors (especially the ones I consider are good) provide a context (mostly verbally) to a problem in the classroom. But on an exam or homework, I honestly don’t have the time to read about Manuel the underpaid immigrant window cleaner. I am aware that if I design for example a controller for a furnace it will be used in households and my mistakes will come with costly consequences.

For this student, the notion of context is reduced to a generalizable household situation where the identity of who is using the furnace doesn’t matter. So context here is defined as the material situation in which the problem is happening. Very few students provided specific examples such as this, so it is difficult to ascertain what these students mean by context when they talk about it in their prompts. For instance, students that invoked the Real world/applied theme generally spoke of the importance of knowing more about a problem to do a better job of solving the problem or making it relevant (Table 4).

Students also saw contextualized problems as giving engineering purpose and making their classes “more interesting and meaningful.” (Table 4) One student identified decontextualized problems as deficient: “I think decontextualized questions are lacking in purpose because they fail to address the real life situation that is requiring the question to be solved. This causes many college graduates to have much decontextualized knowledge but little to contribute to the actual workforce [Purposeful, Professional Development].” Along those lines, several students believed that contextualized problems would help with professional development. In contradiction to most of their peers, some students suggested that contextualized problems made solving problems easier because they contained more information (Table 4 - Easier to understand).

Many students, however, expressed concerns that using contextualized problems would make assessing their knowledge of a subject more difficult and would also make doing coursework more time-consuming and less fair (Table 4 - Pedagogical concerns). According to one student, “Engineering problems that are decontextualized are usually better because they allow the problems to be fairly solved by everyone. Context makes it harder to relate to sometimes.”
<table>
<thead>
<tr>
<th>Coded Theme</th>
<th>Description</th>
<th>Student Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real world/applied</td>
<td>Utilizes complex ways of perceiving and analyzing engineering problems that are embedded in the social, cultural, political and economic context.</td>
<td>“Engineering is about being applied to the real world and not just problems being solved on a paper. Engineering problems should not be decontextualized because that takes away from their connection to the real world.”</td>
</tr>
<tr>
<td>Purposeful</td>
<td>Contextualized problems bring meaning to engineering.</td>
<td>“I think contextualized engineering problems can help an aspiring engineer understand how the problems they are encountering relate to the real world, and this gives value to the work they complete.”</td>
</tr>
<tr>
<td>Unnecessary</td>
<td>Contextualized problems providing too much irrelevant information.</td>
<td>“If I were the one trying to solve this word problem, I would get lost in between finding relevant information to actually solve it and the information given for the purpose of context.”</td>
</tr>
<tr>
<td>Professional development</td>
<td>Contextualized problems are important for professional development.</td>
<td>“Contextualized problem thinking promotes creative thinking, similar to what engineers would be expected to do in the workforce.”</td>
</tr>
<tr>
<td>Pedagogical concerns</td>
<td>Relates to logistical concerns of assessment and getting coursework done, especially as it relates to time and content coverage and depth.</td>
<td>“I don’t think contextualized problems would work well for exams where the extra information takes up time and space.”</td>
</tr>
<tr>
<td>Easier to understand</td>
<td>Contextualized problems provide more information, which helps student understand problem.</td>
<td>“Contextualized problem allows you to think about the problem at a deeper level. I feel it is a bit more easy to tackle a problem when there is a story behind it because you can visualize what’s going on and takes steps from there to solve the problem.”</td>
</tr>
<tr>
<td>Political</td>
<td>The notion that the politicization of problems necessarily introduces unwarranted bias.</td>
<td>“Contextualized engineering problems need to show less of the political and emotional appeal, but rather show a logical approach.”</td>
</tr>
<tr>
<td>Emotional</td>
<td>Putting a humanized face on a technical problem.</td>
<td>“A contextualized problem is simply meant to give the importance/emotions of what solving the problem means.”</td>
</tr>
</tbody>
</table>
Investigating student attitudes about contextualized engineering problems is particularly relevant as it may elucidate the degree to which targeted interventions, like the one described in the next section, will bring about a more nuanced and sophisticated understanding of the consequences that engineering has on societies and their peoples. Furthermore, by disaggregating student attitudes by major, the findings may also have practical significance in relating potential interventions to student retention. In general, engineering majors responded more positively to decontextualized problems (41.4%) than non-majors (28.0%). However, 48.3% of engineering students in the class expressed ambivalence about decontextualized problems. These were mainly students that felt both decontextualized and contextualized problems have a place in engineering education. Only 2 identified engineering students expressed outright negativity toward decontextualized problems (Table 5).

**Table 5 - Descriptive Statistics for Attitudes towards Decontextualized problems by Major**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>missing (%)</th>
<th>Positive</th>
<th>Mixed</th>
<th>Negative</th>
<th>Indeterminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>29</td>
<td>0 (0.00)</td>
<td>12 (41.4)</td>
<td>14 (48.3)</td>
<td>2 (6.90)</td>
<td>1 (3.45)</td>
</tr>
<tr>
<td>Non-Engineering</td>
<td>25</td>
<td>1 (4.00)</td>
<td>7 (28.0)</td>
<td>6 (24.0)</td>
<td>9 (36.0)</td>
<td>2 (8.00)</td>
</tr>
<tr>
<td>Missing</td>
<td>13</td>
<td>0 (0.00)</td>
<td>7 (53.8)</td>
<td>4 (30.7)</td>
<td>1 (7.69)</td>
<td>1 (7.69)</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>1 (1.49)</td>
<td>26 (38.8)</td>
<td>24 (35.8)</td>
<td>12 (17.9)</td>
<td>4 (5.97)</td>
</tr>
</tbody>
</table>

Note: n denotes total sample size within group, missing (%) denotes number of missing information by group and percent missing calculated by group, student attitudes (%) denotes number of student responses coded as positive, mixed, or negative including relative percentage disaggregated by major.

In contrast, attitudes toward contextualized problems were less distinct for both majors and non-majors. Four engineering majors chose to leave that question blank. Only 24.1% of the engineering majors had positive attitudes and 20.7% had mixed attitudes toward contextualized problems. Non-engineering majors showed a similar pattern to engineering majors except 44% had mixed attitudes (Table 6).

**Table 6 - Descriptive Statistics for Attitudes towards Contextualized problems by Major**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>missing (%)</th>
<th>Positive</th>
<th>Mixed</th>
<th>Negative</th>
<th>Indeterminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>29</td>
<td>4 (13.8)</td>
<td>7 (24.1)</td>
<td>6 (20.7)</td>
<td>9 (31.0)</td>
<td>3 (10.3)</td>
</tr>
<tr>
<td>Non-Engineering</td>
<td>25</td>
<td>1 (4.00)</td>
<td>6 (24.0)</td>
<td>11 (44.0)</td>
<td>5 (20.0)</td>
<td>2 (8.00)</td>
</tr>
<tr>
<td>Missing</td>
<td>13</td>
<td>0 (0.00)</td>
<td>3 (23.1)</td>
<td>3 (23.1)</td>
<td>5 (38.5)</td>
<td>2 (15.4)</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>5 (7.46)</td>
<td>16 (23.9)</td>
<td>20 (29.9)</td>
<td>19 (28.4)</td>
<td>7 (10.4)</td>
</tr>
</tbody>
</table>

Note: n denotes total sample size within group, missing (%) denotes number of missing information by group and percent missing calculated by group, student attitudes (%) denotes number of student responses coded as positive, mixed, or negative including relative percentage disaggregated by major.
Research Question 2: What strategies are students using to create context?

Students selected a wide range of topics to provide context, including, for example, aerial drones, household appliances, HVAC systems, electric cars, diffusing bombs, sanitary systems, wiring houses, sprinkler systems, defibrillators, motorized wheelchairs, fire detectors, autonomous vehicles, toys, and cell phones. Topics were diverse, but 7 out of 16 students focused on domestic affairs (issues related to the home, family, or personal items). However, no student stories focus on SJ issues. Perhaps the closest to address SJ was the student that wrote about military drones killing people with the bombs it dropped. But the student didn’t describe who was killed and under what circumstances. Some stories, however, ended with people perhaps becoming economically deprived as a result of the death of a family member. Table 7 provides a summary of the types of physical and non-physical harms students described. The most common physical harms were explosions and fires. The most common non-physical harms were economic loss, mental stress from accidents, and inconvenience due to non-functioning technology.

Table 7 - Summary of physical and non-physical harms described in student stories.

| Physical Harms: explosions (bombs, cell phone batteries), crashes, fires, pollution, slipping hazard, electrocution, freezing to death, car accidents, lack of fire protection, lacerations, property damage. | Non-physical Harms: bullying, economic loss/affordability, mental stress from accident, inconvenience, aesthetic, lack of efficiency, disappointment, water waste, legal action, political conflict, privacy, job loss |

It is difficult to point to a typical story due to the diversity of ways students attempted to provide context. Below is an example of a story that leads to a physical harm:

John is a store manager at a supermarket who wanted to set up a sprinkler system to water his garden. He doesn’t have time to water the plants as he works two shifts every day. The schematic diagram shows the circuit used for the sprinkler where the two resistors which are connected in parallel connections are linked to the pipes where water comes out and one main pipe is connected in series. ... The amount of current passing through the circuit decides the amount of water sprinkled. One physical harm related to this sprinkler system is that if the sprinkler doesn’t work properly and releases a lot of water in different directions making the walking path wet, then he might have a chance of falling down and getting hurt.

In this story, the student portrays a problem with a sprinkler system where if the engineers designing it don’t calibrate the circuit correctly, excess water will escape and potentially cause a
slipping hazard. This story includes three stakeholders: the store manager, engineers, and the employer of the engineers (not shown). In this case, the ethical relationship is simple, a matter of the engineers getting it right. While the company that the engineers are employed at is part of the story, the student doesn’t make an effort to show the potential managerial pressures that might cause the engineers to take a shortcut. While there isn’t a developed plot, most stories displayed these kinds of simple relationships.

When we stop to consider a non-physical harm story, we see a similar lack of complexity:

The content of this decontextualized problem is that an engineer, who is the developer, is helping to construct the electrical circuits within a new home and he wants to determine how much current should be allowed in order to prevent physical problems like creating fires from overheating wires or blowing up an appliance due to too much voltage. … The non-physical harm that the engineer should attempt to avoid is how to make this circuit efficient in terms of economic limitations. The homeowner may not have enough funds to help the engineer solve the problem, leading him to consider other options to solve the problem suggested. This may lead the engineer to suggest the homeowner that he may have to install cheaper but efficient circuit tripper instead of the costly but consistent circuit breaker, which does not need to be replaced as often.

Here, affordability is the potential non-physical harm. The engineer is duty bound to provide transparent economic options to the homeowner. We also see a logic where it is left to the homeowner as a rational consumer to make the best decision, which because of their socio-economic status seems to be by default a safe, but less efficient circuit.

Students engaged in a number of strategies to create context. Two of sixteen students created stories with complex relationships and non-physical harms not directly related to a physical harm. But for the most part, students struggled creating stories with complex context, especially stories with non-physical harms. We briefly describe five strategies below as a way of illustrating some of the challenges students had creating context for decontextualized problems. In general, these strategies reveal that it is more difficult for students to provide context for non-physical harms than physical harms. Non-physical harm contexts were often highly contrived, convoluted, lacking depth, and/or often directly derive from a physical harm.

1. Same story for both physical and non-physical harms: In these cases, the non-physical harm was a continuation of the physical harm. For example, one student constructed a story wherein the physical harm was the death of a father who had improperly installed a light build circuit. The ensuing harm was the father’s
family becoming distraught and unable to make ends meet. Usually these stories had malfunctioning products resulting in a physical harm that causes the non-physical harm

2. **Two different stories for physical and non-physical:** In several instances, students created two separate stories for their physical and non-physical harms. For example, one student described a situation where the improper wiring of an electric car battery could lead to an explosion as a physical harm. The student then switched over to a personal anecdote about an incorrectly wired circuit breaker in their house causing the stove to not work, inconveniencing everyone that lived there.

3. **A focus on blame:** Students often depicted scenarios where a single individual was responsible for determining whether the circuit is safe. In these cases, it was easy to determine who was at fault if the circuit failed, especially in terms of non-physical harms.

4. **Using a circuit metaphor to depict non-physical harms:** Two students used circuit metaphors to describe a non-physical harm. One student described a car as a circuit and the other student used electricity as a metaphor for the flow of information in society. Both of these students struggled describing a non-physical harm. The student with the car metaphor described a situation where the car breaks down, causing the driver to miss an interview. The student describing information flow used the metaphor to describe real-life tensions between various social groups, failing to concretely link a non-physical harm to technology.

5. **Backstory:** Some students created backstories of engineers. For instance, one student talked about how an engineer, working on a circuit problem for a client, was a loving father with a family. However, the student never tied the engineer’s family life back into the story. It is possible that the student felt the engineers’ backstory was a way of layering in context and indicates an opportunity for discussions about engineers’ identity.

**Discussion**

We found evidence to support assertions that engineering mindsets complicate and obstruct efforts to foreground SJ in engineering [3], [4], [15], [18], [34]. Some students acknowledged the added value of having context, and some even indicated that good professors provide context. But overall, many claimed context is unnecessary and perhaps even detrimental to mastering the technical fundamentals of engineering. Beyond engineering mindsets such as technical narrowness, positivism, and uncritical acceptance of authority, students focused on pedagogical challenges to using contextualized problems in their coursework such as the perception that decontextualized problems were easier to test and understand. Many students saw the use of
decontextualized problems as foundational to developing problem solving skills, adopting an instrumental approach to education and reducing engineering problems to a math problem [17]. These student standpoints reflect a “common sense” mentality prevalent within engineering education that suggest a lot of work needs to be done to unpack the social structure of engineering education that privileges decontextualized problems over contextualized problems [36]. Simply introducing contextualized problems into a course might garner a lot of student resistance [18], [34], [35] and even a backlash. Nonetheless, on an optimistic note, we did uncover a diversity of positive ways that some students think about the need for context.

We detected a fair amount of ambivalence about the use of contextualized problems, as most students had a scattered approach to discussing the role of context in giving engineers the skills they need. Students exhibited positive and mixed associations with contextualized approaches, with some students expressing the significance of contextualized problems as a way of communicating the types of problems they will likely encounter in their professional career. Similarly, students expressed support for a scaled down approach to adding context, especially as it improves professional skills, student understanding of engineering identity and the meaning of engineering, understanding of real world applications, and even skills related to empathy. We could build on these desires to develop curriculum that focuses on context. However, we also identified significant challenges to adapting curriculum to include contextualized problems. For instance, there is a danger to relating contextualized problems to professional development, as one student sees it:

I think decontextualized questions are lacking in purpose because they fail to address the real life situation that is requiring the question to be solved. This causes many college graduates to have much decontextualized knowledge but little to contribute to the actual workforce.

Thinking of contextualized problems in this way could lead to a hyper fixation on understanding for the sake of employment, just another form of instrumental thinking—not to be conflated with a sense of social justice as an inherent component of engineer work. Ultimately, most students that embraced some aspects of contextualized problems argued that they would help them understand the importance of real world experiences to engineering work. However, many students qualified their support for contextualized problems with the belief that the real emphasis of engineering education is to learn technical skills. Nonetheless, leveraging the engineering mindset Willingness to help to foreground social justice has promise. Understanding how students construct context around a decontextualized problem is one step toward developing engineering curriculum around contextualized problems.

While creating stories for both a physical and non-physical harm challenged students, it was particularly difficult for them to create stories of a non-physical harm. And stories of non-
physical harms were mostly derivative of the physical harms (e.g. economic hardship as a result of loss of life). Most stories focused on individual agency and didn’t consider the larger social structure in which the story takes place (e.g., company influences, issues of power, etc.), which is consistent with the emphasis on micro-ethical framing of ethical issues in engineering [10]. For example, several students focused on assigning blame as a strategy for illustrating ethical context that reduces ethical issues to micro-ethical concerns of individual responsibility (and detracts from recognizing macro-ethical structural issues that contribute to the problem). It was difficult for students to first imagine a non-physical harm emerging from a circuit problem (e.g., issues of privacy, sustainability, conflict minerals, etc.).

Despite this, we walk away from this pilot study on a positive note. In the ENEE 200 class, students had workshoped storytelling in multiple class periods previous to this, and the reaction has been positive. Storytelling requires considerable practice. For these 16 students, there was value to creating context around engineering problems even though some of their examples revealed only a superficial understanding of the purpose of doing so. As educators and practitioners working to render SJ issues visible in our classrooms, seeing their willingness to participate in the activity represents a positive first step, no matter what kind of “Hail Mary Pass” (our shorthand for the student who created a story by analogizing a circuit to a whole car) they took. In addition to scaffolding this task with storytelling workshops, students will need additional support to transcend the negative association (both for its presumed superior efficacy with teaching and its ability to be assessed) with contextualized problems. Furthermore, it is important to understand what students mean by context as this may differ from academic conceptualizations. Not knowing this can be a barrier to helping them move toward embracing contextualized problems that address SJ and macro-ethical issues in general.

**Future Work**

Having students create context for decontextualized problems, with scaffolding, has potential to integrate SJ concerns in the engineering curriculum. The coding themes suggest some possible avenues for further inquiry. To understand this more fully, need to unpack how relationships among prior K-12 experiences [16], [37], engineering education culture [3], and broader social structure influences (e.g., military and corporate prevalence in engineering education) [4] create challenges to introducing social justice and macro-ethical thinking into courses. The positive support for contextualized problems in a limited role could be investigated in further research. We would be curious to build on the work here by trying this out in courses across the engineering curriculum, not just a course that is focused on ethics. In addition, work needs to be done to build student skills at storytelling and socio-technical systems thinking, skills that can assist students and professionals in all aspects of problems solving. We would be interested to examine how work like this might enhance student motivation in technical courses, especially as
it relates to retention. We look forward to experimenting further with assignments that build on the E4SJ framework [4].

REFERENCES


ASEE Annual Conference & Exposition, Salt Lake City, Utah.


