International Journal of Engineering Education Vol. 35, No. 3, pp. 719–732, 2019
Printed in Great Britain

0949-149X/91 $3.00+0.00

Operationalizing Interpersonal Behaviours of Leadership for Early-Career Engineers*

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This qualitative research employs interview techniques to understand behavioural evidence of early-career engineering leadership. Semi-structured interviews were conducted with nine engineering leaders from three large international engineering companies. Analysis of the interview data through constant comparative open and axial coding methods suggest that traditional notions of interpersonal competencies, such as extroversion and charisma, often may not reflect practicing engineers' preferences toward leadership. Instead, this research reveals four behavioural themes of interpersonal behaviours related to engineering leadership: technical forthrightness, positivity through sociotechnical constraints, builds interdisciplinary alliances, adaptive communication. Further, we view our results through Bartram's Great Eight competency framework, which outlines general competencies for leadership across settings. By mapping our interpersonal behavioural themes of engineering leadership onto the Great Eight competencies, we operationalize leadership behaviours manifest in engineering. We propose that by teaching engineering students—future engineering professionals—the interpersonal behaviours for successful engineering leadership, we encourage a reflective and person-centred approach to teaching the more general leadership competencies.

Keywords: engineering leadership; interpersonal; competency models; engineering education; early-career engineers

1. Introduction

Worldwide, reports and accrediting bodies are beginning to implement criteria based on leadership and professional skills that inform undergraduate engineering curricula. For example, in the U.S., Canada, Australia, and across Europe, engineering accrediting boards emphasize the need for curricular changes addressing professional and leadership skills [1–3]. In the United States, reports like the NAE's "Engineer of 2020" and ABET accreditation board [1] expect that future engineers understand and apply leadership principles throughout their career, remembering the global and societal impacts of engineering [4]. The call for leadership-oriented, globally-minded, technically-trained engineers requires reform in engineering education to include educating and developing non-technical skills within curriculum, since engineers can no longer succeed long-term without acknowledging both technical and non-technical competencies [5].

The challenge for engineering educators is the complexity of leadership as a phenomenon. Scientific research has produced a wealth of theories which prove difficult to disseminate and apply across individuals, groups, and organizational outcomes due to static approaches in attempts to understand leadership [6]. Static approaches within leadership research tend to focus on one point in time and on one level or another, leaving a narrowly confined analysis of the concept. Additionally, leadership literature in the new millennium continues to focus on the study of charismatic leadership styles [6], a traditional notion of leadership with which engineers tend to not identify [7]. These complexities in leadership research reveal a need to explore the phenomenon within the context of engineering and focus on an early-career time frame.

Further, emergent leadership research identified through meta-analysis suggests the appreciation of the social context by which the leader operates [6]. The increased focus on theory based in team leadership, social networks, and interpersonal development suggest the importance of the contextual element by which leadership is observed or developed [6, 8]. The development of leaders therefore requires an understanding of the particular social context by which the leader will be working. Day (2000) specifically identifies the importance of both the contextual influences (e.g., organizational climate/culture, group/organizational composition, economic environment, and organizational support for diversity) and social psychological processes (e.g., self-knowledge, interpersonal skills, communication competence, and cultural competence)

* Accepted 9 January 2019.

related to the relational aspect of leader behaviours and development [8, 9]. Because little literature explores leadership traits required for early-career engineers, and because early-career engineering leaders become senior thought leaders that drive innovation, the aim of this study is to explore the interpersonal aspects of leadership within the context of engineering work during the early-career stage.

The context by which interpersonal behaviours are being explored is outlined in the literature section and further defined through Rottmann, Sacks, and Reeve's (2014) work in establishment of a model of engineering leadership in relationship to the professional identities of engineers [7]. This model, defined by three orientations: technical mastery, collaborative optimization, and organizational innovation serves as the "engineering leadership" definition for this study. Interpersonal competencies are evident in each of the categories. Technical mastery includes subject experts who mentor others and require coaching, listening, and communicating technical concepts to various audiences [7]. Collaborative optimization includes building high performing teams where collaborating, giving critical feedback, motivating, and handling conflict are characteristics of engineering leaders [7]. Organizational innovation includes creativity and problem-solving that drive company innovation and requires relationship building as a change agent [7]. This definition provides the technical context by which leadership is applied and positions interpersonal as a factor for exploration in engineering leadership research.

We contextualize our work with respect to the breadth of leadership and management competency literature across disciplines. For the purposes of this study, we draw distinctions between competencies (and competency models) with the identification of behaviours. A competency is defined as the "dimensions of behaviour lying behind competent performance" (pg. 314) [10, 11], whereas behaviours are observable actions that are the result of a person's competency needed for effective job performance in a particular context [12]. Therefore, this study seeks to identify interpersonal leadership competency by asking senior engineering managers about observed behaviours demonstrated by early-career engineers within the social context of engineering work. We agree with Kotter that the terms "management" or "manager" are not intended to be synonymous with "leadership" or "leader;" however, despite their differences, both functions are needed for organizations to prosper [13]. We also posit that leadership cannot and should not be only defined within certain roles (e.g., management) in a workplace. Lastly, in this study, the term "early-career engineer" is defined as an individual who has entered the workforce from their post-secondary education within three years. These definitions provide the bounded structure by which interpersonal behaviours of leadership within the engineering context will be explored.

2. Literature review

2.1 The work of engineering

The criterion-specific requirements of a job are important to identify when establishing competence in specific job requirements [14]. Educational systems, however, are often void of the context by which engineering is practiced and experienced, which creates a deficit in the transition from school to work [15]. The criterion-specific requirements for engineering are identified in the body of knowledge centred on describing the work of engineering. The duality of engineering work intertwines the technical and the social, each with a different purpose, but both must be mastered for effective engineering work [16–19].

The process of solving ill-defined problems riddled with uncertainty is central to engineering [20–22]. Ill-defined problems require strong technical solutions but also an ability to work with others to solve the problems, as solutions are usually accomplished through interactions across disciplines, conversations with more experienced engineers, and collaborations within teams rather than through individual knowledge [18, 20, 23–26]. Korte, Brunhaver, and Sheppard (2009) note that for early-career engineers, initiating conversations and relationship building early in one's tenure increases the rate of socialization within the work setting and are important predictors of successful job performance [27]. The nature of problem-solving positions interpersonal interactions as a key aspect of effective engineering work.

Technical coordination is another aspect of successful engineering practice related to teamwork, relationships, and strategic collaborations [15, 28]. Trevelyan's (2007) work described early-career engineers who were informally coordinating tasks and recognized the importance of positive working relationships to get a job done [28]. Coordination activities require that engineers work across disciplines, another key aspect of engineering work [25, 29], which exposes engineers to different lived experiences and perspectives and contributes knowledge and learning needed to solving complex engineering problems [25, 29]. The complexity of cross-disciplinary experiences increases as an engineer participates in leadership activities [29]. These competencies have extended to recommendations for undergraduate engineering education. For

example, Passow & Passow (2017) conducted a meta-analysis of literature dedicated to identifying competencies important for undergraduate engineering programs to emphasize, finding that the most important competencies include problem-solving, communication, and teamwork—all of which require an element of interpersonal interactions [17].

2.2 Engineering leadership and interpersonal competence

Engineering leadership in particular is difficult to define, though several engineering-specific studies have identified key elements within engineering leadership. Consensus lies within the idea that while some foundational elements of leadership theory hold across contexts (e.g., interpersonal skills), the underlying assumption is that an engineering leader has technical competency as an engineer [7] and then has or develops the competencies to effectively manage or lead other engineers [for more details, see [30].]

Following the popularity of interpersonal competency in executive development, [31–37], engineering leadership literature promotes that interpersonal competence is an important element to incorporate into leadership development curricula [38–41], and is often included as a factor or theme in empirical studies attempting to operationalize engineering leadership [7, 42–45]. While these studies demonstrate the need for development of interpersonal competency for successful engineering leaders, the contextually-specific behaviours associated with effective and appropriate interpersonal competency related to engineering leadership has not been explored.

Research suggests engineers' personality preferences and tendencies are generalized toward introversion [46–51] with empirical evidence suggesting engineering students lack interpersonal skills [52], adding to harmful stereotypes that engineers lack interpersonal competency and potential for leadership. One way to remedy this is to operationalize behaviours within interpersonal competency related to leadership within the engineering context. Most studies typically provide only brief descriptions of interpersonal competency related to engineering leadership, but do not focus on identifying behavioural indicators or actions [12] that demonstrate effective interpersonal competence relevant to engineering work. For example, Cox et al. (2012) defined 'people skills' within the leadership factor of their study as the "ability to work with and organize people from different backgrounds in work-related situations" (p. 66) [44]. Similarly, Hartmann et al. (2017) defined 'interpersonal interaction' as "having people skills and the ability to build relationships and resolve conflicts" (p. 2), noting that the label 'interpersonal interactions' is labelled and defined differently in other studies [45]. Rottmann et al. observed that the model of engineering leadership identified may not fit in traditional notions of 'great leadership' but the characteristics "reflect engineers' professional experiences with interpersonal, team, and organizational influence" (p. 16) [7]. As such, these studies provide evidence of the importance of research defining and exemplifying the behaviours associated with interpersonal competency related to leadership within the engineering context.

The prior work in engineering leadership is relatively scarce due to the emerging nature of engineering leadership as a subdiscipline, and the aforementioned studies provide a strong motivation for considering interpersonal competency as an important aspect of undergraduate curriculum related to engineering leadership. Second, in the engineering education and engineering leadership literature, we feel there is a lack of literature that seeks to characterize dimensions of leadership of early-career engineers from the perspective of mid to late career engineers. To meet the gaps in the literature, this study seeks to answer the following overarching research question: What interpersonal behaviours do engineering managers associate with early-career engineers' leadership competency?

3. Theoretical framework

As the goal of this paper was not to present a new competency framework, but to understand how interpersonal aspects of leadership emerge within an engineering context, we chose to employ Bartram's Great Eight Competency model as a relevant leadership competency framework [14]. Literature has suggested there is a gap between leadership competency models and competencies required by organizations [53]. Bartram's (2005) framework was chosen because, although it is based on the general approach to leadership competency modelling, contextual elements of the job are at the forefront [14]. However, it is not the only leadership model or theory we could have employed; Dinh et al. (2014) identified more than 40 established leadership models and 26 emerging models [6]. However, Bartram's (2005) Great Eight competency model (Table 1) is attractive in that although it is generalizable across disciplines, the facets are specific enough to highlight distinctions between competencies, and each has a well-defined high-level definition that supports its use as a framework onto which we can map interpersonal behaviours within the criterion of engineering leadership [14].

Because the Great Eight competency model has

Table 1. Summary of Bartram's Great Eight Leadership Competency Framework. Adapted from Bartram [14]. The competency titles and associated definitions are able to be freely used for research with acknowledgement of the copyright holder, SHL Group

Competency	Definition
Leading and Deciding	Takes control and exercises leadership. Initiates action, gives direction, and takes responsibility.
Supporting and Cooperating	Supports others and shows respect and positive regard for them in social situations. Puts people first, working effectively with individuals and teams, clients, and staff. Behaves consistently with clear personal values that complement those of the organization.
Interacting and Presenting	Communicates and networks effectively. Successfully persuades and influences others. Relates to others in a confident, relaxed manner.
Analyzing and Interpreting	Shows evidence of clear analytical thinking. Gets to the heart of complex problems and issues. Applies own expertise effectively. Quickly takes on new technology. Communicates well in writing.
Creating and Conceptualizing	Works well in situations requiring openness to new ideas and experiences. Seeks out learning opportunities. Handles situations and problems with innovation and creativity. Thinks broadly and strategically. Supports and drives organizational change.
Organizing and Executing	Plans ahead and works in a systematic and organized way. Follows directions and procedures. Focuses on customer satisfaction and delivers a quality service or product to the agreed standards.
Adapting and Coping	Adapts and responds well to change. Manages pressure effectively and copes well with setbacks.
Enterprising and Performing	Focuses on results and achieving personal work objectives. Works best when work is related closely to results and the impact of personal efforts is obvious. Shows an understanding of business, commerce, and finance. Seeks opportunities for self-development and career advancement.

sustained popularity and has been employed across disciplines in prior research [54–62], we felt it was a strong choice of framework. Further, a meta-analysis of quantitative studies employing the Great Eight competency model yielded strong validity with personality, motivation, and ability predictors [14].

Epistemologically, the use of a previously established competency framework for leadership aligns both with the relatively abstract definition of ''engineering leadership'' as a construct, which has not been well-defined in literature, and therefore benefits from the structure of a previously established and well-used leadership competency framework. As noted in the methods section, the data were coded in a post-positivistic paradigm, which posits that although each person has her or his own lived experience (as generated by the coding strategy and emergent themes), there is an underlying framework that is universal. In mapping our interpersonal behaviours on to the definitions of Bartram's Great Eight framework, we well-align our methods and methodological considerations with the theoretical framework we employ. Results are further interpreted through this framework later, leading to research conclusions and recommendations for practitioners borne from theory.

4. Methods

This qualitative study identifies interpersonal behaviours of early-career engineers that are important for engineering leadership from the perspective of nine engineering leaders across three large engineering firms. Qualitative methods and methodologies represent an interpretive approach to research that situates the researcher in the world in which the problem resides, using both inductive and deductive analysis to determine patterns and themes [63, 64]. The current study analysed semi-structured interview data from nine practicing engineers to understand the phenomenon (in this case, interpersonal behaviours related engineering leadership) interpreted through another person's perspective [65–67].

4.1 Participants and recruitment

The goal for recruitment was to recruit senior level engineering managers employed by global engineering companies to be interview participants for this study. First, three companies were identified that met two researcher-generated criteria. The first criterion was that each company be a United States company and rank as one of the top ten companies in hiring the most entry-level engineers, based on job placement reports from a large, research-intensive university in the United States. The second criterion set for recruitment was that the company has a history of hiring engineers representing at least three different engineering disciplines. These two criteria ensured that participants would be able to give perspectives applicable to more than one engineering discipline, and that they were attuned to the knowledge, skills, and attributes required for engineering undergraduate students as they matriculate to careers in industry. A

Table 2. Participant and Engineering Company Characteristics

Company Characteristics	Participant Pseudonym	Participant Job Description and Relevant Characteristics
Company 1: Defense company across 70+ countries	Jacob	Manager; 8 years of leadership and management experience; supervises 27 engineers.
	Anne	Software manager; 10–20 years of leadership and management experience; supervises 20 engineers.
	Chris	Manager, 8+ years of leadership and management experience; supervises 24 engineers.
Company 2: Industrial company across 170+ countries	Seth	Manager; 9–10 years of leadership and management experience; supervises 8 engineers.
	Jesper	Principal engineer; 20 years of leadership and management experience; supervises 200–250 engineers.
	Carter	Manager of engineering design group; 10 years of leadership and management experience; supervises 12 engineers.
Company 3: Engineering project management and construction company across 160+ countries	Damon	Chief Technology Officer; 30+ years of leadership and management experience; supervises 200 engineers.
	Dillon	Project engineering manager; 30 years of leadership and management experience; supervises 200 engineers.
	Andrew	Project manager; 25 years of leadership and management experience; supervises 80 engineers.

recruitment email was sent to engineering employees at each of the three identified companies requesting participation in an interview.

Because literature has not agreed on a uniform definition of engineering leadership, a panel of experts in engineering leadership research and education was consulted to agree upon criteria to select participants from the recruited population within the three companies. Three employees at each of the companies were selected based on the following criteria: has at least 10 years of experience working in the field of engineering, holds at least a middle management position, is considered a subject matter expert in their field, and has supervised at least 20 engineers cumulatively over their career. Participants were assigned pseudonyms by the researchers, and a brief synopsis of their characteristics and characteristics of the companies for which they work are provided in Table 2.

4.2 Data collection and analysis

After consenting to participate, semi-structured interviews lasting between 60 to 90 minutes were conducted via phone. Sample interview prompts from the protocol that elicited deep responses specific to early-career engineers included the following questions:

> ''What do you observe about interpersonal behaviours of engineering leaders at the early-career stage?''
>
> ''What interpersonal behaviours are viewed as important for early-career engineers to demonstrate?''
>
> ''Can you talk about a time when an early-career engineer demonstrated positive interpersonal behaviour? Describe the situation. What behaviours did you observe?''
>
> ''What interpersonal behaviours do you associate with engineering leadership?''

The semi-structured nature of the interview allowed the researcher conducting the interview to ask participants to elaborate or provide further examples as necessary, as well as a venue for the participants to tell the researcher more details as they felt were relevant specific to observing behaviours of early-career engineers. Interviews from each of the nine participants were voice recorded using a digital recorder and transcribed verbatim using a professional transcription service. The transcripts were sent back to each participant for member checking [68] to ensure that the transcript was accurate with the participants' intentions. The interview transcripts were analysed using an open- and axial-coding process through a post-positivist approach. This approach was chosen because we seek to understand a shared reality (engineering leadership in large engineering companies) through the unique lived experiences of each of the participants. Initial categories were generated through open-coding and were organized into major themes through axial coding [69]. During coding, we ensured that the excerpts coded pertained to the interpersonal behaviours of early-career engineers, as requested by the prompt. These axial themes, or behaviour groups, were then mapped against the competency domains defined by Bartram's Great Eight framework.

4.3 Limitations of the study and maintaining quality

The main limitation of this study is the small number of participants and their representation of only a small number of engineering companies in the United States. However, qualitative research seeks ''rich, thick descriptions'' of phenomena (p. 126) [70] and rather than seeking for this study

to be generalizable, we expected that the themes of leadership that emerge from the findings of this study would augment the existing body of engineering leadership literature and extend the conversation to other researchers.

The second limitation is that the companies represented by the interview participants live, work, and were educated in the United States. This perspective may lend to a biased lens of engineering leadership from a sociocultural perspective. While this bias cannot be avoided for these participants in the present study, we do explicitly name it as a limitation and suggest that future work could be extended to international branches or companies. The companies were explicitly selected because they hire many employees directly out of university and all three of the companies selected are multi-national with operations spanning the globe.

Another limitation relates to the positionality of the participants. The participants are employed as engineering managers, and we asked them to identify interpersonal behaviours for early-career engineering leaders from their experience. Because of the rigorous recruitment and selection procedures, we posit that the participants we interviewed had experience over their years with many early-career engineers, such that they could reflect on the interpersonal behaviours that are evidence of leadership in early-career engineers. Prior research [16] has indicated that descriptions by practicing engineers do not capture all aspects of their work. This may also be true for this population; however, we anticipate that the decades of experience from engineering managers elicited reflections that span the behaviours of early-career engineers aside from just reflecting on their own roles. While we did ask the participants to discuss the activities of others after time passed, noting that human perception is not always accurate, the themes that emerged from the narratives of the engineering managers regarding early-career engineering leadership behaviours crystallized across participants and engineering industry contexts. Along these lines, we did not capture data on who the participants were describing (for example, if the majority of exemplars of engineering leadership were white and male, with no familial obligations) or the biases that the participants unconsciously hold.

We subscribe to Walther, Sochaka, and Kellam's (2013) argument that quality is not something that is established or proven at the end of a qualitative project, but rather is a series of processes and decisions that is built into the qualitative research project [71]. In this particular research study, we rely heavily on theoretical constructs of Bartram's (2005) ''Great Eight Competency'' framework for leadership as a criterion-centric rather than predictive framework [14]. We establish procedural validity in both the data-making and data-handling phases of the research, as established in the methods section. We rely on techniques to promote validity in qualitative research, especially those described by Creswell and Miller (2000) to show transparency through the recruitment, data collection, transcription, member-checking, and coding phases of this research [70]. Indeed, no research study is without its limitations, but we work toward quality in our research through transparency regarding these limitations as well as the ethical handling of data and protection of participants.

5. Results

Four groupings of interpersonal behaviours emerged after analysis of the interview data collected from the nine engineering leaders: Technical Forthrightness, Builds Interdisciplinary Alliances, Positivity through Sociotechnical Constraints, and Adaptive Communication. These behaviour groups are shown in boldface font in relationship with the Great Eight Competencies [14] in Fig. 1. Of note, the theme of Adaptive Communication engages with all eight competency domains established by Bartram (2005) and encompasses the three other codes [14].

Two of the Great Eight competencies were shared across the four interpersonal behaviour groups: Supporting & Cooperating and Adapting & Coping, as noted in the centre overlap. The interpretation of this relationship is that the interpersonal behaviours of Technical Forthrightness, Builds Interdisciplinary Alliances, and Positivity through Sociotechnical Constraints, together mediate the development of competence in the domains of Supporting & Cooperating and Adapting & Coping. Similarly, the interpersonal behaviours of Positivity through Sociotechnical Constraints and Technical Forthrightness, mediate the development of competence in Leading & Deciding and Organizing & Executing. Interpretations of the model in light of engineering leadership development are discussed after each of the four themes are operationalized for engineering contexts.

5.1 Technical forthrightness

Participants noted that many early-career engineers tend to either act without confidence or with too much confidence, noting the importance of interpersonal behaviours related to leadership that demonstrated what we summarized as Technical Forthrightness. Behaviours associated with this theme included humble confidence, accepting constructive criticism regarding technical ideas, and a

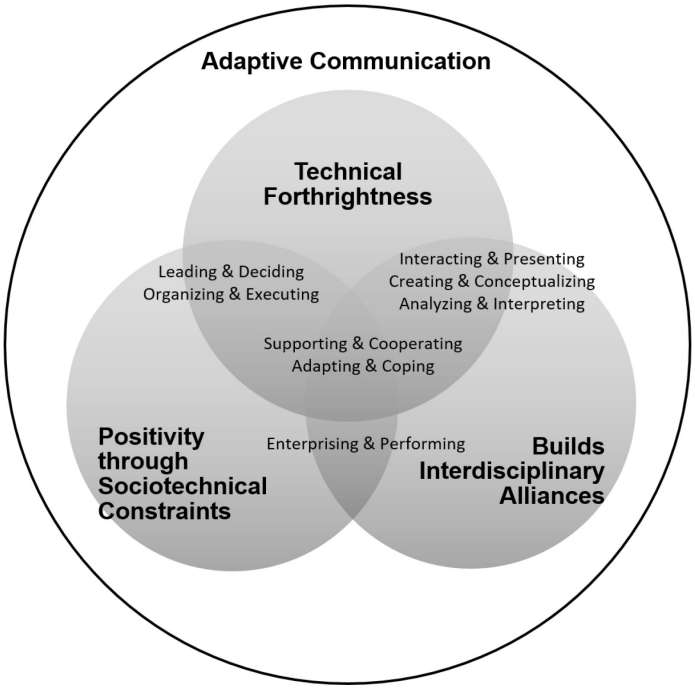

Fig. 1. Engineering interpersonal behaviour themes in relationship with Bartram's [14] Great Eight competency framework for leadership. Our emerging themes for engineering are in boldface.

willingness to say that they lack knowledge in technical understanding. While the engineering leaders noted that early-career engineering leaders should act with confidence in their decisions and communications, they should also willingly accept criticism and seek feedback to learn and improve technical performance. Andrew, as one example, noted that a good engineering leader should recognize that they may not "be successful [one] hundred percent of the time [. . .but. . .] can receive suggestive ways to improve and actually does [...change] behaviour or improv[es during] the next work project." Carter echoed this sentiment, adding that a good leader should avoid becoming defensive, instead learning from their mentors' coaching. Jacob noted humility as a key attribute within a technical leadership example, noting that early-career engineering leaders, in his opinion,

> "[. . .M]ay not be experts in every area but they're confident in themselves and the team that they're working with and knowing that if they aren't the expert they will find out who is and they're again confident in getting it done. The humble piece being that they're not overly confident. So they know they'll figure out what to do but they also know that they're not the expert."

Similarly, Jesper noted that engineering leaders "share their opinion but don't necessarily expect themselves to be right every time [, and be able to ask] 'explain that to me; why is that? What, am I missing? What don't I know?'" With respect to early-career engineers coming out of university, Jasper continued, "the humility is important because you have to be ready to find out that you're not coming out of university and going to be king of the hill in five years." The consequences of failing to have humility in receiving constructive criticism can be severe for an engineering team or company. As an example, Jacob recalled a team that had failed at establishing strong or honest relationships among themselves and other parts of the company, noting that even after running into multiple challenges, this team refused to ask for help:

> "[. . . T]hey didn't leverage expertise in the manufacturing organization [and] kind of figured [the problems] out on their own . . . and basically [this] resulted in missing multiple delivery dates."

5.2 Builds interdisciplinary alliances

All nine participants in this study mentioned the centrality of the ability to build interdisciplinary alliances as a key attribute for early-career engineering leaders, as complex projects often require trust among colleagues and subordinates across disciplines as a way of building strong teams and leveraging relationships to achieve technical goals. According to Seth, leadership at the early-career stage of an engineer's career manifests during "teaming" where interpersonal competencies demonstrate how an "engineer step[s] up to take on new opportunities, show[s] their willingness to learn, and has to get [the job] done through building

relationships with the team, others outside the team, to leverage expertise.''

An early-career engineering leader must also be able to build strong teams, another code within the building interdisciplinary alliances theme of engineering interpersonal behaviours. Interpersonal behaviours related to building strong teams centered on connecting with the right people to get the job done and recognizing the team for hard work. Seth recounted an experience when a young engineer on his team showed strong potential for leadership:

> ''So in our group, we did not have a materials person, [so one of our young engineers] went out and networked with [colleagues] to find out who the right materials person was...and then he just reached out specifically to them. So he took the initiative himself to find the right people to add to the team.''

In addition to building the ''right'' team, most of the participants noted that forming strong relationship in the team comes from the acknowledgment that, as Carter describes, ''other people are very much critical to both your individual success as well as the overall success of the company'' and that some engineers lack the ability to show gratitude for their team's contributions. He noted that ''some people come in very, very brash and [do] not show a lot of willingness to acknowledge the contributions of others.'' As Jacob revealed, even ''giving feedback to [team members] and [. . .] being able to recognize them and thank them for what they did'' can be an indicator of strong relationship-building skills.

Moreover, the relationship-orientation of an engineering leader might include an element of sacrifice. Andrew pointed out that ''it's not only your success but the team's success, so you understand that 'I need to get this done but I also need to support someone else on the team.'" He proposed that engineers need to ''be able to balance the priorities of [their] own work with what other team members might need,'' a behaviour that resulted in trust among colleagues. Trust manifested within the interviews as instrumental to completing an engineering project. First, it reflects interpersonal behaviours that demonstrated building trust among others, as Carter noted, by ''taking some time to build a personal connection and then translat[ing] that into the discussion that's relevant to work.'' Second, participants reflected on the fact that early-career engineering leaders must earn trust of more senior engineers with regard to the quality of her or his work. Carter provided an example of a successful way in which early-career engineering leaders can build rapport and trust among senior engineers in their companies:

> ''When young engineers can connect and say, 'Oh, hey. You're the person who was intimately involved in the development of Product X' (for example), it shows a lot of enthusiasm. It builds a level of rapport with that person. And I think it shows [that the] the young, entry-level engineer is keen not to just advance or be successful based on completing tasks, but by really absorbing the contexts. And they can turn around and share that. And now I've seen folks who are transitioning into managerial roles earlier in their career. They have to use this skill quite a lot because it builds a little bit of credibility. It's like, 'Hey. I've talked with this individual about their experiences over time. And I've taken some learnings from that. And I've talked to another person who'd been through [a] different project and taken some learnings from that.' I've found that has helped people transition to leadership earlier [. . . a]nd certainly I've observed that it gives people a lot more[. . .] credibility with [the] more 'grizzled veterans.' ''

Interestingly, trust was described by many participants, including Carter and Jesper, as a form of ''storytelling'' or ''networking'' as a way of building both friendships and technical expertise. As Carter noted, this storytelling is also a way for ''people, particularly [in] a big company, to be successful that they can take the time to seek out those stories, listen to them, be able to use that as a way to connect with other people.'' Without the ability to listen, build trust, and leverage the relationships and knowledge of others across disciplines, careers are rarely successful. For example, Jesper noted the experience of an unsuccessful engineer who had subsequently left the company ''who did not listen. [. . .], and he purposely didn't communicate [with people around him who had the tools to solve problems.] I think he felt like he'd somehow [was] letting himself down. Or, or somehow he was demeaning himself to network that way.''

It is important to note that in this discussion of building relationships in an engineering leadership context, the extent of extroversion or introversion or being outgoing and social was not discussed by the participants, rather it required engineers to simply listen to others in a non-virtual setting. As Carter noted: ''You can't be one just to sit at your workstation and try to handle everything virtually.'' He continued, ''You have to go seek out some time for discussions, some time for conversation with other individuals on your team as well as those who are one of your internal customers, your technical advisors, [and the] technical experts.'' In none of the interviews did the engineers note the importance of being extroverted or charismatic, but rather, that the simple behaviours related to trustworthiness, building relationships, leveraging relationships, and acknowledging team effort were the basic building blocks to interpersonal competence related to engineering leadership success.

5.3 Positivity through sociotechnical constraints

The engineering companies represented by the participants are global companies that have a variety of internal and external pressures and deadlines, while working with both technical problems and interpersonal social dynamics. As such, the participants in this study noted the requirement for early-career engineering leaders to be able to leverage positivity in the face of looming deadlines for ill-defined problems within diverse teams to continually advance the company's interest. Participants used descriptive words such as "can-do attitude," "upbeat," "enthusiastic," and "optimistic." Jacob noted that interpersonal behaviours related to engineering leadership competence stands out the most under stressful situations, when working under tight deadlines. Jacob gave an example of this positive attitude in action, recalling the experiences of a novice engineer who was given the responsibility of taking over a team after only a year of work experience, having to lead senior technical personnel who he knew were not happy with the fact that they had been overlooked to lead the technical team:

> "It was a pretty overwhelming situation because this guy was relatively new to the environment[:] new to the customer, new to the equipment. [He had] generally demonstrated up until that point this can-do attitude of, 'Yes, you know what? We're not ready to go into internal tests but I'm going to work nights and weekends to make sure we get there [. . .] I will get it done and I'll find a way to work with my internal team.' [He] also maintained that positive attitude of working with the customer and saying 'Okay. You're asking for a very aggressive schedule to get out with the field testing, but I'll do everything I can to make it happen.' "

This anecdote exemplifies a sacrificial attitude to lead the team by example, working to find solutions during a high-stress season of work as well as a leadership transition. The positive attitude can be represented in optimistic language and encouraging conversations, but also through hard work and commitment to the project and team. Elements of this narrative mimic some of the other themes, particularly the theme of trust as it emerges among technical professionals, through sacrificial work and building relationships to accomplish the team's goals. The theme of positivity is related to, but not subservient to, the theme of effective communication. Certainly, attributes of positivity, enthusiasm, or optimism can aid in adaptive communication or building interdisciplinary relationships, but because the examples of positivity from the participants extended beyond communication into a holistic attitude of optimistic perseverance while navigating technical and social situations, it was assigned its own theme in our interpersonal engineering leadership framework.

5.4 Adaptive communication

All participants noted that solving ill-structured problems requires engineering leaders to effectively manage large amounts of the pressure with calm and persuasive communication. Navigating these situations requires leaders to resist becoming overly emotional or panicked in intense project phases, while working with colleagues who might not be strong communicators. Participants described some of the strategies that early-career engineering leaders can use to adapt communications and regulate their emotions during challenges: Some phrases used to describe strategies included "keeping it all business," "sticking to the facts," or "keeping emotions out." Chris recounted:

> "We have some of the sharpest people and you'll be in a meeting and some[one will present a] bad design and they will be, 'Well, that is stupid!' right in a room full of people. [S]omebody else with interpersonal skills would say 'Hey, [. . .]that design seems like it seems like it has some issues or faults, [. . .] here are some of the reasons [. . . and] this might be a better solution for it,' [. . .]as opposed to saying 'Your design sucks!' And I've heard those actual comments in large groups of technical meetings. Now, those people will never be in front of the customer or never lead strong teams."

Tact in handling technical problems or opinions of diverse stakeholders within the company is important in technical design meetings, but also through virtual communications such as email, which are permanent and can irreparably damage rapport and credibility. Anne gave an example of a technical memo sent out that exemplifies poor engineering leadership and bad communication:

> "[The] engineers [. . .] sent out a very detailed [email] technical description of a problem, and at the end they threw in that 'if we don't do it this way we're going to fail, and management are a bunch of buffoons.' And what everybody remembers about that email is not the two pages of very technical data. It was the one sentence at the end. That this individual [. . .] let emotion get in there, and their communication skills suffered because of the emotions."

Rather than responding to stressful situations solely with emotions, the participants in the study posited that good engineering leaders can adapt their communication to the needs of their audiences, therefore being able to effectively convey important parts of the project. Jesper explained that:

> "Young engineers I've seen with good leadership skills [are] equally comfortable speaking with, say, a high-level manager or a high-level technical expert as they are in talking with their [. . .]young engineering peers, but then also people who are support staff (drafting-type people or lab technicians, test technicians) that they might interact with in the job. So they have a real awareness, a 360 [degree] kind of awareness. [T]hey're not afraid to talk to those technicians or manufacturing workers who've been essentially doing the same thing

> maybe for a very long time, but then also not intimidated by [. . .]engineering general managers or vice presidents.''

Anne echoed this thought, extending that the ability to adapt one's communication style extended to being able to adapt their communication to meet their audience's level ''quickly, without making that person feel inadequate. Just saying, 'Hey this is what we're doing' and stuff like that. So they're good presenters.''

Further, the participants noted that part of communicating effectively included developing effective active listening skills. Active listening was described by the participants as listening without interrupting, asking questions, and clarifying strategies when a decision is reached and often demonstrated ''empathetic listening'' or the ability to focus on another person's perspective. Jacob described a story that reflected the behaviours associated with building perspective from both the manufacturing floor and the engineering teams of the company.

> ''[One of our engineers] would go down [to the manufacturers] and say, 'Okay, [. . .] tell me where you're having problems [. . .] so that I can help Engineering give you what you need.' And he would listen [. . .] to their perspective of things. [. . .A]nd he would [. . .] say, 'Okay, well, this is kind of where I think engineering's head was when they made that decision. But I can understand what you're feeling, or why this is frustrating to you. Let me take it back and figure out what we can do to resolve that.' And he would conversely head back to the engineering organization [. . .] and say, 'Listen, this is the situation. This is how our products are being used. This is the challenge they are running into. I understand your frustration with them, but please understand the environment they're in and what they're trying to accomplish.' ''

Rather than reacting with emotion or imposing the engineering team's decisions on other stakeholders, this young engineering leader actively listened and brought salient information back to the engineering team, while defending the autonomy and perspectives of the other party. This strategy required adapting communication to fit the team needs while also practicing empathy for the customer, likely building trust among both parties, and establishing this engineer's reputation as a credible leader.

Other participants, too, noted that the ability to hold multiple perspectives often starts with the ability to ask questions. Chris noted that asking clarifying questions is ''part of the listening language,'' and that ''having the knack to ask the appropriate questions, without necessarily trying to lead or sway somebody, [is] a valuable skill that not everybody has.'' Anne, too, reflected on her own journey in developing engineering leadership, noting her ability to ask good clarifying questions had developed over time: ''Through my career I would just I would just fire off and just assume people knew I was trying to get at. Later on in my career, I realized that you had to follow up and say, 'Hey, this is what I think I was communicating. How did you guys perceive what I was saying?' These behaviours demonstrated concrete aspects of the adaptive communication theme that are especially salient to engineering contexts.

As evidenced within these quotations and personal anecdotes, the adaptive communication theme facilitates success in all the other dimensions, while comprising separate skill sets from any of the others. Therefore, in our model, we placed the Adaptive Communication theme surrounding the other three, interfacing with all of them as an underlying interpersonal competency.

6. Discussion

The interpersonal behaviours categorized by this study expand on prior work to contextualize engineering leadership competence specifically in engineering contexts. Engineering literature usually groups interpersonal competencies together without further operationalizing the embedded behaviours, but the importance of this study is that we operationalize interpersonal competencies within the context of engineering leadership. The four behavioural themes that emerged from this research related to interpersonal competency for engineering leadership (Technical Forthrightness, Builds Interdisciplinary Alliances, Positivity through Sociotechnical Constraints, and Adaptive Communication) are strongly interrelated.

Most leadership literature is relatively adisciplinary and can apply to many disciplinary contexts. Rather than rejecting these past works, this study mapped competencies from the Great Eight leadership competency model onto the emerging engineering-specific themes of early-career engineering leadership. The deep qualitative data operationalize each of these interpersonal behaviours within the context of engineering. Many of the stories and examples that the participants told demonstrated the overlap between competency domains and the interrelated reliance on a variety of interpersonal behaviours to accomplish engineering tasks. This interconnectedness is realistic to the contextual and real nature of leadership, where leaders do not rely solely on one trait to achieve team goals. The interview excerpts provide specific evidence of each of the interpersonal behaviours of engineering leadership themes in the context of engineering.

Findings of this current study particular to the engineering context echo the results of prior work that engineering work is riddled with challenging,

ill-defined problems that require working with other problem-solvers and problem-solving approaches [18, 20–26]. However, the findings from the present study provide specific behavioural aspects related to interpersonal competency that have not been identified in previous studies. For example, we note that effective communication is broader than presentation and oral communication skills and is related to interpersonal competency in the ability to take others' perspectives, and the ability to adapt communication to a specific audience while managing emotions. Our participants noted that engineering leaders need to be able to bring a team of diverse stakeholders together by leveraging relationships, though they noted that engineers stereotypically are not expected to be strong or effective communicators with strong interpersonal competencies.

Professional stereotypes are widely recognized. In engineering, the dominant image of an engineer is white, male, and introverted: A stereotype that engineering researchers and practitioners are working to fight, as one way to broaden participation in engineering from women and other underrepresented populations. For examples of this work, see the ''Messaging for Engineering'' [72] and the ''Changing the Conversation'' [73] reports by the National Academy of Engineering in the United States. Other countries may struggle with different social perceptions of engineers or the engineering profession. These stereotypes have been noted within engineering leadership work in the United States. As examples, Mallette [49], Robledo, Peterson, and Mumford, [74], and Rottmann, Sacks, and Reeve's [7] work observed that engineers failed to connect with traditional notions of leadership and preferred autonomous environments, where energy was stimulated through introverted activities, and much of the work was self-directed.

The results of the present study indicate, conversely, that most engineering leaders highly value the ability to listen to storytelling; to be able to tailor a message to a specific audience, the ability to lead a team of technical experts through one's own technical expertise; hard work; trustworthiness; and spirit of optimism. These competencies potentially lie outside of stereotypical notions of leaders as perpetually outspoken or aggressive. Rather than painting with broad strokes, the present study suggests that strong engineering leaders exhibit traits that help them connect best with the stakeholders with whom they must work, whether that be an internal or external client, team members, outside technical experts, or superiors. Indeed, the participants never mentioned extroversion as one of the elements of engineering leadership, instead focused on connecting with others' technical expertise to solve problems and build rapport. This observation aligns with Bartram's (2005) work that observing competencies based on abilities alone fail to consider the context by which the behaviours are being judged. This observation also aligns with Rottman, Sacks, and Reeve's [7] observations that connecting with others through coaching or mentoring activities is an essential activity associated with engineering leadership.

It should be noted that in engineering, technical skills are foundational to engineering leadership; in other words, to be an engineering leader, one must be an engineer. However, to become successful as an engineering leader, non-technical interpersonal behaviours are critical to success. As noted by participant Carter, strong early-career engineering leaders should find time to go talk to the people with whom they interface and actually have conversations as a way of learning technical content and simply building rapport with more senior engineers. In addition, horror stories like the one Anne told about the infamous email, serve as a warning to engineers that they must learn to exhibit interpersonal competence by demonstrating control over emotionally-charged situations. Therefore, the results of this study support the incorporation of leadership training involving both new communications technology (e.g., email or text messages) and face-to-face communication to engaging with others in the workplace. Further research is needed to explore interpersonal competencies associated with technological advances.

Further, future work in engineering leadership research should confront concerning stereotypes that reinforce the dominant images of leadership noted by our participants such as the ability and willingness to work nights and weekends, indicating few family obligations, which tends to exclude women and single parents. Similarly, we are concerned that our participants used language that suggested the total avoidance of emotions (e.g., ''keeping emotions out,'') rather than discussing the regulation of emotion within leadership contexts, leveraging emotion in a useful and tactful way to build relationships. With respect to changing the conversation, future work could explore these themes in engineering leadership contexts.

While we posit that the nature of this study operationalizes specific behaviours related to engineering leadership, with a focus on early-career engineering leaders in industry settings, we must note that there is a wide body of peripherally-related work that must be acknowledged for global companies. Global engineering competencies are becoming more acknowledged as companies develop international branches, supply chains, or partnerships [for examples of such literature, see Lucena, Downey, Jesiek, and Elber (2008) and

Jesiek, Zhu, Thompson, Mazzurco, and Woo (2013)] [75, 76] and that cultural connotations of strong or appropriate leadership might be different than in the United States context studied here. Similarly, the stereotypes of engineers that are held societally in the United States may not be held worldwide. These facets are outside the scope of the present study, but offer interesting lenses by which future researchers might be able to lend insight into the interpersonal competencies required for strong engineering leadership.

6.1 Recommendations for engineering educators

While interpersonal competencies have traditionally been difficult to observe, define, and assess [77, 78], the relationships that emerge between the engineering interpersonal behavioural competencies and the Great Eight leadership competencies have strong implications for the ways in which educators approach leadership education through communication. While many instructors often teach technical communication from a top-down approach, asking students or teams to produce written reports or oral presentations, our model would indicate that interpersonal behaviours may be an effective way to introduce the skills within "adaptive communication," and demonstrate engineering leadership competence in the process. As one example, engineering students often struggle to target their communication for their audience. However, by re-framing the behaviour of communication by asking students how they would develop a relationship with individuals who are members of the audience, and noting the strong intersection between the competencies of Technical Forthrightness, Builds Interdisciplinary Alliances, students can be presented with examples of how to both tailor information to their audience and to phrase design rationale in a humble, yet confident manner. In teaching these specific behaviours, students can then be scaffolded toward demonstrating Adaptive Communication behaviours, and also in building competence in Interacting & Presenting, Creating & Conceptualizing (in this case, figures or a presentation), and Analyzing & Interpreting (as they choose data to present and consider how to use data to defend a design decision). These themes are one avenue for future research-to-practice exploration.

The results and discussion of the present study also relates to the body of literature that explores leadership with emotional regulation and awareness, and the development of reflective practice. Cherniss [79] promotes emotional learning initiatives, in which students or working professionals can be taught to take multiple perspectives or solve multifaceted social and technical problems, accounting for both the cognitive and emotional domains of learning [80]. Successful emotional learning initiatives must involve four components, including establishing a motivation to change, practicing over a long period of time, modelling, receiving feedback and support [79]. Engineering leadership programmes can start by stimulating a motivation to change by building the awareness of effective interpersonal behaviours associated with leadership competency within the engineering context.

Finally, as Rottmann, Sacks, and Reeve [7] suggested, it is important for engineering educators to acknowledge the disconnect between traditional notions of leadership and engineering identities. From this study, educators should expand on dispositional characteristics associated with engineering leadership during the early-career stage to combat against the idea of leadership being synonymous with extroversion or charisma. The interpersonal competencies related to leadership at the early-career stage (Technical Forthrightness, Builds Interdisciplinary Alliances, Positivity through Sociotechnical Constraints, and Adaptive Communication) can be framed within a context of technical mastery and collaborative optimization aligning with engineering identities.

7. Conclusions

While calls for the teaching of non-technical skills in engineering education and development that emerged in the early 2000s worldwide resulted in the emergence of various leadership development programs and interest in research, there is still a large amount of discipline-specific engineering research to be conducted. This study used interview techniques to study the experiences and perceptions of interpersonal engineering leadership competencies in particular from nine practicing engineering leaders across three global companies with headquarters in the United States. Four interpersonal behaviour groups emerged from the qualitative analysis: Technical Forthrightness, Builds Interdisciplinary Alliances, Positivity through Sociotechnical Constraints, and Adaptive Communication. We mapped these four behaviours against the Great Eight leadership competencies, operationalizing the behaviours for engineering and positing that the behaviours are mediators for developing and demonstrating leadership competencies. None of the participants discussed these interpersonal competencies with regard to classical traits of extroverted leadership; rather, in engineering contexts, focus on strong technical communication and interpersonal awareness are highly valued. As an effort to begin to educate engineering students and practicing engineers on the interpersonal competencies

required for engineering leadership, we note in the discussion section that many non-technical skills require experiential types of learning; therefore, engineers must be open to education, training, and development related to these areas. Specifically, experiential learning needs to incorporate reflection, support, and feedback to impact behavioural change for leading within an engineering environment. A key distinction of this study highlights the importance of developing communication competencies beyond oral and written skills. Engineering leadership education and training initiatives should also incorporate knowledge and practice in adapting communication behaviours to various audiences, personalities, and emotionally charged situations. To continue research in engineering leadership, we propose that research and development of competency models and associated behaviours developed within engineering contexts will be an important step for acceptance within the engineering profession.

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