Design Students Framing and ”Solving” Ethical Quandaries as ”Engineering” Problems

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1: Introduction

For engineers to effectively recognize and act on their responsibilities to protect and improve the health and welfare of the general public, they must understand the sociotechnical nature of technological systems [1], [2], [3], [4]. The techno-centric content and instructional techniques typical of engineering coursework traditionally used by engineering faculty, however, condition engineering students to undervalue and/or disengage from the contextual and social welfare dimensions of engineering work, often referred to as the culture of disengagement [5]. This culture of disengagement can have a significant influence on engineering students' ability to identify, engage with, and resolve ethical challenges. Several facets of its influence on students were made visible to the authors of this paper through the events that led to a cancellation of a senior design project, which this paper will explore.

In response to longstanding critiques of engineering education's distancing of social and contextual matters, reformers have created and implemented innovative curricula that expose students to the social, cultural, and political elements of engineering work—often bundled through a variety of critical lenses, such as contextualization [6], technoskeptical thinking [7], sociotechnical integration [8], challenge-based learning [9], and design pedagogies [10].

Since the 1990s, engineering program builders have increasingly integrated capstone design into engineers' undergraduate education, seeking to prepare engineering students to engage with the "real-world," contextually multifaceted nature of engineering work through the completion of open-ended design projects. At the host institution for the senior design project we will analyze, program builders use that course to showcase students' professional engineering capabilities and provide graduating seniors an opportunity to synthesize skills and knowledge gained during their undergraduate education. The course accomplishes these two objectives by composing student teams across engineering disciplines (mechanical, civil, electrical, environmental, etc.) and connecting them with industry sponsors who in turn provide the program "real-world" projects. Sponsors agree to support student projects logistically and financially for the duration of the course. For almost all students enrolled in the course, satisfactory completion of their design project is required for graduation. These conditions meant that the decision to sever ties with the sponsor came after careful consideration regarding the potential implications for the impact on the students' degree progression as well as for the institution's reputation.

This paper explores firsthand accounts of the experiences of the student team members of the cancelled project. Interview data indicate that several students felt as though the project sponsor misrepresented the true nature of the project, raising concerns that continued collaboration with the sponsor would lead them to contribute their engineering expertise towards a project that conflicted with their values. As a result of these concerns, the team appealed to program leaders to have the project cancelled. This paper treats the cancelled project as an instrumental case study to explore how the normative standards of engineering inform, support, and restrict the ethical sensibilities and ethical courage of the student members of the design team. By centering our inquiry on the students' experiences of the ethical challenges that arose during the cancelled project, we are able to reveal hidden cultural frameworks embedded within structures of engineering education that shape students' definitions of the engineering profession and their subsequent conceptions about their responsibilities as engineers. Furthermore, situating our analysis on how students made sense of the ethical challenges enables us to assess the effectiveness of current pedagogical approaches in cultivating engineers who understand the sociotechnical quality of technology and act on their obligations to protect the health and welfare of the general public. This paper seeks to draw attention to underlying conceptualizations of engineering that insulate it from interrogation along various dimensions of contextual relevance. Specifically, it offers a sustained critique of the ways that traditional engineering curricula condition students to adhere to a "purely technical" definition of engineering to illuminate the effects of this conditioning on students' ethical capacities.

2: Background

Practicing engineers widely understand and describe their work as using their "technical" skills and expertise to "solve problems" [11]. Similarly, Pawley finds that many engineering educators also affirm such definitions of engineering built on "technical" qualities of engineering work [12]. Engineering education program builders often place high value on preparing students for professional employment, part of a broader instrumentalist mindset [13], and subsequently seek to equip students with the "technical" engineering skills they believe are most relevant to industry. Accordingly, many educators allot a majority of undergraduate engineering curriculum to engineering science courses [14], [15] and the engineering problem solving (EPS) process [16]. EPS is widely considered by engineering faculty as the foundation of engineering education [16]. As a result, faculty design engineering science courses in a way that conditions students to adhere to its "Given-Find-Solve" process [17] by completing abstract, close-ended problems [18]. For mechanical engineering students enrolled at the cancelled senior design project's host institution, such engineering science courses comprise nearly two-thirds of their undergraduate education. Engineering educators justify this focus on the engineering sciences by arguing that engineers' mastery and application of "technical" knowledge minimizes the risks posed by engineered technologies related to potential modes of failure such technologies may exhibit (fracture and collapse, short-circuiting, etc.) [11], [18]. While failure prevention is certainly an important dimension of the design of technological systems, educators who adopt a perspective that focuses too narrowly on this facet of the engineering design process often choose to deliberately exclude the environmental, cultural, and political dimensions of technological development while neglecting to question whether "technical" expertise is appropriate for a given context [7], [19]. Such an education can lead engineering students toward a bias that focuses exclusively or primarily on the technological dimensions of problems without consideration of other dimensions relevant to the welfare of the public [20].

While mastery of EPS is typically made explicit as a learning outcome in undergraduate engineering education, engineering science courses serve to contain and disseminate additional values surrounding engineering knowledge and practice, often referred to as the hidden curriculum [21], [22]. Engineering education researchers have uncovered some of the primary functions of the hidden curriculum: Leydens et al. find that traditional engineering pedagogies render invisible the social justice dimensions intrinsic to engineering work [23], [24], and Downey argues that engineering science courses instill the cultures and ideologies of the engineering profession within engineering students [25]. In these engineering science courses, educators largely accomplish this function by directing students to complete abstract "technical" problems, which are frequently removed from any social context. Reaching the correct solutions to these "technical" problems is almost solely dependent on students' ability to deploy the EPS process. Congruently, any effort to consider and incorporate the potential social, political, or cultural dimensions of this "technical" work would impede a student's capacity to quickly and efficiently solve the many problems they encounter in their assignments and exams.

Hence, students are trained to associate "engineering" with the practice of extricating and then largely ignoring social context when approaching design challenges [8], [14], [17]. This engenders what Faulkner and Cech describe as the ideology of technical/social dualism: the belief that the social and technical elements of engineering work are extricable and can be dichotomized [26], [11], [5]. Concomitantly, students learn to adopt the ideology of depoliticization, which Cech defines as "the belief that engineering is a purely 'technical' space and political and cultural concerns can—and should—be removed from that space" [27, p. 204]. These ideological pillars, along with the ideology of meritocracy (which encourages engineers to assume the systems that distribute costs, benefits, risks, and harms are fair), comprise Cech's culture of disengagement [5], which characterizes engineers' general disregard for the inherent social, cultural, and political dimensions surrounding and contained within their work.

Colloquially, engineers' narrow technical focus is often understood by employers and the public as engineers' tendency to lack interpersonal communication skills [28]; however, the mindset also encapsulates engineers' general lack of ethical attunement [29] and awareness of the structural conditions shaping their work [8]. A further product of an engineering education that narrowly focuses on the "technical" dimensions of engineering work is engineers' belief in "positivism and the myth of objectivity" [28] describes engineers' tendency to minimize or ignore non-technical expertise [30], often through the construction of (sometimes artificial) ideological boundaries between the "technical" and the non-technical [31], [32]. Engineers undertake such boundary work to reify the ideologies of technical/social dualism [26], [5] and depoliticization [27]. Engineering ethics scholars frequently attribute the impacts of these cultures and ideologies to instances of professional engineers engaging in unethical conduct [33], [34]. Engineering educators have designed and implemented curricular interventions that intend to address deficiencies resulting from adherence to these normative standards of the profession. Two such interventions most relevant to this research are capstone design and engineering ethics training.

Engineering educators incorporate capstone design courses to give students an opportunity to apply their "technical" knowledge to open-ended, "real-world" design projects [35]. Additionally, program builders also add to capstone curricula a wide range of ABET-required learning outcomes that are typically excluded from engineering science courses, particularly including interpersonal communication skills [36], [37], [38], [39] and ability to function effectively on a team [40], which engineering employers rank as important competencies [41]. Despite such efforts, one study finds that 91 percent of recent engineering graduates who completed a capstone design course struggle with "teamwork & communication" during their first three months of professional employment, while 92 percent struggle with "self-directed learning" [42], which encompasses graduates' ability to navigate and overcome open-ended problems through independent research, self-instruction, and skill development [43].

Beyond the professional development outcomes described previously, longitudinal survey data indicate educators commonly address ABET's "engineering ethics" learning outcomes within capstone courses [40]. Further survey research emphasizes the importance of such ethics training by comparing the responses of engineers who receive ethics training during their undergraduate education and those who received such training in other settings. Cech and Finelli find that engineers who receive ethics training during their undergraduate education are significantly more likely to identify ethical dilemmas and take appropriate action than engineers who receive training in other settings [44]. The senior design program that this paper explores employs a case study-based approach to teach students engineering ethics: Faculty present students with 'landmark' engineering ethics cases, such as the Ford Pinto case [45] and the Space Shuttle Challenger disaster [46], then have students discuss other highly didactic, hypothetical ethical dilemmas.

Hess et al. find that many engineering educators who employ similar approaches to ethics training typically include content centered on unethical engineering practices, minimal depictions of moral exemplars, and little focus on enhancing students' "Ethical courage, confidence, or commitment" (students' disposition to take action when faced with ethical conflicts) [47]. Without providing students examples of engineers using their agency and expertise to uphold ethical principles, educators risk framing "ethics" and "morals" as impediments to or restrictions on "engineering" rather than assets that empower engineers to design better technologies [48].

Winner offers further critique of case-study based approaches to engineering ethics training, arguing that such pedagogies present isolated ethical dilemmas as one-off occurrences in contexts that students are meant to assume are fair and just [49]. Such training reinforces the outcomes of the hidden curriculum embedded within students' technical courses, implicitly teaching them to ignore structural conditions, power dynamics, and, oftentimes, the entirety of the broader contexts of engineering work. Winner asserts that educators, when they frame ethical dilemmas in such a manner, effectively transform ethical dilemmas into decontextualized, "one-right-answer" problems. Such decontextualized "dilemmas" are reminiscent of "technical" problems students complete with the Given-Find-Solve approach of the EPS process [49]. Such techniques discourage students from engaging in more than microethics [50], focusing instead on "ethics as loyalty" and "ethics of efficiency" [33]. These ethical frameworks center on the belief that an engineer's foremost obligation is to optimize the functionality of the technologies they design in a way that best fulfills employers' desires, often without regard for the technology's potential broader social and cultural impacts—that is, without regard for macroethics. Bucciarelli affirms Winner's critiques and argues further that such techniques also fail to recognize that ethical dilemmas are almost never the sole responsibility of an individual engineer [51]. As typically delivered, case-study based ethics training can constrain engineering students' identity development as ethical agents, students' collective recognition of their professional ethical responsibilities, and their overall commitment to protecting the health and welfare of the public more broadly [52], [53], [54], [55], [56].

In summary, an extensive body of literature demonstrates that purely "technical" definitions of engineering shape engineering educators' curricular content and pedagogical techniques, leading engineering students to devalue and to become disengaged from the broader social implications of their engineering work [5]. This research details an educational moment when these concerns became acutely present for a team of senior design students. While past studies on capstone design courses examine the curriculum's productiveness towards preparing students for professional engineering employment, such studies have not explored how students actively navigate an ethical dilemma at the moment, not least one sufficiently acute to lead to severing ties with a project sponsor. In this regard, this research context not only allows the authors of this paper to gauge the efficacy of common engineering ethics pedagogies, but to also shed light on how widespread engineering educational cultures affect students' evolving ethical sensibilities, capabilities, and courage.

By situating our analysis in student experiences, we seek to make visible how the norms and ideologies of engineering education shape, restrict, and define students' conceptions of what it means to be a "good" engineer and to do high quality engineering work, interrogating the following data points: 1) student depictions of the events that led to their project's cancellation; 2) student evaluations of the extent to which the project constituted an ethical dilemma; 3) students' thoughts and feelings surrounding the senior design program's decision to cancel the project; and 4) students' assessment of the value of their previous ethics trainings in navigating the dilemma as it unfolded.

3: Methodology

We approach the cancellation of the senior design project due to ethical concerns as an instrumental case study that reveals the effects of engineering cultures and ideologies on undergraduate engineering students' ethical sensibilities, capacities, and courage [57], [58]. Although this case study is bounded in scope, findings about student experiences of the ethical dimensions of the project illuminate scholarly conversations around the normative structure of engineering education–as affirmed, promulgated, and reified by its curriculum and culture—and the resulting implications for future engineers' capacities as sociotechnically attuned ethical agents. [59], [60].

The authors conducted semi-structured interviews [61], [62], [63] with students that comprised the team of the cancelled senior design project to gain a nuanced understanding of the circumstances that led to the cancellation of the project and how the team members made sense of those circumstances. Interview questions focused on how individual students navigated events prior to, during, and following the cancellation of the project, how they imagined their education prepared them (or not) to respond to the dilemma, and how their overall experience fit (or not) with their conceptions of the engineering profession as a whole. The interview protocol is appended.

Seven of the nine members of the senior design team volunteered to participate in the research project, with one student's decision pending. The research team is made up of authors who were closely involved with the cancelled project and others who act as mentors and collaborators not directly affiliated with the project. The affiliated researchers conducted all primary research, including one-to-two-hour long interviews with volunteer participants, coded the resulting interview transcripts thematically, and identified key themes for analysis. The remaining authors provided mentorship support in research design, data coding, and analysis of findings—with close attention to the affiliated authors' positionality relative to data collection, interpretation, and analysis. All authors collaborated in finalizing the analysis and writing the manuscript. The project also collected data from the research participants' essays submitted for the course "Ethics Assignment" as well as participant observation [64], [65]; however, those data are not directly included in this analysis. Future work is planned to synthesize findings from across these data sets.

This research project was approved for exemption by the Human Subjects Research Committee of the authors' institution under the conditions that the identities of project participants and other immediate stakeholders remain anonymous. Accordingly, we have omitted details that may compromise the anonymity of participants and affiliated individuals/entities within the data and throughout the analysis.

4: Data & Findings

The following data and findings presented in this section of the paper include direct student quotations and the authors' analysis produced through constructive interpretation of key themes observed throughout the interview transcripts. Students have been assigned pseudonyms and are referred to as Parker, Taylor, Cameron, Jesse, and Adrian to protect their anonymity. As described in the introduction of this paper, several members of the design team identified the unique composition of the student team as a key factor contributing to the cancellation of the project. As Cameron suggested:

> If there weren't team members who cared a lot about it, a lot of the team members wouldn't care at all… I think that it took having a few team members who actually cared and took an initiative to do something about [the ethical concerns] instead of just be compliant.

The relevant demographics and important personal background information each research participant depicted in their interview is included in *Table 1* below. All students interviewed were seniors scheduled to graduate in the Spring of 2026.

Table 1: Student Demographics.

Student	*Student major*	*Other key background information*
Parker	Electrical engineering	Parker describes coming from a rural, working-class background.
Taylor	Mechanical engineering (aerospace focus)	Taylor previously attended an engineering trade school and was working for a high-profile engineering firm at the time of their interview.
Cameron	Environmental engineering	Cameron attended an engineering trade school and, at the time of their interview, works for a high-profile engineering firm, and conveyed in their interview that, if money were not a concern, they would pursue a career in the creative arts.
Jesse	Civil engineering	Jesse describes that they majored in engineering because both of their parents obtained engineering degrees (one of whom was working as an engineer at the time of their interview).
Adrian	Electrical engineering	Adrian notes that their parents "majored in liberal arts" and is a member of a leftist, student-run political organization.

The senior design program that was home to the project the authors examine shares many of the primary objectives of capstone design programs depicted within the **Background** section of this paper. Teams of 4-9 students from various engineering disciplines are matched with industry sponsors, faculty projects, or engineering challenge projects. All projects are open-ended in nature and require students to use their "technical" expertise to produce "real-world" engineering deliverables, whether conceptual or physical in nature. Students are also encouraged to develop their "non-technical" skills, such as problem definition and contextualization, leadership and teamwork, and professional writing and verbal communication. These multifaceted learning outcomes intend to demonstrate to students that, to succeed in real-life engineering workplaces, engineers must assume a "heterogeneous" identity [11]. At the start of the course, students interact with sponsors at a project fair and rank their top candidates before being assigned to their projects. Throughout the two-semester course, faculty mentors guide 3-5 student teams through project deadlines, grade team deliverables and individual assignments, and mediate communication between students and sponsors when necessary. A lecture and a studio section comprise the weekly schedule of the course. Lectures cover "engineering" skills (data analysis, risk mitigation, technical writing, etc.), project management skills (scheduling, goal setting, communication, etc.), and professional development (email etiquette, professional attire, etc.). In the 32-week course, the "broader impacts of engineering" (such as environmental pollution, economic impact, and the social appeal of designed technologies) and "engineering ethics" are each covered in a singular lecture respectively. Prior to their enrollment in senior design, all students are required to complete a general, introductory humanities course that exposes them to general ethical/moral frameworks and historical engineering ethics case studies. Interview data indicate that, for many students on the design team, this training was insufficient in providing value towards preparing them to resolve the ethical concerns they encountered with the cancelled project. In the words of Jesse:

> [Course instructors] kind of presented in school [that] you have this specific choice to make. You were presented with an ethical dilemma or whatever. Like, *'you can do this, or you can do this, what is correct?'* Versus, I don't know, [during the cancelled senior design project] we were **given** a situation, and we had to figure out the... the **right** considerations, I guess. And it wasn't going— Like it was through our agency to make that happen, right? Because our [faculty mentor] wasn't gonna look at that for us or encourage anything along that sort. (emphases added)

This student's description of these courses resembles an abstract, closed-ended case study-based approach to ethics training. Moreover, the student's search for "the right considerations" suggests the resonating influence their engineering science courses have had on their ethical capacities: This student applies the EPS terminology towards describing the ethically ambiguous conditions of the cancelled design project; while this approach is useful for solving abstract, closed-ended problems, its practical value for making value judgments in the face of open-ended ethical challenges seems limited [16], [17]. Some students describe having received ethics training in other courses, such as their institution's honors programs, engineering electives, and humanities courses; however, these students dichotomize the "engineering" and "social" content of these courses. For example, Cameron describes that in their degree program,

> [Some engineering faculty] kind of give you a broader picture. Like they don't keep it to **just the engineering**. And I think that that more so has to do with the professors that you have. So like, some of them care; some of them don't… I've been lucky to get professors that actually care, so I appreciate that. **I don't think it's, like, written into the curriculum or anything.** (emphases added)

The student's bracketing of the "broader picture" and accompanying reference to the "technical" bulk of their degree as "just the engineering" seems to demonstrate that, while this student values the "non-technical" context of engineering, they conceive of "engineering" specifically as a "purely technical" enterprise. Moreover, their assumption that gaining an understanding of the context of engineering is *not* "written into the curriculum" draws attention to the central role their engineering science coursework plays in shaping this definition.

We have identified two distinct but overlapping themes emerging across interview data:

Student categorizations of "engineering" and "non-engineering": Throughout interviews, students classify certain elements of the cancelled project, the senior design course content, and their education generally as "engineering" or "non-engineering," with non-engineering mapping to courses and project elements that are not predominantly technical, regardless of their focus on or attention to engineering practice.

Students' engagement with ethical frameworks: Student responses indicate a tendency to rely on ethical frameworks concerning loyalty to their employer and the engineering profession, which itself is distilled to an obligation to design optimally functional technologies through highly "technical" methods.

As alluded to previously, at the start of the semester, the sponsor's presentation of the cancelled project at the initial project fair appealed to students' technical interests as well as their personal values, drawing attention to both the "technical" and professional development learning outcomes of the course. As Jesse describes:

> I mean, at the [fair], [the sponsor] was saying all these things about how the project was going to, I mean, it was gonna demonstrate…all these good things…So, I guess, I mean, I was drawn to that [aspect of the] project.

Adrian depicts having a similar initial understanding of the project:

> You would basically just be trying to create this [technology] for people that…would also be related to sustainability and things like that… And I'd be working with a bunch of other people and we would, our work would actually be used to make this [technology], and this [technology] would actually be used to benefit people.

After the students were placed on the team during the second and third week of the course, however, Adrian describes that the team

> had a couple meetings with [the sponsor], and [the sponsor] sent over the files that [they] had for the project. And they were, I mean, [the sponsor's] project plans that [they] had already come up with…and then [the sponsor's] plans weren't, they didn't align with the stuff that [the sponsor] was telling us [at the project fair].

4.1: Juxtaposing "technical" engineering concerns with ethical concerns:

Parker expressed concern that the project would be "a misuse of [public resources] in order to fund a project that wouldn't have the community actually in mind." After these initial meetings with the sponsor and having received the sponsor's project plans, many students felt somewhat uneasy about the emerging ethical dimensions of the project. Alongside these concerns, several students conveyed they felt further discomfort resulting from their beliefs that the project was not an "engineering" project. Cameron voiced these concerns saying, "I think that it just became very clear that [the sponsor] wanted the team to do stuff that isn't, I feel like, doesn't fit within what an engineer is supposed to do." Later on in their interview, this student describes the "non-technical" nature of the sponsor's requests. Taylor affirmed this perspective, arguing that "[the sponsor] doesn't really understand what we do as engineering students… so, I mean, it would have been hard to even produce something that [the sponsor] would have really accepted." Such fear that the team would struggle to produce a technology that met the sponsor's interest reveals this student's adherence to both "ethics as loyalty" and "ethics as efficiency" frameworks [33]. This discomfort seems to arise from these students' belief that "what an engineer is supposed to do" constitutes "technical" work and excludes "non-technical" dimensions of an otherwise seemingly engineering project. Such beliefs potentially illuminate the way these students' engineering science courses ignore or extricate the social, environmental, political, economic, and cultural elements of engineering work (as described above) leading them to misunderstand the true, sociotechnical nature of engineering. Moreover, the fact that these students present concerns with the non-technical dimensions of the project side-by-side with their emerging ethical concerns suggests they view restricting their work to its "purely technical" dimensions as a pseudo-ethical imperative for "good" engineering, such that attending to the social, cultural, and political elements embedded within engineering work is beyond their "scope of responsibility." Adrian reiterates these students' beliefs, describing that:

> When it comes to the engineering side, too, there was just not really clear instructions at all or even vague guidelines. The resources [the sponsor] sent us were not very useful; it was like a very vague map. [The sponsor] didn't tell us what software [they] recommended… And on top of all that, [the sponsor] just didn't really seem to understand engineering despite claiming [they] did.

When interviewees were asked what they believed would have made the cancelled project resemble an "engineering" project, they asserted that such projects should have a narrow "technical" focus. Such claims indicate their adoption of the ideology of technical/social dualism and the ethical frameworks embedded within this ideology: even "when it comes to the engineering side" (as opposed to the "ethical" side), the sponsor crossed some pseudo-ethical boundary by requiring students to attend to the "non-technical" as a result of the open-ended, ambiguous nature of the project. Taylor argued that engineers "should be on the technical side of things instead of, like, on the whatever side [the sponsor] wanted us to be on." Taylor's response seems to indicate their adoption of a "purely technical" definition of engineering and a general apprehension towards self-directed learning [43]. Both Taylor and Adrian elaborate this thread, claiming that, to do "real" engineering, engineers must be given robust design constraints and requirements. Adrian stated "I feel like a client who is actually giving you a project like that should be like, '*This is the [technology] I want designed. You should give me something in one of these programs. I would recommend starting with this kind of drawing first.'* And yeah, something like that." Taylor conveyed that they "would have liked to see more design constraints…and being really focused on what they wanted our deliverable to be." Such design constraints would have enabled the students to focus solely on the "technical" elements of the project, reiterating their alignment of engineering with its "technical" elements, isolated from the social context by their invocation of technical/social dualism. Taylor elaborates on this desire for requirements further when comparing their new senior design project to the cancelled one:

> *Taylor:* I feel like that's a good, like, path that I've taken since then. More like, I don't know, an isolated project, if that makes sense…like, just making something.
>
> *Interviewer:* Talk to me about *just making something*.
>
> *Taylor:* So just making something as in, like, having a good, like, framework on what to work on.

Such a comparison draws attention to the way the ideology of technical/social dualism encourages engineers to adhere to "ethics as loyalty" and "ethics of efficiency" frameworks. This is further revealed by Adrian's understanding of what professional engineering work looks like:

> What engineers do generally is, you're given a specific deliverable that you, that they ask you to produce, and they give, and the client generally sends you some kind of model or reference or resource.

In these students' depiction of the engineering profession, they imagine engineering employers using engineers in a similar way engineering students are taught to use engineering equations and formulas: Employers provide engineers specific inputs ("Givens") and engineers produce technological outputs ("Solutions"). Such a depiction highlights the role that students' engineering science courses have on their definition of their engineering identities. Their affinity for narrowly constrained problems, with clear boundaries, hearkens back to the EPS process, indicating a key shortcoming of such curricula, which fail to develop students' abilities to employ critical thinking, to devise creative strategies to solve ill-structured problems, and thereby to recognize their role in problem definition [16], [66]. Taylor's positive value judgment about their new project—"isolated" is "good"—seems to reiterate that engineering science curriculum provides engineering students with pseudo-ethical imperatives to pursue only "purely technical" work, leading to their adoption of and adherence to "ethics as loyalty" and "ethics of efficiency" frameworks [33]. Such frameworks are problematic as they often directly oppose or contradict macro-ethical principles—such as the paramountcy clause found in many codes of engineering ethics [55], [56]—leaving emerging engineers uncertain where to place their own ethical convictions.

4.2: Reconciling concerns about microethics, macroethics, and technical feasibility:

During the fourth week of the semester, students attended a key meeting between the project sponsor and an approvals board (which we will refer to as "the Committee" henceforth). During this meeting, students described how the sponsor misrepresented to the Committee both the overall project and their role on the project as engineering students. Jesse describes their experience at this meeting as follows:

> I guess during the meeting specifically…[the sponsor] was giving us credit for things, or [the sponsor] was saying that we were going to help [them] create the plans…which is why [the sponsor] couldn't give [the Committee] specific plans,…which was false, because we weren't contributing to that at all. And so that seemed…that made me angry because it was like, *'Yeah, we'd love to help you come up with ideas…but you already have your mind set on what you're doing. So, it's not fair for you to say that we are going to help you.'*

As a result of the events of this meeting, students described their concern that the project sponsor intended to use the students' engineering expertise and role as disinterested stakeholders to deceive the Committee. In the words of Taylor, "[The sponsor] was deceiving [us about] what the project entailed and [the sponsor] was deceiving [the Committee].” Cameron elaborates this line of reasoning, claiming that “[the sponsor] wanted us there…to maybe even pass some of the blame, like, *‘Oh, I didn’t design this whole thing myself, I have this team of engineers that are making sure everything is right’*.” After this meeting, the students discussed their experiences with their faculty mentor, during which the student team had to reconcile these concerns against the values of an “ethics as loyalty” framework and beliefs about engineers’ obligation to undertake “technical” work. Parker describes that, during this meeting, they felt that their ethical qualms were unheard:

> It felt like the [faculty mentor] maybe didn’t understand the whole issue we were running into fully, because they kind of told us that we have to, *‘that’s part of the real world,’* and that we have to work, *‘you know, you might have to work for those people in the real world.’* But us, as students taking a required course that we’re paying to take? Yeah.

Jesse elaborates on their experience of describing their ethical discomfort to others, saying:

> It was just weird being told from our [faculty mentor] and from other, some other people, *‘Oh, like, it’s just, [the sponsor] is just a difficult client,’* like, ‘*You’ll deal with difficult clients in your professional career’* or whatever. But it’s like, I don’t know. We’re not really taught… What’s the difference between just a difficult client, versus when can I say that *‘This is wrong,’* or, like, *‘I don’t want to be a part of this?’*

These responses seem to expose the limitations of “ethics as loyalty” and “ethics of efficiency” frameworks, especially Jesse’s statement about not knowing when they *can*—as opposed to *should*—say “no” to an employer’s request. Rather than providing a clear direction for the students to resolve their ethical concerns, these frameworks seem to have impeded the students’ ability to determine a resolution that could uphold broader ethical principles related to honesty, transparency, and fairness while aligning with the values contained by “ethics of efficiency” and “ethics as loyalty”—demonstrating an instance of microethics principles existing in tension with macroethics outcomes.

Following these discussions, the student team compiled their concerns surrounding the events of the Committee meeting, the deceptive behavior of the sponsor, and the misalignment between the Committee’s expectations of the project and their understanding of its true intentions. As Parker conveys, the team “looked through and researched the actual, proposals that…[the Committee] wanted” and “made a memorandum, like, ‘*We’ll agree to continue working on this project, you know, as long as you [the sponsor] sign this and agreed to doing this, and this, and this.’*” Once they had created the memorandum, Taylor describes that, in the fifth week of the semester, the team “presented [it] in front of [the sponsor] and…brought in [the lead of the senior design program]…to make sure…there would not be any repercussions.” Jesse described the events following this meeting, saying:

> From there, they’re [senior design leadership] like, *‘Okay, yeah, this is proof that [the sponsor] doesn’t have the same vision,’* and that by us working on [this] project, and [the sponsor] telling everyone that we were doing the work that we weren’t doing, it was best to stop working with [the sponsor] entirely to, I guess, preserve the school’s reputation and the students’ along the way.

The team’s actions were spurred on by their concerns about the deceptive behaviors of their sponsor and fears that the project would misuse public resources (as described in the introduction), demonstrating the student team's attention to both microethics and macroethics. Continually entangled within these students' ethical concerns, however, were concerns about the technical feasibility of the project. Parker describes that:

> During that meeting [with the sponsor and senior design faculty], I kind of had a side conversation with [design faculty] during the meeting of, talking to [senior design faculty], and I expressed that I think working with this [sponsor] is going to be highly **inefficient**. And it's gonna really not [going to] be a valuable learning experience, really, for everyone. It's just gonna be a pain and then we're gonna get to the end of senior design and really presenting something that we don't value, we don't support, we're not proud of. And it would have just kind of ended up being like a half-assed project that was just done to get it done. (emphasis added)

This student's decision to tailor their ethical concerns around "inefficiency" seems to reveal an assumption that framing the problematic ethical dimensions of the project in a way that fits within the bounds of a "purely technical" engineering paradigm makes for a more compelling argument to an engineering audience. Such a strategy presents a direct appeal to an "ethics of efficiency" and "ethics as loyalty" framework [33] by implicitly centering on the student's concerns around the belief that engineers are obligated to produce effective, functional technologies. Furthermore, considering that the "inefficiencies" the student anticipates arise from social elements (juggling client relations and undertaking "non-technical" work) reveals this "ethical" appeal relies on the beliefs found within the ideology of technical/social dualism: a better project would distinguish such social responsibilities from the "technical" ones, then assign engineers only to the latter. The impact of this cultural norm is also found in Taylor's claim that, when they severed ties with the project sponsor, the team "kept it really professional… We didn't talk about the morality necessarily of the project, but we did talk about the project not aligning with what the group wanted to support and that we would just be going our separate ways after that." Such statements indicate these students have been trained to perceive "ethics" and "professional engineering" as oppositional, pointing towards the way that belief in engineering as a "purely technical" profession seems to function as an pseudo-ethical imperative: to do "good" engineering work, the ethical, social, political, and cultural elements must be extricated from the purportedly neutral "technical" aspects of engineering.

As Cameron states: "we dropped [the sponsor] … because [the sponsor] was super unethical and [the sponsor] doesn't really understand what we do as engineering students." Such claims demonstrate the student team (whether intentionally or unconsciously) worked to present their ethical concerns as "technical" considerations to persuade senior design faculty to cancel the project, arguing that continuation of the project would be wrong because it would infringe on their ability to do "good" engineering. Furthermore, students' engagements with these ethical principles demonstrates the ways microethics and macroethics can exist in opposition to one another, thereby inhibiting engineers' ability to resolve ethical dilemmas in a manner that upholds the breadth of ethical standards professional engineers hold themselves to. The authors further examine how engineers' engagement with the normative beliefs and standards of the engineering profession produce and reify "ethics as loyalty," "ethics of efficiency," and a purely "technical" definition of engineering—which together shroud the ideological underpinnings that guide, structure, and regulate engineers' behaviors.

5: Discussion

Across our data set, we found engineering students' reliance on the ideology of technical/social dualism [5], [11] and an instrumental logic [13], [15], invoking a purely "technical" definition of engineering to navigate the circumstances surrounding the cancelled project. Students used this definition to argue that the canceled project was not an "engineering" project, claiming that it should be cancelled because it would not provide them a valid "real-world" experience (where their construct of "real-world" was, perhaps ironically, informed and constrained by their previous experiences with the predefined, closed-ended problems of their engineering science courses). This data makes visible the presence and influence of two of Riley's mindsets in engineering, a "narrow technical focus" and an "uncritical acceptance of authority" [28]: Students avoided directly confronting the sponsor's requests, instead appealing to program faculty. Rather than overtly critiquing the sponsor, the students subverted the sponsor's authority over the work output by arguing the project was not sufficiently "technical" in nature and that this would impede their capacity to fulfill the sponsor's expectations. Furthermore, to make such claims, the students had to assert that the "technical" dimensions of the project (and of engineering in general) should be severed and "isolated" from its social context. Claiming engineers are solely responsible for designing technologies that fulfill their employers' interests while being free of responsibility for their cultural and political consequences requires asserting that "technical" work must be somehow extricated from the social realm. As Cech succinctly puts it: "If engineers do not claim jurisdiction over social issues such as the consequences of their work for public welfare, then they may not hold themselves responsible for those consequences" [27, p. 207].

The findings of this paper indicate that this purely "technical" definition of engineering informs the students' instrumental evaluation of the "real-world" value of the work the project's sponsor requested them to complete. The effects of this instrumentalist logic [15] on students' ethical sensibilities and courage are made apparent not only by Jesse's assertion that their previous ethics training failed to provide them with an actionable strategy for determining when and how to draw the line between uncomfortable and unethical requests from employers. This in turn suggests they have been taught that the primary value of engineering expertise is to serve employers' interests. Furthermore, their question "when *can* I say no?"—as opposed to asking "when should I say no?" illuminates this student's understanding that the act of subverting an employer's request in itself entails breaching "ethics as loyalty." In this case study, students justified the infringement upon the sponsor's authority over their work by appealing to the pseudo-ethical values embedded within a "purely technical" definition of engineering alongside macroethical concerns that arose from their belief that the project intended to misuse public resources. In this sense, it seems that microethical frameworks—which emphasize an engineers' responsibility to work on behalf of their employers' interests [33], [50]—and macroethical frameworks—which encompass an engineers' obligations to society as a whole, as found in the paramountcy clause [55], [56]—compete with or contradict one another when circumstances demand engineers exercise discretion or judgment. Engineering ethics scholars observe the tension between these frameworks, such as Swan et al., who determine that, although engineering ethics training places a strong emphasis on students' comprehension of both utilitarianism and deontology, most documented ethical violations of engineering fall within the category of rule-based deontology [67], as most ethics cases are measured against formalized codes of ethics, such as those published by the NSPE or the NCEES [56], [55]. This reliance on "given" rules that conduct behavior reflects engineering educators' reliance on the Given-Find-Solve problem solving framework to cultivate engineers: Swan et al. find that students are often instructed to learn and reference these sets of codes when analyzing potential ethical violations [67] to determine the "right answer" for a given ethical "problem." The senior design students' accounts of their previous ethics education seem to resemble such an approach, and their overt recognition of the limitations of EPS-style ethics training should signal program builders to avoid implementing these rigid pedagogies in engineering ethics contexts. Moreover, when the student team members were asked what they would improve about engineering ethics courses, their responses suggest that many of them believe *sociotechnically integrated* approaches would prove more valuable and effective. Furthermore, this student's description of the closed-ended nature of their engineering ethics courses seems to resemble the pedagogies used by educators to teach engineering science curriculum.

This case study demonstrates that engineering educators' attempts to "bridge the gap" between the "purely technical" and the social fall short because they inadvertently reinforce the spurious divide between the two. Furthermore, such an approach fails to attend to the significant impact undergraduate students' engineering science courses have on their ability to engage with open-ended, sociotechnical problems. The way students presented their concerns about the "ethical" issues of the cancelled project alongside their concerns surrounding the technical feasibility of the project seem to suggest that, for many of these engineering students, confining their engineering expertise, identity, and responsibilities within the bounds of a "purely technical" definition of engineering serves as a pseudo-ethical imperative that regulates their understandings of what "good" engineering entails. Cameron's assumption that an understanding of more than "just the engineering" is not "built into" their undergraduate degree implicates their engineering science courses (which are often self-consciously "purely technical" in nature) as a key source of this "purely technical" conception of engineering work. While the students' strong preference for decontextualized work points towards the kind of content their engineering science courses have trained them to master, the way they entangle this preference (and subsequently, an aversion to open-endedness) with their ethical considerations suggests that the technical quality of engineers' work is a key consideration for engineers judgments on what activities are "right" or "wrong" for them to undertake. While this pseudo-ethical imperative to self-align with the "technical" may present as an additional, competing ethical framework amidst microethical and macroethical frameworks, Taylor's desire for more design constraints and Adrian's depiction of engineers in professional contexts seems to demonstrate that oftentimes, this "technical" imperative aligns with "ethics as loyalty" and "ethics of efficiency." For these students, "technical" narrowness simplifies the engineering design process by removing complex social concerns, thereby enabling them to focus their productivity towards optimizing the technologies they are tasked with designing to best meet the needs and desires of their employer, while simultaneously constraining their ethical imagination.

In sum, it seems that students had to assert that continuation of the senior design project would be *both* unethical and not "engineering" to convince faculty to cancel the project. To make such dualist claims, they had to adopt and invoke the ideologies of technical/social dualism [5], [26] and appeal to the instrumentalist purpose of the senior design course [13], [15]. The students' choice to present ethical and "engineering" concerns to senior design faculty draws attention to the ways these cultural norms have become institutionalized at their university, and the students' definitions of "good" engineering constrain their understanding of their responsibilities as engineers only to those dimensions of their work that are "purely technical" in nature. While data surrounding students' previous ethical training draws attention to the ill-effects that result from adherence to some of the beliefs, mindsets, and ideologies endemic within spaces of engineering education reviewed in this paper, students' categorizations of authentic "engineering" work illuminate the role that "technical" engineering sciences curriculum play in disseminating and reifying the norms and cultures of the profession. While most students identified the behavior of the sponsor and the potential misuse of public resources that may have resulted from the project's completion, beyond concerns about the technical feasibility of the project, few students considered its technological qualities when describing what made the project "unethical." Such phenomenon further implicates the role of the ideology of technical/social dualism in shaping students' ethical imaginations.

6: Conclusions

The authors support sociotechnical integration as an educational paradigm, both to provide students with a framework that helps them better navigate circumstances like the ones analyzed here and to enhance students' recognition and internalization of their "paramount" responsibilities to the health and welfare of society. Of course, sociotechnical integration pedagogies themselves require a working understanding of how dominant engineering frameworks artificially insulate "the technical" content of engineering practice, so interventions are more likely to be effective when engineering faculty partner with those who possess familiarity with sociotechnical integration [8], [10], [30]. More importantly, however, the authors draw attention to the strong influence that engineering science curriculum has on students' capacities to conceive of the broader context and consequences of engineering work. Accordingly, the authors recommend replacing abstract "technical" problems with open-ended, sociotechnically contextualized ones [6], [14], and we encourage educators to conceive of "technology" not as a passive, neutral artifact, but as an active cultural and political force, shaping how people interact with one another and the material world [1], [2], [3], [4].

The findings of this paper demonstrate that "technical" engineering content does more than provide engineers with tools and skills they wield to "solve problems" and design technologies. Senior design students' experiences with and reliance on EPS shape their conceptions of engineering work and mediate their beliefs around the proper scope of engineers' responsibilities— "technical" and beyond. In this sense, knowledge of "technical" engineering itself provides engineers with a pseudo-ethical framework for determining what is "right" or "wrong" for an engineer to pursue *as an engineer*.

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Appendix

Interview Protocol:

Introductions:

- Tell me about yourself!
    - How did you find engineering / [school]?
    - What have been the best / worst parts of your experience at [school]?
        - What does engineering / a [school] degree mean to you?
        - What do you think makes you an engineer? What makes you different from an engineer?
        - Has your conception of 'engineering' changed over the course of your [school] education? How so?

Senior Design:

- Talk to me about your experience with senior design so far!
    - Could you give a general explanation of your understanding of the purpose and structure of senior design?
    - Could you explain the events of the original project to me as if I wasn't on the team?
        - How did you view the project during its early stages? What elements (if anything) drew you to it (or didn't)? (potential impact, technical opportunities, etc.)
        - How did you understand what the sponsor expected from the team at the start of the project?
        - How did you imagine continued work on the project unfolding if the project hadn't been cancelled?
        - How did these views and understandings change? What factors contributed to these changing views?
            - What did you or other team members try to do to align the project with the team's best interest?
                - How did you think or feel about these actions?
            - What kinds of support (if any) did you get throughout these processes?
                - What kinds of support (if any) do you wish you would have received?
        - How did other team members think or feel about the experience?

Engineering & Previous Education:

- How do you think or feel that your previous experiences prepared you for senior design (prompt for preparation for the cancelled project and the course as a whole)? (prompt for experiences such as education, professional, personal, etc.)
    - Did you rely on any previously learned class 'content' during this experience?
    - How much 'engineering' do you feel like you would have done if the previous project hadn't been cancelled?
        - What does "real" engineering work look like?

        - Is there anything you feel like you should learn / be taught prior to enrolling in the senior design course?
    - How does your new project compare to the cancelled project?
        - How much ‘engineering’ do you think or feel you have done during your new project?
        - What (other) things make it better / worse than the last?

Ethical Considerations:

    - Would you be able to discuss the ethical dimensions of the experience?
        - Were you prepared to navigate these ethical dimensions?
            - What specific experiences prepared you (classes, work experiences, personal experiences, etc.)?
    - What did you feel you learned from the experience?

General Closing Remarks