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LEADERSHIP COMPETENCIES FOR POST-SECONDARY ENGINEERING EXPERIENCES:

A Delphi Study of Industry Perspectives

Abstract

The national society of professional engineers has said, "engineering has a direct and vital impact on the quality of life for all people." The demand for career-ready engineering professionals has been a consistent, high priority area for the U.S. workforce for the last several decades. Specifically, this call expresses a desire for engineers that are deeply prepared in their technical areas, but also broadly capable as participatory leaders and team members. Thus, leadership-coupled professional competencies that enhance teamwork and problem solving are in high demand from the engineering industry. However, contemporary research suggests that postsecondary engineering programs do not adequately prepare graduates in these areas. This Delphi study identified the consensus perspective of an industry panel regarding the most valuable competencies within the organizational culture of engineering firms. After three iterative rounds, 14 leadership-coupled competencies were identified.

Introduction/Literature Review

The U.S. Bureau of Labor Statistics recognizes that Engineering is making steady growth across its disciplines and accelerated growth in areas such as civil engineering (Bureau of Labor Statistics, 2019). It is reasonable to expect this trend to continue, given the growing global demand to meet infrastructural, energy-based, and technological challenges. To this end, the United States has identified Science, Technology, Engineering, and Mathematics (STEM) development as a priority in American education (Committee on STEM Education & National Science and Technology Council, 2013). The challenges of today and tomorrow require increasingly cooperative, complex, and creative solutions driven by innovative teams of professionals. Thus, the call to bolster the U.S. workforce pathways in STEM, in part, requires more collaborative and professionally skilled engineers.

Professional organizations within the engineering field have expressed a need for a workforce equipped with professional skillsets that match technical competencies (American Society for Engineering Education, 2015; National Academy of Engineering, 2004; Williams & Emerson, 2019). Many of the competencies articulated as professional skills within the engineering industry, such as communication skills, problem-solving skills, etc., are thought of as components of leadership among leadership scholars (Mumford, Zaccaro, Connelly, & Marks, 2000; Seemiller, 2016). In an effort to avoid semantic confusion, such competencies will hereafter be referred to as leadership-coupled competencies. The ABET Student outcomes for accreditation of engineering programs (see table 1) serve as the best representation of how leadership-coupled competencies are intended to be integrated into engineering curricula.

Table 1
ABET Student Outcomes

ABET 2019-2020 Student Outcomes
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives*
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

However, as in many postsecondary programs, the implementation of these outcomes varies. Seemiller and Murray (2013) found that U.S. postsecondary engineering programs averaged just 1.3 leadership competencies per program (for comparison, education averaged 13, and public service averaged 18.7).

Despite the expressed need for curricular development of leadership-coupled competencies, engineering students significantly fall behind their counterparts in said competencies (Stephens & Rosch, 2015). Stephens and Rosch found that majoring in engineering was a small, but significant predictor of diminished leadership skills, lower co-curricular involvement, and fewer mentoring experiences in college. The latter observations are troubling, considering that mentoring and co-curricular experiences are among the practices with the highest impacts for leadership development (Priest & Clegorne, 2015). Given industry demands and the lack of expressed outcomes within engineering curricula, this study was developed to understand better what leadership-coupled competencies were valued most in new professionals by their industry leaders.

The focus on leadership-coupled competencies in engineering should not be misconstrued as a need for more positional leaders or managers in engineering firms. Indeed, the managerial structures of most firms are and will remain relatively hierarchical as is organizationally functional. Such hierarchical frameworks were evident during the face validation of the instrument used in this study (described below). The mere mention of the word “leadership” during face validation of the Delphi instrument conjured notions of positional authority and/or top-down management among pilot participants. This notion was despite accreditation standards that suggest engineers have “an ability to function effectively on a team whose members together provide leadership” (ABET, 2018). It is prudent, then, to understand the difference between creating leaders and developing leadership capacity within new professionals.

In seeking to develop better leaders, one assumes that the sum of all human capital within a given organization benefits primarily from the focused training of an elite class (i.e., leaders). In doing so, one assumes these individuals are perfect amalgams of technical expertise and inspirational charisma (i.e., the Great Man and Trait theories of leadership) (Northouse, 2016; Western, 2013). In contrast, the notion of leadership development promotes a shared process that is highly contingent on context and perspective (Heifetz, Grashow, & Linsky, 2009; Jepson, 2009; Skipper & Bell, 2006; Western, 2013). It follows that better teaming and resilience (i.e., Robledo, Peterson, & Mumford, 2012) for solving complex engineering problems might be achieved by developing a culture of leadership across the engineering workforce, rather than a cadre of leaders.

Distributed leadership has become widely used to describe an organizational structure that practices shared ideation and accountability for creating or navigating change (Harris, Leithwood, Day, Sammons, & Hopkins, 2007). Spillane, Halverson and Diamond (2004) have contributed the most developed theoretical work on distributed leadership. They define Distributed Leadership as a socially distributed practice that "stretch(es) over the work of a number of individuals and…is accomplished by multiple leaders" (p. 20). Practically speaking, this workplace ecosystem is at the heart of calls for better leadership competence among emerging engineers (Hacker, 2017).

Distributed leadership, and particularly Eco leadership (Western, 2013), is in keeping with the industry's desire for emerging engineers to function in contemporary society. By framing the research questions around the role of the new professional within the workplace ecosystem, this study was designed to simultaneously disrupt the hierarchical tendency to label leadership as positional and coax out expert opinions on the role of distributed leadership (Gardner, 1987; Spillane et al., 2004) throughout the workplace and world. Closing the gap between industry needs and academic teaching and research is essential when grappling with professional preparation in the 21st century. The purpose of this study was to articulate the leadership-coupled competencies desired by industry leaders in engineering firms.

Methods

The Delphi technique used is a mixed-method pioneered by the RAND Corporation (Brown, Cochran, & Dalkey, 1969; Linstone & Turoff, 1975). The method was designed to gather consensus opinions from experts on a variety of topics since the mid-20th century (Linstone & Turoff, 1975). Delphi studies rely on the informational influence of anonymous panelists through multiple rounds of questionnaires. Anonymity is key because it reduces undue "groupthink" to maintain the individuality of participants while seeking consensus (Gines-Rivera, 2010). During the process, broad opinions are generated and then honed into a more focused list based on statistical consensus (Powell, 2003). This method was chosen to elucidate consensus opinions of engineering industry leaders regarding the most valued leadership-coupled competencies in their organizations. A diagram of the Delphi process used in this study is found in figure 1.

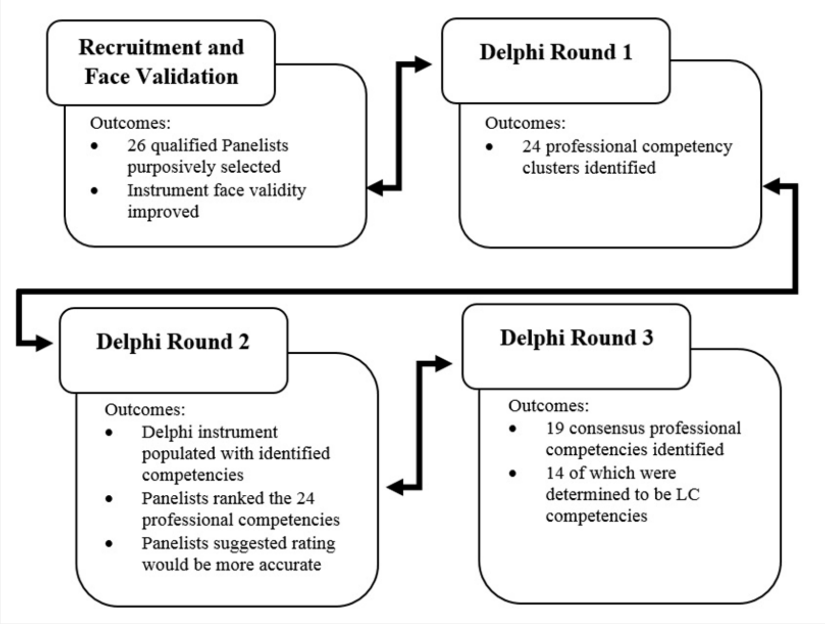

Figure 1. Overview of Delphi Procedures

* LC = Leadership-Coupled

This study used a battery of strategically designed questionnaires distributed to a panel of experts on the organizational culture surrounding new professionals in engineering. Each questionnaire distribution was considered a "round." First, the expert panel shared their qualitative opinions regarding leadership-coupled competencies for new professionals in engineering. The open-ended phase was then followed by subsequent instrument administrations that allowed for quantitative analysis of the panel's ranking/rating of code clusters. Finally, the resultant consensus competency clusters were checked for relatedness to leadership constructs.

Participants. There are no established conventions for panel size in a Delphi study (Hsu & Stanford 2007; Mullen, 2003). Most studies retain approximately 20 expert panelists throughout the process (Hsu & Sandford, 2007; Okoli & Pawlowski, 2004). Reid (in Mullen, 2003) suggests that this moderate panel size encourages participation and helps maintain adequate participation (i.e., Bradfor, 1996).

Sampling for this study was purposive. Delphi panelists were recruited from the civil engineering and construction advisory board at a mid-Atlantic Tier 1 Research University (Carnegie research classification "Very high"). Further, experiential requirements promoted a panel with strong expertise about organizational culture related to new professional expectations. Panelists were required to be employed in construction/civil engineering firms. Civil Engineering and Construction disciplines were selected because their related industry partners include the greatest diversity of engineering disciplines (e.g., electrical, mechanical, chemical, etc.). Panelists were also required to have at least ten years of professional experience and hold a supervisory and/or visionary position in their associated firm. These qualifications ensured a panel with expertise in real-world organizational culture (Kieser & Leiner, 2012) and the connection to the goals of the study (postsecondary engineering curriculum) (see Table 2).

Table 2

Summary of Delphi Expert Panelists

Identifier	Age Bracket	Gender	Race	Current Role Company
Panelist 1	25 to 34	Male	White	Project Manager
Panelist 2	35 to 44	Male	White	President
Panelist 3	35 to 44	Male	White	Vice President
Panelist 4	35 to 44	Male	White	Vice President
Panelist 5	35 to 44	Male	White	Vice President
Panelist 6*	35 to 44	Male	White	Project Executive
Panelist 7 *	35 to 44	Male	White	Senior Vice President
Panelist 8	45 to 54	Male	White	Vice President
Panelist 9	45 to 54	Male	White	President
Panelist 10	45 to 54	Male	White	Executive Vice President
Panelist 11	45 to 54	Male	White	President
Panelist 12	45 to 54	Female	White	Construction Administrator
Panelist 13	45 to 54	Male	White	President
Panelist 14*	45 to 54	Male	White	Principal and Director
Panelist 15	55 to 64	Male	White	President and Chief Executive Officer
Panelist 16	55 to 64	Male	White	Senior Project Manager / Advisor
Panelist 17	55 to 64	Male	White	Executive Vice President
Panelist 18	55 to 64	Male	White	President
Panelist 19	55 to 64	Male	White	Senior Vice President
Panelist 20	55 to 64	Male	White	President and Chief Operations Officer
Panelist 21*	55 to 64	Male	White	Chief Executive Officer
Panelist 22*	55 to 64	Male	White	Senior Vice President
Panelist 23	> 65	Male	White	Retired
Panelist 24	> 65	Male	White	Retired/Consultant
Panelist 25	> 65	Male	White	Retired
Panelist 26	> 65	Male	White	Chief Executive Officer

*Indicates panelists who did not participate in all Delphi rounds

All of the advisory board members (N = 61) were contacted via email and invited to participate in a phone call wherein the study was fully explained. During the phone calls, their qualifications and interest were vetted. Out of the 34 qualified individuals, 26 panelists were able to participate in the study.

The panel was largely homogenous with regard to self-identified race and gender. This lack of diversity was primarily a result of the population rather than the sample itself. The demographic distribution of the final expert panel was predominantly white males. As problematic as such homogeneity may be, it is nonetheless generally representative of the current population of engineering leaders (Bureau of Labor Statistics, 2019). This representative panel was preferred, given the goal of this study to measure extant industry perceptions. Understanding how the industry exists today will allow subsequent critical analysis of current practice, including further examination of equity and access in the field.

Given the “survey-resurvey-repeat” nature of Delphi studies, attrition among panels is common (Brown et al., 1969; Linstone & Turoff, 1975). Bradfor (1996) recommended at least 70% of the panel be retained to preserve statistical power. Throughout the Delphi process, five panelists were unable to maintain full participation reducing the final panel membership to 21 individuals (80% of the original panel).

Instrumentation and Analysis. A pilot panel was consulted regarding the face validity of the initial Delphi Questionnaire. The panel consisted of three members including: (1) A professional development administrator from the Accreditation Board of Engineering and Technology, (2) A representative from the American Society of Engineering Education (ASEE). (3) A qualified panelist from the pool who was unable to participate in the full study. Specific concerns regarding face validity were to minimize dominance and myside biases, which were identified to be the most likely validity concerns with this type of instrument (Hallowell & Gambatese, 2009). Ultimately, the panel identified one issue of primary concern. The panel shared that the language surrounding leadership was too value-laden. They suggested the instrument needed to parse out leadership and professional skills to ensure thoroughness in the responses better. The round one questionnaire was designed based on this feedback.

The number of rounds in a Delphi study is determined by statistical measures on consensus (typically descriptive statistics). Determining when to cease re-surveying is a balance between maintaining participation (Skulmoski et al., 2007) and honing panelist consensus (Gines-Rivera, 2010; Hsu and Stanford, 2007). This study ultimately consisted of three rounds of questionnaires. Open-ended, rank-order, and Likert-style rating items were used to identify and refine opinions on leadership coupled competencies. The Qualtrics online survey application was used to distribute the questionnaires. Panelists were provided a description of the multi-round method verbally (over the phone) and in writing through informed consent documentation within the survey. All panelists voluntarily consented to participate in the study.

The first-round instrument collected demographic data including age, degrees earned, current employment, position in company, years in the profession, gender, race, and ethnicity. The panelists were given a 4,000-word text box in which to "describe any knowledge, skills, and/or abilities [they felt] contemporary, upwardly mobile new (engineering) professionals require." As suggested by the face validation panel, this language was free from leadership jargon and designed to invite authentic expert opinions on general professional competencies for new professionals entering the workforce (many of which were predicted to be leadership-coupled given previous review of literature and anecdotal experiences). The second prompt allowed panelists to respond regarding the value of Seemiller and Murray's (2013) eight leadership competency domains (as seen in table 3) to the engineering field by rating each competency domain as "2 - very important", "1 - moderately important", or "0 - not important at all". Seemiller and Murray's student leadership competency domains were chosen because of their direct connection with postsecondary curricula.

Participants were given one week to reply, reminded via email after the week concluded, and the survey was closed after a second week. A list of 24 competencies and their descriptions was compiled from panelist responses on the two prompts as follows. First, similar sensitizing concepts and language were grouped together from prompt 1. Next, domains with mean scores that indicated moderate to high importance from prompt 2 were included. Finally, the Median Absolute Deviations (MAD) for each domain in prompt 2 were checked for corroboration with open responses from prompt 1. Details of this analysis are provided in the results section. A total of 26 participants participated fully in this round.

The round two questionnaire was created from the competencies identified in round one. The round two questionnaire listed the competencies and descriptions identified in the first round in a randomized order. Panelists were asked to rank the competencies, provided feedback regarding their structures and descriptions, and add any competencies they felt were missing. The list was then analyzed using descriptive statistics (Median Absolute Deviation) as suggested by Hallowell and Ganbatese (2009). A total of 23 participants participated fully in this round.

The quantitative analysis and participant feedback from round two necessitated the distribution of a third instrument (round three). Here, the panel was given the opportunity to rate each competency cluster using a 6-point Likert scale. Using absolute median deviation and observing the frequency distribution of responses for each competency cluster provided a clear picture of the competency clusters that were most agreed upon across the panel. It was determined that no further examination was needed beyond the third round because consensus on each topic was either established or determined to be unlikely through quantitative analysis. This is typical, with two to three rounds being the norm to establish consensus in most Delphi studies (Holey et al., 2007). A total of 21 participants fully participated in this round. Based on the 6-point scale's smallest increment (16.67% of the scale {MAD ≤ 0.5}) it was determined that 19 of the 24 competencies were found to have met statistical requirements for consensus.

Results

Round One. Open responses from the Delphi panel (n=26) generated 87 unique codes noting desired knowledge, skills, and abilities. Additionally, the panel provided opinions regarding the importance of Seemiller and Murray's (2013) Student Leadership Competencies (see table 3). Domains were included if the mean indicated they were moderately to very important (M ≥ 1.0) and they corroborated with any open-ended responses. Ultimately, the extant leadership competency domains of Communication, Learning and Reasoning, Personal Behavior, Interpersonal Interaction, Strategic Planning, Group Dynamics, Self-awareness and Development were found to have enough evidence for inclusion based on descriptive statistics and corroboration with the first prompt. Civic Awareness, was more contested within panelist responses and none of the open responses in the first prompt corroborated any elements of the domain. Thus, Civic Awareness was not included. The implications of the panel's omission of the competency domain will be addressed in the discussion section. Language from the extant domains was subsequently treated as textual data, coded, and integrated into the competency clusters. Like ideas were clustered to create 24 competency names and descriptions as shown in table 4. Many responses were repeated by a majority of the panel. The most popular responses were communication, teamwork, and critical thinking.

Round Two. The list of competencies and descriptions was used to produce the round two questionnaire. The competencies and corresponding definitions were presented to the panel. Panelists were asked to rank the competencies from most important (1) to least important (24). As with the first round, panelists were given a week to respond and then reminded via email. Three panelists did not respond, so a total of 23 panelists participated fully in this round (see table 5).

Table 3
Round 1 Results: Panelist Ratings of Extant Leadership Competency Domains

	Very Important (2)	Moderately Important (1)	Not Important / Unsure (0)	*M*	*Mdn*	*MAD*	Corroborated in prompt 1?
Communication	25	1	0	1.96	2.00	0	Yes
Learning and Reasoning	23	3	0	1.88	2.00	0	Yes
Personal Behavior	23	3	0	1.88	2.00	0	Yes
Interpersonal Interaction	21	5	0	1.81	2.00	0	Yes
Strategic Planning	13	13	0	1.50	1.50	0.5	Yes
Group Dynamics	13	12	1	1.46	1.50	0.5	Yes
Self-Awareness and Development	12	11	3	1.35	1.00	1	Yes
Civic Responsibility	3	16	7	0.85	1.00	0	no

Table 4

Round 1 Results: New Professional KSAs desired by engineering industry leaders

Competency	Description
Critical Thinking/ Problem Solving	Responds to daily tasks, especially adversity or unexpected events, with clear analysis, good decision-making, and successful improvement
Legal Knowledge	Understand legal concepts as related to the industry (mostly contracts)
Professionalism	Maintains an appearance, demeanor that are professional and contributes positively to the work environment
Computer Skills	Is capable with relevant software and hardware
Public speaking	Is able to communicate clearly through face-to-face, video conference, phone, and presentation in a clear and concise manner
"Big Picture" Thinking	Understands how the whole system works, Recognizes the impact that all elements of the system can have on whole and keeps the end goal in mind
Communications Skills	The ability to listen to others and convey ideas effectively
Management	Manages processes and resources well; in general and within project teams
Safety and Risk Management	Maintains protocols and procedures to maintain a safe work environment.
Learning, Discovery, and Research	Desire to learn more, develop as a professional, find new solutions, and/or research new ideas in the industry
Business Skills	General understanding of how business functions (e.g. budgeting and finance skills, marketing, etc.)
Ambition/Drive	Motivated to get better, succeed, rise in the organization, and do more
Economic Principals/trends	General understanding of economic and political ties to company mission and performance
Humility	Receives feedback well, recognizes own personal limitations
People Focus	The ability to maximize human relationships and get the most out of every member of the team
Self-awareness	Understands his/her role and capabilities, manages emotions well, and is aware of his/her impact on others and the company
Patience	Calm and collected when dealing with adverse situations or difficult people
Writing Skills	Communicates clearly, completely, and succinctly in written media (emails, memos, reports, etc.)
Time management	Prioritizes tasks, manages multiple projects, meets deadlines, etc.
Assertiveness	The ability to assert one' own opinion in a firm, but professional, non-aggressive way
Adaptability	Applies his or her skills and resources to new contexts well
Ethics/Responsibility	Performs duties in good faith maintaining the best interests of all parties involved. Understands the impact that his/her actions have on others
Teamwork/Collaborati on/networking	The ability to work well with others, even those who you may find difficult Recognition that shared ideation generally creates solutions that are

Table 5
Round Two Results: Descriptive Statistics of Competency Ranks

Engineering New Professional Competencies		*N*	*M*	*Mdn*	*MAD*
1.	Critical Thinking/Problem Solving	23	2.48	2	1
2.	Communications Skills	23	4.00	3	1
3.	Professionalism	23	6.69	7	2
4.	"Big Picture" Thinking	23	8.83	8	4
5.	Teamwork/Collaboration/networking	23	9.57	8	4
6.	Public speaking	23	10.39	9	3
7.	Management	23	10.39	11	5
8.	People Focus	23	10.87	9	4
9.	Time management	23	10.87	10	3
10.	Ambition/Drive	23	10.91	11	5
11.	Ethics/Responsibility	23	11.13	13	7
12.	Self-awareness	23	13.17	14	4
13.	Writing Skills	23	13.22	14	6
14.	Learning, Discovery, and Research	23	13.57	14	2
15.	Humility	23	14.09	13	4
16.	Patience	23	14.22	13	3
17.	Computer Skills	23	14.30	13	7
18.	Safety and Risk Management	23	14.61	16	3
19.	Business Skills	23	14.96	15	2
20.	Assertiveness	23	16.87	17	5
21.	Adaptability	23	16.87	16	3
22.	Quality Control	23	17.52	17	5
23.	Economic Principals/trends	23	19.65	21	2
24.	Legal Knowledge	23	20.91	23	1

This study was designed to explore the most valued leadership-coupled competencies within engineering organizations. Responses were analyzed using descriptive Mean (M) and Median Absolute Deviation (MAD) statistics. Highly valued consensus required both a relatively high mean and low deviation, respectively. A mean within the top third of the scale was chosen as an indicator of high value among the panel. Hallowell and Gambatese (2009) suggest acceptable consensus can be statistically identified by a MAD value < 1/10 of the scale (p. 102). Given the 24 possible ranks a MAD ≤ 2.4 was required to demonstrate consensus in this round. Ultimately, to meet the goal of "highly valued consensus", competencies were required to have a mean score within the top third of the scale (≤ 8.0) and a MAD of ≤ 2.4. Only three competencies satisfied these requirement including Critical Thinking/Problems Solving (M = 2.48, MAD = 1), Communications Skills (M = 4, MAD = 1) and Professionalism (M = 6.69, MAD = 2).

Panelists were also allowed to offer open feedback regarding the competency names and descriptions. No substantive feedback was provided regarding competency content, however many panelists suggested that ranking the competencies was difficult. These panelists felt that many competencies were equally important and ranking create a false hierarchy. This feedback as crucial to the development of the next questionnaire.

Round Three. Round two of the Delphi process yielded little consensus from the panel. Furthermore, the feedback from the panel suggested that they be allowed to rate, rather than rank the competencies. The round three questionnaires consisted of the same competencies and descriptions used in round two (as no edits were suggested by the panel in round 2). This round, however, panelists were able to rate each competency using a 6-point Likert scale. As with the prior rounds, panelists were given a week to respond and then reminded via email. Two panelists did not respond so total of 21 panelists participated fully in this round.

Consensus was again measured using the guidelines of Hallowell and Gambatese (2009), but adjusted for a scale smaller than the 10-point Likert on which their suggestions were based. Based on the 6-point scale's smallest increment it was determined that consensus would be found if the MAD was no greater than 1 increment (16.67%) of the scale (MAD ≤ 0.5). A detailed account of the descriptive statistics of round three is presented in table 6. A review of the descriptive statistics from the final round of the study indicated that 19 of the 24 competencies including Communications Skills, Ethics/Responsibility, Professionalism, Critical Thinking/Problem Solving, "Big Picture" Thinking, Ambition/Drive, Self-awareness, Humility, Teamwork/Collaboration/networking, People Focus, Time management, Management, Adaptability, Quality Control, Computer Skills, Safety and Risk Management, and Assertiveness, Legal Knowledge, Economic Principals/trends were found to have met the expectations for consensus given their MAD values of 0. Business Skills, Patience, Public speaking, Writing Skills, and Learning, Discovery, and Research were excluded from the list given their MAD values > 0.5 (see table 6).

Both the engineering industry and postsecondary engineering curricula distinguish between technical skills and professional skills. This study focused on Identifying leadership-coupled professional skills. Quality Control, Computer Skills, Safety and Risk Management, Legal Knowledge, and Economic Principals/Trends were all competencies with high means and strong statistical consensus, but were not determined to be leadership-coupled. These non-leadership professional competencies were dropped from the list after round three. The final list of leadership-coupled professional competencies for engineers is as follows in table 7.

Table 6
Descriptive Statistics and Analysis (After Round 3)

Competency	Frequencies						*M*	*Mdn*	*MAD*
	6	5	4	3	2	1			
Communications Skills *	15	6					5.71	6	0*
Ethics/Responsibility *	16	4	1				5.71	6	0*
Professionalism *	13	8					5.62	6	0*
Critical Thinking/Problem Solving *	13	8					5.62	6	0*
"Big Picture" Thinking *	14	6	1				5.62	6	0*
Ambition/Drive *	12	9					5.57	6	0*
Self-awareness *	11	10					5.52	6	0*
Humility *	12	8	1				5.52	6	0*
Teamwork/Collaboration/networking *	12	8	1				5.52	6	0*
People Focus *	14	6				1	5.48	6	0*
Time management *	9	12					5.43	5	0*
Management *	7	14					5.33	5	0*
Adaptability *	9	11	1				5.38	5	0*
Quality Control *	8	12	1				5.33	5	0*
Computer Skills *	8	11	2				5.29	5	0*
Safety and Risk Management *	6	13	2				5.19	5	0*
Assertiveness *	6	11	4				5.10	5	0*
Legal Knowledge *	3	14	3	1			4.90	5	0*
Economic Principals/Trends*	3	14	3	1			4.90	5	0*
Business Skills	10	10	1				5.43	5	1
Patience	10	10	1				5.43	5	1
Public speaking	10	9	2				5.38	5	1
Writing Skills	9	10	2				5.33	5	1
Learning, Discovery, and Research	10	7	3	1			5.24	5	1

6 = Strongly Agree, 5 = Agree, 4 = Slightly Agree, 3 = Slightly Disagree, 2 = Disagree, 1 = Strongly Disagree. * Median Absolute Deviation was required to be ≤ 0.5 to indicate consensus (i.e. Hollowell and Gambatese, 2009) .

Table 7

Round 3 Results: Final Leadership-Coupled Professional Competencies for Engineers

Competency	Description
Critical Thinking/Problem Solving	Responds to daily tasks, especially adversity or unexpected events, with clear analysis, good decision-making, and successful improvement
Professionalism	Maintains an appearance, demeanor that are professional and contributes positively to the work environment
"Big Picture" Thinking	Understands how the whole system works, Recognizes the impact that all elements of the system can have on whole and keeps the end goal in mind
Communications Skills	The ability to listen to others and convey ideas effectively
Management	Manages processes and resources well; in general and withi project teams
Ambition/Drive	Motivated to get better, succeed, rise in the organization, an do more
Humility	Receives feedback well, recognizes own personal limitations
People Focus	The ability to maximize human relationships and get the most out of every member of the team
Self-awareness	Understands his/her role and capabilities, manages emotior well, and is aware of his/her impact on others and the company
Time management	Prioritizes tasks, manages multiple projects, meets deadline: etc.
Assertiveness	The ability to assert one' own opinion in a firm, but professional, non-aggressive way
Adaptability	Applies his or her skills and resources to new contexts well
Ethics/Responsibility	Performs duties in good faith maintaining the best interests of all parties involved. Understands the impact that his/her actions have on others
Teamwork/Collaboration/networking	The ability to work well with others, even those who you ma find difficult. Recognition that shared ideation generally creates solutions that are more effective. Invests time in appropriate connection with colleagues/clients

Discussion. For at least three decades, the United States has focused heavily on bolstering its workforce in the fields of Science, Technology, Engineering, and Mathematics (STEM) (Bybee, 2010; Noble, 2003). Additionally, the movement towards national curriculum standards in P-12 education has widely generated curricular designs that privilege a narrow scope within the curriculum focusing only on core subjects and further privileging STEM disciplines (Taubman, 2015; Taubman, 2010). In combination, such curricula have elevated the technical and computational elements of the STEM disciplines while minimizing Leadership-Coupled Competencies (e.g., leadership, critical thinking, communication, etc.) by labeling them “soft skills” or compressing such content into a single “catch-all” course.

A 21-member Delphi panel provided expert consensus opinion on a list of 14 leadership coupled competencies for new engineering professionals across three iterative rounds. The Delphi panel was constructed from the advisory board of a large research-intensive university in the mid-Atlantic region. Panelists were located all across the region and supervised a wide variety of engineers. The statistical rigor applied to determine consensus (i.e., Hallowell and Gambatese, 2009) and maintaining suitable retention across the panel (i.e., Mullen, 2003; Bradfor, 1996; Reid, 1988) promoted a strong internal validity within the process. While this study cannot be generalized beyond the region, we suspect that, given industry norms (i.e., ABET, 2018; National Society of Professional Engineers, 2004), similar panels from different regions may yield comparable results.

Across the three iterative rounds of the Delphi study, 87 coded responses were combined and statistically winnowed down to 19 professional competencies. Non-leadership competencies were removed, and 14 leadership coupled professional competencies emerged from the analysis. Though postsecondary engineering curricula tend to omit leadership outcomes (Seemiller and Murray, 2013), industry experts have suggested, here, that leadership-coupled professional competencies are important for new professionals. Recognizing which leadership-coupled competencies are most valued by industry can help shape undergraduate curriculum and advising (especially with regards to co-curricular activities). If leveraged meaningfully, such curricular interventions can prepare more career-ready engineers.

In order to prepare a workforce and citizenry equipped to engage in complex participatory leadership, specific competencies and their subordinate skillsets must be developed (Komives & Wagner, 2016). This suggestion is opposed to much of the engineering leadership literature which frames leadership competence as a differentiated expectation reserved for the relatively few in management positions (Simmons, Clegorne & Woods-Wells, 2015). Professional organizations in engineering appear to heed the call for distributed leadership as well. The National Academy of Engineering (NAE) suggests that the abilities referred to here as leadership-coupled are an expectation of all contributing members of the engineering workforce (Williams & Emerson, 2019).

The Delphi Panel recognized that many competencies related to teamwork and distributed leadership were essential in the workplace. However, key elements of functional leadership practice, such as empathy and social judgment, were unable to achieve consensus in the study. Researchers studying leadership competence have identified these elements as some of the most important factors for high functioning teams. Katz (1974) and Mumford et al. (2000) both acknowledge that the ability to empathize and understand others plays a significant role in functioning on teams.

The social judgment attribute described by Mumford et al. (2000), while not wholly omitted from the panel's competencies, is less prevalent than individual characteristics. The intrapersonal competencies that the panel produced are focused generally on achieving for the company while remaining humble, ethical and responsible. Knowledge of one's self appears important in these aspirations. On the other hand, the more interpersonal competencies are more results-driven, and the knowledge of others is discussed more often as a means to an end. Two examples of this are the "people focus" and Teamwork/ Collaboration/ networking" competencies. The "people focus" competency suggests that individuals should "Maximize relationships to get the most out of every member".

Similarly, the Teamwork/ Collaboration/Networking competency suggests "recognition that shared ideation creates solutions that are more effective." While these assertions are not negative per se, they lack the ethic of care and social awareness suggested by other competency frameworks. This phenomenon is further underscored by the fact that Seemiller and Murray's (2013) Civic Responsibility domain (including competencies for understanding and valuing diversity, others' circumstances, social justice, inclusion, social responsibility, and community development) was the only competency domain from the first round to fail to garner consensus.

The lack of consensus around the topic in this study is bolstered by the findings of others (e.g. Jack et al., 2013; Cech, 2014). The struggle to find consensus around social competencies and civic welfare in engineering has been attributed to a technical/ social dualism that troubles social competencies in engineering (Cech, 2014). The inclusion of more civically-minded participatory competencies is likely to create better frameworks for highly functional teams in diverse organizations (Mumford et al., 2000). However, integrating such interventions into the curriculum is easier said than done. The literature in this area suggest that the interplay of social and technical competence is more nuanced.

Several meaningful studies describe a tension between technical and social competencies within engineering (Jack et al., 2013; Cech, 2014). While social competencies are valued among many in academe and industry, prolonged engagement in engineering appears to cause interest in public welfare to wane among students (Cech, 2014). Recent studies have attributed this phenomenon to cognitive function suggesting, based on neurological evidence, that the human brain cannot analyze and empathize simultaneously (Matyszczyk, 2012; Vanasupa, Sochacka, & Streveler, 2018). Given these complex social and cognitive obstacles Walther et al. (2020) explain that the integration of civically-minded skillsets such as empathy are "more complex than simply adding another 'nice to have' professional skill to the list." (p.13). Walther suggests that skills like empathy must be taught and deeply contextualized. Further, Walther explains that underlying assumptions about the practicality of such social competencies must be interrogated in undergraduate education.

Suggestions for Further Study. Further qualitative and quantitative examination of the competencies identified by the Delphi panel is necessary to generate actionable curricular intervention. Though significant care was taken to establish a reliable and trustworthy panel, regional limitations limit the generalizability of this study. A broader quantitative analysis of industry opinions is necessary to produce more generalizable findings. This line of inquiry would also benefit from industry feedback regarding how new professionals actually perform in each competency area. Further, studies examining student and faculty opinions regarding the industry-identified competencies found herein must be conducted to identify any gaps between theory and practice. Such an analysis will help to identify interventions to various elements of the educational pathways that generate new engineers.

Additionally, qualitative analysis must be engaged to better understand competencies that are included and gain a deeper understanding of those that were omitted. Such research also presents opportunities to understand the experiences of underrepresented populations within engineering as related to distributed leadership. Finally, a critical analysis of these emerging engineering leadership competencies must be conducted in relation to general leadership competencies identified by scholars in leadership studies and organizational psychology. Ultimately, further details must be explored regarding the gaps between the engineering industry, academe, and the broader knowledge-base of leadership in order to better understand the manners in which institutions of higher education train and prepare engineers.

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