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Analyzing Engineering Course Emphases: A Closer Look at Social and Contextual Practices Observed in Required Mechanical Engineering Courses*

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Engineers must solve complex problems that require comprehensive engineering skills including technical skills as well as assessing social and community impact, applying engineering ethics, and engaging stakeholders. Thus, researchers stress expanding skill development beyond technical expertise to social and contextual skills, which have been underemphasized in engineering programs. In our study, we observed course content discussed by instructors during lectures in required mechanical engineering courses across an undergraduate program at a large, research-intensive university in North America to examine emphasized practices and whether social and contextual practices were included. Our findings revealed that the most commonly emphasized engineering practice was overwhelmingly learning foundational technical knowledge. In addition, we found that social and contextual engineering practices were rarely emphasized in the required ME courses across five ME subfields. As social and contextual skills can impact comprehensive problem solving approaches and who pursues engineering work, we suggest approaches for better integration of more comprehensive approaches as well as clear messaging about what aspects of engineering are emphasized in engineering programs.

Keywords: engineering practice; social and contextual skills; mechanical engineering undergraduate courses; classroom observations

1. Introduction

Engineering problems are often situated in complex and changing systems that include multiple technical, cultural, environmental, and economic factors. Engineering students need comprehensive engineering skills beyond technical knowledge alone to approach solutions for these socio-technical challenges, including skills in social and contextual engineering practices. Social and contextual skills include: (1) considering social and environmental impacts of engineering solutions, (2) accounting for stakeholders' perspectives, (3) identifying potential future impacts of engineering work, (4) weighing ethical responsibilities for engineering decisions, and (5) considering relationships among the identities, positions, and power of all parties involved in the engineering work.

Social and contextual skills are beneficial for determining appropriate problem solving approaches and achieving successful solutions that limit negative consequences. Without these skills, engineers risk causing harm to communities and/or individuals. Ethical engineering design should consider tradeoffs among various design criteria, including users' safety and/or health concerns, as well as the sustainability of the community [1, 2]. In addition, stakeholder engagement is a critical tool for achieving project goals in various engineering areas, such as sustainability engineering [3, 4], the medical device industry [5], and the transportation industry [6].

Despite their importance, social and contextual skills are often underemphasized in undergraduate engineering programs due to the already dense and packed course loads [7–9]. In particular, mechanical engineering (ME) programs share similar curricula across US institutions [8, 9], limiting opportunities to develop social and contextual skills outside technical electives or general education courses that incorporate these skills [8, 9]. Over 20 years, researchers have called for integrating comprehensive engineering skills, including both social and contextual skills, into the ME curriculum [8–10].

To understand how students learn about the nature of mechanical engineering work, that includes social and contextual skills, we observed eight required ME courses. Class content and

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discussions signal to students which skills matter in the field. Our study focused on how and to what extent topics like social impact, ethics, and stakeholder engagement were discussed in class by instructors.

2. Background

2.1 Engineering requires Social and Contextual Skills

The engineering community has sought to dispel the perception of engineering as a purely technical field. For example, the Committee of Education in the National Academy of Engineering [11] established a vision aimed at improving the public's understanding of the socio-technical nature of engineering. However, societal impacts, environmental considerations, and stakeholder engagement remains underemphasized in engineering undergraduate education. To address this, ABET [12] has strengthened accreditation criteria, requiring students to solve problems that incorporate global, cultural, social, environmental, and economic factors; engage stakeholders; make ethical decisions; and work effectively with teams.

Social and contextual skillsets are a necessary part of engineering work. The American Society of Mechanical Engineers (ASME) emphasizes the need for mechanical engineers to tackle complex challenges, including efficient transportation, clean energy, public safety, efficient housing, public healthcare, and clean water [13], reflecting the crucial impact ME work has on people, communities, and society. Studies show that not only technical competence, but also social and contextual skills, are required for mechanical engineers to address these challenges and thus to achieve competence in the world market [14, 15]. For instance, research has shown that professional mechanical engineers recognize the necessity of gathering information from people and context and integrating the information into their decision-making process. As most sustainability problems involve multiple stakeholders who may have different priorities, and sometimes conflicting suggestions, a great number of researchers developed systematic approaches to engage diverse stakeholders in solving these problems [3, 16].

Further, academic researchers have studied social and contextual aspects of engineering work. For example, a systematic review summarized 16 key competencies, which included social and contextual engineering practices important for engineering professionals [17], calling for a paradigm shift in engineering training to include greater emphasis on a wider range of engineering skills, including social and contextual skills.

In practice, however, these goals are not always met. Mechanical engineers have made decisions with negative impacts on people and communities [1, 2]. Engineers who do not recognize ethical responsibilities of their work risk causing harm to the communities and/or individuals for whom they are designing [18]. The inadequate realization of ethical obligations may arise from neutral and apolitical perspectives that a majority of engineering students and professionals have been shown to hold [19]. This apolitical perspective often coincides with a lack of consideration of social justice concerns, leading to continuous inequities within the field [19, 20]. Research has revealed that even engineers who do consider social justice often feel isolated and powerless to initiate social changes in their workplaces [21]. Another group of researchers found that engineering students interpreted the social skills needed for professional engineers as only social bonding, overlooking the ethical dimensions and larger societal impacts of their work. As a result, this narrow belief hindered students in making appropriate engineering decisions in real-life scenarios [22].

2.2 Social and Contextual Skills are Essential in Undergraduate Engineering Education

While engineering societies and scholars stress the importance of social and contextual skills within engineering work, students and instructors tend to persist in their perception of engineering as a predominantly technical discipline. Students often view engineering with limited awareness of its social and contextual aspects [23–26]. Research has shown that most first-year engineering students view engineers as problem-solvers and designers rooted in science, math, and logic without emphasizing the people and contexts impacted by engineering work [23, 26]. Instructors often reinforce the technical focus; for example, Pawley [27] found faculty defined engineering as applied science and math, problem-solving, and making things. These technically-driven perceptions likely shape their teaching, research, mentoring, and course content.

Engineering curricula often underemphasize social and contextual skills, focusing on foundational engineering knowledge, technical aspects of design, and interpersonal skills [34]. Studies highlight that US ME programs are densely packed with technical content [7–10, 28].

The lack of emphasis on the social and contextual dimensions of engineering work can induce a culture of engineering that is disengaged from issues of public welfare. A longitudinal student survey found that students' interests in public welfare across four US universities significantly declined over the course of their engineering programs [19]. The engineering culture minimized focus on students' development of their social and contextual skills, such as understanding ethical and social issues and the policy implications of their proposed engineering solutions [19].

Though a gap in social and contextual skills in ME curricula is evident, making curricular changes is challenging for multiple reasons. For instance, systemic support needs to be established for instructors to make changes in their courses. Limited time and inadequate departmental or institutional support hinder faculty's ability to redesign activities, assignments, and course content to adopt more comprehensive approaches to teaching engineering [29–31].

Existing inclusion in engineering of social and contextual practices lies primarily in design courses [32]. For example, research shows multiple ways that, through design, instructors support students in investigating the context of their work, which helps students connect technical knowledge with more comprehensive engineering practice [33, 34]. However, another study noted that in most engineering design courses, ethics, equity and justice content were not prioritized [35]. Technical electives in ME programs offer an increasing but still limited opportunity to emphasize, for example, sustainability and social justice in engineering [36, 37]. Further, as electives are chosen based on various factors, not all ME students are likely exposed to social and contextual practices in ME disciplines.

3. Methods

In this study, we focused on engineering practices emphasized by instructors in required mechanical engineering (ME) courses, guided by the following research questions:

- What engineering practices are most emphasized in required engineering courses across ME subfields?
- To what extent are social and contextual practices specifically discussed within required ME courses across ME subfields?

3.1 Approach

To answer these questions, we conducted course content analysis through classroom observations. Classroom observation serves as a tool to track behaviors observed in class [38]. Studies that make use of classroom observations in engineering have primarily focused on instructor performance or behavior rather than the actual content being taught [39–43]. In our study, we did not identify teaching practices or evaluate the quality of teaching; instead, we observed exclusively instructors' messaging (i.e., verbal signals, words) about engineering practices.

3.2 Context

We focused on ME because it is a long standing and broad engineering discipline. ME professionals are required to solve complex and contextualized sociotechnical problems [10]. In order to investigate instructors' messaging about engineering practices, we identified the ways and frequency with which particular engineering practices were discussed in 8 required ME courses across a 4-year undergraduate program at a large, research-intensive university in North America.

3.3 Data Collection

Classroom observations were used to identify engineering practices emphasized in required ME courses. Direct observation provides details about when, where, and how the instructors introduced these engineering practices. We chose to study required courses because theses courses represent disciplinary and department values. We did not observe any electives since not all ME students take the same electives. Additionally, the capstone design course was excluded, despite its importance for all ME students. We excluded the capstone course because of its "flipped" style and its project and team-based learning structure in which students' skill development normally happened outside of the classroom. Courses across different levels and ME subfields were included, as specified in Table 1. We aimed to observe courses from across subfields and with different levels of instructor experience

We opted to analyze course recordings rather than conduct in-person observations to make the observation less obtrusive and to enable a more detailed course content analysis. We gained access to the class session recordings once the instructors agreed to share them. Video recordings of the seven required courses in ME and one introduction to engineering course with a focus on the ME discipline (also required, but students choose from various introduction to engineering course options) were collected. For each course, we randomly selected three separate class sessions for analysis. We excluded the first and last session of each course from analysis as these were often syllabus discussions or finals review days and did not cover new course content. Selected class sessions ranged from 60–120 minutes; the majority of them were 90 minutes.

To categorize the required ME courses by subfield, we identified the ME subfields as (1) Thermodynamics, (2) Materials and Mechanics, and (3) Design and Labs. This division is derived from an

Table 1. Count of courses by faculty ranks, course levels, and ME subfields

Professor Ranks		Course Levels		ME Subfields	
Professorial Ranks	Number of Instructors	Levels of Course	Number of Courses	ME Subfields	Number of Courses
Assistant Professor	3	100-level courses	1	Introductory Engineering	1
Associate Professor	1	200-level courses	3	Thermodynamics	3
Full Professor	4	300-level courses	3	Design and Labs	2
		400-level courses	1	Materials and Mechanics	2

examination of current required ME course requirements across research-intensive universities in the US, along with literature related to ME curricula [40, 60, 61]. In addition to these ME subfields, we created a fourth subfield, introductory (mechanical) engineering, because an engineering introduction course was required but students could select from many options, including both those not focused on ME. The course in our sample was focused on ME.

3.4 Data Analysis

We developed an observation protocol to guide our analysis of instructors' messaging about engineering practices and the extent to which various practices were emphasized in the course recordings. Observation studies often use observation protocols to bring attention to particular classroom behaviors and environments [38, 44–46].

The observation protocol we developed included 35 engineering practices with their definitions drawn from literature on engineering competencies [12, 17], interviews with students' perceptions about the emphases of their courses, and conversations with engineering professors and academic advisors. Definitions of engineering practices used in our protocol are shown in Table 2. Each of the 24 class sessions was divided into 10-minute intervals. The presence or absence of a given practice was indicated for each 10-minute interval as a representation of the emphasis of each practice. For instance, the instructor in the Introduction to Engineering course asked students to talk to potential customers about their needs and figure out customers' "pain points" at the beginning of the students' group project. This assigned task highlighted the importance of the practice of stakeholder engagement.

We conducted training and piloted the observation protocol to ensure consistent analysis. The piloting and training were conducted using several course recordings from external online resources. Researchers' skills were developed and tested for reliability during this phase; for this purpose, three researchers were asked to analyze the same ME course from external resources. Through comparison and discussion among the researchers and with the larger research team, consistency of understanding and application of the protocol was developed, and revisions were made to the protocol. The finalized protocol is located in the appendix.

To observe the courses included in this study, three researchers independently watched the class session recordings, identified practices discussed by instructors from the observation protocol for each 10-minute interval, and wrote comments describing how that practice was discussed. They worked in pairs during the coding process. After two of the researchers finished analyzing the same recording, they came together to check for consistency and to reconcile any discrepancies. Any discrepancies not settled between the two coders were brought to the larger team meetings for members to discuss and come to agreement.

4. Findings

Overall, we found that one practice is overwhelmingly most frequently discussed in the required ME courses we observed: *learning and studying foundational engineering principles or technical knowledge*. Instructors introduced this practice in 90.3% of course intervals. No other practice received mention in more than 9% of course intervals. In Fig. 1, we present the engineering practices that were emphasized across all eight courses in our study. Not included on the figure are five of the practices that were never discussed: *accounting for financial or economic considerations, weighing ethical responsibilities, demonstrating social awareness in interactions with others, understanding or coordinating logistics, or engaging in optimization to identify the most effective decision.* In the following sections, we address the research questions by presenting our findings on the engineering practices most emphasized in required engineering courses across ME subfields and how social and contextual practices are discussed within those courses.

4.1 Practices Emphasized in Introductory Engineering

Course emphases differ from subfield to subfield; Introductory Engineering is distinctive in the breadth of practices given some degree of emphasis,

Table 2. Engineering practices analyzed in classroom recordings

Engineering Practice Code Name	**Practice Description**
Analyze Data	Engage in data analysis, processing, and interpretation.
Build Tangible Artifacts	Build tangible artifacts as models, prototypes, or working products.
Business and Financial	Account for financial or economic considerations.
Coding or Programming	Computer coding or programming.
Data Collection	Collect data following proper procedures.
Design Experiments	Design or develop plans and procedures for experiments.
Ethics	Weigh (often complex) ethical responsibilities.
Evaluate Solutions	Test and evaluate potential solutions.
Foundational Technical Knowledge	Learn or study fundamental engineering principles or technical knowledge.
Future Impacts	Consider or account for potential future impacts of one's work.
Human Factors and Ergonomics	Account for human factors and ergonomics – how bodies physically interact with a potential solution.
Immediate Context	Account for the immediate context in which a solution may be deployed.
Information Gathering & Research	Gather information or conduct research needed to address a problem.
Innovation (and Ideation)	Come up with innovative ideas and approaches.
Interdisciplinarity	Engage in interdisciplinary collaboration or integrate ideas from other fields of study.
Interpersonal Awareness	Demonstrate social awareness, empathy, and self-awareness in interactions.
Iteration	Iterate on and improve on ideas or designs.
Leadership	Use leadership skills to ensure teams work effectively.
Lifecycle of a Solution	Consider a design, product, or process over the course of its lifecycle.
Logistics	Understand or coordinate logistics of a process, problem, or system.
Modeling and Simulation	Develop or work with virtual models or simulations.
Natural Environment	Account for the natural environment and/or issues of sustainability.
Optimization	Engage in optimization to identify the best or most effective decision.
Power/ Position/ Identity	Consider dynamics related to the identities, positions, backgrounds, or relative power of self and/ or others.
Predict Outcomes	Predict outcomes by drawing on engineering principles or methods.
Present on or Explain Work	Present on or verbally communicate about one's work or its value.
Problem Definition	Define a problem to understand it and identify constraints and/or requirements.
Project Management	Manage project work across multiple stages and/or multiple team members.
Relationships and Tradeoffs	Account for relationships or tradeoffs between multiple aspects of a project and/or the larger system.
Social Context	Account for the social or cultural context in which a problem is embedded.
Stakeholders	Engage with or account for stakeholders needs and perspectives.
Teamwork and Collaboration	Engage in teamwork or collaborate towards a common goal.
Technical Communication	Generate technical communication deliverables, including written reports and figures to represent work.
Technical Details	Account for, develop, or refine the concrete details of (potential) solutions.
Troubleshooting	Engage in troubleshooting to systematically identify or assess potential issues.

* The code name represents only the words associated with the practices, and the description conveys a more precise notion of each practice.

including conventional technical practices (e.g., *learning foundational technical knowledge, building tangible artifacts*) and practices requiring social and contextual skills (e.g., *accounting for stakeholders' needs, considering social or cultural context*). The emphasis of various practices in Introductory Engineering is shown in Fig. 2.

We provide an example in Table 3 of each of the practices present in Introductory Engineering.

In the course observed in Introductory Engineering, the most commonly emphasized engineering practice was *learning or studying fundamental engineering principles or technical knowledge* (77.8% of course intervals). For example, the instructor introduced the principles of House of Quality first, and then he gave real-life examples of applying the House of Quality in engineering designs. *Building tangible artifacts as models, prototypes, or working products* was another key engineering practice (40.7% of course intervals) because the introduction to engineering course lab sessions with hands-on group projects. The instructor usually demonstrated the procedures to set up lab work and the requirements for students' group projects in the

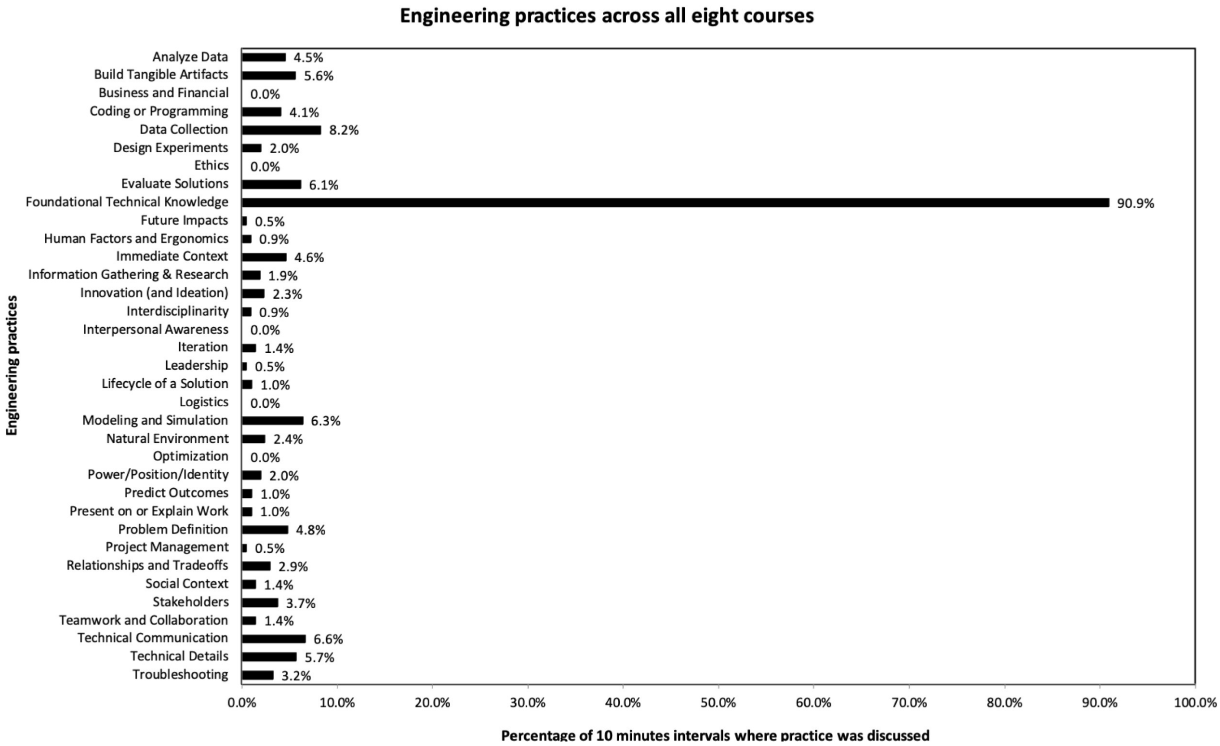

Fig. 1. Frequency of engineering practices (displayed in alphabetical order) discussed across all eight courses, by percentage of total course intervals (within 216 10-minute intervals).

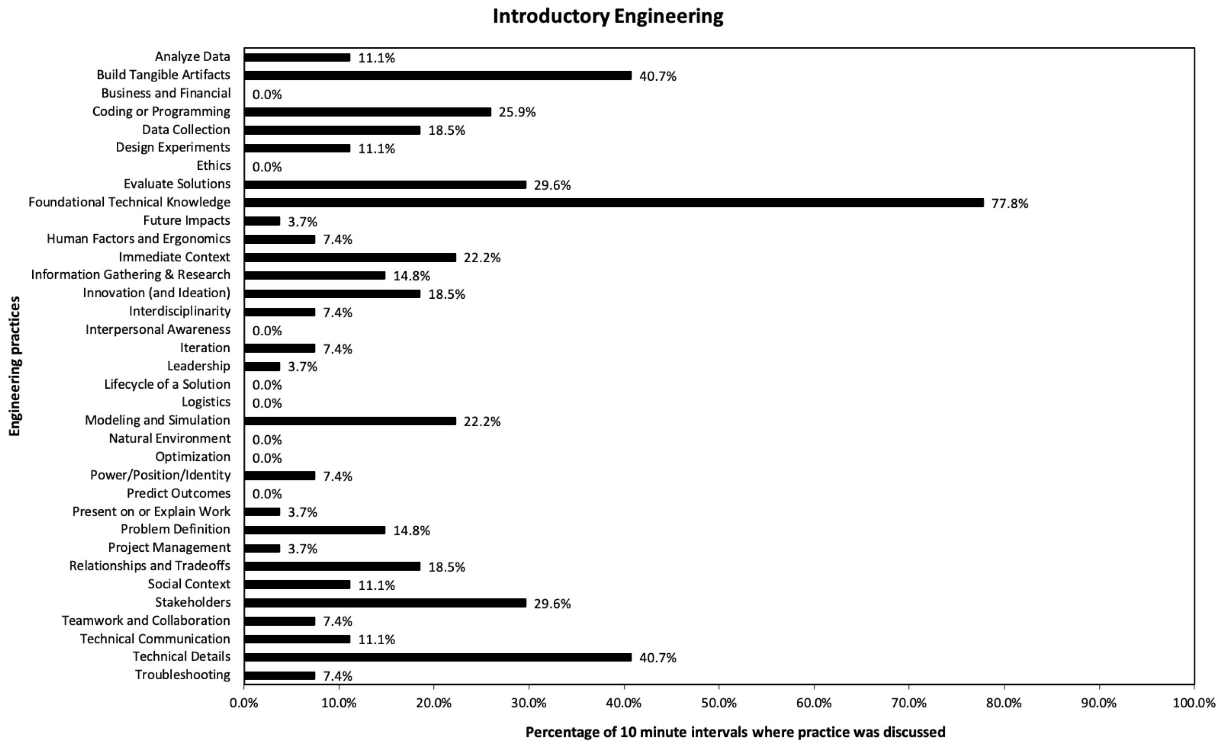

Fig. 2. Frequency of engineering practices (displayed in alphabetical order) discussed in Introductory Engineering, by percentage of course intervals in the course observed in this subfield (within 27 10-minute intervals).

lecture sessions. For instance, the instructor emphasized building tangible artifacts by demonstrating the process for making part of a robot arm in SolidWorks, and for assembling the robot arm for microparticle transfer/collection. The instructor also emphasized a*ccounting for, developing, or defining the concrete technical details of solutions* (40.7% of course intervals) in students' course projects,

Table 3. Examples of engineering practices in Introductory Engineering

Practice	**Example(s) of What it Looked Like in Introductory Engineering Class**
Analyze Data	Instructor demonstrated calculation of maximum torque with pictures and equations.
Build Tangible Artifacts	Instructor demonstrated making and use of robot arm in SolidWorks.
Coding or Programming	Instructor displayed Arduino codes for a servo motor focusing on specific functions and operations.
Data Collection	Instructor showed how to collect data from a robot arm to measure torque.
Design Experiments	Instructor walked through a set of weightlifting tests to find maximum torque.
Evaluate Solutions	Instructor applied the House of Quality method to evaluate engineering products/systems.
Foundational Technical Knowledge	Instructor demonstrated how thermal 3D printer polymerization works.
Future Impact	Instructor expanded on the issue of commercializing nano 3D printing technology when asked about industrial applications.
Human Factors and Ergonomics	Instructor introduced human-centered design with specific examples, such as considering natural and comfortable ways to move the human body as factors when designing a PS controller to play video games.
Immediate Context	Instructor gave the example of the requirement for a high temperature tolerant 3D printer to produce a specific face shield that could be cleaned at the high temperatures demanded by COVID.
Information Gathering and Research	Instructor taught students various approaches to gathering information, including customer interviews, task letters, public media, library, and open-source forum platforms.
Innovation (and Ideation)	Instructor spoke of design and manufacturing courses in ME as great opportunities to learn design and ideation, expanding on the ideation phases of the solution and conceptual design drawing.
Interdisciplinarity	A guest speaker discussed opportunities for students to get involved in interdisciplinary design projects across campus.
Iteration	Instructor showed three iterations of his design of a rover.
Leadership	A guest introduced opportunities to participate in leadership development seminars..
Modeling and Simulation	Instructor showed a quick tutorial about using CAD software SolidWorks.
Power/Position/Identity	Instructor shared his experience collaborating with a researcher from another country on a semiconductor technology that was on the list of sensitive technologies in the US. He was asked by the US university administrator to write a very long justification to guarantee that the materials he would provide to the collaborator would not be used to produce the "sensitive technology".
Present on or Explain Work	Instructor asked students to make a video and include it on their slides to show how their robot functioned in the lab.
Problem Definition	Instructor emphasized that engineers use technical knowledge to define technical features of products, such as speed of a car, power of an engine, or properties of materials. In addition, the instructor suggested learning from customers to define requirements for the product.
Project Management	Instructor introduced a tool (QFD) for project planning.
Relationships and Tradeoffs	Instructor discussed that trade-offs must be considered to ensure that, e.g., a 3D printer designed to be compact can nevertheless produce large prints. At the end, he conceded the difficulty of making decisions in engineering solutions with tradeoffs.
Social Context	The instructor explained that the purpose of designing a 3D printer for home use was to respond to the need of many developers who were working from home and needing something for quick prototyping.
Stakeholders	The instructor emphasized the importance of talking to customers in order to understand their "pain points" and their needs for product design.
Teamwork and Collaboration	The instructor mentioned how, in industry, different teams make different parts (e.g., car window, motor) of a design and work together to create a car.
Technical Communication	The instructor set up requirements for students' lab reports, including a video to report validation accuracy and loss.
Technical Details	The instructor showed the top view of the servo motor, the JD connector, and the procedure for connecting the servo motor on the Arduino board using JD connectors; these detailed demonstrations set students up to assemble their experiment devices in the lab sessions later on.
Troubleshooting	The instructor provided instructional details to show students how to assemble the rover and to build a prototype system in case students need the instruction as a reference for troubleshooting.

which included detailed demonstrations to prepare students to assemble experiment devices used in lab sessions.

In Introductory Engineering, other engineering practices were moderately frequently to infrequently emphasized. The moderately frequently emphasized practices consist of *testing and evaluating potential solutions* (29.6% of course intervals), *accounting for stakeholders' needs and perspectives* (29.6% of course intervals), *computer coding and programming* (25.9% of course intervals), *developing virtual models and simulations* (22.2% of course intervals), and *accounting for the immediate context in which a solution may be deployed* (22.2% of course

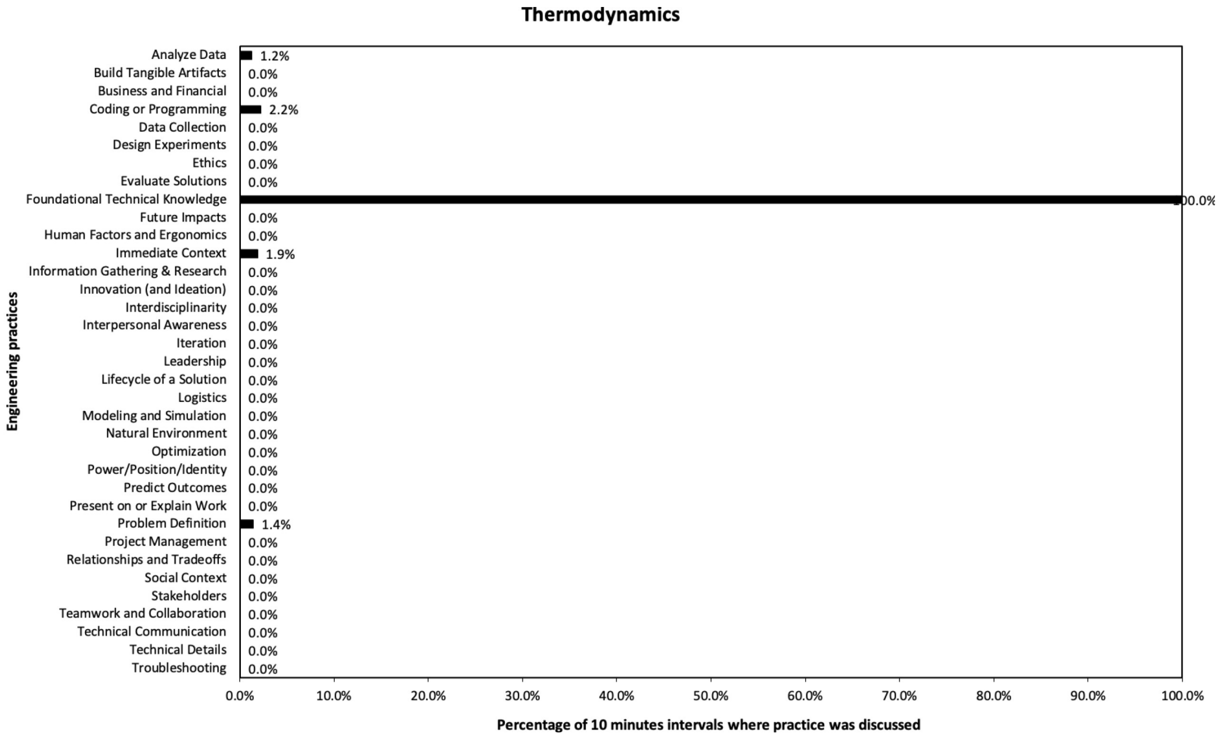

Fig. 3. Frequency of engineering practices (displayed in alphabetical order) discussed in Thermodynamics, by percentage of course intervals (within 69 10-minute intervals).

intervals). The instructor leveraged an example related to the redesign of a microparticle concentrator to encourage students to consider how engineers *account for the immediate context*, as well as to *develop plans and procedures for experiments* (11.1% of course intervals). In this case, the instructor asked students to re-design the microparticle concentrator based on the context and local issues in their own group projects. Another infrequently emphasized practice was *coming up with innovative ideas and approaches* in the subfield (18.5% of course intervals). As an example, the instructor spoke of design and manufacturing courses in ME as great opportunities to learn design and ideation, expanding on the ideation phases of the solution and conceptual design drawing.

As presented in Fig. 2 and Table 3, engineering practices related to social and contextual dimensions of engineering work were also highlighted by the instructor in the course observed in Introductory Engineering. The most commonly emphasized social and contextual practice was *accounting for stakeholders' needs and perspectives* (29.6% of course intervals). The instructor emphasized the importance of talking to customers in order to understand their "pain points" and their needs for product design. To practice stakeholder engagement in student group projects, each team was required to interview the instructor, who acted as a customer. In addition to engaging stakeholders, *accounting for social and cultural contexts in which a problem is embedded* (11.1% of course intervals) was also discussed. For instance, the instructor explained that the purpose of designing a 3D printer for home use was to respond to the need of many developers who were working from home and needing something for quick prototyping. Several social and contextual practices were occasionally discussed, such as *considering dynamics related to the identities, positions, background or relative power of self and/or others* (7.4% of course intervals), and *accounting for potential future impact of one's work* (3.7% of course intervals). To introduce *dynamic relationships among identities, positions, and power*, the instructor shared his experience collaborating with a researcher from another country on semiconductor technology and being asked to provide extensive documentation ensuring their work would not be used to produce the "sensitive technology". *Consideration of future impact* was addressed in the course when the instructor expanded on the issue of commercializing nano 3D printing technology.

4.2 Practices Emphasized in the Thermodynamics Subfield

Across the three courses observed within the Thermodynamics subfield, learning and studying fundamental engineering principles or technical knowledge was emphasized throughout the course

Table 4. Examples of engineering practices in Thermodynamics

Practice	Example(s) of What it Looked Like in Thermodynamics Classes
Analyze Data	An instructor used Excel to find the iterative solution for a problem set.
Coding or Programming	An instructor displayed the codes to solve an equation and to visualize vibration in Matlab.
Foundational Technical Knowledge	Instructors walked through setting up and solving example problems, and deriving the solutions. An example problem was to predict possible motions of a string using an equation of motion.
Immediate Context	An instructor shared an example of a bridge collapse in which the immediate context of a design had not been not considered. The collapse was caused by the failure to consider vortex shedding, which could be at the same frequency of the bridge itself, leading to large amplifications of the system.
Problem Definition	An instructor stated that students should have the ability to interpret problem statements, and understand the problem in a specific context as an engineer in the real world of work.

intervals. Only a few other engineering practices were briefly discussed; these were data analysis and interpretation, computer coding or programming, accounting for immediate context, and defining problems to identify constraints. The uneven distribution of the emphasized practices is shown in Fig. 3.

Examples of what it looked like when instructors introduced this limited number of engineering practices in Thermodynamics are given in Table 4.

In Thermodynamics, the most commonly emphasized engineering practice was *learning and studying fundamental engineering principles or technical knowledge* (100% course intervals) because the majority of course content in this subfield focused on math and physics. Instructors in the three courses observed within this subfield normally walked through setting up and solving example problems and deriving the solutions to introduce fundamental principles or technical knowledge. The remaining practices – *data analysis and interpretation, computer coding or programming, and accounting for the immediate context* – appeared in less than 3% of course intervals individually. Examples of the integration of these practices are provided in Table 4.

It is noteworthy that none of the practices observed in Thermodynamics courses related to social and contextual dimensions of ME work.

4.3 Practices Emphasized in the Materials and Mechanics Subfield

Similar to Thermodynamics, across the two courses observed in Materials and Mechanics, instructors emphasized a limited number of engineering practices. Among the five practices discussed in Material and Mechanics, *learning and studying fundamental*

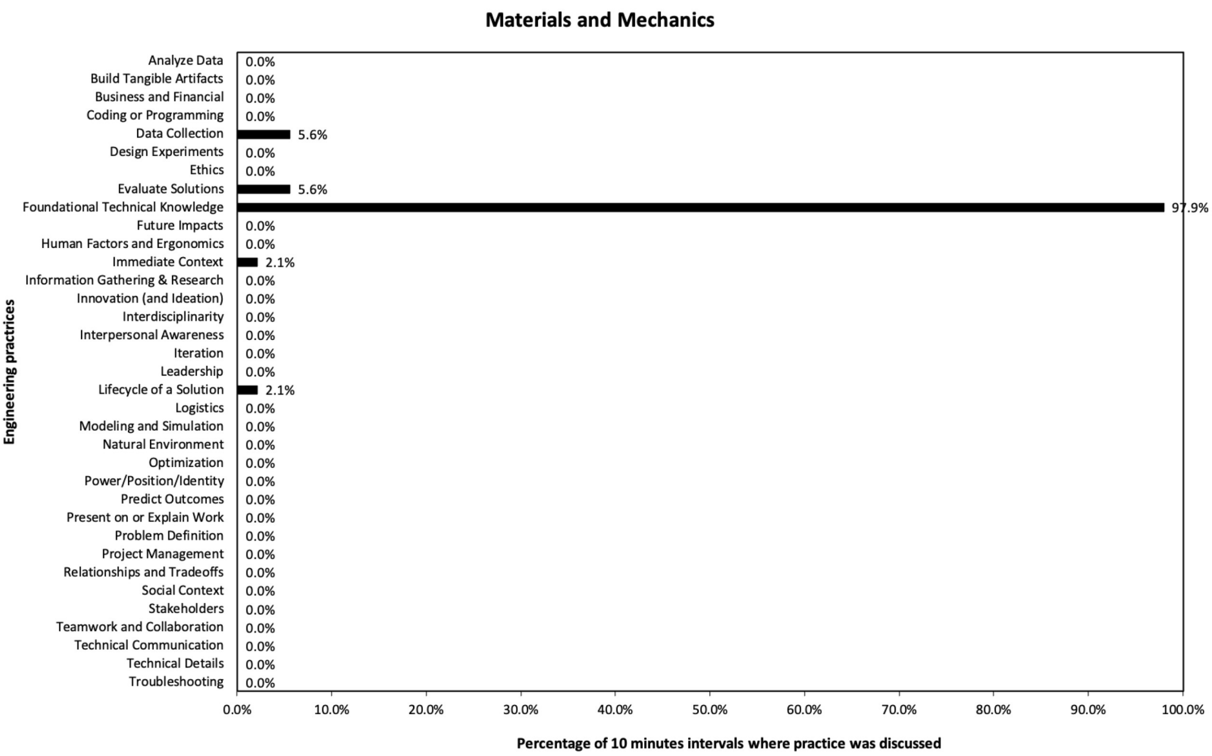

Fig. 4. Frequency of engineering practices (displayed in alphabetical order) discussed in Materials and Mechanics, by percentage of total course intervals (within 37 10-minute intervals).

Table 5. Examples of engineering practices in Materials and Mechanics

Practice	Example(s) of What it Looked Like in Materials and Mechanics Classes
Data Collection	An instructor showed a video to demonstrate how to take a standard fracture toughness measurement, and he also demonstrated each step to measure fracture toughness.
Evaluate Solutions	An instructor taught students to obtain the right value of fracture toughness by ensuring that the plastic zone is the smallest of all the relevant dimensions of the material. In this case, he demonstrated judgments, based on comparison and evaluation, were required to get the right value of fracture toughness.
Foundational Technical Knowledge	At the beginning of one class, an instructor introduced basic concepts of stress transformations, Mohr's circle, principal stresses and eigenvectors. The instructor then walked through several example problems of drawing Mohr's circle and stressing transformation cubes.
Immediate Context	A professor emphasized the importance of considering creep (how fast a material is deforming) for specific applications like tungsten lamps and jet engines.
Lifecycle of a Solution	The instructor asked students to consider the expected lifetime of a tungsten lamp because it would melt under a high-temperature lighting environment (>350 °C).

engineering principles and technical knowledge was the only practice emphasized in almost all course intervals. The other occasionally discussed practices in this subfield were *collecting data, testing and evaluating potential solutions, accounting for the immediate context, and considering a design, product, or process over the course of its lifecycle.* The frequency of each engineering practice shown in Fig. 4; none exceeded 5.6% of course intervals.

We present some examples of each engineering practice in Materials and Mechanics in Table 5.

As Material and Mechanics was heavily science-based, the majority of engineering practices discussed in this field were technically-oriented. *Learning and studying fundamental principles and technical knowledge* was the most commonly emphasized engineering practice (97.9% of course intervals) across the two courses observed in this subfield. At the beginning of one class, an instructor introduced basic concepts of stress transformations, Mohr's circle, principal stresses and eigenvectors. The instructor then walked through several example problems of drawing Mohr's circle and stressing transformation cubes. The remaining four engineering practices in Fig. 4 were only occasionally discussed in one of the two courses observed in Materials and Mechanics.

Both *collecting data following proper procedures* and *evaluating solutions* were discussed in 5.6% of course intervals. The instructor discussed both processes for measuring fracture toughness and making judgements based on comparison and evaluation in order to get the right value of fracture toughness. In addition, the two practices of *accounting for immediate context* and *the lifecycle of a product, design, or process* each accounted for 2.1% of course intervals. Both practices were introduced when the professor emphasized the importance of considering creep (how fast a material is deforming) for specific applications like tungsten lamps and jet engines.

Unsurprisingly, the instructors in Material and Mechanics did not emphasize any engineering practices related to the social and contextual dimensions of ME work.

4.4 Practices Emphasized in Design and Labs

Like the course in Introductory Engineering, the courses observed in Design and Labs covered a diverse range of engineering practices, placing the greatest emphasis on conventional technical practices (e.g., *learning fundamental principles and technical knowledge, data analysis and collection*), but also including social and contextual practices (e.g., *accounting for the natural environment*, *considering dynamics related to identities, positions, backgrounds*). While we grouped design and lab courses together to reflect how they are commonly discussed in the literature and in university course groupings, we present examples from the design and lab courses observed separately to best highlight observed differences in our data. The emphases of various engineering practices in one of the three design courses in required ME courses are summarized in Fig. 5.

We present an example of each engineering practice in the design course under Design and Labs in Table 6.

The design course observed in Design and Labs emphasized *learning and studying fundamental engineering principles or technical knowledge* throughout all course intervals (100% of course intervals). To introduce the engineering principles and knowledge, the instructor brought a bucket of machine components, such as belts and chains, to teach students about engine components. Later on, the instructor talked about the fundamental law of gearing, loads of gears, gear review, and theory/questions behind these concepts. In addition to the practice of *learning fundamental principles and knowledge*, the instructor moderately emphasized two additional engineering practices, *accounting for the natural environment and sustainability issues* (19.0% of course intervals) and *defining a problem* (19.0% of course intervals). When demonstrating *defining a problem to understand it and to identify*

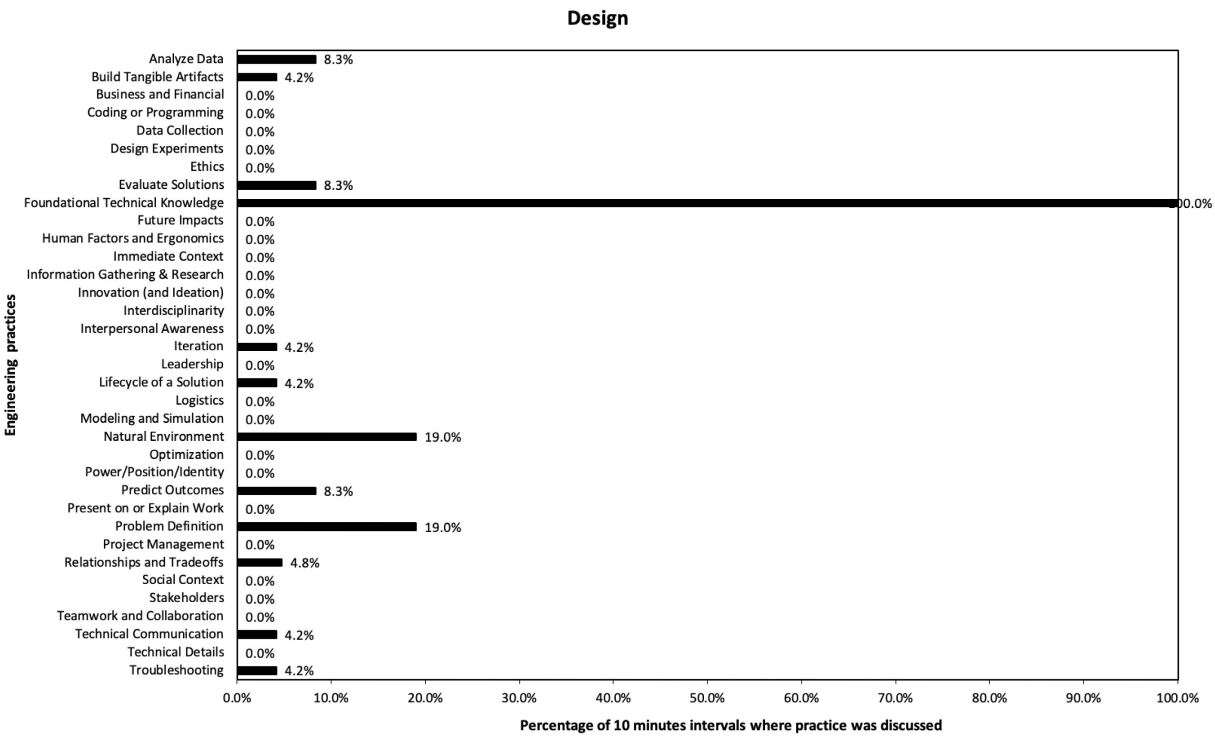

Fig. 5. Frequency of engineering practices (displayed in alphabetical order) discussed in the design course under Design and Labs, by percentage of course intervals (within 23 10-minute intervals).

Table 6. Examples of engineering practices in the design course under Design and Labs

Practice	Example(s) of What it Looked Like in Design/ Lab Classes
Analyze Data	The instructor walked the students through reading and interpreting the radial load experimental data for ball bearings using a table and a graph.
Build Tangible Artifacts	The instructor created opportunities for students to improve performance of their design products in the final project of the course.
Evaluate Solutions	The instructor gave an example of selecting a more reliable bearing for a design problem by comparing actual and required values of an important parameter.
Foundational Technical Knowledge	In one case, the instructor gave an example of linkage in the prosthetic knee, and then introduced Grashof linkage and four-bar linkage with additional examples.
Iteration	The instructor showed how iteration was used to solve an example problem of selecting the best bearing. During the process, the instructor iterated values and calculations to make the best educated guesses until the calculated data converged.
Lifecycle of a Solution	The instructor solved an example problem about the desired lifespan for the bearings.
Natural Environment	The instructor emphasized that the optimal gear ratio is designed to maximize acceleration but results in lower fuel efficiency, so he encouraged students to think about the impact of fuel consumption on the natural environment when working on their own design projects.
Predict Outcomes	The instructor illustrated, both visually and through analysis, how to predict failures of the bearing by identifying whether bearings are starting to overheat.
Problem Definition	The instructor introduced an example problem of a gear setup by reading the problem statement, and then clarifying the language about the constraints of the problem. In another realistic example, the instructor walked through the constraints and information for the problem before students started to solve the problem themselves.
Relationships and Tradeoffs	The instructor mentioned that transmission ratios can be used to change speed-torque gradient; however, the cost of size and efficiency of transmission should be considered as well.
Technical Communication	The instructor reminded students to update their final reports and incorporate feedback from the GSIs.
Troubleshooting	The instructor introduced different tools to use in order to detect whether the bearings would fail. He also added technicians could be another resource in the workplace to help detect the bearing failure.

constraints and/or requirements, the instructor gave an example problem of a gear setup by reading the problem statement; he then clarified students' understanding of the setup/constraints of the problem. *Testing and evaluating potential solutions* (8.3% of course intervals) was occasionally discussed in the subfield; this practice was often discussed in relation to the practice of *iteration* *and improvement of ideas or designs* (4.2% of course intervals). For instance, the instructor gave an example of selecting a reliable bearing for a design problem based on the comparison between actual and required values of an important parameter. Iterating on ideas was required for selecting the most reliable bearing. It is worth noting that two other practices that were rarely mentioned in other ME subfields were occasionally discussed in the design subfield: *considering a product or process over the course of its lifecycle* (4.2% of course intervals) and *accounting for relationships and tradeoffs between multiple aspects of a project* (4.8% of course intervals). In the design course, the instructor solved one example problem about the desired lifespan of the bearings. The other practice is *accounting for relationships and tradeoffs between multiple aspects of a project* (4.8% of course intervals). To demonstrate the practice of *considering the relationships and tradeoffs*, the instructor mentioned using transmission ratios to change speed-torque gradient while cautioning that cost of size and efficiency of transmission should be considered as well.

While the design courses more frequently mentioned social and contextual practices than some ME subfields, *accounting for the natural environment and sustainability issues* (19.0% of course intervals) was the only emphasized social and contextual practice in the course observed. The course instructor encouraged students to think critically about the impact on the natural environment when working on their own design projects. For example, the instructor asked students to think about the optimal gear ratio of a car carefully because it was designed to maximize acceleration but lowered fuel efficiency.

A lab course was also included to capture instructors' messaging in Design and Labs. The course emphasized both developing understanding of foundational technical knowledge and applying this knowledge through the design of experiments, data collection and analysis. The lectures of the lab course were co-taught by two instructors focusing either on traditional technical practices or interpersonal practices; this distinctive instructional strategy resulted in a diverse range of engineering practices in the lab course. The wide range of engineering practices is summarized in Fig. 6.

Examples of what it looked like when instructors introduced each engineering practice in the lab course under Design and Labs are listed in Table 7.

In the lectures of labs observed in this study, the frequently emphasized engineering practices were *learning and studying fundamental principles and technical knowledge* (53.6% of course intervals), *preparing technical communication deliverables* (37.5% of course intervals), and *collecting data* (36.3% of course intervals). The instructor introduced *learning fundamental principles and knowledge* by lecturing on modeling system dynamics and

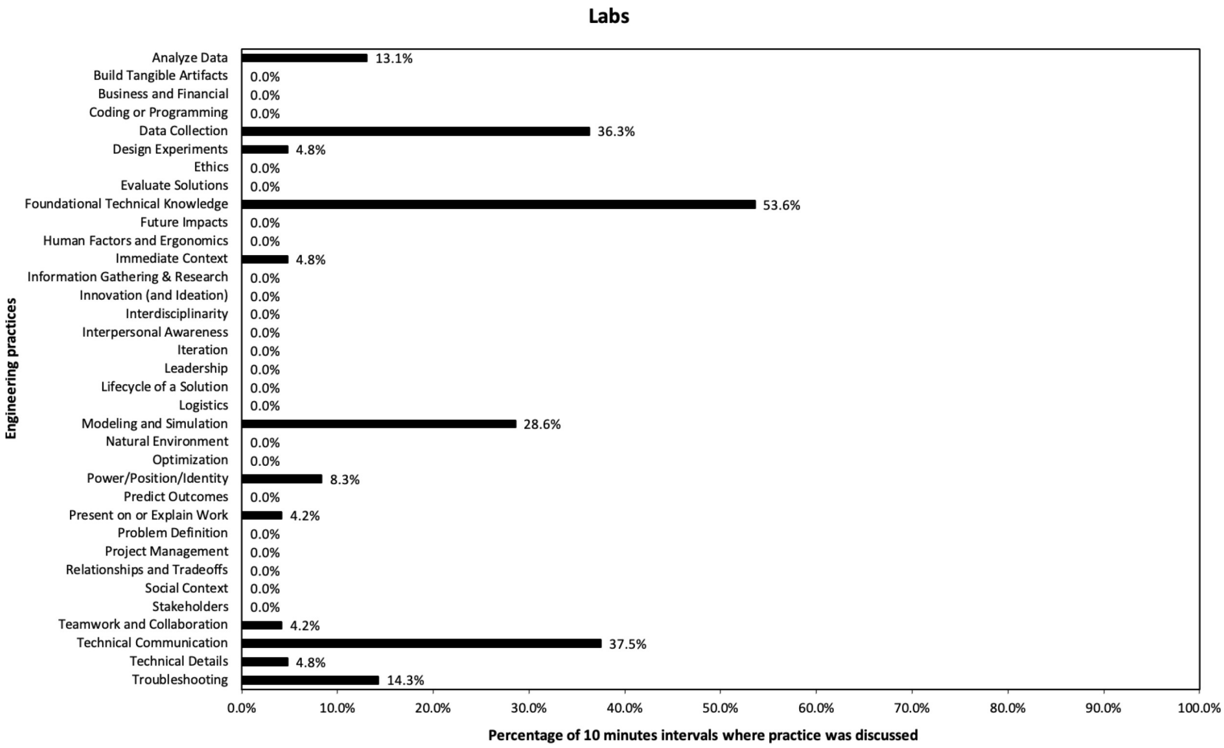

Fig. 6. Frequency of engineering practices (displayed in alphabetical order) discussed in the lab course under Design and Lab, by percentage of course intervals (within 23 10-minute intervals).

Table 7. Examples of engineering practice in the lab course in Design and Labs

Practice	Example(s) of What it Looked Like in Design/Lab Class
Analyze Data	The instructor introduced how to validate the model against frequency response, and then he drew comparisons between model data and system data.
Data Collection	The instructor walked through an experimental setup, the procedure to obtain/extract two values of thermal contact resistance from the experiment.
Design Experiments	The instructor set students up to design a test procedure to determine damping coefficient.
Foundational Technical Knowledge	The instructor lectured on modeling system dynamics and parameters of the system using transfer functions.
Immediate Context	The instructor walked students through procedures and requirements of the upcoming lab tasks, and he especially emphasized the need to 'take everything about the system into account' when working in the design lab, as the lab task in this course is a more realistic design scenario.
Modeling and Simulation	The instructor set students up to develop a motor axle model, perform computer simulation to validate a model, refine the model, and propose design modifications to solve problems in the following lab sessions.
Power/Position/ Identity	The instructor talked about considering accommodation for color blindness when designing visuals.
Present on or Explain Work	The instructor showed a Netflix movie to demonstrate thinking about what the movie called 'the impulse of work.' He emphasized understanding audiences' interests and needs when presenting work.
Teamwork and Collaboration	The instructor made suggestions for working effectively with team members on lab memos/reports writing in shared Google docs.
Technical Communication	The instructor introduced a basic outline for lab reports, including background, method, findings, discussion, conclusions, limitations and recommendations. In particular, the instructor emphasized the importance of tailoring writing to both technical and non-technical audiences.
Technical Details	The instructor demonstrated the details of how to model the system, in which students need system parameters and system equations, and the different parts of the system and what parameters are associated with each.
Troubleshooting	The instructor set students up for the following lab to figure out how to fix a realistic design problem of vibration in the drivetrain. The instructor showed the way to reproduce the problem in the lab and gave additional information to solve the rest of the problem.

walking through thermal circuit analysis calculation for a chip.

To *prepare technical communication deliverables*, the instructor introduced a basic outline for lab reports and discussed the importance of tailoring writing to both technical and non-technical audiences. In order to help students understand procedures for collecting data and also discussed *the process of developing plans for experiments* (4.8% of course intervals), and asked students to design a test procedure to determine damping coefficient. Moderately emphasized engineering practices in the lab class included *developing or working with virtual models or simulations* (28.6% of course intervals), *analyzing and interpreting data* (13.1% of course intervals), and *engaging in troubleshooting* (14.3% of course intervals).

To demonstrate the practice of *developing virtual models or simulations*, the instructor set students up to develop, validate, and refine a motor axle model. When the instructor demonstrated *engaging in troubleshooting*, the instructor set students up for the following lab to figure out how to fix a realistic design problem of vibration in the drivetrain. *Developing or refining the concrete details of solutions* (4.8% of course interval) was occasionally discussed in the lab course, including an example in which the instructor demonstrated a process for modeling a system and identifying appropriate parameters and equations.

The only social and contextual practice introduced in the lab course was *considering dynamics related to the identities, positions, backgrounds, or relative power of self and/or others* (8.3% of course intervals). The instructor used the example of accommodating color blindness when designing visuals to demonstrate how power, position and identity were closely connected with visual design and communication.

5. Discussion

Across all eight ME courses, the most commonly emphasized engineering practice was overwhelmingly *learning fundamental engineering principles and technical knowledge*, ranging from 53.6% to 100% of course intervals within the five ME subfields and occurring in a total of 91% of all course intervals observed. The next closest practice emphasized across all courses was *collecting data*, accounting for 8.2% of all course intervals. All other practices were discussed in fewer than 7% of all course intervals. The striking gap of course intervals between foundational technical knowledge and other practices clearly showed that *studying fundamental engineering principles and technical knowledge* was the dominant practice in the required ME courses.

Within each subfield, various engineering practices were also emphasized in the courses observed, but all with less frequency than *learning fundamental principles and technical knowledge*. In Introductory Engineering, 40.7% of course intervals included an emphasis on *building tangible artifacts* and *accounting for technical details* for each of these two practices. In the lab course under Design and Labs, *generating technical communication deliverables* (37.5% of course intervals) and *collecting data* (36.3% of course intervals) were the next most common practices emphasized. Then, in the design course under Design and Labs, 19% of course intervals emphasized *accounting for the natural environment* and *defining problems*, respectively. The predominant emphasis on foundational technical knowledge and other mostly technical engineering practices within each subfield of the required ME courses observed is consistent with prior scholarship highlighting engineering's depoliticized nature and its techno-centric stance [19, 47].

We found that social and contextual engineering practices were rarely present in the required ME courses across all five subfields. These social and contextual practices – *weighing ethical responsibilities, considering potential future impact, accounting for social or cultural context and the natural environment, considering dynamic relationships among power, position, and identity* – were infrequently present in the observed courses. Even the most commonly mentioned social and contextual dimension, related to *accounting for stakeholder perspectives*, was mentioned in fewer than 4% of all observed course intervals.

Across ME subfields, the course observed in Introductory Engineering had the broadest coverage of engineering practices (27 of the 35 practices listed in Table 3), including the majority of social and contextual practices (4 out of 5 social and contextual practices). Several other researchers have reported that the first-year introduction to engineering courses were designed intentionally to recognize the broad collection of practices that connect engineering technical knowledge with the situated social and contextual engineering world of work [48, 49].

The two courses observed within Design and Labs each covered 12 out of 35 practices (Tables 6 and 7). However, each course in Design and Labs included only one social and contextual practice. The fewest number of distinct engineering practices were observed in Thermodynamics (5 of the 35 practices listed in Table 4) and Materials and Mechanics (also 5 of the 35 practices listed in Table 5). Social and contextual practices were never discussed in the five courses observed in these two subfields. It is worth noting that we did not include the capstone design course, which typically is recognized as covering many of the social and contextual practices [9, 32, 50, 51]. A number of studies show that making ethical decisions and considering social impact are more common elements of both first-year design courses and capstone design courses due to the integration of project-based learning and service-learning experience [2, 18, 21, 50]. Our findings also suggest that students have limited opportunities to learn social and contextual skills after the first-year introduction to engineering course.

Because of the broad and multidisciplinary nature of the ME discipline, social and contextual engineering skills are recognized as essential for enabling professional mechanical engineers to work in various industries [1, 2, 4]. Further, integrating social and contextual skills in the curriculum can shape who participates in the ME work; a great deal of research suggests that social and contextual dimensions of engineering work attract a more diverse student body [52–55]. These studies show that women and minority engineering students may be particularly interested in or motivated by the social impacts of engineering work.

Literature shows that many engineering students have limited access to ways to learn and practice social and contextual skills in their classes except for design courses (i.e., the first-year introduction to engineering course, the senior capstone course, and specific design courses) and a few technical electives [9, 32, 36, 50, 56]. After students declare their ME major, much of their coursework in the second and third years of their undergraduate study consists of required courses that are predominantly technical-focused. The limited emphasis on social and contextual practices throughout the ME undergraduate curricula risks reinforcing students' misconception that ME is an exclusively technically-oriented field isolated from society, community and people involved. This misconception potentially creates a barrier for students' development of a sense of belonging in engineering [19, 47, 57].

Despite the demonstrable importance and long-standing ABET accreditation student outcomes associated with social and contextual practices, integrating these skills into engineering education can be challenging for several reasons [58]. As recognized in the literature, ME curricula across the United States are often already content dense [7–9], which can serve as a barrier to introducing additional social and contextual content into ME courses. In addition, the restricted structural support in higher education has created multiple barriers (e.g., restricted time, inadequate departmental resources, lack of institutional incentives) for engineering faculty to make pedagogical changes [29–31]. These impediments may make instructors reluctant to develop and integrate content related to social and contextual practices into their required ME courses. Scholarship suggests that instructors' technically-oriented conceptions about the nature of engineering could be an additional barrier to integrating social and contextual skills into ME undergraduate curricula [27].

5.1 Limitations

There are several limitations of this study related to sampling strategy that are worth noting. First, we randomly selected the course sessions that we observed in order to determine the engineering practices emphasized (excluding the first and last sessions, as detailed in the "Methods" section). By randomly selecting three course sessions (averaging 90 minutes each), we considered approximately 12% of the course content (270 over 2250 minutes) for each course, calculated based on an average of 150 minutes of classroom time per week in a semester-long 3-credit course. Class sessions we analyzed may not represent the practices emphasized in the courses as a whole, and some of the practices not identified in our analysis could or could not have shown up if we had analyzed other class sessions in the course. Further, counting the introductory course, only 7 out of 12 required ME courses at the institution studied were included in this study. Thus, our sample may not provide the whole picture of how often and to what extent engineering practices were introduced by instructors in various required ME courses.

An additional limitation is that our sample of courses did not include the capstone design course. We were not able to include it because the course was not offered in lecture-based teaching format, so no class recordings were available for these courses. Because capstone design courses have been shown to cover a variety of skills including stakeholder engagement, multidisciplinary teamwork, design and iteration, modeling and simulation [9, 32, 59, 60], the lack of access to them means that our findings may incompletely reflect the variety of practices emphasized in the design courses.

5.2 Implications

The purpose of this paper is to examine the extent to which social and contextual practices are integrated into engineering classrooms. This is important because recent research shows that if engineering culture is continuously disengaged from public welfare, social and ethical issues and policy implications, engineering students may be less motivated to consider people and context when seeking engineering solutions. It has been shown that highly technically-oriented engineering undergraduate programs can shape and reinforce techno-centric and objective engineering mindsets among students [19, 47]. In response to increasingly complex engineering systems, rapidly advancing technologies and the ever-changing world, the engineering programs in many institutions have included comprehensive skill development in their vision and mission statements in order to show that their program goals fulfill industrial job market and societal needs. However, our findings suggest that social and contextual skills, a subset of comprehensive engineering skills which are critical for their role in connecting engineering technical solutions to a broader social and contextual world, are not deeply integrated across ME required courses. There is a risk of inconsistencies between how engineering work is talked about at an institutional level and what students experience as the emphasis of engineering work in their day to day classroom experiences. Discrepancies between institutional or departmental messaging about the nature of engineering work and the foci of engineering course may be common; Lachney et al. [61] has found that misalignments exist between educational approaches used in K12 (open-ended, creative, hands-on projects) and college level engineering education (decontextualized, narrowly technical-analytic "fundamentals first" approach), with the result that prospective students may choose an engineering major while holding a conflicting or erroneous understanding of the nature of engineering. The authors posit that this disconnect may contribute to student retention issues in engineering. Engineering departments should ensure their messaging, communicated through channels like their websites and recruitment materials, aligns with the curricular content experienced by students in required departmental current engineering courses.

If engineering departments want to acknowledge the importance of social and contextual practices and support their integration into engineering classrooms, we offer several suggestions for doing so – including both large scale efforts and simpler more tangible strategies. Administrative leadership (e.g., Deans of Colleges of Engineering or Department Heads) could revise existing reward systems in higher education to ensure that they support instructors' initiatives to integrate social and contextual practices into their own classrooms. Since engineering instructors have limited time and energy to (re)design class activities and assignments that align with social and contextual dimensions of engineering work, we propose four potential small-scale approaches. (1) Instructors could ask students to consider how the detailed technical aspects of a lesson might connect to broader social and contextual aspects of engineering work. For instance, instructors might ask students "what are some ethical considerations when designing automotive vehicles?" "How can we design sustainable products?" "Who are the stakeholders for a community-engaged engineering project?". (2) Researchers and/or engineering educators might create templates or prompts to guide engineering instructors in (re)designing class activities and assignments that reflect social and contextual dimensions of engineering work. Gelles et al. [62] developed a preliminary framework to integrate some social and contextual practices into engineering courses. (3) Instructors could design homework assignments that are contextualized. For example, to contextualize homework problems in the ME industry, McConnell [63] developed a database that consists of industry-based problems and examples by conducting an inventory across 15 required ME courses in an undergraduate program. (4) Departments could enhance connections and communications among engineering instructors as an effective way to improve pedagogical practices [42, 64]. For instance, teaching spotlights can be organized, where instructors gather together and share their ideas about the ways in which they have integrated social and contextual practices in their own classrooms so that colleagues can learn from each other.

6. Conclusions

While the importance of social and contextual skills is increasingly recognized by researchers, engineering professionals, and engineering educators, our observation study clearly showed limited emphasis on social and contextual practices in required ME courses. Instead, these courses were predominantly focused on learning fundamental engineering principles and technical knowledge. Within the limited coverage of social and contextual skills in ME required courses, we observed that the majority of these skills were explicitly taught and practiced in the first-year introduction to engineering course and the design course; this finding comports with those of other studies, which also identify these courses as the ones that most commonly cover a wide range of engineering skills. We recognize that although the integration of social and contextual skills into traditional engineering disciplines like Mechanical Engineering (ME) is important, it may be challenging because of the misconceptions that faculty and students hold about the ME discipline – specifically, the view of ME as an exclusively technical discipline – and the existing structural barriers and lack of sufficient incentives for ME instructors to adjust their course content and their pedagogical approaches. These obstacles notwithstanding, more fully integrating social and contextual skills into engineering classrooms will, we believe, better prepare engineering students to solve engineering problems in their future workplace.

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Appendix

1. Template of the observation protocol

Practice	**Description**	**0–9 min**	**10–19 min**	**20–29 min**	**30–39 min**	**40–49 min**	**50–59 min**
Analyze Data	Engage in data analysis, processing, and interpretation						
Build Tangible Artifacts	Build tangible artifacts as models, prototypes, or working products						
Business and Financial	Account for financial or economic considerations						
Coding or Programming	Computer coding or programming						
Data Collection	Collect data following proper procedures						
Design Experiments	Design or develop plans and procedures for experiments						
Ethics	Weigh (often complex) ethical responsibilities						
Evaluate Solutions	Test and evaluate potential solutions						
Foundational Technical Knowledge	Learn or study fundamental engineering principles or technical knowledge						
Future Impacts	Consider or account for potential future impacts of one's work						
Human Factors and Ergonomics	Account for human factors and ergonomics – how bodies physically interact with a potential solution						
Immediate Context	Account for the immediate context in which a solution may be deployed						

Practice	Description	0–9 min	10–19 min	20–29 min	30–39 min	40–49 min	50–59 min
Information Gathering & Research	Gather information or conduct research needed to address a problem						
Innovation (and Ideation)	Come up with innovative ideas and approaches						
Interdisciplinarity	Engage in interdisciplinary collaboration or integrate ideas from other fields of study						
Interpersonal Awareness	Demonstrate social awareness, empathy, and self-awareness in interactions						
Iteration	Iterate on and improve on ideas or designs						
Leadership	Use leadership skills to ensure teams work effectively						
Lifecycle of a Solution	Consider a design, product, or process over the course of its lifecycle						
Logistics	Understand or coordinate logistics of a process, problem, or system						
Modeling and Simulation	Develop or work with virtual models or simulations						
Natural Environment	Account for the natural environment and/or issues of sustainability						
Optimization	Engage in optimization to identify the best or most effective decision						
Power/ Position/ Identity	Consider dynamics related to the identities, positions, backgrounds, or relative power of self and/or others						
Predict Outcomes	Predict outcomes by drawing on engineering principles or methods						
Present on or Explain Work	Present on or verbally communicate about one’s work or its value						
Problem Definition	Define a problem to understand it and identify constraints and/or requirements						
Project Management	Manage project work across multiple stages and/or multiple team members						
Relationships and Tradeoffs	Account for relationships or tradeoffs between multiple aspects of a project and/or the larger system						
Social Context	Account for the social or cultural context in which a problem is embedded						
Stakeholders	Engage with or account for stakeholders needs and perspectives						
Teamwork and Collaboration	Engage in teamwork or collaborate towards a common goal						
Technical Communication	Generate technical communication deliverables, including written reports and figures to represent work						
Technical Details	Account for, develop, or refine the concrete details of (potential) solutions						
Troubleshooting	Engage in troubleshooting to systematically identify or assess potential issues						

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