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Examining How Required Courses Shape Industrial Engineering Students' Career Thinking

Hayley N. Nielsen, University of Michigan

Hayley N. Nielsen (she/her) is a Ph.D. student in the Center for the Study of Higher and Postsecondary Education at the University of Michigan. Her research interests include equity-centered teaching, learning, and curriculum in higher education, with a particular emphasis on STEM fields. She earned a B.S. in Physiology and a M.A. in Teaching and Teacher Education from the University of Arizona.

Vibhavari Vempala, University of Michigan

Vibhavari (Vibha) Vempala is a PhD student in Engineering Education Research at the University of Michigan. Her research interests include access to opportunities, social networks, and career management of engineering students. Vibha received her B.S. in Engineering from the joint department of Biomedical Engineering at The North Carolina State University and The University of North Carolina at Chapel Hill and a M.S. in Biomedical Engineering from the University of Michigan.

Berenice Alejandra Cabrera, University of Michigan

Berenice Alex Cabrera (she/her) is a Ph.D. student in Higher Education at the Marsal School of Education at the University of Michigan. She earned a B.A. in Biology and Latinx Studies and a minor in Chemistry from San Francisco State University (SFSU). She also earned a Master's in Cell and Molecular Biology from SFSU and a Master's in Higher Education from the University of Michigan. Alex taught biology at community colleges in California before attending the University of Michigan where her research interests pivoted to engineering education. Her current research interests focus on examining the messaging undergraduate engineering students receive with respect to the type of work that is valued in engineering. Her research is centered around the goal of making engineering curriculum more socioculturally relevant and the field more inclusive of women and students of color.

Dr. Lisa R. Lattuca, University of Michigan

Lisa Lattuca, Professor of Higher Education and member of the Core Faculty in the Engineering Education Research Program at the University of Michigan.

Dr. Erika Mosyjowski, University of Michigan

Erika Mosyjowski is the Research and Faculty Engagement Manager in the Center for Socially Engaged Design within University of Michigan College of Engineering. She earned a PhD and MA in Higher Education from Michigan and a Bachelor's in Psychology and Sociology from Case Western Reserve University.

Dr. Joi-Lynn Mondisa, University of Michigan

Joi Mondisa is an Associate Professor in the Department of Industrial and Operations Engineering and an Engineering Education Faculty Member at the University of Michigan Ann Arbor.

Dr. Shanna R. Daly, University of Michigan

Shanna Daly is an Associate Professor in Mechanical Engineering at the University of Michigan. She has a B.E. in Chemical Engineering from the University of Dayton and a Ph.D. in Engineering Education from Purdue University.

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Abstract

Scholars have described the social-technical divide that arises in engineering education, in which the technical content is viewed as central to the work of engineering while social contexts and impacts are often only tangentially considered, if at all, despite engineering being an inherently sociotechnical discipline. This raises concerns because the content programs choose to emphasize in their undergraduate curriculum can impact the way students come to view and understand the field, including perceptions of what skills and knowledge are valuable to learn for their future careers. An underemphasis on the social and contextual dimensions of engineering can create a narrow representation of the field that leaves students inadequately prepared to navigate the realities of engineering work. Additionally, previous research has shown that women and students of color often pursue STEM degrees, including engineering, with an interest in how they can leverage their degree to create positive social impact. Thus, examining how the engineering curriculum might underemphasize the sociotechnical nature of careers in the field has implications for how educational experiences can shape the participation of populations that are underrepresented in engineering.

This paper is part of a larger study that seeks to understand the messaging undergraduate engineering students receive about the knowledge and skills that are valued in their discipline through their curriculum and interactions with others in the field. We draw on the figured worlds framework by Holland et al. to understand the mechanisms by which disciplinary culture becomes internalized by students, impacting their values, beliefs, and actions within the field. The present study seeks to answer the question: How do industrial engineering (IE) students' experiences in required courses shape their thinking about their future careers? We draw on data from surveys and observations of key engineering practices emphasized in required IE courses to contextualize findings from semi-structured interviews with fifteen undergraduate IE students at a large midwestern university. All students participated in two interviews either in their first and second or third and fourth year of study, allowing us to capture a range of perspectives across the program's curriculum. Interview transcripts were analyzed using qualitative methods. Findings highlight students' post-graduation plans and how their experiences in their required courses have impacted their career thinking. In particular, we highlight the extent to which students view social and contextual skills and knowledge as central to careers in IE and their reflections on how their required coursework has prepared them for their future careers. Implications for future research and practice are discussed.

Introduction

Engineering is increasingly recognized as a discipline that requires attention not only to the technical work aspects but also to the social contexts in which the work occurs and the broader

impacts of engineering on communities and society [1] - [4]. The social and contextual nature of engineering work has been recognized by the Accreditation Board for Engineering and Technology (ABET), which outlines student outcomes that recognize the importance of considering the social, cultural, ethical, and environmental impacts of engineering solutions [5]. Further, scholars have recognized the importance of social and contextual awareness in the field of industrial engineering (IE) specifically, and have posited that industrial engineers may be uniquely positioned to incorporate these considerations into their work given their focus on higher-level systems and processes [6] - [8]. However, a social-technical divide often emerges in engineering education, in which the technical content is viewed as central to the work of engineering while the social dimensions are often only tangentially considered, if at all. This divide often privileges the technical dimensions of engineering work over the social and cultural dimensions [9] - [11]. An overemphasis on any singular dimension of engineering raises concerns because the content that programs choose to emphasize in their undergraduate curriculum can impact the way students come to view and understand the field, including perceptions of what skills and knowledge are valuable to learn for their future careers [12] - [14]. Students' experiences in coursework, in particular, can significantly affect their perceptions of engineering work, their career aspirations, and their decisions about whether or not to persist in the field [15].

A curriculum that underemphasizes the social and contextual dimensions of engineering can be particularly disenfranchising for underrepresented student populations in engineering, including women and students of color, as previous research suggests that women and students of color often pursue STEM degrees, including engineering, with an interest in how they can leverage their degrees for positive social impact [16] - [19]. This is particularly significant in the context of industrial engineering, as women and racially minoritized students migrate into IE at higher rates than other engineering majors. As a result, IE is more diverse in terms of race, ethnicity, and gender compared to other engineering fields, although it still faces challenges in achieving parity [20] - [22]. Thus examining how the messaging industrial engineering students receive through their coursework informs their career thinking has implications both for preparing students to tackle the realities of the sociotechnical nature of engineering as well as ensuring that curricular experiences are aligned with the aspirations of underrepresented groups in the field.

To understand how an industrial engineering curriculum influences students' career goals, the aspects of their degree that can be leveraged in their careers, and students' broader understanding of industrial engineering work, our team conducted a survey and semi-structured interviews with undergraduate industrial engineering students at a large, R-1, predominantly White university in the Midwest. The study focuses on students' experiences in required courses, as these constitute the majority of the curriculum and provide a common educational experience for all IE students. These required courses are generally regarded by faculty as essential for students in the industrial engineering major, making these courses particularly important to examine. In the present paper, we focus primarily on interview data in which IE students reflect on their career interests and

how those interests relate to the content emphasized in their core courses. Additionally, we contextualize our interview findings in survey data about students' plans following graduation. Specifically, we aim to answer the question: How do industrial engineering students' experiences in required courses shape their thinking about their future careers?

Background

This paper is part of a larger study that seeks to understand the messaging undergraduate mechanical engineering (ME) and IE students receive about the knowledge and skills that are valued in their discipline as communicated through their curriculum and interactions with others in the field. The larger study draws on student and faculty interviews, student survey data, and observations of core courses in ME and IE to examine the nature of engineering curricular messaging and its alignment with students' interests and career intentions within these two majors. Thus, while the present paper draws specifically on survey and interview data of undergraduate IE students to examine how students' experiences in required courses shape their thinking about their future careers, we contextualize these findings with those from the larger project.

One component of the larger study involved examining the prevalence of 35 common engineering practices through classroom observations of seven required undergraduate courses in IE at this institution. Researchers documented the presence or absence of these 35 practices at 10-minute intervals throughout observed course sessions. Analysis revealed that foundational technical knowledge was emphasized far more frequently than sociotechnical concepts such as social context, power, and stakeholder engagement [23]. More specifically, across all levels of the observed required IE courses at this institution, discussion of foundational technical knowledge was observed the most frequently (during 75% of the observed 10-minute intervals), whereas other practices related to sociotechnical considerations were observed at a much lower frequency. Researchers documented the frequency of the following sociotechnical practices: stakeholders (5%), power/position/identity (4%), social context (2%), interpersonal awareness (2%), future impacts (1%), ethics (0%), and the natural environment (0%). They found similar patterns across different subfields of required IE courses. For example, in courses with a focus on engineering design and simulation, there was no mention of concepts such as power/position/identity and social context, and discussion of stakeholders only appeared with 6% frequency.

Figured worlds theoretical framework

In this study, we draw on the figured worlds framework by Holland et al. [12] to understand the mechanisms by which disciplinary culture impacts students' values, beliefs, and actions within the field. This framework describes how individuals engage in social and cultural domains that are meaning-laden and context-dependent. According to the framework, a figured world is a socially and culturally constructed space where specific traits and participants are recognized, certain actions are imbued with significance, and particular outcomes are prioritized over others. Acting within an environment with particular cultural meanings and values, the extent to which

individuals' own practice is recognized by others and aligned with dominant cultural values can serve to reinforce norms, and informs how an individual identifies and is identified by others as a member of that figured world. How others see the alignment between individuals' actions and these norms and values determines their position of power within the figured world, which contributes to perpetuating the preservation of these norms and values.

In the broader study, we draw on this framework as a lens through which to interpret students' culturally constructed perceptions of engineering within the fields of IE and ME. We explore how students' own interests and values related to engineering practice align with normative values and beliefs of what it means to be an engineer in their field that are communicated through the day-to-day messaging students receive in their core coursework. Then, we examine the potential impacts of this alignment, or lack thereof, on students' career paths in or beyond engineering. In the present study, we apply this framework to understand how the messaging IE students receive in their core coursework shapes the skills and knowledge they deem valuable for careers in IE and how this, in turn, influences their career aspirations.

Methods

To ensure anonymity, we provide a general overview of the IE program at the institution where this study took place. All students begin by completing required coursework in mathematics, physics, chemistry, and introductory engineering before declaring their major in IE by the start of their third term. Students then take the majority of their required technical IE courses during their second and third years, covering subject areas such as optimization, statistics, stochastic processes, engineering economics, and human factors. The fourth year focuses on a required capstone experience, along with the completion of student-selected technical and general electives. The required technical IE courses and capstone experience are collectively referred to as "core" or "required" coursework in this paper.

Data collection

Survey data from 152 IE students and interview data from 15 IE students were analyzed for this paper. Survey and interview data were collected from both ME and IE undergraduates as part of the larger study, though only the IE student data was analyzed for this paper. Findings in regard to the ME student interview data can be found in previous work [24].

Students currently enrolled in the IE undergraduate major at this institution were recruited via email to complete the survey, which was distributed via Qualtrics. Survey questions asked about the required classes students have previously taken or were currently enrolled in, students' perceptions of the different practices present in their required courses, messages students received about the nature of engineering in their required courses, students' feelings of belonging in engineering, and their plans for their careers and/or graduate education following graduation. The survey data are cross-sectional rather than longitudinal in nature. Data was collected from students who were in various stages of their studies, ranging from first-year to fourth-year students, to provide a range of perspectives from both lower- and upper-division students. The

survey took approximately 30 minutes to complete and students were compensated $20 for their participation.

Fifteen IE students participated in two semi-structured interviews about their engineering interests, their experiences with the curriculum in core engineering courses, and their thinking about their future careers. Interview participants were recruited through email from a list of students who had declared or were interested in declaring IE as their major. The email contained a screening survey that collected information about the students' current or intended major and demographic information. We aimed to capture a range of students in terms of degree progression and demographics. Students who met the criteria were invited to participate in interviews.

Students were interviewed twice, one year apart: the first interview was conducted during the students' first or third year of study and the follow-up interview was conducted during their second or fourth year of study, respectively. This approach allowed us to capture a range of perspectives across the program's curriculum. The interviews were conducted by four graduate students and were guided by a protocol developed and piloted by the study team based on the study objectives and relevant literature. More details about the development of the protocol and its content can be found in a previous publication [25]. The interviews lasted approximately 30-90 minutes, took place over Zoom, and were audio recorded. Students received $30 as compensation for their participation. The transcribed recordings of the interviews were de-identified and reviewed for accuracy.

Data analysis

Three of the authors conducted the analysis of the IE interview data, supervised by another author serving as a research scientist. The analysis team used a combination of inductive and deductive methods to analyze the interview data [26], [27]. The project leadership team developed prompts to focus the initial data analysis. Specifically, they developed guiding questions that prompted the research team to synthesize information from the interview data relevant to the research question for subsequent analysis. One of the members of the analysis team read each of the 30 interview transcripts in full and used the guiding prompts to develop summaries of each interview. Next, another team member reviewed the transcripts and associated summaries to verify or add to the team member's interpretation.

After summarizing all 30 interviews and resolving any discrepancies in team members' interpretation of the data, the analysis team looked for patterns of meaning across all the participants, paying special attention to students' career goals and descriptions of how their required courses informed their career thinking. Our focus was specifically on understanding how core coursework impacted students' career thinking at a given point in time in their academic journey, rather than tracking changes in their thinking over time. As mentioned, we concentrated on students' reflections on how required coursework shaped their thinking because these courses represent the shared educational experience of all IE students in the program.

Additionally, we engaged in a preliminary analysis of the relevant survey questions, specifically focusing on students' post-graduation plans and the open-ended responses for those who indicated an intention to pursue a career outside of engineering. A more comprehensive analysis, which will include an examination of the remaining survey questions, is planned for a forthcoming publication.

For clarity, we refer to the fifteen students who participated in the interviews as "participants" and the 152 students who completed the survey as "survey respondents".

Findings

Post-graduation plans

We begin this section by overviewing students' post-graduation plans to provide context for discussion of how their required courses informed their thinking about their future careers. Table 1 summarizes the post-graduation plans reported by the 152 IE students who completed the survey. Each survey respondent answered separate questions about their career interests and their plans regarding the pursuit of a graduate degree within the next five years.

Table 1. Post-Graduation Plans Survey Data

Post-Graduation Plans	Number of Survey Respondents
Career Plans (if any)	
Career in industrial engineering	106
Career in different engineering field	11
Career in non-engineering field	18
Unsure about career field	17
Total responses	**152**
Graduate Education Plans (if any)	
Graduate Education – industrial engineering	38
Graduate Education – different engineering field	2
Graduate Education – non-engineering field	33
Unsure about pursuing graduate education	59
Not planning to pursue graduate education	20
Total responses	**152**

As seen in Table 1, almost one quarter of survey respondents indicated wanting a career in a non-engineering field or were unsure if they wanted a career in engineering. In their open-ended responses, survey respondents provided a range of reasons for wanting to pursue careers outside of engineering. The most common reason was an interest in adjacent fields such as business, finance, or computer science. Some survey respondents expressed a general desire to pursue a career more aligned with their personal interests but did not elaborate further. Others mentioned seeking work environments that they believed engineering careers could not offer, specifically roles that were more social or creative in nature; one student wrote, "*I want a less technical and more social job, that involves interacting with people and creative thinking*." Additionally, a handful of survey respondents cited a desire to make a broader impact in a field beyond engineering as a motivating factor. For example, one IE student explained "*I want a career with more interpersonal interactions and a visible impact,"* while another said, *"I've realized more and more that I enjoy the worlds of public policy and governance in general and want to use the avenues to help create a better country and world."*

While the survey did not capture specific career interests, interviews allowed for a more detailed exploration of participants' post-graduation plans. Among the 15 interview participants, the most frequently mentioned plan following graduation was to obtain a job in consulting. Several participants expressed an interest in consulting because it offered the opportunity to explore various industries and, by extension, acquire a diverse set of practical skills. The second most commonly discussed path amongst the participants involved graduate education, with the majority intending to advance their studies in industrial engineering; one participant planned to pursue a degree in computer science, and another an MBA. Other post-graduation plans included roles in operations (e.g. optimization, manufacturing), business and finance (e.g. investment banking), ergonomics (e.g. machine safety), and software engineering. A couple of participants indicated intentions to pursue careers outside traditional IE paths, namely in public policy and education.

Although the level of detail between the survey and interviews differed, looking across these two samples reveals that the post-graduation plans of survey respondents were similar to interview participants in that the majority of survey respondents expressed an interest in careers related to industrial engineering. However, a higher proportion of survey respondents indicated a desire to pursue graduate education in non-engineering fields compared to the interview participants.

In the following sections, we delve deeper into students' career thinking and the related influences of their core coursework through further examination of the qualitative interview data.

Impact of coursework on engineering interests

Many of the fifteen interview participants indicated that their coursework played a significant role in helping them to discover their engineering interests, whether through exposure to topics

that sparked their interest in potential career paths or by revealing areas that held less interest and thus were unlikely career paths. As one third-year participant described,

> "*I think most of all, I've been exposed to so much, and so many different things that have helped me kind of navigate what I'm interested in, instead of, I guess, feeling pigeonholed into only doing one thing. That has really helped, yeah, narrow it down*."

Relatedly, core courses played a role in influencing students' decisions regarding whether or not to attend graduate school, including providing participants with clarity on topics they would be interested in pursuing through an advanced degree. As one fourth-year participant stated,

> "*I think at the very least, taking all of these core classes has helped me decide that I want to go to grad school. Because I've realized I want to focus, hone in on something, and it taught me what I want to focus on*."

Impact of coursework on identification of important skills for future careers

When interview participants reflected on how their core courses prepared them for their future careers, they identified skills they had developed and came to view as essential in the engineering workplace. Among the most frequently cited were teamwork and collaboration, optimization, and technical communication (e.g., presentation skills). Other specific knowledge and skills mentioned included coding, math, statistics, linear programming, modeling and simulation, and an understanding of business operations. Beyond specific technical skills, many participants emphasized the value of broader competencies they developed through their coursework, particularly in problem-solving. Participants spoke about learning problem-solving skills such as the ability to identify a problem, determine the necessary steps and strategies to solve it, and evaluate potential solutions. They noted that this process often involved accounting for numerous details and employing critical thinking to select the most effective solution among many. Two students elaborated further on how their core courses helped them learn to think with an "*engineering lens,*" which they defined as approaching problems with an eye toward efficiency.

Some participants highlighted other skills that their core courses suggested were necessary for success in the engineering workplace, such as effective and professional communication with colleagues or delivering presentations. One student highlighted how these ideas about essential skills were introduced in their very first engineering course and continued to be solidified throughout their core coursework. Another student shared that engaging in multiple classroom presentations in their IE courses cued them to believe that this would be an important element of their future career.

Elements of coursework with lower utility for career thinking

In addition to aspects of coursework that participants found influential on their career thinking and/or feelings of preparedness for their careers, students expressed aspects of their coursework that they found to be less useful regarding their paths after graduation. A third of the participants

expressed in at least one of their interviews that certain courses were not directly relevant to their envisioned or chosen career paths. Some of these participants explicitly described looking to experiences beyond their core curriculum to guide their career thinking, such as extracurricular activities (e.g. consulting clubs) or internship experiences. For example, one participant in their third year described a friend's encouragement to join a consulting club because "*from what I was told, it was the perfect thing for people who had no idea what they wanted to do*." The participant explained that his involvement in this club was the primary factor that shaped his decision to pursue a career in consulting, rather than his experiences in required courses. Similarly, another student indicated that her internship experiences, along with the professional relationships she developed during that time, were key determinants in guiding her job search.

As mentioned, while many participants emphasized how they expected to apply broader skills like problem-solving in their future careers, a few noted that they didn't foresee applying much of the specific content they had learned. For example, one second-year participant interested in a career in operations explained that the types of problems they expected to encounter in their job would differ from those that had been addressed in their courses. They explained,

> "*I think that my IE skills will come in just because IE has helped me develop that ability to think of solutions to problems and think more efficiently and think about the details and take things into account. But I don't think I'll specifically apply [the content] I've learned*,".

Another student in his fourth year, drawing on his experiences during his internship in strategy consulting, reported that he needed to engage in substantial "*on the job"* learning. He expressed the belief that there was specific knowledge and skills essential to his career that had not been covered in his coursework, though he did not elaborate explicitly on what these skills were. Nevertheless, he acknowledged that his courses, and the problem-solving methods he learned within them, "*made learning new content [at my internship] a lot easier,"*.

Misalignment between coursework and career aspirations

A couple participants more explicitly critiqued their IE core coursework for not focusing on content or skills they considered important for them to learn on the path to their careers. One second-year student, for example, felt that his IE courses had not yet taught him how to collaborate effectively, despite him considering this "*the most important thing that IE majors need to take away*" from their studies. He explained that, through discussions with peers, he learned that teamwork is a crucial aspect of careers in IE.

Another participant who had transitioned from a major in IE to statistics between her first and second interview expressed a desire to work in public policy, particularly in areas related to affordable housing. She shared that based on her experiences in IE courses, she could not envision a future career in industrial engineering or any other engineering field. She attributed this decision to negative experiences interacting with peers in her courses and dissatisfaction

with the content in her core IE courses. Specifically, she recounted both directly experiencing as well as witnessing both implicit and explicit "*disrespect*" directed at women and students of color. She attributed this, in part, to the lack of content in the IE curriculum that addressed "*internalized racism, homophobia, sexism*." Additionally, she described how certain course projects reinforced her disillusionment with engineering. For example, in one core IE course project, students were tasked with improving the efficiency of a company's warehouse without being prompted to consider the potential impact of these efficiency measures on the employees. Reflecting on this, she stated,

> "*...and so that was just realizing that…I would be the person who is optimizing these facilities in a way that can and has caused harm to other laborers. I think that was a big moment for me because I kind of just stepped back from it and was like, this is not what I thought it was."*

These experiences led her to reassess her career aspirations, which included deciding to pursue a path outside the field of engineering.

Discussion

In this paper, we presented findings from a survey on the post-graduation plans of industrial engineering students at one institution, as well as their reasons for pursuing careers or graduate education outside of engineering. While the majority of survey respondents (106 out of 152) indicated their intention to pursue careers in IE, a portion planned to enter a different engineering field (11 out of 152) or leave engineering altogether (18 out of 152). Additionally, among those intending to pursue graduate studies in the next five years, nearly half (33 out of 73) planned to pursue a degree in a non-engineering field. While these results reflect the intentions of students at a single institution, as part of our larger study, we are surveying IE students at four additional institutions to enable cross-institutional comparisons. This multi-institutional approach will help us understand how IE curriculum may vary across institutions and, in turn, how these differences might impact students' career thinking.

While the survey findings provide a broader understanding of the post-graduation plans of IE students in this program, they primarily serve as contextual background. A central goal of this study was to highlight students' perspectives on how core courses within their IE curriculum influenced their career interests and the skills and knowledge they believe will be valuable in their future careers. Conducting in-depth interviews with 15 IE undergraduates allowed us to look deeply at an IE program to understand the ways in which students' core courses shape their career trajectories and their understanding of careers within the field.

The findings of the interviews underscore the critical role that core industrial engineering coursework plays in shaping students' understanding of both their personal engineering interests and their future career paths. Interview participants indicated that their coursework not only influenced their decisions about which subfields within engineering they wished to pursue but

also helped them determine which they did not wish to explore further. This process of exploration and elimination led students to more focused career trajectories as they advanced through their studies. Previous research indicates that coursework is one of the main factors that helps students decide on their post-graduation plans [15]. Our study extends this work by emphasizing how students' exposure to the core curriculum in an IE program plays a pivotal role in narrowing and refining their interests, ultimately impacting decisions about their careers and/or graduate education.

When asked how they would leverage what they had learned in their core coursework in their future careers, the majority of interview participants indicated value in the broader competencies and skills they had acquired. Several students described the ways in which coursework had shaped their ways of thinking, and in particular, emphasized the problem-solving abilities they had developed. A previous study of 74 engineering students from two different institutions showed that the development of these flexible problem-solving skills influenced many students to choose career paths beyond engineering because of the broad applicability of these skills [28], which was also evidenced by a strong interest in fields such as consulting and business amongst the students in the present study. Additionally, educators have recognized the challenge of preparing students for future jobs that might involve solving problems that do not yet exist. Thus, fostering growth in problem-solving abilities over specific content and tools could be beneficial for preparing students for their future careers [29]. Finally, in the context of industrial engineering, previous research has shown that preparation for a variety of jobs is a common reason that students choose to major in IE [30], suggesting that equipping students with these broader competencies could align with their expectations for their education.

Relatedly, a study of nine engineering students found that participants viewed engineering primarily as a problem-solving discipline, explaining that engineering problems are less defined by their content and more by the approach taken to solve them. However, students in that study explicitly discussed how engineering could be used to solve problems addressing broader societal challenges [31]. The majority of students in the present study focused almost exclusively on the technical aspects of problem-solving as well as other technical skills and knowledge they had learned through their curriculum. This is unsurprising given the findings from the course observation component of our larger study, in which we found minimal to no mention of concepts related to the social dimensions of engineering compared to the exceptionally strong and consistent emphasis in each course on the technical aspects of engineering work [23]. None of the interview participants discussed coursework that equipped them with skills and knowledge necessary to prepare them to account for the social or contextual dimensions of their work such as ethics, social context, nor social impact.

In another study of 45 IE students, the majority cited the nature of the degree as a key factor in their decision to major in IE. Study participants mentioned several aspects of the degree, including its emphasis on problem-solving [32]. Similarly, most students in the present study described valuing the problem-solving skills they had developed. This suggests that this focus

may play a role in recruiting and retaining students in the field. Moreover, how problem-solving is framed – and the focus of the problems presented – could be key to broadening students' understanding of the social and contextual dimensions of engineering. This was clearly illustrated by a participant in this study who, during the data collection period, left the IE major and planned to pursue a career outside of engineering. This student spoke to the lack of content in her IE courses that attended to the broader social and ethical implications of engineering work, including a project in which students were tasked with solving efficiency-related problems without considering the impact of these solutions on the workers who would be implementing them. Scholars have noted this social-technical divide that manifests in engineering education, suggesting this is not solely a characteristic of one institution [9] - [11], though similar study at other institutions would be valuable for understanding the generalizability of findings from this research.

The findings of this study contribute further to these ideas by highlighting how the emphases within IE coursework are translated into students' conceptualizations of the work of industrial engineers including what skills and knowledge are valuable for their future careers. While only one student in this study spoke explicitly to how the lack of social and contextual skills and knowledge in her curriculum led her to leave the field, an equally concerning finding was that none of the other participants described their IE curriculum as preparing them to address these aspects of engineering work in their careers. Furthermore, many did not even acknowledge social and contextual aspects as part of their envisioned careers in IE. This underscores the need for curricular attention to the social and contextual considerations of IE work because of the ways in which curriculum shapes students' perceptions of future engineering work [12], [14].

Additionally, participants discussed benefiting from experiences beyond their coursework, such as in internships, extracurricular activities, and the professional networks cultivated through these experiences, including how participation in these activities sometimes informed their career thinking more than their core coursework. Thus, further study might examine how curriculum, extracurricular, and work experiences holistically shape students' understanding of the field of engineering and their future careers, including how these experiences could be leveraged to prepare students for the sociotechnical nature of the field. However, given that inequities related to socioeconomic status, race, and gender often result in unequal access to and experience within extracurricular opportunities, the field should not rely on experiences beyond the curriculum in preparing students for their future careers [33], [34].

One limitation of this study is that students' decision to participate in interviews may have been impacted by factors that resulted in a sample with perspectives closer to either end of the spectrum–namely, those expressing either high satisfaction or dissatisfaction with the IE curriculum at this institution. Our data collection approach was deliberately designed to provide a rich, nuanced understanding of students' experiences, rather than to seek broad generalizability. Further study of students' experiences with their IE curriculum would help capture an even broader range of perspectives. Additionally, because our survey sample is cross-sectional, we are

unable to examine changes in students' post-graduation plans over time. Future research could focus specifically on how students' plans evolve as they progress through their undergraduate IE curriculum.

Recommendations for engineering educators

The findings of this study offer important implications for engineering educators, certainly at the institution where this study was conducted, but also for other engineering departments seeking to enhance students' understanding of the social and contextual dimensions of engineering. For more than a generation, engineering employers and educators have understood that the complex technological and social challenges that face the world have implications for the preparation of engineering graduates [4], [5], [35] - [38]. To be responsive to these ongoing concerns, engineering leaders can take a number of steps. Department chairs can initiate discussions with faculty regarding program curricula, including its relevance to employers and its capacity to educate engineers who can address the kinds of social and technical problems relevant to their field. In these discussions, faculty can reflect on recommendations from their industry advisory boards, when available, regarding the knowledge and skills that engineering graduates need, and assess where and to what extent such knowledge and skills are represented in required courses. They can also conduct or review surveys of alumni that can provide information on the careers that program graduates enter, their job titles, and their responsibilities on the job. When curriculum committees review new or revised courses, they should evaluate how to complement technical emphases present in degree programs by integrating attention to relevant social concerns and complex problems that require an understanding or examination of social, cultural, political, and other contextual factors.

Instructors might reflect on how they can emphasize the value of social and contextual knowledge and skills alongside technical competencies; relatively minor course adjustments can help students recognize the multiple dimensions of engineering work that they will encounter in their future careers. New content can build students' appreciation for the sociotechnical nature of engineering problems and highlight the knowledge and skills required; such changes can show students interested in careers that leverage social and contextual knowledge that industrial engineering is a viable path for them. Contextualizing the engineering problems that students are asked to solve engages them in solving authentic, real-world problems they are likely to encounter after graduation. Research on culturally relevant problem-solving in engineering may provide useful insights [39], though findings suggest the need for scaffolding beyond merely reframing problems.

Conclusion

The goal of this study was to examine how industrial engineering students' experiences in required courses shape their thinking about their future careers. Guided by the figured worlds framework [12], we examined how the messaging that IE students receive in their core coursework shapes the skills and knowledge they see as valuable for careers in the field and how this influences their career aspirations. Understanding how a curriculum, particularly through

required courses, shapes students' views of their field of study is crucial for gaining insight into how their educational experiences inform their career trajectories and prepare them for the practice of engineering. The most consistent elements of the curriculum are those that students are most likely to remember, while topics touched upon infrequently or in passing are likely to fade from view.

The findings of this study underscore the pivotal role of one institution's IE curriculum in shaping students' understanding of career opportunities in IE, as well as the skills and knowledge that are valued in the field. As was the case in this study, when a curriculum fails to present IE careers as encompassing social and contextual considerations, students may not recognize these skills as integral to their future careers, leaving them inadequately prepared to navigate the realities of engineering work.

Although Cech [40] characterizes engineering education as fostering a "culture of disengagement," wherein students' commitment to public welfare concerns declines significantly over the course of their studies, she also argues that it is this very influence of the engineering curriculum that gives it the capacity to create more socially engaged engineers. This study bolsters that argument by demonstrating the influence of an IE curriculum in shaping students' career thinking. By incorporating social and contextual dimensions into IE curriculum, engineering educators can prepare graduates not only for the technical aspects of their roles but also for the broader societal implications of their work.

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