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Pedagogical Choices for Navigating and Teaching Sociotechnical Landscapes in Engineering Education

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Abstract

In this paper, the four authors consider our roles as engineering educators teaching courses that emphasize engineering practice as a sociotechnical endeavor. [1] [2] Situated in different institutions and schools, we reflect on commonalities and differences in our approaches to sociotechnical education, particularly incorporating scholarship that illuminates the complex relationship between science, technology and society into engineering and humanities courses. We draw heavily from disciplines such as science and technology studies, engineering studies, and the history of science and technology, among others. [3] [4] We also reflect on how our varied institutional homes have influenced how we approach sociotechnical education in the classroom. [5] For example, we examine approaches to engage technically-minded students to consider sociotechnical skills as central to their engineering education. This holds for broad engineering ethics courses as well as ethics modules embedded within core technical courses. Courses that explore engineering culture by integrating ethics and history encourage students, many of whom are interested in using teamwork to solve problems, to think how they might improve upon past collaborations if equipped with hindsight. We also discuss classroom experience with students who are technically-minded (or expertise-minded) but have their home in Colleges of Arts and Science and major in pre-med, pre-law, or pre-business fields such as biology, computer science, economics, or political science. We reflect on how the pedagogical choices we make among the four authors, which we have documented here, are part of an ongoing conversation among us as scholars of science and technology studies and engineering education and between us and the students. We argue that our individual and institutional contexts deeply influence our pedagogical choices. Parts of our experiences transcend our institutional contexts, while other do not scale or travel. Some components are unique to our situations and positionalities, while there are others that are applicable elsewhere. We recognize that our students bring their own choices and expectations into the classroom; that the classroom is a space in which they encounter our choices and those of their peers; and that through this process we hope to inform students how to make their own choices regarding social and technological change.

Introduction

We, four engineering educators trained in science and technology studies (STS) and employed at engineering and engineering-adjacent programs, offer in this paper a multi-institutional survey of *pedagogical choices* that we have made in the service of sociotechnical integration. By pedagogical choices we mean an array of decisions in the context of our institutional homes, courses we teach, and student bodies enrolled. We reflect on the commonalities and differences of introducing sociotechnical material in our disparate contexts, ranging from humanities-based curricula within a School of Arts & Science, to core technical laboratory courses within a School of Engineering & Applied Science, to an interdisciplinary core course fulfilling multiple college requirements, to a communications and writing course. In some contexts, curricula serve newly established programs; in others, they are embedded within long-standing courses and teaching traditions. Thus, this paper offers to illuminate four perspectives on navigating and teaching sociotechnical material to find commonalities and differences that may provide guidance to other instructors at their home institutions.

Our work relies upon the robust body of literature on sociotechnical education for engineers. Reddy et al. ask wittily and on-point, "Sociotechnical Integration in Engineering: What is it? Why do we need it? How do we do it?" We follow them when they explain the term by pointing to continuous iteration "between social and technical dimensions of engineering decision-making" together with consistent refraining from treating "'social' and 'technical' as distinct facets of engineering practice." [2] Another example: Bucciarelli and Drew ask "how engineering education *in itself* might be transformed to pay attention to the social/political as well as technical dimensions of engineering practices" (our emphasis). [6]

When we discuss *pedagogical choices* that we have made, and the tensions inherent in making them, we continue such reflections and aim to bring them into the classroom and beyond. Key to these choices, as Nieusma has suggested, is understanding how to interpret and situate programmatic choices made in engineering education. These choices range from instrumentalist rationales for obtaining a degree to choices of "framing" an educational program to students in broader terms. [5]

There are obvious challenges to reforming engineering education in the image of sociotechnical integration. Continuing from Reddy et al. once again, we recognize the sustained, often opposing forces acting on course-based, local, classroom-specific efforts, on institution-wide and institution-specific program reforms, and, lastly, on state-, nation-wide or international curricular changes and policies. [2] Reddy et al. propose faculty professional development (in the form of workshops, etc.) as part of their degree program and, crucially, point to disagreements among constituents in such cross-disciplinary and cross-institutional teaching initiatives. They emphasize that such disagreements do not necessarily revolve around the distinction between the "technical" and the "social," and they call for sustained deliberation on sociotechnical integration, with the goal of making changes in the teaching of engineering students.

Three further proposals that inspire us include, first and mentioned above, Bucciarelli and Drew's well-known proposal for an undergraduate, pre-professional degree program, a Bachelor of Arts in Liberal Studies in Engineering which they design, not least, for undecided students who might want the door to an engineering profession to be left open in the future. [6] Second, Krones, Tonn, and Powell, offer an example of sociotechnical integration at the course-level in a new undergraduate engineering program which included co-instruction and navigating nested institutional and curricular contexts. [7] Third, Salinas and Nieusma explore how a sociotechnical lens has been used in a new undergraduate program at Colorado School of Mines, a bachelor's of science in Design Engineering. [8] Salinas and Nieusma explain that the program carefully integrates content from engineering and STS when teaching engineering problem-solving, and that both technical and social dimensions are consistently and directly made relevant to students' design processes. They created a curriculum around a "design spine" to keep sociotechnical integration a priority.

The proposals resonate with what we are trying to grasp: how you have to do sociotechnical integration in a consistent, direct way, in the face of a variety of challenges and resistances. Those appear locally on-the-ground and involve ad hoc, short-term pedagogical choices. They appear with the widely varying conditions in the institutions in which we provide engineering education through sociotechnical integration. And they appear with region- and nation-wide policies and requirements that operate long-term on engineering education.

The four of us would like to contribute by offering examples from our teaching, experiences, impressions, informal conversations among faculty, and inspiration for further conversation. Our pedagogical choices have a bearing on our course-level content, curriculum design, and student outcomes. First, we briefly describe our institutional settings and commitments.

Institutional settings and commitments

Secules, et. al. establishes the importance of positionality for researchers in engineering education, which we extend to each of our pedagogical roles. [9] Here we reflect on our academic training, our identities as teacher-scholars, our institutional homes, and the impact of these factors on our commitments in the classroom.

Author A

As a historian of technology trained originally as a physicist, and a faculty member in a School of Arts and Sciences at a large research university in the Mid-Atlantic, my responsibility is to teach courses that take engineering from the outset to be about both technology and society. A large introductory lecture course offered in our department is called “Technology and Society” (as it is at many other schools). In it, I aim to appreciate together with the students technology and society as phenomena that we can subject to systematic analysis just as phenomena elsewhere in the universe (physics, genetics, linguistics, etc.). I also try to appreciate together with them that, at this point, we have at our disposal well-developed and widely shared methodical techniques to do this. I assign texts, film, music, and photography/painting, and by reading, watching, and listening to, others’ work, we learn how several generations of scholars and artists before us have done exactly this: scrutinized technology and society as phenomena with evolving and well-developed analytic tools and concepts.[1]

Author B

I am a historian and sociologist of science and technology developing and teaching engineering ethics curricula at a large, private engineering school within a research university. My teaching activities are two-fold. First, I teach a general engineering ethics course which serves six departments and consists of both lecture and recitation meetings. Second, I lead an engineering ethics initiative, collaborating with interdisciplinary Engineering Ethics Fellows to develop ethics curricula embedded within core, required, technical courses. In both the standalone course and the embedded ethics initiative, I aim to provide students with a comprehensive understanding of the societal, political, and economic dimensions of engineering practice. This approach draws on interdisciplinary scholarship from fields such as STS, history and sociology of science, organizational behavior, and philosophy. The curriculum encourages students to view engineering as a sociotechnical endeavor, equipping them with an ethics toolkit to identify and address ethical challenges in their careers.

Author C

I am a historian of science and technology who teaches in a relatively new Department of Engineering in a private Catholic, Jesuit liberal arts university in the Northeastern part of the United States. As the only “non-engineer” faculty member within the department, my role is to connect engineering to the wider liberal arts by designing and offering large, core courses to first-year students that integrate history and engineering. For the past several years, I have been co-teaching “Making the Modern World: Design, Ethics, and Engineering” (MMW) with

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[1] Examples include teaching the Cold War through films such as *Dr. Strangelove* or *Failsafe*; historical change during the digital age through films such *Die Hard* or *Mission Impossible* and their sequels; class conflict in Britain during deindustrialization through heavy-metal songs from the 1970s and ‘80s; and slavery economy in the American South through gospel songs and paintings. Examples of texts about how to subject society to systematic analysis include excerpts from Talcott Parsons, *Essays In Sociological Theory*, Glencoe, Ill., 1949; Thorstein Veblen, *The Theory of the Leisure Class*. New York, 1918; Fredrick Engels, *Principles of Communism*, 1847; and Gayatri Spivak, “Can the Subaltern Speak?” in *Marxism and the Interpretation of Culture*, eds. Cary Nelson and Lawrence Grossberg. Basingstoke, 1988, 271-313.

engineering colleagues. [10] The course introduces students to the history of engineering and technology through the lens of engaging difference and justice since 1800 and to engineering and the engineering design process. MMW is a university-designated "Complex Problem" course, which means that it is team-taught, interdisciplinary, and delivered via lectures, weekly engineering labs, and weekly evening reflection sessions. The learning objectives reflect the college's core curriculum, with learning objectives designed to meet requirements for History II (history since 1800), Natural Science, and Cultural Diversity. In addition, for engineering majors the course also fulfills a first-year engineering design program requirement (as informed by our ABET student outcomes). I use historical methods to anchor course conversations about engineering in specific times and places and in relation to specific people and social, cultural, economic, and political systems. This means teaching students how to engage with primary and secondary sources that reveal how different stakeholders view engineering and the impact of technical decisions on society. I include newspaper articles, book excerpts, archival footage, patents, letters, documentary film, archival materials, oral histories, census records, paintings, and a range of material culture examples for students to engage with so that together we can think through how engineering and engineering decisions have shaped society.

Author D

I am a historian of technology who teaches in an interdisciplinary department within the engineering school of a mid-Atlantic research university. The dean of engineering recently referred to the responsibilities of my home department as teaching "engineering plus." By this, he implied that we, a teaching-track faculty of about twenty, teach subjects outside engineering education in the narrow sense of engineering as applied mathematics, engineering science, design, and laboratory work. While other departments incorporate ethics or communication modules in their courses on theory or laboratory work, our department teaches courses that each specialize in writing and speaking, entrepreneurship and leadership, business and finance, and engineering culture. Our courses help other departments in the engineering school fulfill two ABET requirements: "an ability to communicate effectively with a range of audiences," and "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts." My own responsibilities in the communications program (consisting of seven faculty) involve teaching courses in writing, speaking, and engineering culture. I was trained and worked as an electrical engineer before completing doctoral research in the history of science and technology. In this paper, I focus on my work integrating engineering history and historical lessons-learned into a course on engineering culture. The course is based on the simple premise that today's engineering culture has a history. That culture is pluralistic, rather than monolithic, and historical perspective helps students navigate its contours.

Four authors, four institutional contexts

Reflecting on our positionality statements, we share experiences of academic training in science and technology studies and adjacent fields, which we deploy in different settings across three private institutions (and four schools) in higher education. Each of us takes seriously the commitment to translating sociotechnical frameworks to the studies of engineering. We make pedagogical choices about the most effective ways to do this.

Our pedagogical choices are framed by: our institutional departments or schools; our institutional history, as seen in longstanding schools and programs as compared to new departments; the alignment of our engineering education programs related to the mission of our particular institutions; our lines of employment, whether they be teaching track or tenured; our student demographics; the specific, often fine-grained, responsibilities we have acquired at our respective institutions over time, inside and outside engineering education; and the very particular ways in which our courses and curricula fit into programs of study, as electives, as embedded ethics modules, and as required courses. In the next section, we describe four pedagogical choices, one from each author. These are choices we made *because* of our institutional contexts.

Pedagogical choices within our institutional settings

Pedagogical choice #1: Are engineers part of social orders?

I often begin by showing the 1995 film *Apollo 13*. Asking students to watch in close detail the filmmakers' and actors' work, and watching and rewatching certain passages, I try to explore together with them how the engineers in the film's drama organize themselves into a group, develop common ground and differences among each other, find themselves in conflicts and rivalries, create and re-create hierarchies, and challenge, or agree to, emerging stratifications within their group. The film also arguably depicts this group of engineers as a model of government in regards to participation, decision-making, and representing voices and constituencies.[2] [11]

Examples from architecture and interior design serve to make visible to students social hierarchies at a broader level. I focus on the Gilded Age as it connects to the Second Industrial Revolution in the U.S., in which immense wealth was accumulated by the proverbial robber barons. This social phenomenon is also widely depicted in popular culture, a recent example is

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[2] Great inspiration here comes from Cyrus Mody who says: "Just note how much content put out by the film, television, gaming, and publishing industries presents historical narratives – much of it content about the history of engineering and technology."

the Netflix show "The Gilded Age," colloquially known as Downton Abbey for Americans. For the class, I organize a museum visit to view a sample living and working space of heirs of wealthy industrialists in the Second Industrial Revolution. These rooms occupied buildings such as the "Cornelius Vanderbilt II" mansion in Manhattan (Figure 1). Among the museum's "period rooms" is the drawing room of a 1920s Manhattan mansion, bequeathed to the museum by the owner in 1923 (Figure 2). I show other images and film clips of exteriors and interiors of the largest mansions built in the U.S., such as Biltmore House in Asheville, North Carolina, built for a Vanderbilt heir in the early 1890s (Figure 3).

Figure 1: The so-called "Cornelius Vanderbilt II" mansion on the corner of 57th Street and 5th Avenue in Manhattan, 1908.

Figure 2: Drawing Room from a Town House at 71st Street and 5th Avenue in Manhattan, 1923. Bequest to a local museum.

Figure 3: Biltmore Mansion, NC, built for George Washington Vanderbilt II between 1889 and 1895.

I alternate such class material with the reading of classics of American social theory to understand together with the students that, for at least 150 years, scholars have studied and analyzed social groups and societies and their stratification, and that we can follow their example by conceiving of engineers as a social group. [12] [13] [14] [15] [16] [17] [18] [19] [20]

A critical element for me of Bucciarelli and Drew's above-mentioned proposal for a B.A. degree program in Liberal Studies in Engineering is that they intend it to attract "students undecided about the choice of a major" who are "open to the possibility that they might pursue a career in engineering." [6] This describes in some ways also pre-med students, a relevant student population for many departments at Faculties of Arts and Sciences at large research universities, regarding both their numbers and their needs. There is a parallel that I suggest between the students that we as scholars in engineering education teach and work with, and the pre-med student population that scholars in the medical humanities teach and work with. My experience coincides with Bucciarelli and Drew's description of the constituency of their proposed undergraduate degree in the sentence above: it captures pre-med students' needs, interests, ambitions, and plans for the future as well. [6]

My department offers survey lecture courses as well as advanced undergraduate seminars in the history of science, technology, and medicine, broadly conceived, and, to varying degrees, those count as requirements for my university's School of Engineering. Engineering students who take a class in our department typically "leave behind" the Engineering School entirely when they take one class in the School of Arts and Sciences for a requirement. They immerse themselves in a profoundly different experience from their main education. They often encounter the liberal arts only on this one occasion.[3]

My classes seem to have an impact on those engineering students in particular who take a class to fulfill a requirement stipulated by their home department. Such students often tell me that they have never taken a class "like this one." It has taken me a while to understand what this could mean. I have collected impressions over the years, and the one example I have chosen here is how to make visible to students the fairly abstract concepts that underlie issues of class, hierarchy in society, and social stratification. At the end of the class, some are even able to name differences that we make in our own current society and that they are, in whatever ways, complicit in, or subjected to, or both. The images, movies, readings of classics in social theory, are a surprisingly effective way to get students closer to the idea that we can analyze "society" or "social groups" in ways similar to how we analyze other abstract or concrete entities, such as planets in gravitational fields, the information content of electrons, or the inevitable dissipation of energy in an open system.

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[3] I experience this as a huge responsibility. We have a few minors in the two undergraduate programs that we run out of our department, one called "Science, Technology, Society," the other "Health and Societies." The latter is popular among pre-meds and is a large major, but it is not typical for engineering students to double-major or minor in our department in either of those undergraduate programs.

Pedagogical choice #2: Embedding ethics

While we offer a standalone engineering ethics course that provides a broad, foundational set of knowledge in engineering ethics, the embedding of ethics modules within the technical courses emerged to address several goals. These included delivering discipline-specific ethics content and establishing a broader sociotechnical framework that is consistently reinforced throughout the four-year curriculum. Embedding ethics within the core technical courses underscores the principle that societal considerations are an integral part of the engineering design process, rather than a separate or peripheral domain. In 2020, the School of Engineering & Applied Science launched a pilot program which I have been leading to embed ethics modules within core technical courses and since then, a comprehensive ethics curriculum has been developed within the Bioengineering Department, with modules in the first-year introductory course, a sophomore lab course, the junior year two-semester lab sequence, and senior design. Here, I elaborate on the pedagogical choice for embedding ethics within these technical courses, including a specific curriculum example and findings from student surveys.

The decision to develop ethics modules within the bioengineering major stemmed from a semester-long committee analysis, in which I participated, to evaluate the effectiveness of the existing ethics and writing curriculum. The committee engaged with school and departmental faculty leadership, undergraduate students, and alumni, while also reviewing secondary literature and best practices from other institutions. The committee concluded that while a standalone engineering ethics course should remain a requirement for all six engineering departments, incorporating additional ethics curricula within core technical courses would provide students with a deeper understanding of the societal context of engineering practice, using discipline-specific examples tied directly to technical material. The goal was to create modules that introduced scholarly frameworks, practical strategies, and a comprehensive vocabulary for identifying and addressing ethical challenges. Ultimately, the curriculum aimed to dissolve the false dichotomy of technical *and* social aspects and to emphasize engineering as a *sociotechnical* endeavor.

A rich body of literature explores efforts to employ sociotechnical learning into engineering education. Johnson et. al. define "sociotechnical thinking as the interplay between relevant social and technical factors in the engineering problem definition and solution process." [3] They identify successful interventions, such as using micro-insertions of sociotechnical material and redefining problems as sociotechnical. They also identify challenges in grading and assessing these interventions. Roberts and Lord, supported by an NSF Revolutionizing Engineering Department Program grant, led an effort to develop new courses and modules, run faculty workshops, and support a cluster hire in this field. [21] As Dean and Department Chair, they identified challenges such as the ideological complexity of who defines engineering, the revolutionary nature of sociotechnical engineering education, and faculty concerns about rigor. Martin et. al. propose a robust agenda for a "socio-technical orientation of engineering education *for* ethics," advocating for systemic changes, emphasizing public policy, the humanities, social sciences, STS and liberal arts in engineering education. [22] The Harvard Embedded EthiCS program also serves as a model for embedding ethics into technical education through interdisciplinary collaboration. [23]

Like these other institutional endeavors, the engineering ethics initiative employs sociotechnical thinking as a foundation for engineering education, and specifically, for teaching engineering ethics. This framework helps students gain a broader and deeper understanding of the dynamics of technical systems and empowers them to navigate these complexities in their future engineering careers. The ethics modules in the bioengineering courses include in-class discussions, homework assignments, and teamwork activities, carefully mapped out across the four-year curriculum to build a cumulative body of knowledge and to normalize societal considerations within engineering practice. In the first-year introductory course, students complete four ethics modules, each consisting of a written discussion board post and in-class discussion, covering topics such as democratic deliberation, ethics education, principles of bioethics, stakeholder mapping, responsible development of medical technologies, and professional decision making. In the sophomore lab course, students explore topics such as animal research ethics, the sociology of technology, and the ethics of wearable health technologies. In the junior lab sequence, the modules cover empathy in engineering, universal design principles, global public health and point-of-care diagnostics, biocontainment of genetically modified organisms, and human subjects research. In senior design, students workshop key concepts and values, such as professional responsibility, sustainability, and fairness, and apply them to their projects. The team is currently building out additional materials for senior design that will likely address intellectual property and generative artificial intelligence. Each ethics module is thoughtfully designed to align with the technical material the students are learning.

One example from the introductory course is an ethics module that complements the course's introduction to biomedical devices and technical training with Adobe Illustrator software. While detailed lesson plans are published in *Biomedical Engineering Education,* this section explains how the ethics module complements the technical material. [24] The students begin by learning about various medical devices, including examples related to rehabilitation and diagnostics. Then they complete a module on cell and tissue engineering and biomaterials. In the technical lab on medical devices, students learn about pulsometers and construct an electric circuit using an LED. The students also complete software tutorials on Adobe Illustrator. After completing the technical modules, students participate in a dedicated class meeting focused on the ethics of medical devices. This session explores how commitments to the responsible development of medical technologies and considerations of end users, such as patients, practitioners, and caregivers, should influence engineering design. To illuminate these themes, students read an article by anthropologist Amy Moran-Thomas. [25] Students first write discussion board posts reflecting on the article, then engage in an in-class discussion about the importance of considering end users in engineering design. During the second half of the class, students participate in a design challenge to design a wearable thermometer employing user-centered design principles. They begin by imagining an end user, such as an athlete, an infant, or a hospitalized patient, and then design the thermometer. For homework, the students use Adobe Illustrator to draw their design and include an explanation of their design choices in their submission.

Student surveys, conducted with IRB approval, indicate that the students gained tremendous insight from the modules which embedded the socio with the technical. For example, student comments include:

- "I really enjoyed the ethics component and found the discussions to be very interesting! If possible, I would love to have more opportunities to have these discussions (particularly in breakout rooms) throughout the semester in other Engineering classes!" (Fall 2020)
- "I thought the way that the ethics modules blended in with our core course content (the thermometer design) was really cool." (Fall 2023)
- "I particularly liked the assignment where we designed a thermometer with ethical considerations in mind. I would suggest that similar creative assignments be included in the future." (Fall 2024)

As reflected in the student comments, embedding the ethics material within the technical coursework enables the students to understand the dynamic and relevant connections between technology and society, as well as the responsibilities inherent in the engineering profession. Rather than seeing ethics as separate from their technical training, this sociotechnical perspective directly shapes their understanding that social factors *are* critical design factors.

Pedagogical choice #3: Bodies, embodiment, and the built environment

Each fall, I co-teach the first-year integrated engineering and history course "Making the Modern World: Design, Ethics, and Engineering" (MMW) along with my engineering colleagues. One of the most important sociotechnical threads that knits together MMW's approach to engineering education across lecture, reflection and labs relates to the history and practice of access and accessibility in engineering and design. As the resident historian on the teaching team, I introduce this aspect of the course through lecture modules related to disability, design, and its history and an active-learning reflection session that ties this content to the built environment of the college campus.

To introduce access and accessibility to first-year students in MMW, I have designed a unit on critical access. The critical access unit introduces students to the history of disability and design and argues that the built environment has a history co-constructed by engineers, architects, designers, users, medico-legal categories, and legislation.

Our entry point into this unit comes from the work of scholars in disability studies including Aimi Hamraie, Rosemarie Garland-Thomson, and Bess Williamson, scholar-artists like Sara Hendren, and design organizations like the Adaptive Design Association in New York City. [26] Key to tying together this unit are three concepts: "disability" as a framework, identity, theory, and language; Garland-Thomson's concept of "misfitting" which emphasizes the lived experiences of disability as one that is embodied, dynamic, and generative; and Hamraie's concept of the "normate template" which draws attention to the ways in which historically a mythical notion of the normal or average body has been used as a reference point for constructing the built environment. [31] [27] [28]

Students learn about how scholars define and use these frameworks and then students connect them to the history of anthropometric data gathering. Designers, architects, and engineers rely upon accepted standards of human dimensions; and these standards have a history. I show students primary source images of human data gathered as part of the American eugenics movement, such as pamphlets from the Eugenics Record Office, early 20th century eugenic pedigrees, and sculptures of the supposedly eugenically fit citizens, "Norma" and "Normann," commissioned by the doctor Robert L. Dickinson. [29] We then connect this eugenic history of disability and notions of eugenic fitness to the use of human dimensional data in architecture, design, and engineering, the impact the disability rights movement has had on intervening in the designed world, and the role of universal design, adaptive design, and bespoke design on spaces, tools, objects, and experiences. [30] [31] While many students have learned about the U.S. eugenics movement in high school, it is often a surprise the extent to which eugenics data-gathering has influenced human dimensional forms in design and engineering since the 1920s.

As part of this unit, we have designed an evening reflection session, based on a design scavenger hunt originally developed by Sara Hendren, that takes our first-year students through the campus on an access-oriented scavenger hunt. Our aims are to provide an opportunity to reflect on the embodied experience of the built environment of the campus as well as to start building community among students. In small groups, students move through campus for an hour to identify examples of evidence of the built environment having a history. Students are asked to look for examples for or against design for a range of dimensions: access, help, historical legibility, sustainability, and aging, among other dimensions.

As they are moving, students contribute photos of this evidence to a shared Google Slides deck. At the end of the activity, we sit together and reflect on students' individual experiences as well as how we – as a classroom community – have represented points of access and inaccessibility in the spaces around us. Afterwards, students write brief reflective statements about their own embodied experiences with the exercise.

- Students shared how they started to decode the spaces of the campus. As one student wrote: "*However, as me and my group looked around, it became apparent to me how* *much effort it took to make the school as accessible as it is today. The campus was still littered with stairwells that had no ramp or handicap accessible transportation, making it even more difficult to do things as simple as getting food at the [building name] after class. The process to find a fully accessible route around campus felt foreign, and pretty much impossible. More than this, it helped me see campus through the perspective of design and accessibility and how difficult it truly is to design something accessible for everybody within confounding restrictions such as aesthetics*." (Fall 2024)

- Students also discussed what it felt like to start to notice the built environment differently. As another student wrote: *"It was the things we saw every day that we never considered to be accessible (handrails, lower water fountains, signs that directed you to certain rooms), and at the same time, we began to notice how the campus might be inaccessible (missing labels on buildings, paths with only stairs, etc.). This process was unfamiliar to me. I have never been asked about or even been taught (in a school setting) about accessible technologies, but I enjoyed it."* (Fall 2024)
- In addition, they wondered what it would mean to construct universally inclusive spaces. As a third student reflected: *"Ideally, a truly accessible design would be built from the ground up with everyone in mind, seamlessly integrating those with disabilities and (potentially) helping ensure they feel not just accounted for, but equal. Such a design is very ambitious, though, and (for instance) would require fundamental changes to modern building techniques just to account for the physical range of disabilities."* (Fall 2024)

The critical access unit and the design scavenger hunt prepare students for a seven-week human-centered design project in the engineering lab portion of the course. This project charges students with designing an intervention related to access and accessibility on campus using the engineering design process. Students work in teams of 3-5 to integrate skills from history—interviewing stakeholders, understanding the context of the current built environment, and doing research into future design interventions—with practices from engineering design.

The culmination of this project is a campus-wide MMW Design Conference, in which guest judges from engineering, history, and the university core office evaluate student work. This year student groups who earned judges' awards presented prototypes of tactile campus maps and updated bus hand grips; designed more accessible methods of integrating course learning platforms with other technology platforms on campus; mapped ways for students to access limited study spaces on campus; and reimagined origami-like napping furniture and health services information kiosks to promote health and wellbeing.

Pedagogical choice #4: To navigate engineering culture, read the history of technology

In this section, I describe the course "Culture of the Engineering Profession," which I inherited in 2023 and have taught and revised ever since. The name of the course misleads: the engineering profession has many cultures, not just one—and there are too many aspects of those professional cultures to explore in a single semester. The course fulfills writing and ethics requirements for engineering majors. This context creates a logjam, with no clear indication of what the course should and should not include. But the course's vague title and multiple requirements afforded me the opportunity to integrate history of technology into my students' already crowded engineering curricula.

The course syllabus design reflects my own perspective on the engineering profession, based on my training and professional experience both as a historian of technology and as an engineer. I selectively draw from the wide range of available sources, relying heavily upon the work of scholars from history of technology, engineering studies, and engineering ethics. The course's structure follows the seminar model: nineteen students are put in small groups to discuss readings and generate questions. The course's spirit is anthropological: we analyze professional culture by thinking through the people who call themselves engineers. Three main learning objectives for students are: to question what engineering is, to realize that culture shapes engineering, and to practice some of the methods that scholars have developed for analyzing professional cultures.

In the course, students explore two questions introduced on the first day of class. The first question I ask on the first day of class is: What is engineering? Asking this question first encourages students to review their prior knowledge. In Fall 2024, students answered that engineering is:

- problem-solving using science, math, critical thinking, and creativity/art
- a bridge between old and new technology
- identifying needs and designing or building the means to meet them
- connecting people
- making human tasks easier or better in some way

Engineering is a bridge, a problem-solving activity, and a means to connect people. Throughout the course, I invite students to revisit and refine their definitions of engineering.

After hearing from students, and instead of sharing my own definition of engineering, I point out a problem with the standard representations of engineering that I have observed. I present students with a montage of images I scraped from Wikipedia's entry on "Engineering" (Figure 4). Engineering is represented by the International Space Station, a 300-year-old bridge, fluorescent mice, the Hoover Dam, and an offshore oil rig, among other images. Where are the people? From this exercise, students begin to notice how society abstracts people from its representations of engineering, much as engineers themselves abstract details from engineered artifacts using the so-called "black box." Those who are absent include not only the users of engineered technologies, but also the engineers themselves. To bring people to the foreground, students in my course engage with the history of technology and engineering ethics—two intensely people-centered literatures.

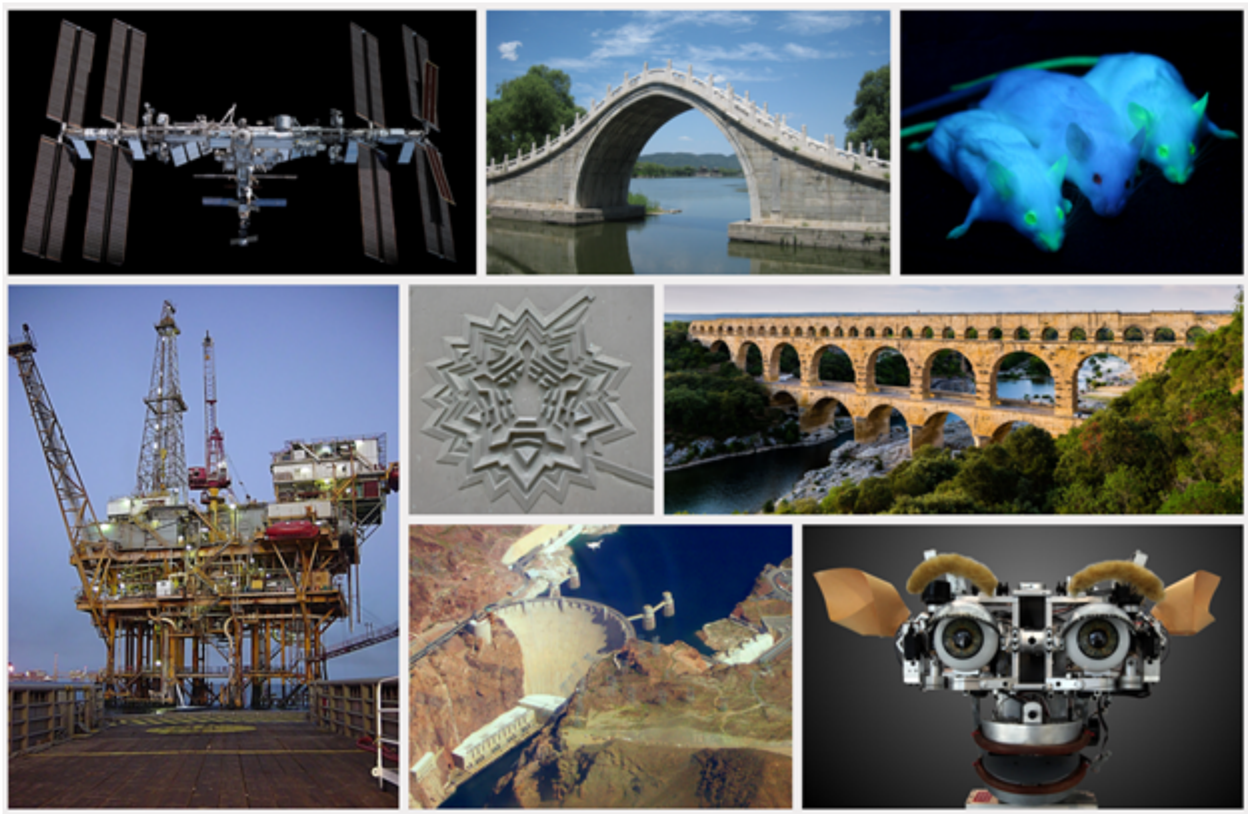

Figure 4: Images scraped from the Wikipedia entry, "Engineering," in December 2022. These are the iconic representations of engineering. But even in the case of the offshore oil rig, which cannot operate autonomously, people are absent.

Within a few weeks, the literature suggests another way to define engineering: engineering is a societal experiment. Kline captured this metaphor's significance: "engineers," he wrote, "do not know precisely how their structures, machines, and electronic devices will work technically or socially once they are in the hands of users. Nor do they know their long-term social implications." [4]

Like Kline and other engineering ethicists, I encourage students to take seriously the idea of societal experiments, which collapses the social and technical by focusing our attention upon engineers' inability to determine how their artifacts will work in the world. [32] [33] If engineering is a societal experiment, what does that imply for engineering ethics?

Engineering is also defined by the roles and practices of engineers, who interact with non-engineers, both lay and professional. Historians of technology emphasize that engineers operate in a trading zone. Over twenty years ago, Williams argued that engineering in the late twentieth century experienced a process of "expansive disintegration," blending with other professions. [34] For Williams, the expansive disintegration was caused primarily by engineers' engagements with information technology, which spans so many professional areas, and with biology, a subject that—unlike the physics and chemistry that undergirded the engineering profession by the mid-20th century—resists reduction to first principles. Engineering fields have adapted to these expansive encounters. For example, scholars such as Jesiek and Jamieson built upon Williams's claim, arguing that electrical engineering disintegrated as it came into contact with computing. [35] By alerting students to these developments, I encourage them to question the status and stability of the engineering profession. If most engineers work in a trading zone, what does that imply about the importance of communication and continual learning?

The second question I ask on the first day of class is: How can we systematically explore the *culture* of engineering? Students' first-day answers include:

- read message boards, such as Reddit or Glassdoor
- interview practicing engineers
- start an internship
- work as an engineer

I agree with them, but then ask: What are the costs of these methods? Message board posts can mislead you, interviews and internships take time, and working only reveals to you the professional culture that you happened to join (e.g., working at Apple, you learn what it is like to work at Apple). And is it not preferable to plan ahead before you begin working?

Once my students acknowledge such costs, I inform them that our course is structured around individual research projects and the discussion of shared readings—two hallmarks of the academic seminar. My department caps the course at nineteen students, enabling a reasonable although crowded seminar. Students are often surprised and excited to learn that there are books and articles written about engineering culture. In 2024, for example, we read three books, including *Engineering the Future, Understanding the Past*, which narrates a global history of technology from a European perspective. [36] The book was purposefully written for an audience of engineering undergraduates.

Students explore other perspectives over the semester, from articles about workplace cultures published in the journal *Engineering Studies* to cases in engineering ethics. But the seminar structure, by emphasizing inquiry and discussion, ties the course together. I follow scholars such as Spero and Ortiz, who claim that historical, sociotechnical inquiry can and should become part of engineers' core methodological toolkit. [37] The need for inquiry in engineering is a major lesson from the history of technology, one that both shapes my decision to structure the course as a seminar and promotes reading and discussion as important long-term skills for engineers.

Beginning the course with two questions—what is engineering, and how can we systematically explore the culture of engineering—affords me the opportunity to emphasize important themes from the history of technology. Here I have articulated three lessons: engineering is a societal experiment, engineers operate in a trading zone, and humanistic inquiry is a central, not peripheral, skill of the engineering profession. I validated these three lessons first against my prior experience as an engineer, then as a historian of science. The three lessons I've chosen to integrate into my course on engineering culture are a small subset of the possible resonances between history of technology and engineering education. Another reason for reading widely and appreciating a global perspective on engineering culture is, as Downey pointed out two decades ago, to know that people define problems differently. [38] Carlson reminded engineering educators that there is always a plurality of representations of a problem that are possible, and engineers are unique in their facility with representations. [39] Practicing engineers must deal with words, images, numbers, and simulations, often in equal parts, and more so than other professions, which focus heavily on one or the other of these representations, or sometimes two. Downey's and Carlson's claims about representation suggest a fourth lesson from the history of technology. By bringing such insights from STS and history of technology into the engineering classroom, we encourage engineering students to reflect critically on what engineering has been, so that they can become more informed and creative engineers.

Conclusion

As we reflect on our shared experiences of making pedagogical choices in each of our classroom and institutional settings, we have found it striking the extent to which the sociotechnical as a framework has permeated our disciplinary, school, and departmental contexts. We use STS and adjacent fields to model and illustrate a sociotechnical understanding of engineering and engineering practice adapted to our home teaching contexts.

We acknowledge that some students will inevitably persist in their assumptions about the distinction between technical and social aspects of engineering. Occasionally, however, for some of our students, the sociotechnical has become so familiar and obvious that these individuals forget that they used to think of technology and society as separate things. This both might be an ambition for all of us and also recalls the importance of aspirational thinking in programmatic work suggested by Nieusma and Bucciarelli and Drew. [5] [6] The fact that students' potential resistance to, or lack of understanding of, sociotechnical integration often coincides with their sudden (and sometimes unexpected) full-on embracing of sociotechnical thinking may also remind us that, in whatever setting we operate with whatever teaching tools and institutional policies, students do find their own entry into the material that we offer, and they do so at their own pace. The often divergent pedagogical choices and plans we make among the four authors, which we have documented here, are after all part of an ongoing conversation among us as scholars of engineering education and between us and the students. Not only do students bring their own choices into the classroom, to encounter ours, we also seem to be able, occasionally, to empower them to make their own choices regarding social and technological change.

But what takeaway from our conversation can we offer to engineering educators? As further research, we suggest that educators acknowledge that our research conclusions and pedagogical proposals are inflected by our institutional contexts, including but not limited to representation of student demographics, location, nation, place of course within a broader curriculum, place of instructor within the larger academic organization, university mission, and the academic background and commitments of instructor. These institutional contexts change over time. They constrain, but do not determine, our pedagogical choices. Importantly, across our four experiences, we acknowledge how ABET student outcomes influence and enable these decisions. Pedagogical research might find its way into classrooms more broadly if researchers explain the contexts in which they made their own pedagogical decisions. Our own conversation revealed to us that our contexts are often more different than we imagined, even as we share many similarities, and work toward the shared goal of sociotechnical integration in our courses.

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