

Article

Examining Industrial Engineering Students' Perceptions of Course Skills and Knowledge and Alignment with Their Interests

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Abstract

Representations of engineering work in the curriculum influence students' perceptions of valued skills and knowledge in the field. Industrial engineering attracts a diverse group of students and is well positioned to incorporate longstanding calls for comprehensive skills because of its systems-level approach to problem-solving. Examining students' perceptions of the curriculum of industrial engineering can elucidate how the curriculum shapes diverse students' understandings of engineering practice and their decisions to persist or leave. Using Holland's framework of figured worlds, we examined the role of the core industrial engineering curriculum at a Midwestern university (MU) in the United States (U.S.) in shaping undergraduate students' perceptions of valued skills and knowledge and sense of fit in engineering. Findings from a series of two interviews with 15 upper and lower division industrial engineering students indicate that students perceived the core curriculum at MU to minimally emphasize comprehensive skills, reinforcing a purely technical view of engineering. Further, students expressed a desire for course content that emphasized application of theoretical concepts and social and cultural context and impact. Findings indicate a continuing need for curricular reform incorporating comprehensive skills to engage students, align coursework with real-world engineering practice, and shape the perception of engineering work as inherently sociotechnical.

Keywords: engineering curriculum; industrial engineering; sociotechnical engineering; comprehensive skills; figured worlds



Academic Editor: Sharifu Ura

Received: 3 June 2026

Revised: 31 July 2026

Accepted: 2 August 2026

Published: 5 August 2026

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1. Introduction

Industrial engineering addresses complex systems-level problems, such as designing and improving supply chains, manufacturing facilities, and large healthcare and educational systems (Fraser & Boardman, 2020). These problems require engineers to not only be technically competent but also to possess the skills to interface between different technologies, disciplines, policies, and people. Recognizing the responsibility of engineers to address increasingly complex problems, various scholars and organizations have

called for a greater emphasis on skills beyond the technical in the engineering curriculum (Lattuca et al., 2014; National Academy of Engineering, 2004; Passow & Passow, 2017), including in the industrial engineering field (Eskandari et al., 2007). Specifically, along with strong technical competencies, there have been longstanding calls for greater attention to comprehensive skills such as accounting for the social, cultural, ethical, and environmental dimensions of engineering work and collaborating across disciplinary boundaries to solve problems (Passow & Passow, 2017). Similarly in its criteria for engineering programs, the Accreditation Board for Engineering and Technology (ABET) describes that industrial engineering curriculum must include “design, analysis, operation, and improvement in integrated systems that produce or supply products or services in an effective, efficient, sustainable, and socially responsible manner.” (ABET, 2025, p. 33). In addition, ABET’s student outcomes for all engineering programs include abilities related to teamwork, communication, ethical responsibility, and accounting for a range of social and contextual factors in problem solving.

The engineering curriculum plays a major role in representing the nature of engineering practice to students and socializes them into performing acceptable and “valuable” engineering work. Accredited engineering programs follow ABET criterion for curriculum to structure their programs. The criterion includes foundational courses in math and science, core engineering coursework, courses to complement technical content, and a cumulative design experience (ABET, 2025). Therefore, industrial engineering programs typically include instruction in foundational math and science, core industrial engineering topics such as operations research, probability, human factors, engineering statistics and engineering economy, and a capstone experience to apply the knowledge from earlier coursework (ABET, 2025). Despite the longstanding calls for promoting sociotechnical thinking, comprehensive skills are often underemphasized in the engineering curriculum (Cech, 2013; Lattuca et al., 2014; Riley, 2008). A purely technical and narrow representation of engineering practice in the curriculum could discourage the participation of students whose interests extend beyond technical aspects of engineering. Such a curriculum could also inadequately prepare students for professional practice and reinforce the dominant cultural view of engineering as a solely technical discipline. In fact, scholars have noted how the depoliticized nature of the engineering curriculum socializes students into disregarding consideration of social issues as part of engineering practice (Cech, 2013).

In addition to the need to prepare students for the sociotechnical nature of modern engineering work, research also suggests that engineers who persist in the profession find it more satisfying to be involved in both technical and social dimensions of engineering work, rather than concentrating exclusively on purely technical tasks (Trevelyan, 2014). Further, women and minoritized students, groups who are underrepresented in engineering, are more likely to have social impact motivations for pursuing engineering and are interested in developing these comprehensive engineering skills to achieve their goals (McGee & Bentley, 2017; Ozkan & Andrews, 2022; Swartz et al., 2019). Therefore, emphasizing comprehensive skills and promoting sociotechnical thinking, i.e., the “ability to identify, address, and integrate social and technical dimensions of engineering” (Rodrigues & Seniuk Cicek, 2024, p. 807) is integral to preparing students for solving problems in the real world, attracting and retaining women and minoritized students who are underrepresented in engineering, and increasing the persistence of engineers in the workforce.

Given the role of engineering curriculum in socializing students into the profession and shaping their perceptions of “real” engineering work, it is important to understand how representations of engineering work in the curriculum influence students’ perceptions of the field. Further, some scholars view majors such as industrial engineering as well positioned to incorporate comprehensive skills because of their systems-level approach to

problem-solving (Eskandari et al., 2007; Nazzal et al., 2015). Industrial engineering also attracts more women and racially minoritized students and is more gender and racially diverse than other engineering majors (Brawner et al., 2012; Pilotte et al., 2017). Therefore, examining students' perceptions of the curriculum of industrial engineering could help us understand how the curriculum shapes diverse students' understandings of engineering practice and their decisions to persist or leave.

In this study, we utilized the figured worlds framework (Holland et al., 1998) to explore students' perceptions of the emphasized skills and knowledge in their core industrial engineering curriculum at a large Midwestern research university. Additionally, we also explored when students were expressing misalignment between the skills and knowledge emphasized in the core industrial engineering curriculum and their personal engineering interests. We specifically chose to focus on students' self-reported perceptions rather than a direct analysis of the curriculum and its characteristics as how students' experience the curriculum ultimately informs their perception of the field, sense of fit, and career plans. Therefore, we leveraged interview data from 15 undergraduate industrial engineering students at two points in time during their undergraduate careers to explore this topic.

2. Background

2.1. Engineering Culture and the Nature of Engineering Work

Engineering education and practice have historically been shaped by positivist perspectives that elevate the pursuit of objectivity, technical mastery, and decontextualized problem-solving over considerations of the ethical, societal, and human-centered impacts of engineering. Ideologies of depoliticization and meritocracy, which promote beliefs that engineering is neutral, apolitical, and technically oriented, are prevalent in engineering culture and further devalue the non-technical expertise that is essential for engineering innovation (Cech, 2013; Riley, 2008). This persistent divide and hierarchy between technical and non-technical dimensions of engineering, also known as technical/social dualism (Cech, 2014; Faulkner, 2007), is seen in engineers' perceptions and mindsets and the engineering curriculum.

Research in engineering education indicates that many engineers view their work as purely objective and that engineering students' public welfare beliefs decline through the course of their studies as a result of the enduring cultural emphasis on technical content in engineering education and practice (Cech, 2013, 2014). These beliefs about the technical nature of engineering work also contribute to students' disregard for examining the social implications of engineering work (Cech & Sherick, 2015; Loweth et al., 2021). Similarly, the curriculum plays a major role in shaping and reinforcing the dominant culture, or the ways of thinking and doing, valued by a discipline (Holland et al., 1998; Lattuca & Stark, 2009). In the engineering curriculum, the prioritization of technical skills and content is demonstrated by the emphasis on close-ended problem sets, math and science principles, and assessments with one correct answer (Mills & Treagust, 2003; Stevens et al., 2014). Despite growing efforts to integrate more sociotechnical content in engineering courses (see Hoople & Choi-Fitzpatrick, 2020; Judge et al., 2022; Lord et al., 2019b), the engineering curriculum is predominantly focused on presenting engineering problems devoid of context (Lattuca et al., 2014; Polmear et al., 2019). Recent research on the content of engineering curricula also points to an absence of sociotechnical knowledge and skills in most engineering courses (Clancy et al., 2023), including industrial engineering (Cabrera et al., 2024).

Research shows that socially engaged engineering (i.e., work emphasizing the broader impact of engineering) attracts diverse populations (McGee & Bentley, 2017; Ozkan & Andrews, 2022; Swartz et al., 2019). Students are increasingly interested in addressing social

problems through their work, and women and minoritized students are likely to foreground these motivations in their decisions to pursue different types of work (Colvin et al., 2013; Swan et al., 2014). Research also shows that students may feel alienated and experience a decreased sense of “fit” with their discipline when they notice a disconnect between their engineering interests and the nature of engineering (i.e., characteristics and valued practices of the field) communicated to them (Mosyjowski, 2020; Smith et al., 2014). The engineering curriculum is often one of the primary ways through which novices are socialized into engineering. For students who prioritize the societal impacts of engineering, a curriculum that communicates a devaluation of social and contextual dimensions of engineering work may prove discouraging and serve to diminish their sense of connection to the field. Thus, understanding how the curriculum shapes students’ perceptions of engineering work can illuminate the role of the curriculum in shaping the technical/social dualism pervasive in engineering culture and, by extension, some students’ sense of fit with the engineering discipline.

2.2. Theoretical Framework: Figured Worlds

We leveraged the figured worlds framework by Holland et al. (1998) to explore how students came to understand the nature of engineering work through curricular messaging and how these perceptions aligned with their engineering interests and shaped their decisions to persist. The framework provides a socio-cultural lens to understand how individuals engage in and navigate “figured worlds” to negotiate their sense of self. Holland et al. (1998) characterize a figured world as “a socially and culturally constructed realm of interpretation in which particular characteristics and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others” (p. 52). In the context of engineering and this study, the framework helps us understand how students came to learn about the culturally accepted and prevalent ways of “doing engineering,” which were communicated through students’ day-to-day interactions with the curriculum, and how these dominant ways aligned with their understandings of engineering practice. Therefore, in this study, we used the figured worlds framework as a lens to guide our attention to the dominant skills and knowledge students perceived as emphasized in their core coursework. We also sought to understand how the dominant skills and knowledge perceived by students in their core coursework aligned with their engineering interests.

3. Materials and Methods

The present study is part of a broader mixed-methods study to understand students’ perceptions about the nature of engineering practice based on the messaging conveyed through the engineering curriculum at a large Midwestern research university in the United States (U.S.). The broader study examines how industrial (IE) and mechanical engineering (ME) students experience the engineering curriculum and how it shapes their perceptions of engineering practice, their sense of fit with engineering, and future career plans. While the broader study focuses on both ME and IE students, these disciplines have some key differences that warrant separate examination of student experiences within them. Industrial engineering, for example, is more gender- and racially diverse than mechanical engineering and tends to attract students who transfer from other engineering majors. Compared to ME, IE also has a higher percentage of students who start in the major and persist to graduation, a phenomenon also known as “discipline stickiness” (Lord et al., 2019a). Finally, as previously stated in the introduction, IE is considered well-positioned to integrate sociotechnical dimensions of engineering due to the inherent nature of the work (Eskandari et al., 2007; Nazzal et al., 2015). Given these differences in ME and IE disciplines as well as our desire to engage in-depth with IE-specific course emphases as perceived by

students, we chose to examine the experiences of students in these majors separately, with the present study focused on IE students to answer the following research questions:

1. What do undergraduate industrial engineering students perceive to be the engineering skills and knowledge most emphasized in their core coursework?
2. What are the instances in which students' express misalignment between the skills and knowledge emphasized in their core industrial engineering coursework and their engineering interests?

3.1. Researcher Positionality

The authors of this work include a postdoctoral researcher, a doctoral student, and a leadership team consisting of a research scientist and three tenured faculty members. The authors bring their collective expertise and experiences across engineering education research, higher education, industrial engineering, biomedical engineering, and mechanical engineering to inform this work. The authors have diverse experiences as learners within engineering and education, with some of the authors having extensive experience teaching foundational courses in the engineering curriculum. The authors' experiences as learners and educators in engineering have shaped their understanding of the importance of engineering curriculum in influencing students' perceptions of engineering work and sense of fit in the field. As a result, the authors share a commitment toward broadening participation in engineering and are motivated to inform the development of the engineering curriculum to be responsive to industry needs and more inclusive for all students.

3.2. Research Context

This study took place at a large public Midwestern university (MU) in the United States. MU is designated as a "Research 1: Very High Research Spending and Doctorate Production" institution by the Carnegie Classification of Institutions of Higher Education. The university has a large college of engineering offering both ME and IE undergraduate degree programs. Like most public universities, MU aims to foster a sense of civic duty in its students, as evidenced by its mission statement. Since most engineering students are educated in public universities, MU was a strategic site to examine undergraduate engineering students' experiences.

3.3. Participants and Data Collection

To capture students' reflections of their experiences in lower division courses and later division courses, we recruited undergraduate industrial engineering students who were in their first or third year of study to participate in semi-structured interviews. With IRB approval, we first sent a recruitment email to all third-year undergraduate students enrolled in IE at the institution ($n = 125$), as well as all the students who were first-year IE declared, expressed strong interest in majoring in IE, or participated in an introduction to IE engineering course ($n = 200$). The recruitment email consisted of a screening survey which collected information about the students' major and demographics. After extending the invitation to participate in the study to all 325 students as described above, we emailed the 26 first and third-year students who completed the screening survey in the recruitment email. We interviewed the 20 students who responded to the interview invitation in year one of data collection, with the 15 students included in the study consisting of those who completed both years of interviews.

Research team members leveraged relevant literature and their previous research experiences to develop, pilot, and iterate the protocols used to guide the semi-structured interviews. Specifically, they developed and iterated a draft interview protocol internally followed by piloting and iterating it further before conducting the first set of interviews.

After completing the first set of interviews, the interview team considered lessons learned and differences in student experiences across the years in their major before developing and iterating a second interview protocol, which was used for the second set of interviews. More details about the development and piloting of the protocols can also be found in our earlier publication (Clancy et al., 2023). The interview protocols included questions on students’ prior engineering experiences, the content emphasized in their courses, any changes they would like to see in the content of their core coursework, their career plans, and how their coursework shaped their career plans. A list of sample interview questions can be seen in Table 1.

Table 1. Sample interviews questions used in semi-structured interviews with students.

Sample Questions Used in Student Interviews
What engineering skills and knowledge do you think are most emphasized in your IE courses?
Thinking of the engineering courses you’ve taken, were there any that seemed to emphasize different knowledge and skills than the others? Can you tell me about that course?
Is the work you are doing in your engineering courses what you hoped you would be doing?
Thinking broadly about your engineering OR IE course experiences, how much has this course material aligned with what you are personally most interested in about engineering work?

Four graduate students conducted the semi-structured interviews, with each interview lasting approximately 30–90 min. The interviews took place over Zoom and were audio recorded. All participants who completed an interview were compensated \$30 for each interview. Each of the 15 first- and third-year industrial engineering students were interviewed twice, with one year between the first and second interviews, totaling 30 interviews used as data to analyze our research questions. Our team interviewed seven students once in their first year, with the follow-up interview taking place in their second year, and an additional eight students in their third year, with the follow-up interview taking place in their fourth year. Participants included an Arab American man, two Asian men, one Hispanic woman, one Latino man, two South Asian women, three white men, and five white women, all self-identified. The self-identified demographic information of the participants can be seen in Table 2.

Table 2. Year of study, gender, and race information of the study participants (self-identified).

Year in Major When Interviewed	Gender	Race/Ethnicity
Year 1 and 2	Men (4), Women (3)	White (3), Asian (2), Hispanic (1), Arab American (1)
Year 3 and 4	Men (3), Women (5)	White (5), Asian (2), Latinx (1)

3.4. Data Analysis

We used a third-party service to transcribe the interview data prior to the team’s analysis of the interview transcripts. The research team analyzed the transcribed data using an inductive approach, (i.e., codes and themes emerging from the data) (Saldaña, 2013) and guided by the interview questions. Specifically, the leadership team developed guiding questions that promoted the synthesis of information relevant to the research questions from each interview. Examples of guiding questions used to synthesize the individual

interviews are included in Table 3. The first author read each of the 30 transcripts in full and used the guiding questions developed by the leadership team to compile summaries of participants’ perceptions along with specific quotes from the interviews as evidence. A second research team member then read the transcripts in full and reviewed the first author’s summaries to verify or add to the first author’s interpretation of the interview data. Both researchers documented and resolved discrepancies in their interpretations of students’ experiences during bi-weekly meetings with the larger research team. After summarizing all 30 interviews, the researchers involved with the data analysis of the transcripts looked for patterns of meaning across each participant’s first and second interviews and then across all 15 participants to answer the research questions. Excel spreadsheets were used to document individual level interview summaries as well as summaries across participants and discrepancies between researchers’ interpretations of the data.

Table 3. Examples of guiding questions used to synthesize information relevant to the research questions from the student interviews.

Examples of Questions Used to Guide Data Analysis
What skills and knowledge do they perceive to be emphasized in their required courses? (could name courses, emphasized practices, how these emphases may compare with other coursework)
What aspects of engineering work (even if not currently included in their courses) do students find most interesting, important, or motivating?
How do students’ personal values and interests align with the messages they receive about engineering work in their required courses?

Specifically, to answer the first research question (RQ1), the first and second authors used the summaries developed from the guiding question, “What skills and knowledge do [students] perceive to be emphasized in their required courses?” to identify and categorize the skills and knowledge students’ perceived as emphasized in the core curriculum. Specifically, we developed a list of “emphasized skills and knowledge” and their definitions to categorize students’ responses (see Table 4). The list was developed iteratively based on previous literature (Passow & Passow, 2017) and how the participants described the emphases in the interviews. We then reviewed summaries across participants and noted the number of students who named or described a particular item from the “emphasized skills and knowledge” list in their core coursework. Required or core coursework in this study constituted all the engineering coursework, outside of electives, that all students in the industrial engineering program are required to complete to graduate.

For the second research question (RQ2), we were interested in understanding where there might be a disconnect between the emphasized skills and knowledge in core coursework and students’ engineering interests. To explore this, we focused on instances in which students specifically named dissatisfaction with the “emphasized skills and knowledge” in the core coursework. Specifically, for each “emphasized skills and knowledge” from the list developed for answering RQ1, we examined instances where students discussed disliking the content or how it was emphasized in the core curriculum. We also examined instances where students described wanting more or less of a specific skill and knowledge, revealing areas of misalignment between core courses emphases and students’ engineering interests. While capturing dissatisfaction, we were careful not to conflate student dissatisfaction of instructional practices with their dissatisfaction of course content. Therefore, misalignment with course emphases was operationalized as instances in which students expressed dissatisfaction with or a dislike of course topics, or otherwise described a disconnect between the content they wished had been included and what they perceived to be emphasized in

the curriculum. Given that the focus of this study is on students' subjective experience of the IE curriculum at MU, identifying instances of student dissatisfaction with course content allowed us to understand perceived instances of misalignment with the core course emphases and students' engineering interests.

Table 4. Descriptions of the skills and knowledge named by participants as emphasized in their courses along with the number of participants naming the emphasis or lack of emphasis (counts based on the number of students who mentioned each practice).

Emphasized Skills and Knowledge in Core Coursework	Description	No. of Students Who Perceive the Emphasis ($n = 15$)	No. of Students Who Perceive the Emphasis as Minimal, Not Explicit, or Missing ($n = 15$)
Coding and Programming	Use or learn coding or programming of any form.	13	-
Math, Statistics, and Linear Programming	Use or learn math, statistics, and linear programming principles for problem solving.	12	-
Professional Communication	Prepare technical communication, including written and oral reports or use of figures to represent work.	12	-
Optimization and Efficiency	Use engineering tools or methodologies to make a solution as efficient or effective as possible.	11	-
Problem Solving and Critical Thinking	Use engineering techniques/tools/thinking to address a problem.	10	-
Modeling and Simulation	Develop or work with virtual models, simulations, and/or visual representations of problems/solutions.	9	-
Teamwork and Interpersonal Skills	Work in groups or collaborate with others by sharing expertise, ideas, resources, etc. to achieve a common goal.	8	4
Business, Finance, and Management	Account for financial or economic considerations of engineering work.	6	-
Data Analytics	Follow proper data collection procedures and interpret data, such as results from modeling or validation.	5	-
Ergonomics and Human Factors	Account for how a range of humans/bodies may physically interact with a given design, product, or process.	4	-
Social and Cultural Context and Impact	Account for the social or cultural context in which engineering work is embedded; benefiting people, environment, or society.	2	7

Throughout data analysis, we followed established and recommended practices for demonstrating trustworthiness and rigor in qualitative research (Lincoln & Guba, 1985). Researchers involved with the data analysis engaged in the process of peer-debriefing to guard against confirmation bias and validate the findings (Lincoln & Guba, 1985). Positionality statements were also developed and shared to help unpack how the research and project team backgrounds and motivations might shape their understanding of the phenomena (Secules et al., 2021; Guba & Lincoln, 1994). Any discrepancies or difficulties in interpreting students' perceptions of emphases or dissatisfaction during data analysis were first documented and then resolved through discussions between the researchers, with a senior research scientist serving as an advisor as needed (Miles et al., 2014).

4. Results

RQ1: What do undergraduate industrial engineering students perceive to be the engineering skills and knowledge most emphasized in their core coursework?

4.1. Skills and Knowledge Emphasized in Core Coursework

Students described a consistent set of skills and knowledge they perceived as emphasized in their core courses. Based on their responses, five primary areas emerged: **(1) coding and programming, (2) math, statistics, and linear programming, (3) professional communication, (4) optimization and efficiency, and (5) problem-solving and critical thinking.** These emphases reflect students' interpretations of what the curriculum prioritized and communicated about industrial engineering practice. Table 4 provides the full list of skills and knowledge named by participants as emphasized in their courses, along with descriptions grounded in both participant language and prior literature. Students generally talked about their introductory-level engineering coursework emphasizing skills and knowledge such as professional communication. In the 200 and 300-level coursework, students discussed a heavy technical emphasis on various industrial engineering topics, such as optimization and efficiency, modeling and simulation, statistics, ergonomics, and various types of coding/programming software. Finally, students talked about problem-solving and critical thinking being generally emphasized across all core coursework, and a few of the students interviewed in their third or fourth year of study described their upper-level courses and senior design as an opportunity to apply the skills and theoretical concepts learned in their earlier coursework to real-world projects, as shown in the example below:

There was a lot more emphasis on real world application over the last year. A lot of our examples in class, projects, homeworks were all based off of real-world companies, people, examples, things as opposed to maybe more hypothetical models that were emphasized in the past. I think most notably in [200-level course], there's a project about an...olive manufacturer...and I don't think that one was based off of real numbers. I think it was just a hypothetical scenario.

In the sections below, we provide more details about the top five skills and knowledge students perceived to be emphasized in their core coursework.

Coding and programming. Nearly all of the students referenced an emphasis on coding and programming within their core curriculum, frequently citing their experiences learning languages such as C++, R, Python, and SQL to perform tasks such as “manipulat[ing] data and display[ing] it in different ways.” They described this emphasis as being integrated throughout their curriculum, with 100-level courses serving as an introduction to coding and later courses continuing to expand on it. A couple of students expressed surprise at the centrality of these skills within IE. As one student noted:

I think there has been quite a big emphasis on computer programming, which I wasn't expecting when I chose IE, but it seems like it is a pretty big part of the field, especially now. I mean, it seems like every engineering [course] in some capacity touches on computer programming.

Another student echoed this sentiment, *"I was pretty shocked that we have actually quite a bit of coding in different classes, like we always have some random unit where you learn some new coding language."*

Math, statistics, and linear programming. The second most frequently cited area of emphasis in the core curriculum was mathematics, statistics, and linear programming. When asked what they felt was most emphasized in their courses, one student responded unequivocally, *"Definitely mathematics, no question,"* going on to describe that the IE curriculum could be broadly divided into two categories: courses that are *"math-heavy"* and those that are *"heuristic-heavy."* Several students also specifically highlighted the prominence of statistics across their coursework. One student noted, *"With statistics, it's everywhere . . . it's pretty prevalent in every class,"* while another similarly observed, *"Most courses I've had, have been talking about statistics."* Students also recognized differences in how mathematical and statistical skills were applied. For example, one student explained that they had learned both *"engineering statistics that are used in the workforce. . . and then more academia-focused math. . . that are used in research more."*

Professional communication. Many students (12 out of 15) noted an emphasis on professional communication, particularly in the form of written and oral reports designed to convey their work clearly and effectively to others. One student described needing to *"re-learn how to write papers and research memos"* in their IE courses, explaining how this style of writing differed from what they had been taught in high school. In particular, students highlighted the importance of precision and attention to detail in these assignments, often linking these expectations to grading criteria. For instance, one student remarked on *"a big emphasis on a lot of how the document should be formatted, especially proposals and final lab reports and things of that nature have been a big component of my grade so far."* Another student shared a similar experience:

The teachers would take off points for very specific things in our report. For example, not spacing out the pictures right or missing a margin or having some title italicized instead of bolded or the other way around which kind of just reminds you to pay attention to everything.

Optimization and efficiency. Over two-thirds of students frequently discussed the recurring emphasis on optimization and efficiency across their courses. As one student explained, *"There is that underlying base of optimization. . . in a lot of different classes,"* while another observed, *"They always circle back to why you're doing this, to make something better, to make something more efficient."* This emphasis appeared to shape how students conceptualized their major overall. One student remarked,

Mostly the biggest thing about IE is efficiency, optimization. . . that's probably the main part of what IE is, to make things better. I think every single class I've taken has done that in some sense.

Another student echoed this sentiment, describing how they communicated the purpose of their degree to others:

It just seems like everything is about making something better, making a process better. When I explain to people what my degree is, that's exactly what I say, 'It's about making things more efficient and optimizing that.'

Problem-solving and critical thinking. Additionally, two-thirds of the students highlighted the emphasis on problem-solving across their coursework, both in class and through homework assignments. One student described this process as:

...the ability to problem solve, especially by gathering only key information and making conclusions without having, I guess, a step by step hand holding guidance taught. It's more providing the skills and allowing you to draw those conclusions and solve those problems, in pretty much every class.

Similarly, students described critical thinking as a transferable skill that extended beyond specific course content. As one student reflected,

I think there's been a really big emphasis on...being able to think critically about the problem at hand. I've kind of noticed those skills are touched on in every class I've taken regardless of the content of the class.

A couple of students interviewed in their third and fourth year of study noted that this emphasis became particularly salient in upper-division courses, where they were expected to apply previously acquired skills and knowledge to address complex problems. As one student explained, "Every single thing we do is about using the skills we've learned to make problems easier to solve."

4.2. Emphases Missing or Not Explicit in Core Coursework

In addition to categorizing the emphasized skills and knowledge, we also categorized instances where students mentioned certain content as missing or not explicitly emphasized in core coursework. The skills and knowledge students perceived to be missing or not explicitly emphasized in their core coursework include **(1) teamwork and interpersonal skills, and (2) social and cultural context and impact**, which are further discussed below.

Teamwork and interpersonal skills. Four of the students cited a missing or lack of explicit emphasis on teamwork and interpersonal skills in their core coursework. For example, one of the students talked about how her coursework involved a lot of teamwork and thinking about working in teams without explicit instruction on how to work with others, as described in the excerpt below,

I think we do a lot of stuff with teamwork. It's not necessarily like that we're learning a lot about teamwork and it's like, being successful in a team, but we're just put into groups a lot, which has like caused us to learn about teamwork.

Social and cultural context and impact. Almost half the students noted social and cultural context and impact as missing or not explicitly emphasized in their core coursework, with many of these students comparing their core coursework to an elective course which allowed them to engage in consideration of social and cultural context and impact related to engineering. Students also discussed topics such as sustainability not explicitly present or emphasized in their core engineering coursework. The themes related to this emphasis and the misalignment it generated for students are further discussed in the findings related to RQ2 below.

RQ2: What are the instances in which students' express misalignment between their engineering interests and the skills and knowledge emphasized in their core industrial engineering coursework?

Students reported several areas of dissatisfaction with the skills and knowledge emphasized in their core curriculum, revealing where their interests diverged or misaligned from what the courses prioritized. Most frequently, students felt misaligned with emphases on **(1) math, statistics, and linear programming, (2) coding and programming, (3) professional communication, and (4) social and cultural context and impact**. For most of the emphasized skills and knowledge, student misalignment generally centered around an

over- or underemphasis of this content in their core curriculum, often accompanied by a desire for more real-world applicability. Table 5 presents the full list of reasons students cited for feeling misaligned with each emphasized skill or knowledge area. In the next section, we first unpack the content toward which students expressed the most misalignment. Then, we briefly discuss the themes present across the other emphases where students also described some misalignment.

Table 5. Emphases that generated misalignment for students along with the number of students expressing misalignment and the reasons for it.

Emphasized Skills and Knowledge in Core Coursework	No. of Students Expressing Misalignment ($n = 15$)	Students' Reasons for Misalignment
<i>Emphases that generated the most dissatisfaction</i>		
Math, Statistics, and Linear Programming	10	Students expressed desire for content that is relevant to IE and emphasized application of concepts. Almost all students disliked statistics and/or found it repetitive.
Coding and Programming	8	Students expressed a desire to learn coding/programming that is applicable to real-world problems or problems of interest to them. Some students also wanted more coding, programming, and fundamentals of coding content, such as material teaching Python, alongside existing coursework.
Professional Communication	8	Students desired greater emphasis on public speaking, presenting, and communicating in job interviews. A student mentioned wanting general writing classes for better communication.
Social and Cultural Context and Impact	8	Some students expressed a desire for content emphasizing sustainability and humanitarian examples and applications of engineering. Others wanted content related to race/culture/historical considerations of engineering and its impact on people.
<i>Emphases that generated some dissatisfaction</i>		
Teamwork and Interpersonal Skills	7	Students expressed wanting more emphasis on group projects and collaborative work in courses as well as guidance on how to work in teams/resolve conflict.
Business, Finance and Management	6	Students expressed wanting more business-focused content, increased breadth of business topics, and application of theoretical concepts in business settings.
Ergonomics and Human Factors	5	Some students expressed wanting ergonomics content focused on user experience research and design. Some students talked about being generally disinterested in ergonomics or disliking it.
Modeling and Simulation	4	Students expressed wanting more coursework on simulation as well as up-to-date software in courses.
Data Analytics	2	Students expressed wanting more content focused on data analytics.
Optimization and Efficiency	1	A student expressed wanting more content focused on optimization and lean principles.
Problem Solving and Critical Thinking	1	A student expressed wanting content that presented different perspectives and promoted critical thinking.

4.3. Emphases That Generated the Most Dissatisfaction

Across the perceived curricular emphases that generated the most student misalignment (i.e., math, statistics, and linear programming; coding and programming; professional communication; social and cultural context and impact), some of the dissatisfaction centered around students' desire for more course content that emphasized the application of theoretical principles to real-world problems. For example, a student who expressed dissatisfaction with their statistics course content said that sometimes *"it is hard to grasp how the theory can be applied."* Another student focused on her coding coursework and mentioned that:

A lot of what we do in the classes is like, it's a made-up prompt, which I understand is helpful for learning at the beginning. . . . I kind of just thought that we would be doing more like coding for like real-life analysis. Like some of the classes that I've seen at other universities have [you] like analyz[ing] graphs about poverty rates and other things like that. So I guess I was just hoping for more real-world application.

Another student echoed the concern about the general lack of applied and project-based coursework in their program by saying,

You're sitting there in a closed note exam with zero application outside the real world, and you sit there, and you memorize everything you need to know or write it down on a note card or whatever, and you go in there, take the exam and then drop the rest of the knowledge.

In addition to wanting applied course content, students also expressed a desire for specific topics within each of the emphases to supplement the focus on math, statistic, and programming and to bring real-world examples into the curriculum, which we detail below.

Math, statistics, and linear programming: An overemphasis on statistics and theoretical content. Many students who expressed misalignment with math, statistics, and linear programming course content talked about an overemphasis on statistics in the curriculum. While some students mentioned generally disliking statistics, others felt that their coursework was very repetitive. For example, one student said, *"It just kind of seems that every statistics-type class that I've taken and talking to friends [..about] statistics classes they've taken, it seems like they all cover the same stuff over and over again, but it is important stuff I think."* In addition to the overemphasis on statistics, a student also expressed that the content can sometimes be theoretical and hard to grasp.

Coding and programming: A need for course content that is applicable to the real world, relevant to students, and focuses on the fundamentals. Many students expressed that they wanted to learn coding and programming that can be applied to real-world problems or topics of relevance to them. For example, one student described his disappointment about his introductory coding and programming class and said, *"If they [class projects] were more engaging and had to do with more real-life problems that us students could connect with, problems that would affect 18-year-old kids, then everyone would have a better time in that class."* Some students wanted coding and programming core coursework focused on teaching the fundamentals of coding. For example, one student said that her *"IE courses will use programming but they don't teach it. I was okay because I have a CS minor but I know a lot of people who didn't know how to code and I feel like everyone in IE should know how to code."* Students also expressed an interest in having more core content focused on languages such as Python instead of C++ or MATLAB, which some felt would be useful in their later coursework. For example, one student said,

I would've appreciated having a little bit more experience with Python before jumping into [300 level classes] because some of the problem sets I feel like I'm a little bit confused about because I don't have that prior knowledge. So I do wish that maybe part of [introductory

coding class] did a little bit of Python because I don't think I'm really going to use C++ or MATLAB as much in my classes.

Professional communication: A need for more course content emphasizing verbal communication. Several students expressed an interest in more opportunities to develop public speaking, presentation, interviewing, and general communication skills. One student said he wished he was “forced to do a speaking assignment of some sort in [his] class” because he feels that engineers need to get better at it. Similarly, another student talked about how his internship made him realize the importance of presenting his work. He expressed wanting more opportunities to present and said, “maybe a little bit more presentation work and working with slides and just translating your thoughts into a physical form. I think the department does a pretty good job in general. . . .but I think there could be more room for more group presentations and group work.” Another student also felt that a general writing requirement would benefit engineering students by helping them formulate their thoughts. In contrast to the above examples, some students’ misalignment also stemmed from generally disliking technical writing or finding it boring or too rigid in style.

Social and cultural context and impact: A desire for more emphasis on sustainability topics and social and cultural considerations of engineering work. As evidenced in Table 4 and discussed in the results of RQ1, students perceived social and cultural context and impact as being only minimally emphasized, if at all, in core coursework. Therefore, unsurprisingly, students with this engineering interest expressed wanting content that emphasized social and cultural consideration of engineering work. Specifically, students expressed a need for coursework that incorporated considerations of race, culture, history, and impact on people as it relates to engineering work. Some students who had chosen to take an elective engineering course that examined the cultural considerations of engineering work expressed that it should be a core course. For example, one student said,

I mentioned, [elective] a more cultural class, and expanding on different cultures and how they react differently to different designs, and that sort of stuff. . . .I think that is a very important aspect, and we should all be conscious as engineers of the world around us and not just be focused on, oh, what makes this better, what parts need to fit here, that sort of thing. I think it should be more of a requirement.

Students also talked about wanting greater attention in their core courses to sustainability and learning how engineering work can have a positive impact on people and society, including how IE concepts can be applied to humanitarian causes or to real-world problems beyond industry applications. For example, one student said, “I would love to see some more like humanitarian applications to industrial engineering, because I feel like all I hear too is like, ‘Oh, I worked at a factory and I did this optimization for the factory’, but I don’t hear a ton about like how they’re improving, I don’t know, some sort of basic human need?” Another student also expressed a need for more opportunities to understand the impacts of engineering work, as shown in the example below,

I wish that we had spent more time in engineering emphasizing welfare and kind of the impact of what we do. . . . I’m going into manufacturing, great, but how is it impacting communities and people who aren’t engineers and where they live. We read a book before we came to engineering about a nuclear power plant that was leaking into local communities and that really made me start thinking about it. I wish I had more opportunities to learn about examples like that and how to prevent things like that as an engineer.

4.4. Emphases That Generated Some Dissatisfaction

Students also expressed some dissatisfaction with how topics like teamwork and interpersonal skills, business, finance, and management, ergonomics, and modeling and simulation were presented in courses. Specifically, students were interested in content

emphasizing collaboration and group projects in their courses as well as more explicit guidance on working in teams and resolving conflict. Students also expressed some desire for an increased range of business topics in coursework, such as marketing and finance. For example, one student said, “I would be interested in taking a marketing class or a finance class because I think those are pretty applicable skills.” Similarly, another student mentioned “I think IE has a good reputation of being the bridge between business and engineering. I wish there was more of the aspects of business within it.” Some students’ dissatisfaction with the business, finance, and management content also appeared to be rooted in unmet expectations of IE being a business engineering major, as one student described in the excerpt below,

I guess there’s a certain level of disappointment that I’m just like, “Oh, I didn’t really. . .” I think I was under the illusion, when everyone was telling me it’s the business degree for engineers, I was going to be learning a little bit more business principles, and understanding organizational philosophy a little bit more, but it’s been a little bit different than that, and there’s been a bigger focus just on manufacturing, and stats, and I feel like. . . I wish that was a little bit marketed more to me, because I still. . . I don’t really know how to explain my major to people still, there’s no understood—I just feel like the industrial engineering department doesn’t exactly do a great job of marketing what it does.

Finally, for ergonomics, a student suggested that they would be interested in user experience research and design topics being introduced in their coursework, and for modeling and simulation, students felt that the software they used in classes was outdated.

5. Discussion

Our findings highlight the role that curriculum played in reinforcing technical dominance and the devaluation of comprehensive skills in engineering by revealing the skills and knowledge communicated as valuable in engineering through students’ learning experiences in the core industrial engineering curriculum at MU. Specifically, students in our study perceived a heavy emphasis on technical topics, such as coding and programming; math, statistics, and linear programming; and optimization and efficiency, in their core industrial engineering curriculum. Students also perceived content such as social and cultural context and impact as missing from the core coursework. Even when professional engineering skills, such as written and verbal communication and teamwork were perceived as emphasized, some participants described them as not explicit in the curriculum or mostly present in their earlier coursework. Students’ perceptions of the core course content at MU align with previous literature which indicates that the undergraduate engineering curriculum remains overwhelmingly technical, with little progress being made over decades to integrate the knowledge and skills required for the contextualized and interdisciplinary approaches to engineering that industry, practitioners, and scholars have advocated (Cabrerera et al., 2024; Clancy et al., 2023; Lattuca et al., 2014; Mills & Treagust, 2003; Stevens et al., 2014).

When viewed through the lens of the figured worlds framework (Holland et al., 1998), our findings demonstrate that students’ experiences in core IE courses at MU send signals about the nature of engineering practice. Students encounter and engage in forms of engineering practice in their day-to-day coursework that create and continually reinforce a predominantly technical form of engineering. These dominant forms of engineering practice that are communicated through core courses have implications for how students view the field and judge their fit in engineering. Moreover, how students see themselves and how they are seen by instructors and peers may depend on the extent to which their own engineering interests and practices align with the technical engineering work that is stressed in their core courses. The lack of emphasis on comprehensive skills and knowledge in core engineering curriculum at MU is concerning given that industrial engineering prac-

tice involves engaging with different disciplines, stakeholders, and communities to address complex system-level problems. While students in our study talked about industrial engineering as a people-facing discipline, almost none of the students perceived course content addressing ethics and perspectives of different stakeholders as emphasized in their core curriculum, further speaking to how engineering practice is presented as decontextualized to the students through their curriculum (Lattuca et al., 2014; Polmear et al., 2019). The findings also point to a disconnect between students' experience of the IE curriculum at MU and key ABET student outcomes such as, "an ability to apply engineering design... with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" and "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" (ABET, 2025, p. 6). A disconnect between the skills and knowledge students recognize as emphasized in the curriculum and those comprehensive skills and knowledge essential for engineering innovation could inadequately prepare engineering students for engineering practice and reproduce the cultural perception of engineering as a purely technical discipline.

Our findings also provide insights into the misalignment between students' engineering interests and the skills and knowledge they perceived as emphasized, as reflected in their dissatisfaction with the different curricular emphases in core courses at MU. Specifically, some of the students expressed dissatisfaction with the decontextualized nature of the core engineering curriculum. They expressed a desire to encounter real-world problems in their math, statistics, and coding coursework, which would allow them to apply their theoretical knowledge to solve problems. Students in our study also explicitly mentioned a need for content focused on social and cultural context and impact as well as content emphasizing a variety of professional communication skills. While students acknowledged that their capstone courses provided opportunities to apply theoretical knowledge, some also described feeling discontent with their earlier coursework which focused on purely theoretical concepts. In some instances, students' desire for more content related to topics such as sustainability might point to a lack of explicitness or visibility of these topics in the curriculum rather than their complete absence. Still, the findings related to students' dissatisfaction with this curricular emphasis indicate that students who desire to learn comprehensive skills that account for the social, cultural, ethical, and environmental considerations of engineering work might find the curriculum lacking and misaligned with some of their engineering interests.

Beyond perpetuating overly narrow and limiting ideas about the nature of engineering practice, previous literature suggests that misalignment of students' interests with the dominant values of engineering could negatively impact their sense of fit and desire to persist in engineering (Benedict et al., 2017; Mosyjowski, 2020; Verdín, 2021). While most students in our study who expressed some dissatisfaction with their curricular emphasis chose to continue in their program, one of the students changed their major to statistics between the first and second interview, citing a misalignment between their interests and the content they perceived as emphasized in the core coursework. This student's experience illustrates the consequences of misalignment between the dominant engineering culture and personal engineering interests. The consequences of misalignment might be more pronounced for minoritized students who are more likely to foreground social impact motivations for pursuing engineering (McGee & Bentley, 2017; Ozkan & Andrews, 2022; Swartz et al., 2019) and are present in larger proportions in industrial engineering programs (Brawner et al., 2012; Pilotte et al., 2017).

Previous literature highlights the role of co-curricular experiences in fostering engineering students' comprehensive and professional skills (Finelli et al., 2012; Fisher et al., 2017; Young et al., 2014). However, research also indicates that the packed engineering curriculum limits students' ability to engage in co-curricular activities (Lichtenstein et al., 2010; Olewnik et al., 2023; Simmons et al., 2018). Further, some research suggests that participation in and exposure to these experiences varies across demographics and can be hindered by structural barriers that limit participation (Memarian & Olewnik, 2023; Silver, 2020). If the core curriculum of engineering majors is the site where valued knowledge and skills are not only introduced but practiced through repeated learning experiences, then our findings highlight the continuing need for curricular reform to incorporate sociotechnical content so as to engage students, align coursework with real-world engineering practice, and shape the perception of engineering work as inherently sociotechnical.

6. Limitations and Future Research

The findings presented in this study are based on students' self-reported perceptions at a single, large Midwestern research university in the U.S. Given our focus on a single institution, our findings are not meant to generalize the nature of engineering practice that engineering curriculum at other institutions are conveying to its students. Rather, our results point to how representation of various skills and knowledge in engineering curriculum might shape students' perceptions of valued skills and knowledge in the discipline. Further, this study was not a direct analysis of the IE curriculum at MU. Rather, we used students' subjective descriptions and perceptions of emphasized content in core coursework to understand the nature of the engineering curriculum at MU. Because our focus was on students' perceptions, which can be shaped by a number of factors, we do not intend to claim that their perceptions represent a comprehensive account of the focus of the core engineering curriculum in IE. It is also possible that the participants who chose to take part in this study represent a subset of students who are more reflective, disengaged, or dissatisfied with the IE curriculum at MU. While triangulating our findings with various course artifacts such as syllabi, assignments, and lesson plans could provide a more holistic understanding of the IE curriculum, for the present study we privileged the subjective experience of the curriculum over its objective characteristics given our focus on exploring how students' perceptions of the curriculum shape their understanding of the nature of engineering practice. Our broader study included analysis of video observations of required IE courses at MU and the findings from the observations similarly reflect a minimal emphasis on concepts related to social and cultural dimensions of engineering work (Cabrera et al., 2024). However, the qualitative design of this study is not meant to provide broad generalization about the IE curriculum but is meant to present a rich and nuanced understanding of diverse students' perceptions at a single institution in the U.S. Accordingly, our findings point to how misalignment between students' interests and perceived focus of engineering curriculum could shape students' understanding of engineering practice, sense of fit within engineering, and decision to persist. Future research should explore how students at other institutions experience the core engineering curriculum and how their perceptions shape their sense of fit and career plans. Future research should also explore and compare how the skills and knowledge emphasized in engineering curricula vary by institutional and global geographic contexts

7. Conclusions

In the present study, we examined 15 industrial engineering students' perceptions of emphasized skills and knowledge in their core engineering courses to understand the nature of engineering practice that is communicated to them by the curriculum at a

single large Midwestern research university in the U.S. We also examined the instances in which the skills and knowledge emphasized in the core engineering courses misaligned with students' engineering interests by exploring student dissatisfaction with the core coursework. Findings revealed that the core engineering curriculum at MU reinforced a predominantly technical view of engineering practice through its primary emphasis on a range of technical topics and minimal emphasis on comprehensive skills and knowledge. Further, students in this study expressed a desire for course content that emphasized the application of theoretical concepts and social and cultural context and impact, indicating a continuing need for curricular reform.

Author Contributions: Conceptualization, E.A.M., J.-L.M., S.R.D. and L.R.L.; methodology, E.A.M., J.-L.M., S.R.D. and L.R.L.; formal analysis, V.V. and H.N.N.; writing—original draft preparation, V.V. and H.N.N.; writing—review and editing, V.V., H.N.N., E.A.M., J.-L.M., S.R.D. and L.R.L.; supervision, E.A.M., J.-L.M., S.R.D. and L.R.L.; funding acquisition, J.-L.M., S.R.D. and L.R.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Science Foundation (Award No. 2054823). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of the University of Michigan (HUM00199123) on 5 April 2021 for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available to protect participants identity.

Acknowledgments: The authors would like to thank Sarah Jane Bork, Berenice A. Cabrera, Shannon Clancy, and Kayleigh Merz for assisting with collecting interview data related to this research.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ABET	Accreditation Board for Engineering and Technology
MU	Midwestern university
U.S.	United States
IE	Industrial engineering
ME	Mechanical engineering

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