Performing at the Boundaries: Narratives of Early Career Engineering Practice

Brent K. Jesiek (corresponding author: bjesiek@purdue.edu)
School of Engineering Education, Purdue University, West Lafayette, IN

Natascha T. Buswell
Department of Mechanical and Aerospace Engineering, University of California, Irvine, CA

Swetha Nittala
Department of Mechanical Engineering, Stanford University, Stanford, CA

Abstract
The realities of engineering practice remain opaque and constantly evolving, often leaving graduates underprepared for the workplace and employers dissatisfied with new employees. In this study we shed new empirical light on the lived working experiences of early career engineers in large manufacturing firms. We adopt boundary spanning as the primary framework for our research given growing recognition of its importance in the workplace and potential utility for conceptualizing engineering practice. We specifically address the research question: What kinds of boundary spanning do early career engineers experience in their daily work? Our study is based on interviews with 23 early career engineers analyzed using a thematic analysis approach to code for boundary spanning and other related themes. We then wrote third-person constructed narratives to holistically portray the day-to-day work of three participants. Our findings illustrate how engineers frequently encounter many different types of boundaries and perform specific boundary spanning activities. The narratives also illuminate early career progression, including evidence of increasing leadership responsibilities as engineers navigate evolving job role demands and organizational expectations. We conclude with directions for future research, and discuss how our findings speak to ongoing efforts to reimagine professional practice while improving engineering education and professional development.

Keywords: boundary spanning; early career; engineering practice; narratives; thematic analysis

Introduction

Navigating the early stages of an engineering career is often fraught with challenges. Recent scholarship on the school-to-work transition has highlighted persistent skills gaps between education and practice[1], tensions related to personal and professional identity development[2], and socialization difficulties as employees adjust to new organizations and full-time job roles.[3] Women and other minoritized groups in engineering often face additional

[1] Brunhaver et al., "Bridging the Gaps Between Engineering Education and Practice," 2018.
[2] Huff et al., "Identity in Engineering Adulthood," 2019.
[3] Korte, "How Newcomers Learn the Social Norms of an Organization," 2009.

challenges transitioning and socializing into engineering careers.[4] Many engineers also work in companies and industries characterized by frequent organizational restructuring, intensified globalization dynamics, ongoing demographic shifts, and new patterns of remote work. One recent report additionally describes the pervasive impacts of accelerated technological change across fields and sectors, creating and transforming jobs while increasing pressure for upskilling and reskilling.[5] These and other trends are only likely to accelerate due to the COVID-19 pandemic.[6]

One obstacle to addressing these issues is the dearth of research on engineering practice; in particular, we know surprisingly little about the lived experiences of engineers within and across career stages.[7] Efforts to critically evaluate and positively transform engineering education and practice are potentially undermined by a relative lack of empirically-grounded portrayals of technical work and associated conceptual and theoretical frameworks.[8] Without such empirical insights, academic and corporate stakeholders are at a disadvantage in addressing widespread and persistent difficulties related to recruiting and retaining minoritized groups[9], and more generally improving career satisfaction, productivity, and job tenure.[10] Realizing the full potential of engineers as responsible professionals and engaged citizens will also likely be hindered if engineers themselves do not understand the roles they are expected to play in their employing organizations – and society more generally.

Seeking innovative ways to conceptualize and investigate what engineers do, our own research starts with the proposition that engineering work frequently involves boundary spanning. In brief, boundary spanning occurs when individuals coordinate, collaborate, and/or communicate across various types of boundaries, e.g., organizational, stakeholder, demographic, time and space, knowledge, etc.[11] We adopt this framing for two main reasons. First, boundary spanning has been recognized as relevant and important for professionals in many fields, including engineering.[12] Second, the concept of boundary spanning is complementary to views of engineering as a thoroughly sociotechnical enterprise.[13] That is, engineering practice often

---

[4] Faulkner, "Doing Gender in Engineering Workplace Cultures I," 2009; Faulkner, "Doing Gender in Engineering Workplace Cultures II," 2009; Hill, Corbett, and St. Rose , *Why so Few?*, 2010; Ross, "A Unicorn's Tale," 2016. We use the term "minoritized" to make explicit the active structural dynamics that force people into groups and enable discrimination. See Smith, "Minority versus Minoritized," 2016.

[5] World Economic Forum (WEF), *The Future of Jobs Report 2018*, 2018.

[6] Lund et al., "The Future of Work After COVID-19," 2021.

[7] Stevens, Johri, and O'Conner, "Professional Engineering Work," 2014.

[8] With some notable exceptions, e.g., Trevelyan, *The Making of an Expert Engineer*, 2014, Appendix 4.

[9] National Center for Science and Engineering Statistics (NCSES), *Women, Minorities, and Persons with Disabilities in Science and Engineering*, 2021.

[10] Gonzalez, "Is the Engineering Profession Still a 'Good' Job?," 2018.

[11] Jesiek et al., "Becoming Boundary Spanners in Engineering," 2015.

[12] Hanneman and Gardner, "Under the Economic Turmoil a Skills Gap Simmers," 2010; Johri, "Boundary Spanning Knowledge Broker," 2008; Lynn and Salzmann, "Collaborative Advantage," 2006.

[13] Cohen, "Introducing Engineering as a Socio-technical Process," 2014; Jesiek et al., "Toward a Typology of the Sociotechnical," 2019.

involves both the application of technical expertise *and* social interactions. While boundary spanning may appear to emphasize the latter, it does not require *a priori* distinctions between the social and technical, and also accommodates individual encounters with boundaries that are not as directly social, e.g., time, physical space, knowledge embedded in documents or systems, etc.

The present study is focused on the specific question: "What kinds of boundary spanning do early career engineers experience in their daily work?" To address this question, we draw on data from a larger qualitative study involving semi-structured interviews with 23 early career engineers in the U.S. manufacturing sector, and with three of these participants as the main focus of this paper. We begin with a literature review that introduces related scholarship, and then present our methods and findings. Using a mix of thematic and narrative approaches, we highlight how early career engineers experience and perform boundary spanning, especially as they encounter and become attuned to their job roles, workgroups, and organizations.[14] We close the paper by critically evaluating and discussing future directions for research on engineering practice; early career pathways and job roles; and considerations for individuals from minoritized groups. We additionally note some implications for engineering education and professional development.

Literature Review

Prior research on engineering practice includes a variety of empirical studies across disciplines and time. Williams and Figueiredo[15] cite important precursor works from the early 20th century, as well as quantitative studies in the 1960s and 1970s that generated detailed characterizations of technical practice.[16] Empirical studies of engineers and engineering attracted renewed attention in the 1980s, especially among science and technology studies (STS) scholars, followed by the emergence of engineering studies as a distinct field in the 1990s and 2000s.[17] Nonetheless, Stevens, Johri, and O'Conner observe a relative "dearth of empirical descriptions of professional engineering work."[18] This gap is especially striking compared to the ongoing proliferation of engineering education scholarship mainly focused on formal teaching and learning; we know much more about how engineers are taught than about how they practice. At the same time, broader processes of technological, organizational, and social change are transforming technical work and threaten to make earlier research obsolete.

Stevens, Johri, and O'Conner also underscore that "field study" approaches are predominant in research on engineering practice, with interviews and on-site observations frequently serving as primary data sources.[19] Bucciarelli's early ethnographic studies of

[14] While we do not adopt a fully performative approach to analyzing practice in this paper, we take inspiration from related works such as Hodgson, "'Putting on a Professional Performance'", 2005; Faulkner, "Doing Gender in Engineering Workplace Cultures I," 2009; Faulkner, "Doing Gender in Engineering Workplace Cultures II," 2009.
[15] Williams and Figueiredo, "Engineering Practice as an Emerging Field of Inquiry," 2016.
[16] For example, see Heywood, "The Education of Professional Mechanical Engineers," 1966.
[17] Downey and Lucena, "Engineering Studies," 1994; Downey, "What is Engineering Studies For?," 2009.
[18] Stevens, Johri, and O'Conner, "Professional Engineering Work," 2014, p. 120.
[19] Stevens, Johri, and O'Conner, "Professional Engineering Work," 2014, p. 120.

practicing engineers are important touchstones for this type of scholarship.[20] He particularly emphasized how engineers often negotiate different "object worlds," or technical conventions and cultures that are partially or wholly specific to particular disciplines and job roles. Trevelyan and colleagues have more recently undertaken a series of ambitious efforts to develop detailed characterizations of engineering practice using field observations, interviews, and time use surveys of engineers in Australia, Asia, and Portugal.[21] These and other studies provide strong evidence that the average engineer spends much more work time on "technical coordination" and other types of social (or sociotechnical) interactions as opposed to solitary technical work.[22]

Another related vein of scholarship centers on studies of the school-to-work transition and early career experiences. For example, Brunhaver et al. used interview and survey data to examine gaps between engineering education and practice, including comparing skills and knowledge taught in school versus what early career engineers use in their job roles.[23] Like others, these researchers note the prevalence of "non-technical tasks that require significant social interaction, such as managing projects and coordinating the work of other people."[24] Along similar lines, Martin et al. used interviews with recent chemical engineering graduates in South Africa to explore their perceived readiness for work in industry.[25] They found that technical, teamwork, communication, and interpersonal skills were viewed as most important among participants. Huff et al., on the other hand, used interviews to reveal the psychological journeys of engineers as they transitioned from school to work[26], while studies by Korte and colleagues used interview data to investigate socialization experiences among early career engineers in corporate/industry settings.[27] Such research sheds further light on the personal and professional challenges faced by early career engineers.

A final body of literature worth noting invokes the concept of boundary spanning to describe aspects of technical practice. For example, Johri used interviews and field observations to investigate global work practices among software and R&D professionals in two firms.[28] One main finding was that participants were frequently challenged and expected to assume roles as "boundary spanning knowledge brokers." Additionally, Jesiek et al. performed a qualitative systematic review of 72 papers on boundary spanning and related topics, resulting in a synthesis framework with six boundary types, three boundary roles and definitions, and four kinds of boundary spanning activities.[29] Further, 20 of the 72 papers in this review included engineers or other technical professionals as research subjects, and seven of these were exclusively focused

---

[20] Bucciarelli, *Designing Engineers*, 1996.
[21] Trevelyan, "Reconstructing Engineering From Practice," 2010; Trevelyan, *The Making of an Expert Engineer*, 2014; Williams and Figueiredo, "Finding Workable Solutions," 2013.
[22] Trevelyan, "Technical Coordination in Engineering Practice," 2007.
[23] Brunhaver et al., "Bridging the Gaps Between Engineering Education and Practice," 2018.
[24] Brunhaver et al., "Bridging the Gaps Between Engineering Education and Practice," 2018, pp. 149-150.
[25] Martin et al., "Engineering Graduates' Perceptions of How Well They Were Prepared," 2005.
[26] Huff et al., "Identity in Engineering Adulthood," 2019.
[27] Korte, "How Newcomers Learn the Social Norms of an Organization," 2009; Korte & Li, "Exploring the Organizational Socialization of Engineers in Taiwan," 2015; Korte, Brunhaver, and Sheppard, "(Mis)Interpretations of Organizational Socialization," 2015.
[28] Johri, "Boundary Spanning Knowledge Broker," 2008.
[29] Jesiek et al., "Boundary Spanning and Engineering," 2018.

on engineers or engineering.[30] The present study builds on and extends this prior effort to establish a more comprehensive understanding of boundary spanning, particularly in relation to engineering practice.

Methods

Conceptual and Theoretical Background

The aforementioned qualitative systematic literature review enhanced our conceptual and theoretical understanding of boundary spanning, as illustrated in Figure 1.[31] The shaded cells were initially the main focus of the present investigation, and are at the heart of the data analysis codebook described below. The solid white cells are emergent, secondary themes mentioned or alluded to in our findings, while the dashed cells are topics identified in our literature review but not specifically discussed in this paper.

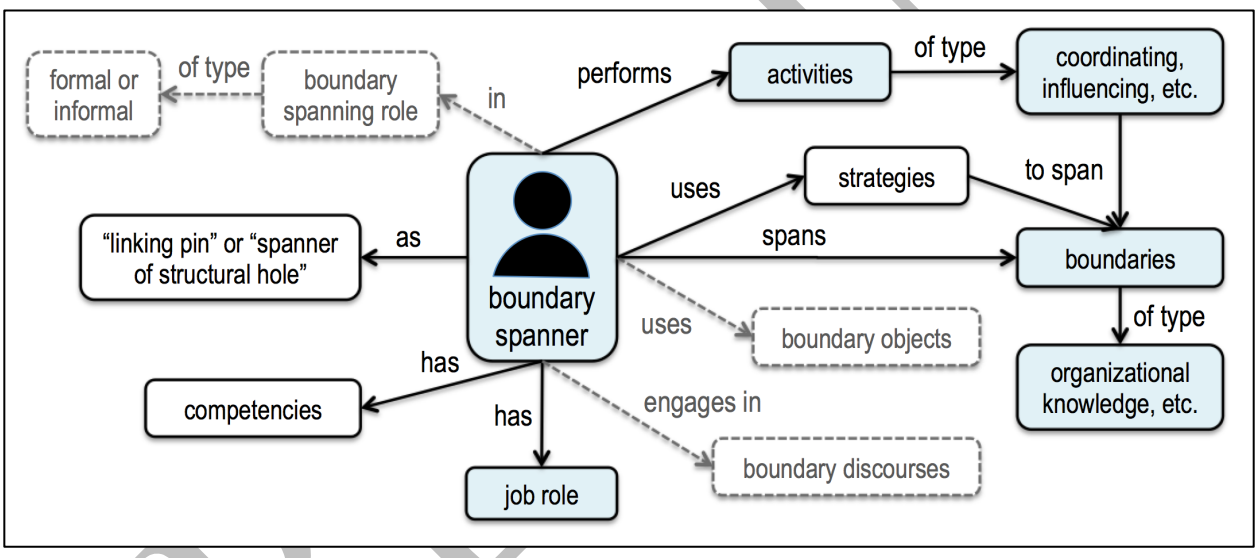

Fig. 1. Synthesis of boundary spanning concepts (adapted from Jesiek et al., "Boundary Spanning and Engineering," 2018)

Positionality Statement

The research team employs a constructivist research paradigm, believing that people construct unique understandings of the world based on their own identities and experiences.[32] All co-authors hold degrees in both engineering and the social sciences, and all have worked in corporate environments, including in technical roles. Given their experiences and affiliations in the engineering education field, the researchers acknowledge potential biases associated with their desire to improve how engineers are prepared to serve their employers and society.

[30] Jesiek et al., "Boundary Spanning and Engineering," 2018. For example, see Hsiao, Tsai, and Lee, "Collaborative Knowing," 2012.
[31] Jesiek et al., "Boundary Spanning and Engineering," 2018.
[32] Guba and Lincoln, "Competing Paradigms in Qualitative Research," 1994.

Recruitment and Selection of Interview Participants

Recruitment for this larger study targeted engineering students with multiple internship or co-op work experiences and graduates in the early years of their first full-time job roles. We sought participants with experience in large manufacturing companies, as this is a common employment setting for engineers and set practical bounds on the study context. Recruitment occurred through contacts and networks maintained by members of the lead author's research group. Convenience and purposeful sampling helped stratify the participant pool. Of 23 interviewees, 13 identified as male and 10 as female, and 17 identified as White or Caucasian, two as South Asian, one as East Asian, one as Black or African American, and two as multi-racial. The participants held or were pursuing bachelor's degrees in aerospace, chemical, electrical/computer, industrial, and mechanical engineering. One interviewee held a Master's degree in engineering. Some participants held or were seeking a degree from the lead author's university.

Participants identifying a female were overrepresented in our sample, i.e., about 43.5% versus a U.S. national figure of 14.5% in 2015.[33] Respondents identifying as Caucasian/White were also overrepresented, comprising 73.9% of our sample as compared to a U.S. national figure of 63.1% in 2015.[34] One of the participants who is specifically highlighted in this paper identified as female and of South Asian ethnicity, and the other two identified as male and Caucasian/White. We present this demographic information mindful of the argument that we should "shift the default" in research studies, including by explicitly naming and framing the presence of "whiteness and maleness."[35]

Interview Procedures

We conducted 27 total interviews with 23 participants. Of 19 participants who completed only one interview, 10 were students with multiple internship or co-op experiences, and 9 were engineers in full-time job roles. We conducted two interviews with the remaining four participants, once prior to graduation and once after starting full-time employment. Each interview lasted between 30 and 90 minutes and was conducted and recorded face-to-face or via Skype. Participants received $50 compensation for completing the study procedures. All data collection was carried out following appropriate human subjects research procedures, approved under Purdue University IRB protocol no. 1208012567. Pseudonyms are used to refer to each participating individual in our findings, and we do not include any other identifying details.

A semi-structured interview protocol, as shown in Appendix A, guided our data collection. Our approach had three key features. First, we used ethnographic interviewing techniques to explore the day-to-day work experiences of participants.[36] For example, we started the interview with "grand tour" questions to encourage participants to share what is most important and meaningful to them. We also told participants that we wanted them to do most of the talking since we saw them as experts on their own lives. Second, we used a critical incident approach to delve deeper into the experiences of participants.[37] For instance, we often asked them to discuss specific examples, successes, and challenges in current and previous job roles.

---

[33] National Science Board, *Science and Engineering* Indicators, 2018, Ch. 3.
[34] National Science Board, *Science and Engineering* Indicators, 2018, Ch. 3.
[35] Pawley, "Shifting the 'Default'," 2017.
[36] Frank, *Ethnographic Interviewing for Teacher Preparation and Staff Development*, 2011.
[37] Webster and Mertova, *Using Narrative Inquiry as a Research Method*, 2007.

A third feature to our data collection approach involved asking all interviewees to review a one-page primer document that was developed based on the aforementioned literature review.[38] We used this document to help sensitize participants to the concept of boundary spanning, and to elicit further insights from them during interviews. However, the primer usually received little attention until the final part of the interviews when participants were invited to comment on boundary spanning activities and/or boundary types that had not yet been discussed.

Multiple members of the research team conducted interviews. To improve the quality of data collection, new interviewers were first asked to review and/or code previous interviews. Each interview was transcribed verbatim by a member of the research team or third-party service provider, then reviewed for accuracy and anonymized for further analysis.

Qualitative Analysis of the Interview Data

Each transcript was loaded into the NVivo application and coded using a hybrid deductive/inductive thematic analysis process.[39] Much of the codebook was developed deductively based on the aforementioned literature.[40] We also let the data challenge and modify the codebook as other themes emerged inductively. For example, communication was listed as a competency in our original framework, but during data analysis we coded for "general or cross-cutting communication-related activities" (see Table 1 below) that did not fit in other activity categories. We also added a "technical" activity code to track specific interactions or tasks that involved technical expertise, e.g., performing calculations, modifying CAD drawings, etc. Every interview was coded independently by at least two members of a larger research team, who then met to discuss and resolve any disagreements. The final set of codes appearing in this paper are summarized in Table 1, while a prior publication gives an overview of the entire codebook.[41]

We originally sought to separately illustrate each of the boundary spanning activities and boundary types presented in Table 1 by drawing examples from the coded data. However, this approach proved ill-suited to capturing the frequent and dense co-occurrence of boundary spanning activities and boundary types mentioned by participants. We additionally realized that shifting our focus to individual participants could generate richer and more complete portrayals of day-to-day work experiences, especially since accounts like this remain relatively rare in the extant literature.[42] We thus adopted a narrative approach to more holistically represent how select participants experienced boundary spanning in their job roles as engineers.

[38] Jesiek, Trellinger, & Mazzurco, "Becoming Boundary Spanning Engineers," 2016; Jesiek et al., "Boundary Spanning and Engineering," 2018.
[39] Boyatzis, *Transforming Qualitative Information,* 1998; Fereday and Muir-Cochrane, "Demonstrating Rigor Using Thematic Analysis," 2006.
[40] Jesiek et al., "Boundary Spanning and Engineering," 2018.
[41] Jesiek, Trellinger, & Nittala, "Closing the Practice Gap," 2017.
[42] With some notable exceptions, such as Gerwitz and Paretti, "Becoming After College," 2021.

Table 1. Data Analysis Codebook with Descriptions

Category **/ Code**			**Description**
General			
	Participant's Job Role(s)		participant describes aspects of his/her job role
Activities – Boundary Spanning			
	Building and Maintaining Networks		activities that involve building and maintaining relationships, usually over multiple/repeat interactions
	Communication		general or cross-cutting communication-related activities that do not fit in other categories
	Coordination		activities such as cross-boundary organizing, negotiating, aligning goals, and managing conflict; also includes more general management tasks/activities, and simply "getting things done" (across boundaries)
	Information and Knowledge Management		activities such as scouting (e.g., searching for information), filtering or buffering (e.g., selecting relevant information), translating and transforming (e.g., manipulating information to make it accessible to others), integrating different information/knowledge, etc.
	Representing and Influencing		activities that involve promoting the legitimacy of one's efforts or work, representing one's work, seeking to influence stakeholders, etc.
Activities – Other			
	Technical		activities that involve technical expertise or tasks (e.g., calculations, analysis or modeling, design, CAD work, etc.)
Boundary Types			
	Job Roles and Expertise		boundaries separating individuals based on profession, occupation, job function or role, discipline, etc.
	Knowledge		boundaries between different bodies of knowledge and/or knowledge communities
	Organizational		
		Intra-Organizational - Hierarchical/Vertical	boundaries that are hierarchical or vertical in nature (e.g., employees of different rank)
		Intra-Organizational - Inter-/Intra-Team	boundaries among members of a team or between multiple teams
		Intra-Organizational - Divisions or Units	boundaries within organizations at the division or unit level (e.g., HR, R&D, manufacturing)
		Inter-Organizational	boundaries between two or more organizations
	Individual Characteristics		boundaries involving different individual/group characteristics (e.g., gender, age, culture, education, class, race/ethnicity), and personal traits (e.g., political views, personality)
	Time and Space		boundaries involving different geographic locations or regions, physical contexts or sites of work (e.g., HQ vs. plant), time zones, project phases or stages, shift work

To identify participants to potentially spotlight in this paper, we used a multi-step process and three criteria. First, we sought interviews with higher coding counts – both overall and in specific areas – in order to have the breadth and depth of evidence needed to build up rich and textured narrative accounts. Second, earlier data analysis efforts drew our attention to how early career engineers often shoulder heavy job responsibilities.[43] Thus, we identified participants whose stories could collectively illustrate the theme of early career progression, including how different job roles map onto different boundary spanning challenges and expectations. As noted below, we also selected interviews with contrasting patterns of coverage across the codebook. Third and finally, to avoid an overly homogeneous sample we sought to write a narrative for at least one participant with a non-normative gender and/or racial/ethnic perspective. Based on these criteria, we identified three promising participants.

We next started writing three narratives, one for each highlighted participant, that would re-present the events, views, and reflections from their interviews in a coherent and thematic portrayal of each individual's story. In writing the narratives we adopted a third-person constructed narrative style with the goal of balancing the stylistic strengths and weaknesses articulated by Kellam, Gerow, & Walther.[44] More specifically, first-person narratives tend to prioritize the fidelity of each interviewee's story, such as through extensive or even exclusive use of direct quotations. By contrast, a third-person approach brings forward the researcher's voice and interpretations, often reducing reliance on quotes. This style is especially appropriate for studies that make extensive use of an analytical or theoretical framework as the primary lens for understanding the interviewees' experiences, e.g., boundary spanning in our research or structure-agency in the paper by Gerwitz and Paretti in this same issue.[45] The third-person style also reflects high authorial distance, i.e., the narratives reflect a gap in time between the events described and when the narratives were written. This style can be critiqued for giving a false impression of objectivity and credibility while potentially distancing the reader from the stories told. However, it accurately portrays the actual timeline of the study and is aligned with our research design and goals. In order to increase narrator reliability, or "the degree to which the reader can trust the narrator"[46], we describe our data collection and analysis approaches in detail and make use of direct quotes from participants.

Each of the co-authors independently wrote one narrative for a single participant. All co-authors had prior experience conducting and/or coding interviews for this project. The transcripts were frequently reread during this process, using an NVivo format with visual "stripes" showing what codes apply to what segments of text. Each author wrote up paraphrased examples and pulled quotes to illustrate the experiences of the participant whose narrative they were assigned to write, with boundary spanning themes used to further anchor and organize the text. The co-authors discussed their drafts repeatedly to improve the accuracy, clarity, and consistency of their accounts. After sequencing and harmonizing the three independent narratives to create an overall draft of the study findings, the co-authors continued to explore and write about the larger discussion points that cut across the three narratives, as presented below.

---

[43] Jesiek, Trellinger, & Mazzurco, "Becoming Boundary Spanning Engineers," 2016; Jesiek, Trellinger, & Nittala, "Closing the Practice Gap," 2017.
[44] Kellam, Gerow, & Walther, "Narrative Analysis in Engineering Education Research," 2015.
[45] Gerwitz & Paretti, "Becoming After College," 2021.
[46] Coulter & Smith, "The Construction Zone," 2009, p. 581.

The first and third narratives presented below were newly developed for this paper, while the second (for "Albert") evolved from earlier publications.[47] To more holistically portray the experiences of each participant, during the drafting and revision process we also reorganized each narrative around job roles and responsibilities, but with relevant boundary spanning themes threaded throughout. Thus, some boundary spanning themes discussed in each narrative are aligned with each participant's current role(s) and day-to-day work experiences but might not be treated in proportion to the more comprehensive coding counts as presented below.

Findings

Descriptive statistics for all codes mentioned in this paper are given in Table 2. It is notable that almost all codes occurred in a large majority of the interviews. The prevalence of boundary spanning codes in our larger data set supports the claim that boundary spanning has considerable utility as a lens for investigating and representing the day-to-day work experiences of engineers. Table 2 also reveals considerable variation in coding counts between interviews. This likely stems in part from differences in interview length, as well as variations in each participant's job role, primary responsibilities, and perceptions of what is most salient. To further explore such patterns in the coded data, the researchers compared and contrasted these coding counts to identify participants with relatively high counts for select activities and types, as illustrated by the shaded cells in Table 2.

Table 2. Summary of Coding Counts for All Interviews and Selected Participants

	CODES	**No.** of interviews that included this code (of 27 total)	**Range** of coding instances for all 27 interviews	**Average** coding instances for all 27 interviews	Manda's Interview	Albert's Interview	Cam's Interview
	Participant's Job Role(s)	27	1 - 31	9.2	10	21	31
ACTIVITIES	**Building and Maintaining Networks**	22	0 - 8	3.6	**7**	6	4
ACTIVITIES	**Communication**	26	0 - 26	9.2	10	**23**	**19**
ACTIVITIES	**Coordination**	25	0 - 18	4.7	7	**18**	5
ACTIVITIES	**Information and Knowledge Management**	25	0 - 19	6.7	**12**	**18**	10
ACTIVITIES	**Representing and Influencing**	25	0 - 9	3.0	2	1	**9**
ACTIVITIES	**Other - Technical**	26	0 - 28	9.1	10	17	13
BOUNDARY TYPES	**Job Roles and Expertise**	27	2 - 21	9.6	12	**15**	8
BOUNDARY TYPES	**Knowledge**	26	0 - 16	4.2	6	**8**	5
BOUNDARY TYPES	**Organizational - Hierarchical or Vertical**	25	0 - 14	6.6	9	7	**12**
BOUNDARY TYPES	**Organizational - Inter- or Intra-Team**	23	0 - 22	7.0	**18**	9	**22**
BOUNDARY TYPES	**Organizational - Divisions or Units**	24	0 - 16	5.4	3	7	**12**
BOUNDARY TYPES	**Organizational - Inter-organizational**	22	0 - 13	4.6	7	10	**13**
BOUNDARY TYPES	**Individual characteristics**	27	3 - 29	11.4	**16**	11	9
BOUNDARY TYPES	**Time and Space**	25	0 - 28	6.3	6	3	**28**

We next turn to narratives for the three selected participants (Manda, Albert, and Cam). Table 3 provides more information about these individuals, including how long they had been in their positions when they interviewed with us. We use italicized text for all codes originally introduced above in Table 1. The narratives are ordered by increasing duration of full-time employment, offering a composite view of early career engineering practice, including considerable variations in job roles and levels of responsibility. The narratives are also sequenced from the most to least minoritized participant, hinting at how characteristics like

[47] Jesiek, Trellinger, & Nittala, "Closing the Practice Gap," 2017; Jesiek et al., "Toward a Typology of the Socioetechnical," 2019.

gender, race/ethnicity, and nationality may powerfully inflect early career experiences, as further illustrated by Beddoes' paper in this same issue.[48]

Table 3. Demographic Characteristics of Selected Participants

Participant Pseudonym	Gender Identity	Ethnic Identity	Highest Degree	Time in Current Job Role
Manda	Female	South Asian	Master's	5 months
Albert	Male	White	Bachelor's	1.5 years
Cam	Male	White	Bachelor's	3 years (first 2 years in rotational program)

Manda: Becoming a "point of contact"

Manda, whose highest degree is a Master's in mechanical engineering, is an Application Controls Engineer at a U.S.-based equipment manufacturing firm. At the time of our interview (February 2016), she had been in her first full-time position for about five months. She had also completed two prior internships with the same company, one in her home country of India, and another at the same U.S. location as her current position, but with a different team. Manda is now part of a five-member team that is situated in a larger work group of about 30 total employees. As the following narrative suggests, Manda portrays a largely successful transition into a focused technical role and has become a key point of contact in her group, albeit with some challenges and frictions along the way.

Manda's job role involves configuring and troubleshooting electronic control modules (ECMs) for large engines. More specifically, she works on calibrating and tuning the fuel systems. She describes that most of her days consist of "a bunch of meetings, and in between I have some time to work on the things I am responsible for." As she further elaborates:

> So we have our software and I have to implement it in different platforms, so if there is a complaint from a customer, I have a little lab set up where I work and then, so I kind of go and try to replicate the problem and see what's going wrong. I have some testing that I do once in a while, so sometimes I have to go a test cell which is […] somewhere else, or sometimes if there is a customer complaint I have to go that location which can be anywhere in the US and then try to figure out what the problem is. […] Once in a while we might need to run some tests to validate what we are doing. So then I work with technicians, test cell engineers to make sure we get time on the rig, time on the engine, and then we can do our test. We also talk to the hardware team to understand what the hardware does because we mostly have software.

As this quote demonstrates, Manda interacts across social (*inter- and intra-team*) and work site (*time and space*) boundaries to troubleshoot problems with the technical systems she supports. Some of these interactions involve working across *divisions or units*, such as other groups in her company that assemble components into still larger systems. Manda also sometimes interacts with the suppliers who make the components controlled by the ECMs (*inter-organizational*).

Manda additionally describes how her role requires intensive "multi-tasking" and prioritizing to manage a complex workload (*coordination*), especially in light of scheduling milestones associated with her projects. In addition, Manda must balance her technical work with

[48] Beddoes, "Examining Privilege in Engineering Socialization," 2021.

a variety of *communication*-related tasks required to achieve her goals. For example, Manda explains how she initially "hit a wall" when trying to work with technicians in her company's test facility, in part because they were unionized and not used to being told what to do, especially by a woman with an international background. Manda explained that initially, she "didn't know how to talk to them without offending them and the other way around but we got over it." She reports how she in turn adjusted her *communication* approach by "ask[ing] them nicely" so she does not "sound like his [the technician's] boss." She also strategically managed her interactions with this same group through *influencing* activities, like when she "bought them cupcakes one day and they were happy after that." These examples additionally demonstrate Manda's awareness of, and sensitivity to, *job role and expertise* and *hierarchical/vertical* boundaries.

Manda also experiences challenges within her team due to her age. She describes with some emotion how her teammates "kind of pick on me [and] joke around that, I am so young, which kind of pisses me off because even I have important things to say sometimes. Even though […] I lack experience, I might have a different perspective." She additionally shows how these dynamics have influenced her approach to *communication*, describing initially how "I fe[lt] like I shouldn't speak up because I don't know much," but adding that over time she came to "understand what I can say and what I cannot say or on what things I should comment on." Manda also describes feelings of disappointment when her immediate manager pointed out her faults or mistakes but offered little in the way of positive encouragement. Yet things improved when she helped her boss "understand what makes me motivated," once again demonstrating her effectiveness at improving bidirectional *communication* across boundaries.

Elsewhere Manda describes needing to adjust her *communication* strategies depending on who she is talking to. For example, she notes that technical discussions may be more difficult and require a "little bit of explaining" when interacting with a "hardware guy." She adds that a design engineer may "care about every little detail," but for the marketing staff she "probably won't go into too much detail about the technical things, but just give them the highlights." Manda also describes her awareness of different communication styles, such as when she responds to situational preferences for details or the "big picture," more or less data, more or less text, documents versus presentations, and face-to-face or phone meetings. In many of these examples we in turn see how *communication* often shades into *information and knowledge management* as Manda selectively filters and transforms what she shares based on who she is interacting with, and to what end. As Manda aptly summarizes, "So, just understanding people, like what they'd like to hear, what would make them understand a concept, [it] helps."

In general, Manda seems largely satisfied with her immediate team interactions, stating that she "gets a lot of encouragement, especially from team members." She reports getting better projects to work on when she speaks up and demonstrates "that you know your stuff." In fact, she adds that she now has "people come and consult me when they have questions, they try to ask me to troubleshoot their problems or just general understanding of everything, I've become a point of contact now for different questions." She also describes how she has become more inclined to scout for or seek information, like when she mentions that she is "not so shy anymore about asking questions. […] If I need help, I don't hesitate to ask." Here we can additionally see how Manda strategically uses her *communication* skills to *build and maintain networks*, and in doing so becomes a kind of link between her coworkers and the information they need.

While her *intra-team* experiences are generally positive, Manda continues to feel tensions related to her gender and the desire to both have great mentors and serve as a mentor to other female engineers. For instance, she observes that there are only four women in her larger work

group, and reports that she is continuing to look for a female mentor, explaining that "they are a little hard to find and I haven't clicked with anyone really well." On the other hand, she describes favorable interactions with a male mentor from her own team in terms of getting day-to-day guidance and support, including advice for handling issues like the aforementioned tensions with her manager. This same mentor also helped Manda with *building and maintaining networks*, including by "giving me more opportunities to present, more opportunities to meet customers, to meet other people within [company], and this helps in me making connections with people."

Manda also mentions the positive work environment at her company, explaining that it is "a company that really encourages, they're very diverse so, and they like to encourage that everyone participates, they're very inclusive." Further, Manda points out that her interactions with the company's CTO, a woman, have been positive and encouraging. Manda explains that the CTO is "chatty" and interested in Manda's work. After an encounter where the CTO expressed interest in what Manda was doing, Manda explained why this was so meaningful: "the fact that someone in her position is interested in what I have to say makes a difference." It is also worth noting that Manda aspires to be a mentor: "I want to coach younger women, be […] mentors to them."

In summary, Manda's transition into a full-time technical role was significantly defined by her success in strategic *communication* and *building and maintaining networks*. She became more adept at communicating effectively in the midst intersecting differences in individual characteristics and status/rank, established herself as a knowledgeable "point of contact" in her own work group, and proactively sought out sources of mentoring and support to help improve her own performance and success.

Albert: Getting everyone on the same page

Albert is a white male plant engineer employed by a large German-based chemical company. At the time of his interview with us (June 2015), he was stationed at a production facility in the Midwestern U.S. Albert had been in this position for a year and a half, following his 2013 graduation with a B.S. in Chemical Engineering from a large public university in the Midwestern U.S. Albert is originally from Germany, and as an undergraduate student did four internships back in Germany. He decided to pursue a position in the U.S. with a German-based company, in part so he could get more work experience before potentially going back to school for a graduate degree, and in part to make it easier to seek a future position in Germany if he wishes to do so.

When asked about his job role, Albert described two major areas of responsibility. Especially salient for Albert was his growing involvement with "initiating, creating, and structuring small to mid-large capital projects." In this narrative, we especially focus on this project managerial part of Albert's job role by delving into a "distillation column installation" effort he had recently led. As further background, Albert inherited this project "mid-stream" from a retiring colleague, so most of the design and planning was done when he took over the effort. Albert's main role was thus to ensure the column was installed properly and "coordinate with the contractors to put everything in place." As a project manager, it is not surprising that Albert's work involved extensive *coordination*. As a more specific illustration, he described how he was responsible for managing an inventory of more than a hundred instruments needed for the distillation column, and then making sure those parts were turned over to a contractor and installed in the right sequence to avoid a "ripple effect" of delays. Albert's interactions with the

contractor thus involved an *inter-organizational* boundary. Underscoring the unique complexities and challenges associated with this part of the project, Albert stated: "Coordinating that was *interesting*." Albert also spanned *intra-organizational* boundaries, especially between *divisions or units*. This is evident when he describes how an "internal R&D unit helped design the basic requirement" for the installation column.

The distillation column project also demanded that Albert navigate several scheduling pressures to ensure there were no delays in the installment (*time and space*). On the one hand, one of the plant's customers had set a specific deadline for getting the new equipment up and running. On the other hand, a contractor was to install the column according to a mutually agreed schedule. Albert was thus serving as an intermediary between these stakeholders to ensure the relevant project deadlines are met. As time pressures increased, Albert also needed to bring the contractor's goals and perspective into alignment with the expectations of others through various *representing and influencing* activities. Albert more specifically described a "pretty intense" and "very honest" meeting with the contractor to reopen communication channels, determine why the schedule had slipped, and keep the installation effort moving forward. He described how the contractor had a divergent view of the project timeline, and added: "Honestly, it's pretty rough at times, because given a specific due date, not everyone is as compelled to meet that […] Having a certain amount of influence on people, […] verbally, it can be hard, but I mean, that's just part of life." Demonstrating interpersonal sensitivity, Albert also reached out to a larger group of key stakeholders to organize "a little pow-wow meeting" to directly elicit their perspectives and concerns. Elsewhere, hinting at the importance of *representing and influencing* activities, Albert noted how he makes interpersonal interactions and relationships a priority by taking "the time to talk to people both in terms of what they're doing at work, but also to get to know them aside from that. Understand if they have other things going on in life that might be a lot more important than work."

As a project manager, Albert described how on several occasions he worked to get everyone on the same page. For instance, speaking about his experiences in regular weekly project meetings, Albert describes the need to cultivate shared understanding among diverse members of a team:

> One of the really important things was to make sure that, because everyone was coming from a different perspective, make sure that we're all talking about the same things and speaking the same language, so to say. I think one of the main tools for that was to have the P&ID [piping and instrumentation diagram] out and showing specific names of instruments or parts of that system, so that everyone could call without, everyone sitting at the table could call it out and it had a picture in front of us to make sure that we're all talking about the same thing.

As this quotation suggests, Albert's work with this group involved *information and knowledge management* activities to help span knowledge boundaries. The P&ID came to serve as a kind of "boundary object" in these meetings, providing attendees with a physical document that helped them span knowledge boundaries due to their different terminology preferences and varying levels of background knowledge and expertise. [49] Albert's depiction of these exchanges

[49] For an expanded discussion of the boundary object concept as it relates to this particular example, see Jesiek et al., "Toward a Typology of the Sociotechnical," 2019.

additionally reveals his sensitivity to how information is translated and transformed to establish shared meaning and understanding within a diverse work team.

Reflecting on his experiences, Albert noted that "interacting with people was probably, actually, the key aspect of this project." Yet the technical dimensions of Albert's work were not superfluous or unimportant. *Technical* activities repeatedly co-occurred with boundary spanning activities in Albert's discussion of this project, such as when he discussed how the PNID was used in project meetings, or his sensitivity to different audiences in determining how much technical detail to share with other people and groups. Albert's technical knowledge, as well as his awareness for the limits of that knowledge, were critically important in his job role – both in terms of having credibility and being able to solve technical problems. Yet as this overview suggests, it is often not possible to draw a clear line separating Albert's technical work and qualifications from his manifold social interactions which crossed many different kinds of boundaries and helped him successfully manage a large capital project to completion.

Similar themes are reflected in the second part of Albert's job role, which he describes as "coordinating the day-to-day business, maintenance activities. If a pump goes down or if there is any type of repair on basically any of the equipment, then I help coordinate that." Albert reports that he is often assigned such tasks in regular morning meetings with a group of key stakeholders, ranging from the plant engineer down to the operations staff (*intra-organizational*). He additionally offers a specific example of this type of work by describing how he addressed ergonomic and performance issues associated with the filters installed on a production line. While a detailed discussion of this case is beyond the scope of this account, it involves a rich mix of *coordination*, *communication*, *representing and influencing*, and *technical* activities.[50]

Yet when asked about what he was proud of toward the end of his interview, Albert ultimately concluded that his "biggest achievement probably was just the fact that a distillation column, which is something like 40 or 50 feet tall, is installed. […] It's very valuable to be able to physically see what you've been working on." Albert was ultimately successful in overseeing this major capital project, frequently spanning *inter-organizational, time and space, and knowledge* boundaries through a variety of *coordination, representing and influencing,* and *communication* activities. Repeatedly getting everyone on the same page was central to his effectiveness in delivering value to the firm, often under major time and budget pressures.

Cam: Leadership across multiple projects

Cam is a white male engineer employed in the research division of a large, multinational manufacturing firm. At the time of our interview (June 2016), Cam held the title of Senior Associate Engineer and had been a full-time employee at the company for almost three years. His first 18 months with the firm were spent in an onboarding program where he rotated through three different work assignments. Cam holds a B.S. degree in mechanical engineering from a large research university in the Midwestern U.S. While still in college he completed four internships, three with a different multinational manufacturing firm and one with his current company. Among the participants in our study, Cam was one of the most experienced in terms of different positions held and total years worked.

When asked about his day-to-day work experiences, Cam described how his role is split – both in *time and space* – between two different job roles. On Mondays and Tuesdays he is

[50] For a more detailed account, see Jesiek et al., "Toward a Typology of the Sociotechnical," 2019.

mainly focused on a project that has entered a prototyping phase, where a new subsystem is being installed and tested on a demonstration machine. Cam is quite familiar with this effort since he had previously served as a design lead for the same project, often spanning *inter-organizational* boundaries by "working with the supplier day to day" on the detailed design of the subsystem. With this project more recently entering what Cam called a "troubleshooting engineering" phase, he noted some typical work tasks such as visiting an off-site "demonstration facility" where he interacted with – and gave direction to – the group that builds prototype machinery for testing (*time and space* and intra-*organizational* boundaries). He also noted continuing solitary *technical* work associated with this same project. For instance, when specific issues were reported as the prototype got built and tested, he brainstormed solutions, designed sensors to gather more data, and ran calculations to predict possible component failures. Such tasks in turn led to more instances of both *inter-* and *intra-organizational* boundary spanning, as when Cam would "meet back up with that team [to] let them know" the results of a given analysis, or contact the supplier to discuss the behavior or performance of specific components.

Cam's other major work role – which he described as "the main project that I'm on right now" – involves spending the rest of his week in another building with a different team. This effort is still in a "high level initial concepting phase" and is focused on developing autonomous capabilities for a specific piece of equipment. As Cam explained, "I spend Wednesday through Friday there experimenting with a new idea for the project that I'm on where we actually take our team and we locate ourselves down with what would be our customer. My team's customer would be the, what we call product groups." He observed some significant benefits associated with this embedded, *intra-organizational* work arrangement, such as enabling more frequent and efficient face-to-face *communication* with coworkers who are in close proximity. As Cam elaborated, "we can just walk over to their team members and have a conversation with them or set up a meeting. […] So it's pretty effective, actually, locating us down there so we can do that work."

Also notable about Cam's story as an early career engineer is his role as "team lead" for this project, responsible for coordinating and overseeing the work of two other engineers who Cam refers to as "my peers." He assumed this role after another colleague went on military leave, and describes it as "a more interesting transition from a member of a team into the team lead versus going from intern to full time." Revealing awareness of *individual characteristic* boundaries, Cam elaborates that "the people that are on my team are my peers, I mean I went to school with one of the guys and the other guy is actually a couple years older than me. […] Initially, going into that, you just feel like, you know, who am I to tell them what to do on a day-to-day basis?" Here one senses Cam's unease with his formal leadership responsibilities, and elsewhere he downplays his title: "It's a really small team. It's me and two other guys, so team lead is kind of a funny name, but it is a team I guess."

Cam reports that his previous experiences with "design and project management" helped prepare him for the *coordination*-related demands of this role. He additionally notes that about "10-20%" of his time involves "project management stuff," where he is "getting ahold of outside teams to get information that we need," "setting up meetings," and "trying to figure out what the next steps we're going to take in the project." Cam also describes challenges related to balancing his leadership responsibilities with continuing opportunities to make *technical* contributions: "I'm not just leading the team, I'm not just setting out project tasks and goals and organizing it. I'm also actively a member of the team, I'm also producing designs and things like that."

As Cam further elaborated, his early work on this project was “extremely frustrating” and “really daunting because you feel like there's no way you could possibly be successful because you don't even know what the definition of success is.” Such tensions and ambiguities in turn spurred Cam to further develop and leverage his *coordination* skills. For instance, he described how “reaching out to different designers and experts” for additional guidance helped him realize the need to “come up with a plan” and develop a “vision” for his team’s work. He also gained more appreciation for the power of delegation, or “transitioning from basically being given work to do in a sense to, okay, now I've got to figure out what we're doing next. That's a lot. I didn't realize how much of the work that actually is.” He more specifically described two *coordination* strategies he found useful: assigning work based on the strengths and weaknesses of individual team members, and being open to feedback from those same individuals.

Representing and influencing activities are also very prominent for Cam, likely due to his formal leadership role. For example, he describes how management was disappointed with his design team’s progress during the previous year, which Cam argued was caused by a lack of personnel time on the project. In response, “the previous team lead and myself were able to advocate for more resources.” Specifically, they held a series of meetings at the start of the new year to refine the project vision, followed by another review in April where management moved from being “not very satisfied” to “really, really excited and happy and looking forward to the next thing that was going to come out of the project.” Cam describes this as “one of the bigger successes that I feel like I’ve had so far in my short career.” Two kinds of *representing and influencing* activities are evident here, namely formally representing a project or team and attempting to influence or persuade other actors in the firm, and with *hierarchical or vertical* boundaries prominent since the key decision-makers were his superiors. Similar themes can be found when Cam described how he sought resources for project-related expenses, such as building a small prototype. He explained how he did so by approaching the appropriate funding manager to “put in that request and explain to them why I need that.”

Cam’s position in the research division of the company can also be linked to other *representing and influencing* activities. In contrast to being part of a product group where the needs of customers might be more apparent, Cam notes that “here within research we basically have to sell our ideas to them [the product group], so you have to have a good idea of what its proposed value is.” Referring to this same challenge, Cam alludes to both *hierarchical or vertical* and *knowledge* boundaries when describing how the chief engineer of the product group is “my customer and who am I to go here and tell him what they need to do on the next iteration of the machine?” He adds that the chief engineer is “a lot higher up in the company” and “much more of an expert for that product than we ever were.” As a result, Cam explains that his team had to “get up to speed and then come up with new ideas and present them to him [the chief engineer].”

Taking a broader view of Cam’s work, it is worth underscoring his frequent and intensive crossing of *intra-organizational* boundaries. Internal *divisions and units* are spanned often given that he is formally in his company’s research group, but is partially co-located with a product group. He also makes numerous mentions of interactions with his fellow team members (*intra-team)*, and describes how “almost all the projects I'm on have involved probably at least four different teams in the company” (*inter-team*). Again showing awareness of *space* boundaries, Cam adds that these teams are often “not in the same building, not even in the same area, like one team might be in a different part of the company or even the world and then maybe another team is in local area and a third one's somewhere totally different.” Cam also describes how he

strategically navigates what he calls "horizontal boundaries": "it's really what network do you have, and then what network do the people you know have, and that's basically your full network that you use to get a hold of the different groups that you need to get the questions answered." Here we see how Cam's efforts to *build and maintain networks* in turn help enable *information and knowledge management.*

Cam also repeatedly stresses the importance of *communication-related* activities. For instance, he notes the limitations inherent in various modes of communication, explaining how reliance on e-mail and voicemail "drags out the process a little longer when you need to interact with people who aren't there." By contrast, Cam notes that it is often more effective to "walk over to their desk and talk to them." Cam additionally describes how the same chief engineer mentioned above is scarcely in his office and rarely responds to e-mails. As a result, Cam explains how he would "just go down to people who work under him and say, 'hey, I've got this question can you answer it for me?' Usually they're able to answer it." On a related point, Cam describes how he uses various strategies for moderating communication with management and other stakeholders, such as when he notes how "you have to watch how you present things, at least until you get to know them," and underscores the importance of "trying to present this project in a certain way and we don't want to have any bad feelings about it." Elsewhere he shows awareness of challenges associated with spanning national, cultural, and/or language differences (*individual characteristics*). He explains that during some interactions "you can tell people are a little bit less than on the same page" and elsewhere observes: "someone might say yeah, but they don't really mean yeah. They mean maybe. And you learn that as you interact." This is one among a number of examples where Cam shows keen awareness of various boundary characteristics, including the relative permeability of certain types of boundaries, and the relative difficulty of engaging in different kinds of boundary spanning activities.[51]

Cam's role as a team leader likely increases the prevalence of certain kinds of boundary types and boundary spanning activities in his day-to-day work. Especially prominent are the *time and space*, *organizational*, and *hierarchical or vertical* boundaries associated with his roles on two distinct projects, coupled with a wide-ranging mix of *coordination*, *communication*, and *representing and influencing* activities.

Discussion

The preceding coding overview and participant narratives illustrate that the engineers in our study frequently experience boundary spanning in their job roles, consistent with findings from multiple prior studies.[52] *Communication*-related activities were found to be especially prominent, followed by *information and knowledge management* and *coordination*. While direct comparisons to other studies are difficult due to the different typologies employed, our findings are generally consistent with Trevelyan's portrayal of "technical coordination" as a key

[51] For more on boundary characteristics such as permeability and flexibility, see Fellows and Liu, "Managing Organizational Interfaces," 2012; For more on interactions across multiple boundaries, see Espinosa et al., "Team Boundary Issues," 2003.

[52] Hanneman and Gardner, "Under the Economic Turmoil a Skills Gap Simmers," 2010; Hsiao, Tsai, and Lee, "Collaborative Knowing," 2012; Johri, "Boundary Spanning Knowledge Broker," 2008; Lynn and Salzmann, "Collaborative Advantage," 2006.

dimension of engineering practice.[53] We additionally document the frequent crossing of *individual characteristic*, *job role and expertise*, and *inter/intra-team boundaries* by all of the participants in our study, and as further illustrated in the narratives.

Yet in light of these findings, one might wonder what aspects of early career engineering work do *not* involve boundary spanning. In the narratives we highlight multiple examples of solitary technical work, but even these are typically bound up with various kinds of boundary spanning. Further analysis of our larger data set reveals that about 25% of the interview segments coded with any activity included the *technical* code, and only about half of these (or 13% of the total) did not co-occur with boundary spanning activities. Other researchers have similarly found that about 60% of the average engineer's time is spent "interacting with other people either directly or through documents," adding that their study participants "typically spent relatively little of their working week involved in activities that could have entailed design or innovation development (less than 15%, and in most cases less than 7%)."[54] Such findings lend support to a growing body of research showing the heterogeneous or sociotechnical nature of engineering work, frequently involving intertwined human/social and technical/material considerations.[55]

Even more generally, we intentionally arranged the narratives to paint a composite portrait of practice showing how early career engineers start to make sense of their place and value as employees, often in tandem with steadily increasing levels of responsibility. We also sought to highlight the experiences of participants from both majority and minoritized groups. Still relatively new to her first full-time position, Manda was primarily an individual contributor and perceived her own value as tightly linked to developing technical expertise in the context of her local work team. Albert, on the other hand, had significant project management responsibilities after just a year and a half in his position, and showed considerable awareness for how his role – and hence his value to his employer – involved overseeing projects while ever mindful of time and budget pressures. Finally, Cam was formally leading a small team after just three years of employment, and was frequently challenged to demonstrate how his groups and projects were contributing value to the larger organization, especially through interactions with higher-level managers. The story of career progression suggested by these three narratives can in turn be related to shifting competency demands. As shown in Table 2 and illustrated in our findings, different boundary spanning activities and boundary types are more prevalent for certain participants, likely in part due to their particular roles and responsibilities.

These observations resonate with a growing body of evidence suggesting that engineers are often assigned informal and formal managerial responsibilities early in their careers.[56] In fact, Trevelyan has more generally framed technical coordination as first and foremost a kind of "informal leadership" activity.[57] As early career engineers encounter such expectations, they are challenged to "learn the plays and signals" of their workgroup and the larger organization, as so

---

[53] Trevelyan, "Technical Coordination in Engineering Practice," 2007.
[54] Trevelyan and Tilli, "Longitudinal Study of Australian Engineering Graduates," 2008, p. 10; see also Williams and Figueiredo, "Finding Workable Solutions," 2013.
[55] Stevens, Johri, and O'Connor, "Professional Engineering Work," 2014; Jesiek et al., "Toward a Typology of the Sociotechnical," 2019.
[56] Lyons, Anselmo, and Kuller, "Engineering Education for Competitive International Economy," 1993; Wilde, "An Investigative Study of the Difficulties Experienced," 2009.
[57] Trevelyan, "Technical Coordination in Engineering Practice," 2007; Trevelyan, *The Making of an Expert* Engineer, 2014, Ch. 4.

aptly described by William Wickenden nearly a century ago.[58] Yet as Williams and Trevelyan note, it is rare for engineering students or professionals to directly reflect on questions about their "value" to employers.[59] The preceding narratives suggest that the effectiveness of early career engineers as boundary spanners is likely an important part of the value proposition they bring to their organizations.

While not the main focus of the study, our findings also resonate with prior research on the experiences of women and other minoritized groups in engineering. For example, it is notable that Manda, who held a Master's degree, had the most formal education among our larger pool of study participants. Yet she admitted harboring doubts about her own expertise, and reported reluctance in speaking up at meetings. This observation resonates with Williams' discussion of "prove-it-again" bias, where competency demands on women of color and the challenges associated with proving themselves are often greater as compared to dominant groups (e.g., white men).[60] Manda also reported how she actively worked to build and maintain her professional networks, but noted difficulties identifying and connecting with female mentors. This is a point of concern given that such relationships have been identified as especially important for minoritized individuals.[61] The unique challenges faced by Manda help underscore that the early career landscape is often an uneven playing field for women and people of color.

Limitations

As described in our methods section, we followed a variety of best practices to improve the quality and trustworthiness of our research process. However, we acknowledge some remaining limitations with our study. First, the data may reflect self-selection biases since all subjects freely volunteered to participate. In previous work we discuss how this approach can attract more conscientious and reliable participants, but it may also limit the range of perspectives and experiences reported in the study.[62] Second, compensating participants can introduce a social desirability bias, with subjects feeling a need to speak favorably about their experiences. Third, introducing our participants to the concept of boundary spanning during the interview process may have skewed the data toward our chosen framework. Fourth, our analytic approach (thematic and narrative) offers one among many possible ways of interpreting the data, and other approaches would likely generate different kinds of findings. Fifth and finally, while the experiences reported by our participants may be typical for some early career engineers, we are not reporting on a representative sample and acknowledge the likelihood of considerable variation in work experiences across different job roles, companies, and industry sectors.

Conclusion

The findings presented in this paper suggest that boundary spanning is a significant and likely even predominant dimension of early career engineering work. This has significant implications for many stakeholders. Educational organizations and employers, for instance, often do a poor job of communicating the kinds of competency demands realistically faced by early

---

[58] Wickenden as quoted in Noble, *America by Design*, 1977, p. 49.
[59] Trevelyan and Williams, "Identifying Value in the Engineering Enterprise," 2019.
[60] Williams, Phillips, and Hall, *Double Jeopardy?*, 2014.
[61] Ross, "A Unicorn's Tale," 2016.
[62] Jesiek et al., "Interns in the Wild," 2017.

career engineers, much less encouraging them to critically reflect on the roles they are asked to play – and value they are expected to provide – in both their employing organizations and society more generally. Boundary spanning, as a kind of "meta-attribute" or "meta-competency,"[63] can help educators and students see engineering practice not only in terms of discrete technical and professional skills that require active development, but also as a complex and often thoroughly sociotechnical kind of human performance. Problem/project-based learning (PBL), case studies, and internships appear well suited as mechanisms for helping students learn to become boundary spanners, especially when such experiences include opportunities for explicit reflection on the role of engineers in organizations and society. Corporate employers, in turn, can improve early career experiences by providing engineers with formal training in leadership and management, informal and formal mentorship, and early opportunities to lead small projects and teams.[64]

Nonetheless, further research is needed to confirm and expand the results reported in this paper. For instance, we are further exploring the wide variety of specific boundary spanning strategies mentioned by the participants in our study. Additional investigations could also help clarify how boundary spanning competency demands vary by job role, career stage, industry sector, and company; examine the relative permeability and ease of spanning certain types of boundaries; and investigate how engineers experience career progression.[65] In addition to enriching what remains a relatively sparse body of research on engineering practice, such studies can provide ever more solid empirical foundations for interventions designed to empower engineers as leaders and change agents early in their careers – rather than simply casting them adrift in hopes that they somehow manage to learn the plays and signals of the corporate team.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. 1254323 and 1939272. The authors also gratefully acknowledge the study participants who so generously shared their time and perspectives with us, along with larger research team that assisted with collecting and analyzing data for this project. We especially note assistance from Scott Campbell, Neha Choudhary, Andrea Mazzurco, and Matthew Scheidt. Finally, we offer thanks to the reviewers whose feedback considerably improved the final version of this paper.

References

Beddoes, Kacey. "Examining Privilege in Engineering Socialization Through The Stories of Newcomer Engineers." *Engineering Studies* 13, no. 2 (2021).

Boyatzis, Richard E. *Transforming Qualitative Information: Thematic Analysis and Code Development.* Thousand Oaks, CA: Sage Publications, Inc., 1998.

[63] Radcliffe, "Innovation as a Meta-Attribute for Graduate Engineers," 2005.

[64] Bowmann and Farr, "Embedding Leadership in Civil Engineering Education," 2000; Howard, "From Engineer to Engineering Manager," 2003.

[65] For example, on the engineer to manager transition see Nittala, "Lived Experiences of Recently Transitioned Engineering Managers," 2020.

Bowman, Bruce A., and John V. Farr, John V. “Embedding Leadership in Civil Engineering Education.” *Journal of Professional Issues in Engineering Education and Practice* 126, no. 1 (2000): 16-20.

Brunhaver, Samantha R., Russell F. Korte, Stephen R. Barley, and Sherri D. Sheppard. “Bridging the Gaps Between Engineering Education and Practice.” In *U.S. Engineering in a Global Economy*, eds. Richard B. Freeman and Hal Salzman, 129-163. Chicago, IL: The University of Chicago Press, 2018.

Bucciarelli, Louis L. *Designing Engineers*. Cambridge, MA: MIT Press, 1996.

Cohen, Benjamin, Jenn S. Rossmann, and Kristen L. Sanford Bernhardt. “Introducing Engineering as a Socio-technical Process.” Paper presented at the ASEE Annual Conference and Exposition, Indianapolis, IN, 2014.

Coulter, Cathy A., and Mary L. Smith. “The Construction Zone: Literary Elements in Narrative Research.” *Educational Researcher* 38, no. 8 (2009): 577-590.

Downey, Gary L., and Juan C. Lucena. “Engineering Studies.” In *Handbook of Science, Technology, and Society*, eds. Sheila Jasanoff, Gerry Markle, James Petersen, and Trevor Pinch, 167-188. Newbury Park, CA: SAGE, 1994.

Downey, Gary L. “What is Engineering Studies For?: Dominant Practices and Scalable Scholarship.” *Engineering Studies* 1, no. 1 (2009): 55-76.

Espinosa, J. Alberto, Jonathon C. Cummings, Jeanne M. Wilson, and Brandi M. Pearce. “Team Boundary Issues Across Multiple Global Firms.” *Journal of Management Information System* 19, no. 4 (2003): 157-190.

Faulkner, Wendy. “Doing Gender in Engineering Workplace Cultures. I. Observations From the Field.” *Engineering Studies* 1, no. 1 (2009): 3-18.

Faulkner, Wendy. “Doing Gender in Engineering Workplace Cultures. II. Gender In/authenticity and the In/visibility Paradox.” *Engineering Studies* 1, no. 3 (2009): 169-189.

Fellows, Richard, and Anita M. M. Liu. “Managing Organizational Interfaces in Engineering Construction Projects: Addressing Fragmentation and Boundary Issues Across Multiple Interfaces.” *Construction Management and Economics* 30, no. 8(2012): 653-671.

Fereday, Jennifer, and Eimear Muir-Cochrane. “Demonstrating Rigor using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development.” *International Journal of Qualitative Methods* 5, no. 1 (2006): 80-92.

Frank, Carolyn. Ethnographic Interviewing for Teacher Preparation and Staff Development: A Field Guide. New York, NY: Teachers College Press, 2011.

Gerwitz, Christopher, and Marie Paretti. "Becoming After College: Agency and Structure in Transitions to Engineering Work." *Engineering Studies* 13, no. 2 (2021).

Gonzalez, Carlos. "Is the Engineering Profession Still a 'Good' Job?" *Machine Design* (August 17, 2018). Available online at: https://www.machinedesign.com/learning-resources/engineering-profession-still-good-job

Guba, Egon G., and Yvonna S. Lincoln. "Competing Paradigms in Qualitative Research." In *Handbook of Qualitative Research*, eds. Norman K. Denzin and Yvonna S. Lincoln, 105-117. Thousand Oaks, CA: Sage Publications, Inc., 1994.

Hanneman, Larry, and Phil Gardner. "Under the Economic Turmoil a Skills Gap Simmers." CERI Research Brief 1 (2010). Lansing, MI: Collegiate Employment Research Institute, Michigan State University, 2010.

Heywood, John. "The Education of Professional Mechanical Engineers for Design and Manufacture." *Lancaster Studies in Higher Education* 1 (1966).

Hill, Catherine, Christianne Corbett, and Andresse St. Rose. *Why So Few? Women in Science, Technology, Engineering, and Mathematics.* Washington, DC: AAUW, 2010.

Hodgson, Damian. "'Putting on a Professional Performance': Performativity, Subversion and Project Management." *Organization* 12, no. 1 (2005): 51-68.

Howard, Chris A. "From Engineer to Engineering Manager: A Qualitative Study of Experiences, Challenges, and Individual Transitions for Engineering Managers in Aerospace Companies." Published PhD diss., The Pennsylvania State University, 2003.

Hsiao, Ruey-Lin, Dun-Hoi Tsai, and Ching-Fang Lee. "Collaborative Knowing: The Adaptive Nature of Cross‐Boundary Spanning." *Journal of Management Studies* 49, no. 3 (2012): 463-491.

Huff, James L., Jonathon A. Smith, Brent K. Jesiek, Carla B. Zoltowski, and William C. Oakes. "Identity in Engineering Adulthood: An Interpretative Phenomenological Analysis of Early-Career Engineers in the United States as They Transition to the Workplace." *Emerging Adulthood* 7, no. 6 (2019): 451-467. Available online at: https://doi.org/10.1177/2167696818780444

Jesiek, Brent K., Natascha T. Buswell, Andrea Mazzurco, and Tasha Zephirin. "Toward a Typology of the Sociotechnical in Engineering Practice." Paper presented at the Research in Engineering Education Symposium (REES), Cape Town, South Africa, 2019.

Jesiek, Brent K., Andrea Mazzurco, Natascha Buswell, and Julia Thompson. "Boundary Spanning and Engineering: A Qualitative Systematic Review." *Journal of Engineering Education* 107, no. 3 (2018): 380-413.

Jesiek, Brent K., Andrea Mazzurco, Natascha Trellinger, and Kavitha Ramane. "Becoming Boundary Spanners in Engineering: Identifying Roles, Activities, and Competencies." Paper presented at the Frontiers in Education (FIE) Conference, El Paso, TX, 2015.

Jesiek, Brent K., Natascha M. Trellinger, and Andrea Mazzurco. "Becoming Boundary Spanning Engineers: Research Methods and Preliminary Findings." Paper presented at the ASEE Annual Conference and Exposition, New Orleans, LA, 2016.

Jesiek, Brent K., Natascha M. Trellinger, and Swetha Nittala. "Closing the Practice Gap: Studying Boundary Spanning in Engineering Practice to Inform Educational Practice." Paper presented at the Frontiers in Education (FIE) Conference, Indianapolis, IN, 2017.

Jesiek, Brent K., Natascha M. Trellinger, Swetha Nittala, and Scott J. Campbell. "Interns in the Wild: Using Structured Reflection and Interviews to Investigate Early Career Engineering Practice." Paper presented at the ASEE Annual Conference and Exposition, Columbus, OH, 2017.

Johri, Aditya. "Boundary Spanning Knowledge Broker: An Emerging Role in Global Engineering Firms." Paper presented at the 38th Annual Frontiers in Education Conference, Saratoga Springs, NY, 2008. http://dx.doi.org/10.1109/FIE.2008.4720407

Kellam, Nadia N., Karen S. Gerow, and Joachim Walther. "*Narrative Analysis in Engineering Education Research: Exploring Ways of Constructing Narratives to Have Resonance with the Reader and Critical Research Implications."* Paper presented at the ASEE Annual Conference and Exposition, Seattle, WA, 2015.

Korte, Russell F. "How Newcomers Learn the Social Norms of an Organization: A Case Study of the Socialization of Newly Hired Engineers." *Human Resource Development Quarterly* 20, no. 3 (2009): 285-306.

Korte, Russell F., and Jessica Li. "Exploring the Organizational Socialization of Engineers in Taiwan." *Journal of Chinese Human Resources Management* 6, no. 1 (2015): 33-51.

Korte, Russell F., Samantha Brunhaver, and Sheri Sheppard. "(Mis)Interpretations of Organizational Socialization: The Expectations and Experiences of Newcomers and Managers." *Human Resource Development Quarterly* 26, no. 2: 185-208.

Lund, Susan, Madgavkar, James Manyika, Sven Smit, Kweilin Ellingrud, Mary Meaney, and Olivia Robinson. *The Future of Work After COVID-19*. McKinsey Global Institute, 2021. Available online at: https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19

Lyons, William C., Peter C. Anselmo, and Robert G. Kuller. "Engineering Education for Competitive International Economy." *Journal of Professional Issues in Engineering Education and Practice* 119, no. 4 (1993): 378-395.

Lynn, Leonard H. and Hal Salzman. "Collaborative Advantage." *Issues in Science and Technology* (Winter 2006): 74-82.

Martin, Rosanna, Bryan Maytham, Jennifer Case, and Duncan Fraser. "Engineering Graduates' Perceptions of How Well They Were Prepared for Work in Industry." *European Journal of Engineering Education* 30, no. 2 (2005): 167-180.

National Center for Science and Engineering Statistics (NCSES). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2021*. Arlington, VA: National Science Foundation (NSF), 2021. Available online at: https://ncses.nsf.gov/pubs/nsf21321/downloads

National Science Board (NSB). *Science and Engineering Indicators 2018*. NSB-2018-1. Alexandria, VA: National Science Foundation, 2018. Available online at: https://www.nsf.gov/statistics/indicators/

Nittala, Swetha. "Lived Experiences of Recently Transitioned Engineering Managers: An Interpretative Qualitative Study." Published PhD diss., Purdue University, 2020.

Noble, David F. *America by Design: Science, Technology, and the Rise of Corporate Capitalism.* Oxford: Oxford University Press.

Pawley, Alice L. "Shifting the 'Default': The Case for Making Diversity the Expected Condition for Engineering Education and Making Whiteness and Maleness Visible." *Journal of Engineering Education* 106, no. 4 (2017): 531-533.

Radcliffe, David F. "Innovation as a Meta-Attribute for Graduate Engineers." *International Journal of Engineering Education* 21, no. 2 (2005): 194-199.

Ross, Monique. "A Unicorn's Tale: Examining the Experiences of Black Women in Engineering Industry." Published PhD diss., Purdue University, 2016.

Smith, I. E. "Minority vs. Minoritized: Why the Noun Just Doesn't Cut It." *Odyssey* (Sept. 2, 2016). Available online at https://www.theodysseyonline.com/minority-vs-minoritize

Stevens, Reed, Aditya Johri, and Kevin O'Conner. "Professional Engineering Work." In *Cambridge Handbook of Engineering Education Research*, eds. Aditya Johri and Barbara M. Olds, 119-138. New York, NY: Cambridge University Press, 2014.

Trevelyan, James. "Technical Coordination in Engineering Practice." *Journal of Engineering Education* 96, no. 3 (2007): 191-204.

Trevelyan, James. "Reconstructing Engineering From Practice." *Engineering Studies* 2, no. 3 (2010): 175-195.

Trevelyan, James. *The Making of an Expert Engineer.* Leiden, The Netherlands: CRC Press, 2014.

Trevelyan, James. "Appendix 4: Classification of Engineering Activities and Specialist Knowledge." Leiden, The Netherlands: CRC Press, 2014. Retrieved from https://www.crcpress.com/The-Making-of-an-Expert-Engineer/Trevelyan/p/book/9781138026926

Trevelyan, James, and Sabbia Tilli. "Longitudinal Study Of Australian Engineering Graduates: Perceptions Of Working Time." Paper presented at the ASEE Annual Conference and Exposition, Pittsburg, PA, 2008.

Trevelyan, James, and Bill Williams. "Identifying Value in the Engineering Enterprise." In *The Engineering-Business Nexus: Symbiosis, Tension and Co-Evolution,* eds. Steen H. Christensen et al., 281-314. Spring Nature Switzerland AG, 2019.

Webster, Leonard, and Patricie Mertova. Using Narrative Inquiry as a Research Method: An Introduction to Using Critical Event Narrative Analysis in Research on Learning and Teaching. New York, NY: Routledge, 2007.

Wilde, Joseph A. "An Investigative Study of the Difficulties Experienced by Engineers Transitioning into Leadership/Management Positions." Published Masters thesis, Brigham Young University, 2009.

Williams, Bill and José Figueirido. "Engineering Practice as an Emerging Field of Inquiry: a Historical Overview." Paper presented at the ASEE Annual Conference and Exposition, New Orleans, LA, 2016.

Williams, Bill and José Figueirido. "Finding Workable Solutions: Portuguese Engineering Experience." In *Engineering Practice in Global Context: Understanding the Technical and the Social*, eds. Bill Williams, José Figueirido, and James Trevelyan, 159-184. Boca Raton, FL: CRC Press, 2013.

Williams, Joan C., Katherine W. Phillips, and Erika V. Hall. *Double Jeopardy? Gender Bias Against Women of Color in Science*. San Francisco, CA: The Center for WorkLife Law, UC Hastings College of Law, 2014.

World Economic Forum (WEF). *The Future of Jobs Report 2018.* Cologny/Geneva, Switzerland: Center for the New Economy and Society, World Economic Forum, 2018.

Appendix A: Interview Protocol

Tell me about your current (or most recent) job position/role, potentially including:

- What is your job title?
- How long have you been at this organization? (And in this position?)
- What are your main job responsibilities?
- Who do you work with? Tell me about your work group, supervisor, etc.

Walk me through a typical workday. What kinds of things are you doing hour-to-hour?

What is one of your biggest accomplishments or successes in your current job role?

What is one of your biggest challenges or disappointments in your current job role?

Critical incident approach

- Seek out examples of specific boundary-spanning incidents and situations, and ask participants to describe them in detail: who, what, where, when, and how
- Specific boundary spanning themes to probe:
    - What kinds of boundaries were being crossed?
    - What was your role? What were you doing or expected to do?
    - What knowledge or information was most important in this situation?
    - What strategies, skills, techniques, etc. did you utilize in this situation?
    - What did you learn from this experience?
    - What would you do different next time?

Follow-Up Probes

- Did you naturally fall in to the role you assumed?
- How might your personality come it to play in how you handled these boundary spanning incidences?
- Were you comfortable in these roles?

How does your current position compare with previous positions you've had?

- What were those positions? (e.g., job title, type of organization, period of employment, responsibilities, etc.)

We've talked about some boundaries (name some of them). Have you encountered any others listed here? (see primer document)

What has helped prepare you for boundary spanning? What do you wish you had known or learned? What skills or capabilities would you still like to develop?

What is your ideal job? What kind of work is most fulfilling or rewarding for you?