

Redefining Engineering Work: How Recent Engineering Graduates Classify Their Roles, Occupations, and Competencies*

SAMANTHA R. BRUNHAVER

The Polytechnic School, Arizona State University, 7171 E Sonoran Arroyo Mall, Peralta Hall Room 330H, Mesa, AZ, 85212, USA.
E-mail: samantha.brunhaver@asu.edu

CHERYL CARRICO

E4S, 22289 Hampton Dr., Abingdon, VA, 24210, USA. E-mail: ccarrico@enr4success.com

HOLLY M. MATUSOVICH

College of Engineering, Virginia Tech, 3048 Torgersen Hall, 620 Drillfield Drive, Blacksburg, VA, 24061, USA.
E-mail: matushm@vt.edu

RACHEL L. KAJFEZ

Department of Engineering Education, The Ohio State University, 3042 Smith Laboratory, 174 W 18th Ave, Columbus, OH, 43210, USA. E-mail: kajfez.2@osu.edu

SUSAN SAJADI

Department of Engineering Education, Virginia Tech, 354 Goodwin Hall, 635 Prices Fork Rd, Blacksburg, VA, 24060, USA.
E-mail: ssajadi@vt.edu

SHERI D. SHEPPARD

Department of Mechanical Engineering, Design Group, Stanford University, Building 550, Room 131, Stanford, CA, 94305, USA.
E-mail: sheppard@stanford.edu

Engineering practice is inherently sociotechnical, yet perceptions of the field often prioritize technical skills over professional competencies. This study explores how recent engineering graduates (REGs) define and navigate their roles, focusing on their self-identifications of engineering versus non-engineering work and the key competencies required in their positions. Using a mixed-methods approach, data were collected from 484 survey participants and 30 interview participants across four U.S. institutions. The findings reveal a disconnect between job titles and self-perceptions, with many REGs identifying as engineers despite their roles being classified otherwise under traditional frameworks. REGs associated technical competencies with engineering and professional tasks, such as communication and management, with non-engineering work, highlighting a technical/social dualism. However, they recognized the importance of both skill sets, emphasizing the need for inclusive definitions of engineering that integrate technical and social dimensions. These insights inform strategies for curricular reform, workplace practices, and research to better align engineering education with the interdisciplinary demands of modern practice.

Keywords: engineering graduates; engineering pathways; professional practice; competencies; mixed-methods research

1. Introduction

The rapid pace of social and technological change is reshaping the workforce and redefining what it means to be an engineer [1, 2]. Traditional views, tied to narrowly defined job titles and technical problem-solving, increasingly fail to capture the complexity of modern practice [3–5]. For instance, while only one-third of U.S. engineering graduates hold engineering-titled jobs, half work in related fields, and 90% report using engineering skills in their roles [6].

This disconnect underscores the need for more inclusive definitions of engineering that integrate its interdisciplinary and sociotechnical dimensions. Undergraduate engineering students frequently

graduate with a limited understanding of the field, equating it with technical competencies and overlooking its broader dimensions, such as communication, collaboration, and management [7–9]. These perceptions persist in the workplace, leading to job misalignment, lower satisfaction, and disengagement, for underrepresented groups especially [10–12]. Addressing these challenges requires reinforcing technical and professional skills in both education and practice, fostering a more inclusive understanding of what it means to do engineering work [2, 13–15].

This study uses a mixed methods approach to examine how recent engineering graduates (REGs) define their work as engineering or non-engineering, perceive their competencies, and navigate the

boundaries of engineering. For instance, why might one REG in an engineering-titled role feel their work is not engineering, while another in a non-engineering-titled role identifies it as such? By focusing on REGs during their transition from education to practice, this research explores how academic preparation aligns with workplace demands and challenges traditional narratives about engineering. To guide the inquiry, the study addresses two questions:

- RQ1. How do REGs' self-identifications as doing engineering or non-engineering work align (or fail to align) with their self-reported occupations? What characteristics distinguish engineering from non-engineering work in their self-identifications?
- RQ2. How do REGs' self-identifications of engineering or non-engineering work align with their self-reported occupations and the competencies they report as important to their roles? How do participants describe applying these competencies in their jobs?

This research reveals critical insights into the evolving boundaries of engineering, highlighting the need to redefine the field to integrate technical expertise with sociotechnical competencies. These findings have profound implications for education, workplace practices, and policy, equipping engineers to meet the complex challenges of the 21st century. The next section reviews literature on engineering work, competencies, and professional identity to provide a foundation for analyzing REGs' experiences.

2. Background

2.1 Field Understandings of Engineering Work

The increasing complexity of engineering practice has prompted efforts to define engineering work, emphasizing the integration of technical and social dimensions. These frameworks position engineering as a sociotechnical profession, requiring both technical problem-solving and interpersonal collaboration.

Frameworks defining engineering roles highlight this duality. Craps et al. [16] identified three domains of engineering work – product innovation, process optimization, and solution customization – while Magarian and Seering [3] differentiated between “traditional engineering” (design-focused) and “engineering-proximate” roles (e.g., computing, management, quality assurance). Trevelyan and Williams [5] similarly described two facets of engineering: innovation and design versus analysis, collaboration, and due diligence. Across these models, engineering consistently blends technical

expertise with social skills, as seen in tasks such as process optimization (analytical skills and teamwork) and solution customization (technical knowledge and client communication).

Research on engineering competencies further supports this perspective. Passow and Passow's [17] meta-analysis highlighted core competencies, among them, communication, teamwork, and applying math and science to real-world problems. Similarly, in a mapping review of journal articles from the last two decades, Mazzurco et al. [18] found that professional skills, such as communication and teamwork, often rival technical skills in importance. These findings reinforce that engineering is not purely technical but requires an equal emphasis on social and technical skills.

2.2 Perceptions of Engineering Work

Despite the recognition of engineering as a sociotechnical profession, perceptions of “real” engineering remain narrowly focused on technical work, reflecting a persistent technical/social dualism that marginalizes essential professional skills [10, 15, 19, 20].

In engineering education, students often prioritize problem-solving and design over teamwork and communication, despite recognizing the importance of these interpersonal skills [7–9]. In professional practice, engineers value competencies that include business knowledge, ethics, and lifelong learning, among others. Yet, they frequently dismiss these competencies as “non-engineering” because they lack an explicit technical component; instead, they equate their work with tangible technical outcomes while simultaneously undervaluing interpersonal and managerial responsibilities [21–24]. Even some engineering managers feel distanced from their engineering identity due to their focus on supervisory responsibilities [10, 25, 26]. However, some engineers in non-traditional roles maintain their professional identity by leveraging their technical training, e.g., [21, 27], highlighting the field's enduring emphasis on technical expertise.

This technical/social dualism reinforces a reductive image of engineering as a “generic” [26] technical profession that neglects interdisciplinary and interpersonal dimensions crucial for modern practice. It also perpetuates gendered stereotypes, associating technical skills with masculinity and social skills with femininity, exacerbating gender-based tensions and undermining inclusivity [10–12]. Disciplinary differences reinforce this dualism, with some fields prioritizing technical rigor, while others emphasize integrating technical and social dimensions, fostering more holistic views of engineering [17, 28, 29]. While accreditation standards, most notably ABET [30], emphasize both technical

and professional competencies, the extent to which this dualism shapes perceptions among recent engineering graduates remains unclear.

This study examines how REGs perceive their work as engineering or non-engineering, how these perceptions align with their reported occupations, and how they prioritize competencies. By investigating these dynamics, this research provides a nuanced understanding of engineering's evolving definition and practice. It challenges traditional views by emphasizing the integration of technical and professional skills to prepare graduates for success in complex, interdisciplinary roles and offering insights to guide educational curricula, professional development, and organizational strategies.

3. Theoretical Framework and Approach

This study is grounded in role identity theory, which defines role identities as the internalized meanings individuals attach to the roles they perform [31]. These identities are socially constructed and evolve through interactions, encompassing the goals, norms, and behaviors associated with a role [32]. A key concept in the theory is *role legitimation*, where alignment between an individual's role identity and performance reinforces their identity, while misalignment can create role conflict, leading to identity negotiation or change [33]. This framework is particularly relevant for understanding how REGs navigate professional contexts and evolving definitions of engineering work.

For REGs, the classification of work as engineering or non-engineering depends on how their role performance aligns with their internalized understanding of engineering. Factors including job tasks, required skills, and adherence to professional norms influence this perception [16, 34, 35]. Technical markers such as problem-solving, design, and expertise can reinforce their engineering identity, while non-technical tasks such as management or communication may create tension, e.g., [22, 23]. These dynamics make REGs an ideal group for exploring identity formation during the transition from education to the workforce. Recent literature has also emphasized the need for more studies on

early career engineers [14, 36].

The current study uses a mixed-methods approach [37] to investigate these dynamics. Quantitative survey data compares REGs' self-identifications of their positions as engineering or non-engineering work with their reported occupations and the competencies they consider important in their roles. Occupations are categorized using the National Science Foundation's (NSF) Scientists and Engineers Statistical Data System (SESTAT) classifications [38], adapted from the U.S. Bureau of Labor Statistics Standard Occupational Classification System [39]. Competencies are drawn from ABET Criterion 3 student outcomes [40] and the National Academy of Engineering's (NAE) *Engineer of 2020* report [41], ensuring alignment with established frameworks for engineering education and practice. Qualitative interviews provide deeper insights into how REGs define engineering, apply competencies, and reconcile their role identities in professional contexts.

Building on prior research into engineering identity [42–45], this study extends role identity theory into new areas. While previous studies have focused on engineering students [46–48] or established professionals [10, 12, 34–35], this research targets REGs, a critical yet understudied group navigating the transition from academia to the workforce. This study examines the immediate influence of job roles and responsibilities on early-career engineers' role identity, providing a nuanced understanding of how they perceive and define their professional roles.

4. Methods

This study used a concurrent mixed-methods approach [37] to explore how REGs classify their work and prioritize key competencies. By collecting and analyzing qualitative and quantitative data simultaneously, this design balanced statistical generalizability with detailed narrative insights. Surveys captured broad trends, while interviews added contextual depth, providing a holistic view of competency prioritization and professional identity. Fig. 1 illustrates the study's methods.

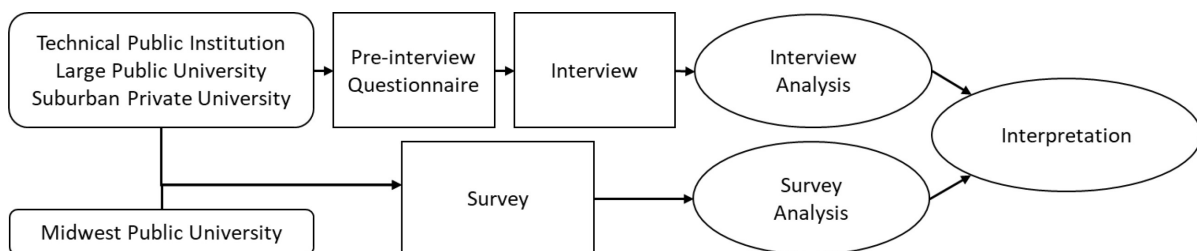


Fig. 1. Concurrent mixed methods design illustrating data collection sites and methods.

4.1 Research Sites

Data were collected in 2011 from REGs who graduated four years earlier with bachelor's degrees in engineering from four U.S. research-intensive universities: Technical Public Institution (TPub), Large Public University (LPub), Suburban Private University (SPri), and Midwestern Public University (MPub). These institutions were selected for their diverse locations, sizes, and missions, offering varied educational experiences. As part of a prior longitudinal study on undergraduate engineering [53], this established cohort provided a robust foundation for the research. Institutional review board approval was obtained from all participating universities.

4.2 Qualitative Interviews

The qualitative component involved semi-structured interviews with 30 REGs from the prior longitudinal study who had earned engineering degrees. Participants were purposefully selected to reflect diverse perspectives, with a balance of gender (16 men, 14 women) and racial/ethnic identities: White/European American (18), Asian/Asian American (5), Hispanic/Latin American (2), and multiple identities (5). Their undergraduate majors included chemical (7), mechanical (5), electrical (3), petroleum (3), civil/environmental (2), engineering physics (2), and other fields (8). At the time of the interviews, 21 participants were employed full-time, eight were in graduate school, and one was not employed or in school.

Conducted between March and May 2011, the 30- to 60-minute interviews followed a standardized semi-structured protocol developed collaboratively by the research team. The protocol, refined after piloting with early-career engineers and graduate students, included 13 open-ended questions exploring professional identity, perceptions of engineering work, and critical competencies. The key questions analyzed included:

- *On your questionnaire, you said you are currently working at [company/school] as a [job role]. Tell me more about that.*
- *On your questionnaire, you said that your current job is (or is not) engineering. Can you explain what you mean by that?*
- *What knowledge and skills do you see as most important for succeeding in your job?*

To ensure consistency, the protocol specified the purpose of each question and included follow-up probes [49, 50]. Interviewers were trained to apply the protocol uniformly, enhancing reliability and validity. Interviews were audio-recorded, transcribed verbatim, and analyzed using MAXQDA

software. Participants received \$40 as compensation for their time.

4.3 Quantitative Survey

The cross-sectional survey complemented the qualitative strand by capturing broader trends among REGs. It included 45 questions across five thematic areas: (1) degrees and employment, (2) pre- and post-graduation learning experiences, (3) self-efficacy, outcome expectations, and interests, (4) career satisfaction and plans, and (5) background characteristics. Informed by role identity theory [31, 32], persistence frameworks [51, 52], and preliminary interview findings, the survey featured competency-related questions based on ABET Criterion 3 outcomes [40] and the NAE Engineer of 2020 attributes [41]. Iterative pilot testing with engineering graduates, faculty, and administrators ensured validity. Key questions analyzed included:

- *Current position: Please describe your current and primary employed position (or, for respondents not currently employed, your most recent employed position). "Employed position" can include research or teaching fellowships/assistantships. (Respondents selected their primary employed position from a list adapted from NSF SESTAT [38].)*
- *Work classification: Would you describe your current and primary employed position (or your most recent position, if not currently employed) as: an engineering position, or a non-engineering position?*
- *Competencies: In your current employed position (or your most recent position, if not currently employed), how important is each of the following in your work? (Respondents rated the importance of 20 competencies on a five-point scale, from 0 = not important to 4 = extremely important.)*

The survey was emailed to 1,801 engineering graduates from four institutions (TPub, LPub, SPri, and MPub), representing a 2007 graduating cohort. Of these, 543 responded (30% response rate), and 484 completed the survey. Chi-square tests confirmed respondents were representative of the alumni population in gender and major ($p < 0.05$, Cramer's $V < 0.01$, for all). Respondents were eligible for one of 40 \$50 Amazon gift cards (10 per school). Further details about survey administration are provided in [53].

Among completers, 85% were employed full-time, 7% were graduate research or teaching assistants, and 8% were unemployed. Of employed respondents, 25% identified as women, 73% as men, and 2% as "other" genders. Racial/ethnic identities included White/European American (72%), Asian/Asian American (16%), Hispanic/

Latin American (4%), Black/African American (2%), and multiple or “other” (6%). Majors spanned mechanical/aerospace (26%), chemical/materials/metallurgical (18%), electrical/computer (18%), civil/construction/environmental (12%), industrial/manufacturing (8%), and “all other” engineering (18%). Institutions were represented as follows: MPub (39%), TPub (27%), LPub (18%), and SPri (16%).

4.4 Data Analysis

Data analysis was conducted concurrently to integrate qualitative and quantitative findings, providing a comprehensive understanding of REGs’ professional identities, work classifications, and competency priorities. Table 1 summarizes how each research question was addressed with specific data sources and analysis techniques.

4.5 Classification of Engineering and Non-engineering Work

Survey responses were analyzed to explore how REGs classify their work as engineering or non-engineering by comparing participants’ self-identifications with their reported occupations. Occupational classifications were adapted from the NSF SESTAT framework [38], categorizing roles such as engineering practitioner, consultant, and manager as engineering-related (E), while other roles were classified as non-engineering (N). These classifications were cross-referenced with participants’ self-reported work descriptions as either engineering (e) or non-engineering (n), resulting in four analytic groups:

- E/e: Engineering work in an engineering occupation.

- E/n: Non-engineering work in an engineering occupation.
- N/e: Engineering work in a non-engineering occupation.
- N/n: Non-engineering work in a non-engineering occupation.

Qualitative interviews provided deeper insights into how REGs perceive and define engineering work. These interviews were coded using MAXQDA software, following methods by Patton [50] and Miles and Huberman [54], to capture participants’ reflections on whether they considered their job or degree program to be engineering-related and how they described engineering versus non-engineering work. Coding criteria, along with examples, are detailed in Table 2. To ensure trustworthiness, multiple researchers reviewed coding criteria and segments, applying researcher triangulation [50, 55]. Discrepancies, such as participants being assigned conflicting codes (e.g., “non-engineering” and “some engineering”), were resolved collaboratively through team discussions to ensure accurate sub-code assignments.

4.6 Analysis of Engineering Competencies

To investigate how and why REGs classify their positions as engineering or non-engineering, we analyzed the relevance of 20 engineering competencies to their current work. These competencies, based on ABET Criterion 3 outcomes [40] and the NAE *Engineer of 2020* attributes [41], were rated by survey respondents on a 5-point scale (0 = not important to 4 = extremely important). Mean rank scores for the four analytic groups (E/e, E/n, N/e, N/n) were compared using non-parametric

Table 1. Research methods

| Research Questions | Data | Analysis |
|--|---|--|
| Engineering and Non-Engineering Work Classifications and Identifying Characteristics | | |
| RQ1a. How do REGs’ self-identification as doing engineering or non-engineering work align (or fail to align) with their self-reported occupation? | Cross-sectional survey | Quantitative: Analyzed participants’ self-identification as performing engineering or non-engineering work and their self-reported occupations. |
| RQ1b. In self-identification, what are the distinguishing characteristics of engineering and non-engineering work? | Interviews; Pre-interview questionnaire | Qualitative: Explored participants’ statements about the characteristics of engineering and non-engineering work, along with job titles and self-identification as performing engineering or non-engineering work, as self-reported on the pre-interview questionnaire. |
| Important Competencies Associated with Engineering and Non-Engineering Work | | |
| RQ2a. What is the alignment between REGs’ self-identification as doing engineering or non-engineering work, their self-reported occupation, and the competencies they report as important to their work? | Cross-sectional survey | Quantitative: Examined competencies identified by participants as important to their current jobs, categorized by their self-identification as performing engineering or non-engineering work and their self-reported occupations. |
| RQ2b. How do participants who self-identify as doing engineering or non-engineering work describe applying various competencies in their jobs? | Interviews; Pre-interview questionnaire | Qualitative: Analyzed participants’ descriptions of how competencies are applied in their current roles, incorporating job titles and self-identifications as reported in the pre-interview questionnaire. |

Table 2. Qualitative codes

| Code/Sub-code | Criteria | Examples |
|--|---|--|
| Job Title | As given via open-ended response in the pre-interview questionnaire | Start-up Manager, Regulatory Trainee, Process Engineer, Petroleum Engineer, R&D Engineer, Software Development, Software Engineer, Research Metallurgist, Marketing Development Engineer, Graduate Research Assistant |
| Characteristics of Engineering Work | | |
| <i>Technical</i> | Uses the associated sub-code word or a synonym | "I would say on a basic level engineering work is where I'm using technical skills whether that is thermodynamics or heat transfer or mass transfer." |
| <i>Problem-solving</i> | | "Engineering . . . is dominated by complex problem solving." |
| <i>Design and build</i> | | ". . . coding and designing . . . are things I associate with being an engineer." |
| Characteristics of Non-Engineering Work | | |
| <i>Communication</i> | Uses the associated sub-code word or a synonym | "Things like writing procedures, I don't think that's an engineering task . . ." |
| <i>Management</i> | | "My other rotations involved being a supply chain project manager, being a supervisor, and a research scientist. Research scientist was somewhat close to being an engineer in terms of problem solving but I think a little more [non-engineering] on the supervisor and supply chain project manager." |
| <i>Working with other people</i> | | "The organization as a whole will involve a lot more than just engineering, it also involves interfacing with um, people specializing in marketing and product development and communication." |

Kruskal-Wallis H tests, with significant results further examined through post-hoc Mann-Whitney U tests with Bonferroni corrections. Additional analyses explored variations by gender and undergraduate major, to understand demographic and educational influences on competency prioritization. All statistical analyses were performed using IBM SPSS Statistics Version 28.

Qualitative interviews were coded for the competencies that participants identified as most important to their work using an *a priori* approach. Codes were applied when participants explicitly mentioned survey competencies or used close synonyms. Challenges, such as overlaps and ambiguities in responses, are discussed in the results section. Trustworthiness was ensured through strategies including researcher triangulation and systematic review, as detailed in the previous section.

4.7 Researcher Positionality

Recognizing the importance of researcher positionality, we provide key information about our team. All members identify as both engineers and women, shaping our perspectives on engineering competencies and work classifications. Our experiences in engineering practice, ranging from two to 35 years, bring nuance to this analysis. While most team members have worked in engineering practice, one identifies more closely with academia, and another has no professional engineering experience, reflecting diverse insights. All members have worked as graduate research assistants and view such roles as employment, aligning with the study's focus on early-career professionals. Our shared backgrounds in ABET-accredited undergraduate programs provide familiarity with the competencies emphasized in engineering education, though we

analyze this study with a retrospective lens. These similarities and differences between our experiences and those of the study participants highlight the need for reflexivity in interpreting engineering work.

4.8 Study Limitations

While the sample includes participants from diverse institutions, the findings are limited to the context of REGs and do not capture the experiences of individuals who did not complete their engineering degrees. This excludes insights into how non-graduates perceive engineering or how their educational experiences shape their careers.

Our data from 2011, while providing valuable historical insights and a baseline for early-career engineers, may not fully reflect contemporary challenges due to advancements in technology, workplace culture shifts, and updates to accreditation standards, e.g., [30]. Future research should assess whether the findings remain applicable today. Additionally, the four-year time gap between participants' graduation and data collection highlights the need to understand how the immediate transition from school to work influences perceptions of engineering careers longitudinally.

The study also has limitations in its framing and sample size. Binary classifications of work (engineering or non-engineering) and gender identity (male, female, "other") do not align with more inclusive frameworks, potentially oversimplifying the complexity of professional roles. (Refer to [3, 5, 16], related to classifying engineering work, and [56], related to classifying gender). Further, while the sample size supports broad analyses, it is insufficient to examine granular patterns within individual majors or demographic groups.

Finally, this study focuses on the U.S. context, using U.S.-specific job classifications and educational standards. While some findings may not directly apply internationally, they offer insights into the transition from education to professional practice that are relevant for global discussions on engineering education and workforce development. Future research could explore similar dynamics in other countries to enhance the global applicability of these findings and inform efforts to prepare engineers for evolving professional landscapes.

5. Results

5.1 Classification of Engineering and Non-engineering Work

Analysis of the first research question revealed two key findings. First, survey data showed that more REGs self-identified as performing engineering work (77%) than those who selected engineering as their occupation based on predefined job titles (72%). Those who did not identify as engineers were primarily in business and management roles, as shown in Table 3. Second, interviews highlighted that REGs commonly associated engineering with

technical tasks, problem-solving, and design/build activities, while tasks such as communication, management, and collaboration were often categorized as non-engineering, although not consistently.

Chi-square analyses (Tables 4 and 5) revealed statistically significant differences between occupational titles and self-perceptions ($\chi^2(1, n = 448) = 183.9, p < 0.001$). For instance, 94% of occupational engineers identified as performing engineering work (E/e), while only 33% of occupational non-engineers did so (N/e). First-line engineering managers were less likely to view their work as engineering ($p = 0.027$), while REGs in computer-related and sales-related roles were more likely to do so ($p = 0.039$).

Qualitative interviews further explored these classifications. Among 30 participants, 19 (63%) identified as engaged in engineering work or study, with the remaining 11 reporting non-engineering roles or mixed responsibilities. REGs frequently described engineering as inherently technical, emphasizing problem-solving and design, but often struggled to define non-engineering work, framing it as tasks that lacked a technical component, such as communication or manage-

Table 3. Self-identifications of engineering or non-engineering work by occupation ($n = 448$)

| | Percentage (100.0%) | Percentage who were in: | |
|----------------------------|---------------------|-------------------------|---------|
| | | e Group | n Group |
| Occupational engineers (E) | 72.3 | 93.5 | 6.5 |
| Occupational non-engineers | 27.7 | 33.2 | 66.8 |

Table 4. Occupational titles for occupational engineers (E) ($n = 324$)

| | Percentage (100.0%) | Percentage who were in: | |
|--|---------------------|-------------------------|------------------|
| | | E/e Group (93.5%) | E/n Group (6.5%) |
| Engineering practitioners | 89.5 | 94.1 | 5.9 |
| Engineering researchers or research assistants | 4.0 | 100.0 | 0.0 |
| Engineering managers, first-line or mid-level | 3.7 | 66.7 | 33.3 |
| Engineering consultants | 2.5 | 100.0 | 0.0 |
| Engineering teachers or teaching assistants | 0.3 | 100.0 | 0.0 |

Table 5. Occupational titles for occupational non-engineers (N) ($n = 124$)

| Occupational title ¹ | Percentage (100.0%) | Percentage who were in: | |
|---|---------------------|-------------------------|-------------------|
| | | N/e Group (33.2%) | N/n Group (66.8%) |
| Computer related occupations | 16.9 | 57.1 | 42.9 |
| Management, non-engineering related | 16.1 | 30.0 | 70.0 |
| Consultant, non-engineering related | 11.3 | 28.6 | 71.4 |
| Business and finance occupations | 10.5 | 15.4 | 84.6 |
| Researchers or research assistants, non-engineering related | 8.1 | 30.0 | 70.0 |
| Military related occupations | 7.3 | 33.3 | 66.7 |
| Sales related occupations | 4.8 | 83.3 | 16.7 |
| Teachers or teaching assistants, non-engineering related | 4.8 | 0.0 | 100.0 |
| Legal related occupations | 4.0 | 20.0 | 80.0 |
| Other occupations (e.g., arts/entertainment, health, service) | 16.1 | 25.0 | 75.0 |

¹ Occupations comprising > 1% of occupational non-engineers shown.

ment. For example, Karen described writing procedures as non-engineering, even while acknowledging its necessity due to her expertise.

“There [are] parts of the job that I don’t think make use of my engineering skills, but . . . things like writing procedures . . . it’s necessary just because I’m the one with the knowledge in order to write that procedure.”

Some participants viewed their roles as a blend of engineering and non-engineering tasks. John, for instance, described his job as “50/50” split between them, distinguishing technical calculations from broader responsibilities such as collaboration and time management. Similarly, Grace, an engineering manager, felt disconnected from “real” engineering work due to her focus on supervisory tasks, despite recognizing problem-solving aspects of her role.

“I kinda joke with my programmers that when someone new comes in and they ask like, ‘Oh, what do you do?’ I kinda joke like, ‘Oh, I don’t really do anything.’ Because I’m not actually in there coding, working at the specific problems. I think my job is a little more general in how it gets described . . . It’s making sure everything’s running smoothly. I think that’s part of the management aspect of my job. But there’s also . . . this element of solving problems, which would define, at some point, engineering.”

Even participants with engineering-related titles did not always perceive their work as “pure engineering.” Paige, a program manager, noted her role lacked technical activities, such as coding or design, influencing her perception of engineering as primarily technical.

“I’m not sure if my idea of a pure engineering job has changed that much except for my opinion of what a program manager in engineering [is] . . . but I’ve been told that it is not a pure engineering job but that it falls under . . . engineering.”

These reflections underscore a tension between traditional definitions of engineering and the evolving nature of roles that integrate technical and professional competencies. They highlight the challenges REGs face in aligning their responsibilities with conventional engineering identities.

5.2 Analysis of Engineering Competencies

Analysis of competencies REGs found most relevant to their work revealed three key findings. First, the survey results showed that REGs consistently rated both technical and professional competencies as important, regardless of occupational classification. Second, REGs who self-identified as engineers prioritized technical competencies more highly and professional competencies less highly compared to non-engineers, with these preferences further shaped by gender and undergraduate major. Third, interviews revealed that participants often struggled to separate competencies such as pro-

blem-solving and engineering tools, underscoring the interconnected nature of skills in practice. Together, these findings highlight the shared and distinct ways REGs value competencies and the complexities of articulating these distinctions.

Quantitative analysis (Table 6) identified problem-solving, communication, analytical skills, teamwork, and professionalism as the most valued competencies, with ratings in the “very” to “extremely” important range. Conversely, competencies such as planning experiments, understanding societal contexts, and knowledge of economic or environmental issues were rated as less important.

Further, while professional competencies such as communication and teamwork showed no significant differences across groups, technical competencies such as engineering tools ($U = 172.64$, $df = 1$, $p < 0.001$) and design ($U = 94.64$, $df = 1$, $p < 0.001$) were rated as significantly more important by E/e compared to N/n respondents, who placed greater emphasis on leadership ($U = -44.30$, $df = 1$, $p = 0.024$) and management skills ($U = -47.914$, $df = 1$, $p = 0.010$). E/n respondents rated technical competencies such as design ($U = 89.21$, $df = 1$, $p = 0.010$) and analytical skills ($U = 86.35$, $df = 1$, $p = 0.007$) as less important and leadership ($U = -85.82$, $df = 1$, $p = 0.013$) as more important than E/e respondents. N/e respondents rated engineering tools ($U = 120.33$, $df = 1$, $p < 0.010$) and science ($U = 69.22$, $df = 1$, $p = 0.024$) as more important than N/n respondents, suggesting that N/e respondents perceived their roles as requiring greater technical expertise.

To further examine group differences, we analyzed results by gender and undergraduate major, identifying statistically significant omnibus tests in both cases. Among REG men, E/n respondents rated technical competencies such as analytical skills ($U = 68.07$, $df = 1$, $p = 0.014$) and engineering tools ($U = 86.35$, $df = 1$, $p = 0.002$), as less important than E/e respondents. REG women in the E/n group placed greater importance on leadership ($U = 40.71$, $df = 1$, $p = 0.025$) than E/e women. Additionally, REGs with mechanical/aerospace and electrical/computer engineering degrees in the N/e group rated engineering tools significantly higher than their N/n counterparts ($U = 48.03$, $df = 1$, $p < 0.001$; $U = 24.47$, $df = 1$, $p = 0.047$), showing a strong association between these competencies and engineering, even in non-engineering roles. No other significant differences by gender or major were observed.

Qualitative interviews revealed communication as the most frequently cited competency, aligning with survey results where it was consistently rated as “very” to “extremely” important. Participants

Table 6. Participants' views of the importance of ABET/*Engineer of 2020* competencies to their work (n = 448)

| Knowledge or Skill | Mean (SD) | | | | | Kruskal-Wallis <i>H</i> Test | | |
|---------------------------------|-----------------------------|-----------------|-----------------|----------------|-----------------|------------------------------|----|-------------------|
| | Employed respondents (100%) | E/e Group (67%) | N/e Group (11%) | E/n Group (4%) | N/n Group (18%) | <i>H</i> | df | <i>p</i> -value |
| Problem solving | 3.48 (0.75) | 3.56 (0.68) | 3.41 (0.67) | 3.29 (1.06) | 3.27 (0.89) | 9.93 | 3 | 0.001 |
| Communication | 3.40 (0.73) | 3.40 (0.69) | 3.24 (0.83) | 3.57 (0.68) | 3.45 (0.80) | 4.07 | 3 | 0.254 |
| Analytical skills | 3.30 (0.75) | 3.37 (0.70) | 3.32 (0.72) | 2.76 (0.89) | 3.17 (0.85) | 12.47 | 3 | 0.006 |
| Teamwork | 3.24 (0.83) | 3.29 (0.77) | 3.12 (0.75) | 3.14 (0.85) | 3.12 (1.05) | 2.67 | 3 | 0.446 |
| Professionalism | 3.08 (0.91) | 3.08 (0.90) | 3.05 (0.84) | 2.95 (0.97) | 3.14 (0.99) | 1.68 | 3 | 0.643 |
| Engineering techniques/tools | 2.57 (1.18) | 3.00 (0.87) | 2.54 (1.03) | 2.00 (1.10) | 1.19 (1.12) | 131.27 | 3 | < 0.001 |
| Managing uncertainty | 2.90 (1.03) | 2.86 (1.02) | 3.10 (1.04) | 3.19 (0.87) | 2.86 (1.07) | 4.30 | 3 | 0.231 |
| Ethics | 2.80 (1.13) | 2.84 (1.09) | 2.54 (1.21) | 2.90 (1.30) | 2.77 (1.20) | 2.81 | 3 | 0.422 |
| Leadership | 2.65 (1.03) | 2.56 (1.00) | 2.61 (1.07) | 3.24 (0.83) | 2.87 (1.14) | 15.91 | 3 | 0.001 |
| Lifelong learning | 2.51 (1.11) | 2.54 (1.05) | 2.20 (1.35) | 2.43 (1.08) | 2.58 (1.23) | 2.97 | 3 | 0.396 |
| Design | 2.24 (1.23) | 2.52 (1.15) | 1.78 (1.06) | 1.62 (1.16) | 1.58 (1.22) | 48.90 | 3 | < 0.001 |
| Management skills | 2.62 (1.08) | 2.51 (1.04) | 2.66 (1.15) | 3.14 (1.01) | 2.87 (1.15) | 16.43 | 3 | 0.001 |
| Creativity | 2.33 (1.00) | 2.38 (0.95) | 2.17 (0.89) | 2.14 (1.06) | 2.25 (1.17) | 2.24 | 3 | 0.523 |
| Math | 2.19 (1.13) | 2.37 (1.05) | 2.12 (1.17) | 1.86 (0.85) | 1.65 (1.25) | 26.45 | 3 | < 0.001 |
| Science | 2.04 (1.21) | 2.28 (1.07) | 1.93 (1.25) | 2.00 (1.05) | 1.23 (1.32) | 48.88 | 3 | < 0.001 |
| Business knowledge | 2.22 (1.10) | 2.11 (1.00) | 2.46 (1.03) | 2.71 (0.96) | 2.36 (1.40) | 12.51 | 3 | 0.006 |
| Planning/conducting experiments | 1.81 (1.38) | 2.00 (1.35) | 1.73 (1.47) | 1.33 (1.11) | 1.27 (1.34) | 21.61 | 3 | < 0.001 |
| Environmental context | 1.52 (1.16) | 1.69 (1.16) | 1.15 (1.09) | 1.95 (1.07) | 0.99 (1.02) | 31.72 | 3 | < 0.001 |
| Economic issues | 1.63 (1.17) | 1.67 (1.15) | 1.27 (1.12) | 1.81 (1.03) | 1.63 (1.30) | 4.92 | 3 | 0.178 |
| Global/societal context | 1.65 (1.22) | 1.60 (1.18) | 1.68 (1.25) | 1.81 (1.33) | 1.76 (1.34) | 1.15 | 3 | 0.766 |

Responses for each item measured on a 5-point ordinal scale, from 0 = not important to 4 = extremely important. Significant Kruskal-Wallis *H* tests ($p < 0.05$) are **bolded**.

emphasized its critical role in professional success. For example, Samantha, a graduate student, highlighted its importance in sharing ideas effectively:

“I’d say number one would be communication, skills in writing, oral presentations . . . you can do the most amazing work but if you don’t know how to show other people, then I think it’s not going to really help you too much.”

In industry, participants such as Laura and Josh stressed the need for clarity when working with both technical and non-technical audiences:

“I see communication being very key because I have to communicate recommendations and changes to operations to a wide variety of people . . . from people with engineering experience in my own group, to operators who typically have a high school education, to operating management who maybe were operators who have many years of experience who are now management. And so, being able to communicate to a wide array of people our goals and what we want to do is very important.” [Laura]

“Definitely communication. I’m responsible for writing out projects in a clear way that will make sense to non-engineers and engineers.” [Josh]

While communication was universally valued, other competencies, such as problem-solving, analytical skills, professionalism, managing uncertainty, ethics, and lifelong learning, were less

frequently discussed in interviews despite their high survey ratings. This discrepancy may reflect the open-ended interview format, which allowed participants to describe their roles broadly but did not probe specific competencies. In addition, some skills may have been embedded within broader tasks and not explicitly recognized by participants.

Competencies often overlapped, further complicating their categorization. For instance, problem-solving frequently encompassed analytical skills and technical expertise. Leah described her “technical skills” as essential to problem-solving, while Oscar highlighted the integration of technical and analytical tasks in life-cycle assessment: “Manipulating data to make it easily readable.” These examples underscore the fluid and interconnected nature of competencies in real-world practice.

6. Discussion

In a departure from prior studies focused on established professionals or students, e.g., [12, 34, 46–48], this study examined how REGs define and navigate their roles relative to engineering during the critical transition from education to the workforce. By focusing on this early career stage, the research provides a unique perspective on the alignment between academic preparation and pro-

fessional demands, as well as early-stage development of engineering identities.

Findings revealed a persistent tension between traditional, technically focused views of engineering and the sociotechnical realities of modern practice. REGs often rooted their identities in technical markers that include problem-solving, design, and analysis, reflecting a longstanding technical/social dualism in engineering [10, 15, 19, 20]. This dualism prioritizes technical tasks over professional skills such as leadership, managing uncertainty, and collaboration, creating identity conflicts in hybrid and interdisciplinary roles.

Role identity theory helps explain REGs' struggles to reconcile technical and professional competencies. This theory highlights the interplay of internal beliefs, societal norms, and external validation in shaping professional identities [31]. REGs in this study often struggled to legitimize professional activities, such as communication or management, within their engineering identity, particularly in roles where their professional competencies were undervalued. The study also shed light on how REGs categorize their work as engineering or non-engineering. Many REGs framed non-engineering work as lacking technical elements and thus "not engineering," aligning with McCall's [57] concept of identity and counter-identity. These tensions challenge binary definitions of engineering and call for more holistic frameworks that reflect the integration of technical and professional dimensions [2, 13–15].

The research also revealed variability in how REGs perceive engineering work, even within similar roles. For instance, some REGs working as engineering managers viewed management tasks as integral to their engineering identity, while others felt these responsibilities distanced them from technical work. This variability reflects the fluidity of engineering identity, shaped by job roles, workplace culture, and prior educational experiences, e.g., [16, 34, 35, 58–60]. REGs with technical-heavy undergraduate degrees were more likely to associate technical competencies with the engineering identity, even in non-engineering titled roles, supporting previous research that certain engineering curricula emphasize technical skills over social and collaborative competencies [17, 28, 29]. Gender dynamics added further complexity: men were less likely to view non-technical tasks as engineering, while women often categorized leadership roles as non-engineering. These differences reflect the gendered association of technical tasks with engineering and masculinity, and social tasks with non-engineering and femininity [10–12].

Lastly, while communication emerged as a universally valued competency bridging technical and

interpersonal tasks, other skills such as managing uncertainty, lifelong learning, and professionalism were less frequently mentioned in the interviews, despite their high importance ratings in the survey. This discrepancy highlights the interconnected nature of competencies, as REGs often viewed problem-solving as encompassing analytical skills and technical tools. These findings reinforce the need to integrate and articulate professional competencies within educational and professional frameworks.

7. Implications

This study highlights the need to redefine engineering education and professional development to better reflect the sociotechnical realities of modern practice. While our findings did not directly assess outcomes such as satisfaction or retention, prior research shows that when REGs feel both their technical and professional competencies are valued, they are more likely to experience belonging and fulfillment in the workplace [25, 61, 62]; thus, to support REGs' success, both skill sets must be developed and recognized.

Engineering educators play a crucial role in shaping these perceptions, yet curricula often prioritize technical problem-solving while downplaying leadership, communication, and collaboration [8, 17, 22]. These professional competencies should be embedded into real-world learning experiences such as interdisciplinary projects, sociotechnical case studies, and capstone design to reinforce their relevance [29, 63, 64]. Accreditation standards already support this approach (e.g., [30]), but implementation remains uneven. Introducing sociotechnical thinking early, including in K-12 education, can help shift perceptions of engineering before students reach college [65–67].

Employers and professional organizations also shape how engineering is defined. Expanding definitions to include both technical and professional work can help REGs feel more validated in interdisciplinary roles. Mentorship, professional development [15, 22, 68], and recognition of engineers who integrate these competencies [12, 17, 69] can also challenge outdated norms and promote more inclusive pathways.

Policymakers and accrediting bodies can further drive systemic change by funding interdisciplinary programs, supporting collaborative learning, and encouraging curricula that reflect real-world practice [70–72]. Co-ops and summer bridge programs that emphasize sociotechnical collaboration can be particularly effective, e.g., [73–74]. Integrating social justice, civic responsibility, and inclusive frameworks into engineering education is also

essential for preparing engineers to address the full scope of today's challenges [60, 75, 76].

8. Future Work

This study relied on a binary classification of work as either engineering or non-engineering, a choice that simplified analysis but oversimplified the complex, blended nature of professional roles. REGs often described responsibilities integrating both technical and professional skills, highlighting the limitations of such frameworks. Revisiting these classifications with more nuanced categories or open-ended questions could better capture how REGs perceive their roles and responsibilities. Future research should explore approaches focused on competencies and tasks rather than rigid categorizations, uncovering more integrated conceptions of technical and professional dimensions, e.g., [5, 16, 17]. For instance, participants identified communication as essential but struggled to articulate its intersection with technical tasks. Broader frameworks capturing the holistic nature of engineering work would address this gap and provide deeper insights into how these dimensions coexist in practice.

Building on these insights, future research could focus on how educational experiences shape students' perceptions of engineering as technical or sociotechnical, which pedagogical strategies inform more inclusive definitions of engineering, and how integrating professional skills into education

impact engineering graduates over time [14, 36, 77]. Additionally, research on workplace dynamics, including mentorship, leadership development, and organizational culture, is needed to understand how they influence REGs' perceptions of their technical and professional responsibilities and, subsequently, their development of engineering identities. Further studies on gendered and disciplinary patterns in engineering perceptions and global comparisons of cultural and institutional influences could also provide valuable insights for fostering inclusive and adaptable professional frameworks.

9. Conclusions

This study examined how recent engineering graduates define their work, prioritize competencies, and navigate the boundary between engineering and non-engineering roles. Findings show that REGs often associate engineering with technical tasks, while viewing essential professional skills as outside that definition. This disconnect reveals a narrow understanding of engineering that does not reflect the realities of modern practice. To address this, engineering identities must evolve to integrate both technical and professional competencies. Narrow definitions limit how REGs see themselves and how their work is recognized. A more inclusive view of engineering will better support graduates in the interdisciplinary, collaborative roles that define today's workforce.

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Samantha R. Brunhaver, PhD, is an Associate Professor at The Polytechnic School within the Ira A. Fulton Schools of Engineering at Arizona State University. She earned her bachelor's degree from Northeastern University and her master's and doctoral degrees from Stanford University, all in mechanical engineering. Her research leverages both quantitative and qualitative methods to explore critical issues in engineering education and workforce development, including undergraduate persistence, early career pathways, and faculty mentorship.

Cheryl Carrico, PhD, is the owner of E4S, LLC, which provides value through a combination of research and practice in industry and engineering education. Her research focuses on engineering education to understand and improve engineering pathways for students and how to improve students' and early career professionals' metacognitive skills. Combining methods such as Cognitive Apprenticeship with over 30 years of industry experience, Dr. Carrico works with people from interns to C-level management and university faculty to help improve employee knowledge, productivity, and efficiency.

Holly M. Matusovich, PhD, is the Associate Dean of Graduate and Professional Studies and Professor of Engineering Education at Virginia Tech. She is also the Director of the Studies in Motivation and Identity in Learning Engineering research group. Dr. Matusovich's research uses motivation and identity related theories to examine ways to break down

barriers, create opportunities, and engage all stakeholders (students, parents, teachers, co-workers) in thoughtful teaching and learning processes.

Rachel L. Kajfez, PhD, is an Associate Professor in the Department of Engineering Education at The Ohio State University. She earned her BS and MS degrees in Civil Engineering from Ohio State and earned her PhD in Engineering Education from Virginia Tech. Her research interests focus on the intersection between motivation and identity of undergraduate and graduate students, first-year engineering programs, mixed methods research, and innovative approaches to teaching. She is the principal investigator for the Research on Identity and Motivation in Engineering (RIME) Collaborative.

Susan Sajadi, PhD, is an Assistant Professor of Engineering Education at Virginia Tech. She earned her BSE and MS degrees in Biomedical Engineering and PhD in Engineering Education Systems and Design from Arizona State University. Before pursuing her PhD, she worked as a biomedical engineer and in corporate social responsibility related to STEM outreach. Her research interests span STEM educational settings and the engineering workplace.

Sheri D. Sheppard, PhD, is Professor Emerita of Mechanical Engineering at Stanford University. Her research spans fracture mechanics, finite element analysis, and engineering education, namely, how people become engineers. She has led several large, multi-institutional initiatives, including the Center for the Advancement of Engineering Education (CAEE) and the National Center for Engineering Pathways to Innovation (Epicenter). With industry experience at Ford, GM, and Chrysler, she holds a BS from the University of Wisconsin and a PhD from the University of Michigan.