Professional Skill Opportunities Survey: Development and Exploratory Factor Analysis

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***Abstract*—This full research paper presents the exploratory factor analysis (EFA) results for the Professional Skill Opportunities survey (PSO) we designed to measure undergraduate engineering students' opportunities to develop and practice important nontechnical professional skills. We use Dall'alba's "ways of being" as the theoretical framework for the survey development and generated construct definitions based on past literature, expert review, and cognitive think-aloud interviews. We administered the survey in an engineering class at the beginning of the Spring 2022 semester. After comparing the three EFA models based on goodness-of-fit indices and model interpretability aligned to the theoretical model, the researchers selected a five-factor model. The EFA result and literature on leadership and teamwork showed these two skills are highly interrelated and could be combined into one construct to stress the "sharedness" of leadership responsibilities in teams. The result allowed our team to refine our item pool, revise construct definitions, and generate new items. In future work, we will administer the revised PSO survey to the same population at the end of the same semester as further validation. We also plan to explore the relationship between professional skill development opportunities and students' social support. We hope the PSO survey can provide educators and institutions a means to offer scaffoldings and more opportunities for professional skill development and better prepare students for the engineering workforce.**

Keywords—professional skills development, exploratory factor analysis, instrument validation, ways of being

I. Introduction and Background

Non-technical professional skills are essential for today's practicing engineers because the discipline has become increasingly complex, interdisciplinary, global, and diverse. As a result, industrial demand for engineers who are well-rounded professionals, instead of merely good technicians has increased [1] and professional skill development has been the emphasis of many engineering accreditation standards, professional organization reports, and research topics since the mid-1990s [2], [3]. On an individual level, professional skills not only help engineers get a job, but also help maintain one and promise a better outlook in the future [4]. On a broader level, training engineers who are fluent in both technical knowledge and professional skills can help the U.S. retain its competitiveness in manufacturing and design [5].

Professional skill development opportunities need to be studied because they are inherently different than technical skills. Unlike technical skills, professional skills usually take longer to develop and often occur outside of classrooms [3]. Research has shown that students' opportunities to develop professional skills vary depending on their social capital developed through participation in co-curricular and extra-curricular activities [6]. In other words, students have varying levels of opportunities to engage in professional skill development because they have different circumstances and resources. As such, understanding and assessing the opportunities themselves is needed to provide educators insights on how to better support different groups of students to become professionals and be successful in the engineering workforce.

Professional skills have been *operationalized* in multiple ways by different entities. The term encompasses a range of individual skills that can be thought of broadly, or applied in very specific contexts. For example, the Accreditation Board for Engineering and Technology and the National Society of Professional Engineers provided comprehensive lists of competencies that are necessary for engineers' professional growth, including skills such as communication, ethical responsibilities, teamwork, and life-long learning [2], [7]. In other cases, several related professional skills are grouped and examined together in different ways. For example, communication, problem-solving, and teamwork are categorized as "interpersonal skills" as a whole [8]. Others combine leadership, communication, and teamwork skills and define them as "engineering performance skills" [9]. Other studies discuss engineering students' professional skill development through the lenses of individual skills [10].

Professional skills have also been *assessed* in a variety of ways for different purposes. A common approach to assessing professional skills is to directly ask students about their confidence or self-efficacy in a particular skill (e.g., Global Engineering Competency [11]). Other assessments focus on students' development of reasoning (e.g., Engineering Ethical Reasoning Instrument [12]) to evaluate the decision-making or other reasoning processes students go through while demonstrating certain professional skills. Third-party evaluations (e.g., the Comprehensive Assessment for Team-Member Effectiveness [13]) rely on pre-developed, usually web-based instruments and offer distant evaluations that resemble an external view of students' demonstration of professional skill competencies. Behavior-based measurement is another common type of assessment, (e.g., the Global Engineering Competency – Situational Judgement Test [14]) and focuses on specific behaviors that reflect successful demonstration of professional skills to measure students' performance. Other assessments [15] evaluate the professional preparedness of engineering graduate students and assess the opportunities they are getting to gain more research experiences and becoming a professional.

The *self-reporting* nature of many professional skill measurements is problematic because it can lead to inflated results. While asking students about their self-efficacy in some areas has given insight into students' true capabilities, oftentimes self-reporting measurements can lead to the Dunning-Kruger effect and introduce cognitive bias due to respondents' tendency to overestimate their abilities [16]. For example, Douglas et al. found that students rated their skills in information literacy much higher when compared to their actual abilities [17].

Many assessments also focus on the evaluation of the actual skills, instead of students' *opportunities* to develop these skills. While skill competency level assessments can yield meaningful findings, it is equally or perhaps more important to measure how many opportunities students have to engage in professional skill development and hone these skills to prepare for the job market [18]. For example, students' participation in co-curricular or extra-curricular activities makes important contributions to their perceived chances to develop and practice professional skills [6], [19], [20]. Research also indicates that the social bonds students cultivate during these activities impact their perception of professional skill development [6].

Finally, most of the existing assessments only focus on a *single* professional skill, rather than a comprehensive list. Because professional skills include a wide range of competencies, these competencies often overlap and have interrelationships in their definitions, development processes, and attainment—practicing one usually simultaneously hones other professional skills as well [21]. The most common example is perhaps leadership and teamwork skills. Being a good leader simultaneously requires a person to demonstrate superior team-building abilities [22]. Multiple studies have presented interventions and activities that facilitate student development in more than one professional skill at the same time [20], [23], [24]. Thus, assessing single professional skills may not yield holistic results about students' professional skill development, since it does not provide insights into possible interrelationships between different skills.

The complex interrelations between various professional skills necessitate assessment be on a *holistic level* and focus on *multiple skills simultaneously*. Comprehensively assessing engineering undergraduate students' opportunities in professional skill development will help educators to holistically identify when and where support should be offered. This type of assessment is especially important since the COVID-19 pandemic, social distancing, and online learning negatively impacted students' experience in their professional skill development [25]. Our team created an assessment, the Professional Skills Opportunities survey (PSO), to measure students' opportunities to develop and practice a range of professional skills. In this paper, we present initial validation evidence for PSO and answer the following research questions:

A. Research Questions

1. To what extent does the factor structure of the PSO align with the theoretical model?
2. What are the necessary revisions based on the EFA results?

B. Theoretical Framework–Ways of Being

Theoretical frameworks play a critical role in assessment development, as these provide a lens to view the desired attributes [26]. In our study, we employ Dall'Alba's ontological "ways of being" framework [27], which focuses on the process of students being and becoming a professional. Dall'Alba's "ways of being" framework pays special attention to students "learning professional ways of being [that] occurs through the integration of knowing, acting and being" [27], which means through the opportunities that students have to practice the skills that are being assessed. Thus, this allows us to focus the assessment on students' opportunities to practice the particular skills, not on the self-assessment of their skills and the known drawbacks of such assessments. Recent assessments of engineering graduate students utilizing Dall'Alba's "ways of being" framework have shown strong evidence of validity [18] when measuring students' opportunity to practice skills in their professional preparation.

II. Method

A. Data Collection

Our team created the PSO survey following the steps proposed by Netemeyer and colleagues [28] for instrument construction, undergoing the process of definition generation, expert review, and cognitive think-aloud interviews to revise the survey [29]. The resulting survey included 35 items that asked respondents to rate the frequency with which they engage in activities that allow the practice of specific professional skills. For further validation, we piloted the PSO survey in a 3-credit sophomore engineering class within a large public university at the beginning of Spring 2022. The class is required by most engineering disciplines and focuses on the fundamentals of electrical engineering. The course content mainly focuses on the basic concepts of circuits, electronic components such as diodes and transistors, as well as the underlying concepts such as current, charge, voltage, etc. The students were encouraged to complete the pilot survey for extra credit. In total, the survey received 686 responses. The data cleaning process includes two steps. First, we eliminated the responses that did not pass a filter question embedded in the survey. Next, we eliminated the responses that had overall response rates of less than 50%. The final sample size was reduced to 477. Table 1 below shows the demographic information of survey respondents.

TABLE I. EFA RESPONDENTS DEMOGRAPHICS

Demographics	% of students	Number of students
Gender		
Female	23.69%	113
Male	76.10%	363
Race/Ethnicity		
African American	1.47%	7
Asian or Pacific Islander	28.09%	134
Hispanic or Latino	0.84%	4
White or European American	64.78%	309
Multiracial	3.98%	19
Other	2.31%	11

Note. Total n = 477. The demographic information as reported by students. No students reported non-binary genders.

B. Exploratory Factor Analysis

To examine the factor structure and identify the latent constructs that make up the larger measurement construct, we conducted an exploratory factor analysis (EFA) using Rstudio [30]. Before conducting the EFA, we computed the descriptive statistics and the bivariate correlations of items within each construct to eliminate items with scores that are skewed and items that correlate poorly with the others in the same construct. Since all items' skewness and kurtosis are within ±3 and ±10, respectively, and no elevated means are found, thus the skewness and kurtosis fell into an acceptable range for all items [31]. Next, we examined the bivariate correlations between items written to be within the same factor. Two items (one from business and management principles, and one item from ethics and professional responsibilities) were eliminated due to low correlation with other items in the same construct [32].

A scree plot (refer to Figure 1) was generated with the EFA dataset (n = 477) to determine the suitable number of factors [33]. As suggested in Figure 1, the possible factor number ranges from four to six.

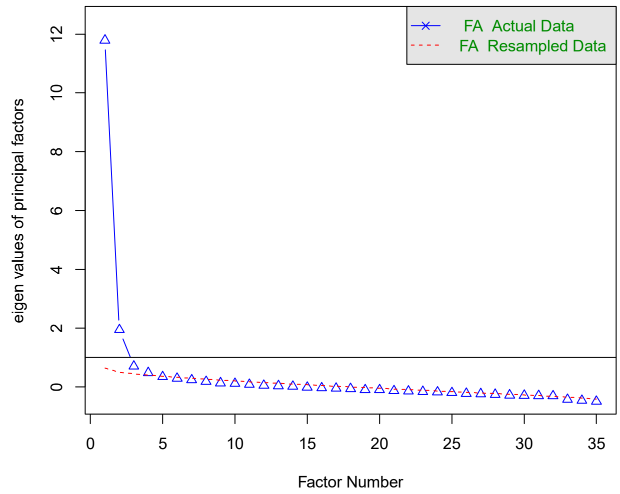


Fig. 1. Scree plot for EFA dataset (n = 477)

We then performed three EFAs to compare different models: four-factor, five-factor, and six-factor models. We used promax rotation and maximum likelihood factoring due to the potential interrelations between professional skills [33]. Comparisons between the models were made based on the goodness-of-fit indices and the corresponding acceptable ranges, including Chi-squared value, root mean square of the residuals (RMSR<0.05), root mean square error of approximation (RMSEA<0.08), Tucker-Lewis Index (TLI>0.9), and Bayesian information criterion (BIC) [34]. In addition, we took the occurrence of cross-loading into account when evaluating the fitness of models. Finally, model interpretability was also a vital issue when selecting a best-fitting model.

III. RESULTS

A. Comparison of factor structures

Based on the scree plot, we ran EFA and compared the facture structures and goodness-of-fit indices for four-factor, five-factor, and six-factor models. Table 2 below lists the comparison of the different model.

TABLE II. MODEL CAMPARISON OF DIFFERENT FACTOR STRUCTURE

Model	χ^2	*df*	*p-value*	*RMSR*	*TLI*	*RMSEA*	*BIC*	*# of cross-loading items*	*# of items that do not load*
4-factor	744	402	9.7E-23	0.03	0.930	0.042	-1737.86	6	0
5-factor	639.67	373	2.4E-16	0.03	0.941	0.039	-1663.16	0	3
6-factor	556.24	345	4E-12	0.02	0.950	0.036	-1573.71	3	0

The fitness indices indicate that all three models have acceptable fit. Although the four-factor model is suggested by the scree plot, it yields the highest Chi-squared value, indicating that this model is significantly different from the data. Compared with the five- and six-factor model, the four-factor structure has the poorest fitness indices. It also produces the highest number of cross-loading items among the three models.

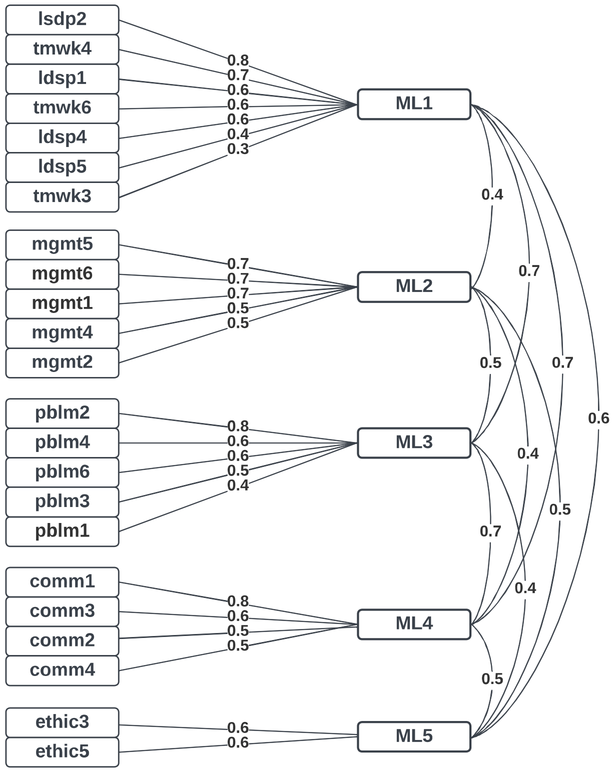
After examining the goodness-of-fit indices, we looked closely at the factors and corresponding items. In the four-factor model, all items met the standard of communalities for educational research by using the acceptable range of 0.25 or higher [35]. The factor loadings range from 0.325 to 0.754. In this model, there is a large factor consisting of most of the items from problem-solving, leadership, and teamwork load together. Items from communication largely load into their own factor, while ethical and professional responsibilities items are dispersed among the four factors. Items from business management principles are divided into two factors. One management factor consists of items that are associated with the consideration of current and future stakeholder needs. The other management factor consists of two management items that touch on consideration of legal and financial constraints and two ethics items about social consideration of students' engineering design. The interpretability of this model is relatively low due to the large factor containing 18 items.

In the five-factor model, the factor loadings range from 0.303 to 0.857. All the items have a communality value that is higher than 0.25. This model was able to disentangle the large factor resulting from the four-factor structure into two new factors. One factor consisting of mostly problem-solving items and another factor made of a mixture of leadership and teamwork items were formed. Compared to the previous model, the other factors stayed largely the same with minimal differences of one or two items. Interpretability is improved in this model due to the separation of the problem-solving items.

A six-factor model should be the one that is most aligned with the theoretical model we used to develop the survey. Ideally, each factor would map into their corresponding professional skills we originally developed. The item factor loadings are within the range of 0.304 to 0.823. All items meet the communalities standard proposed by Beavers and colleagues, having communalities of higher than 0.25 [35]. The six-factor model is very similar to the five-factor model, except that a factor consisting of problem-solving and teamwork items emerged instead of the leadership-teamwork factor in the five-factor structure. This difference lowered the interpretability of the six-factor model. The problem-solving items were drafted to measure students' opportunities to engage in tasks that do not differentiate individual problem-solving from team problem-solving. On the contrary, most of the leadership items describe an activity that happens in a group or team setting. Therefore, we determined that the six-factor model has lower interpretability than the five-factor model.

B. *Selecting the best-fitting model*

Overall, we determined that the five-factor model would be the most ideal for the PSO survey. This decision was based on considerations of model interpretability and fitness indices. Considering interpretability, the four-factor model is the least interpretable, with an 18-item factor consisting of three different skills. The six-factor model is clearer and easier to interpret. However, when compared to the five-factor model, it lacks interpretability and theoretical support for one of the six factors. Thus, we deem the five-factor structure to be the most interpretable model. In terms of fitness indices, all three models have acceptable fit. Again, the four-factor model was eliminated first due to its high number of cross-loading items. Among the five- and six-factor models, although the six-factor model presented better goodness-of-fit indices, the differences between them are minor. As a result, after considering the results holistically, we determined that the five-factor model was the best-fitting model. We also proceeded to revise the five-factor model by eliminating poor-performing items. Figure 2 below presents the revised five-factor model structure.



items that did not fit the theoretical model first, one teamwork item (that originally did not load) now loaded into the leadership-teamwork factor. From the revised five-factor model, the remaining items for business and management principles, problem-solving, and communication skills load neatly into their corresponding factors. Ethics and professional responsibilities only have two items left, and they make up one factor by themselves. The fifth factor consists of a mixture of leadership and teamwork items. We calculated Cronbach's alpha for all factors in the best-fitting model [36]. Except for the factor consisting only two items, all factors have acceptable Cronbach's alpha values (>0.7) [37].

IV. Discussion

A. *Necessary revisions based on improved factor structure*

Based on the EFA results, the PSO survey needs several improvements. Revision is necessary regarding teamwork and leadership skills in the revised five-factor model. All models presented have one factor that contains an almost equal mixture of leadership and teamwork items. This result confirms prior research indicating that leadership and teamwork are usually interconnected [22]. Past research on leadership skills also studied the concept of shared leadership, a type of leadership individuals cultivate when they work in teams and equally share the responsibilities of making leadership decisions [38], [39]. In other words, leadership opportunities arise when people are working in teams. It is possible that these two professional skills have a larger overlapping area in terms of the activities and opportunities students typically need to engage in to develop these skills. As a result, we decided to merge leadership and teamwork skills together into one construct to measure a less authoritarian and vertical way of practicing and demonstrating leadership skills [40].

The definition and items for ethics and professional responsibilities skill also need revisions. In all the models presented, items in this construct disperse across different factors. Even after revisions to the five-factor model, only two items remained. The deleted ethics and professional responsibilities items focused on ethics about financial decisions and consideration of social impacts. They load with the business and management principles items in all models. We went back to existing ethics assessments in engineering with validation results [41] and the Code of Conduct proposed by the National Society of Professional Engineers [42] for guidance to refine the definition for this skill and generated new items according to the revised definition. We will use the revised definition and items for this skill in later survey administrations and validation study. The revised definitions for the five professional skills and the revised items are documented in Table 3 below.

TABLE III. REVISED PROFESSIONAL SKILL DEFINITIONS & SURVEY ITEMS

Professional Skill	Definition	Items
Shared leadership	Engineering students' capacity to demonstrate commitment to learning, drive for excellence, integrity, and result orientation while working with others, translating to the abilities to treat others with good intention and respect, motivate others, assist in others' development, encourage others to stay on goals, and take responsibility of continuous self-improvement [43], [44].	Motivate others to produce quality work.
		Encourage others to focus on achieving goals.
		Support others to develop skills or improve performances.
		Accept responsibility for your personal growth.
		Share the workload among team members throughout the project.
		Support team members when they faced a challenge.
		Work to resolve conflicts within the team.
Communication	Engineering students' development of written and oral skills to convey information and express opinions to audiences, and tailor their communication according to different situations using a variety of communication formats, including presentations, emails, letters, reports, via digital platforms, etc. [45]–[47].	Adjust the content of your communication based on your audience.
		Change the style of your communication according to different situations.
		Use written formats of communication (e.g., emails, reports, letters, etc.)
		Adapt to the mode of communication (e.g., PowerPoint, Zoom, Google doc, etc.) as needed.
Problem-solving	Engineering students' development of the ability to generate, conceptualize, implement, and optimize original and applicable solutions using cognitive skills, including problem finding, ideation, evaluation, convergent thinking, divergent thinking, constraint analysis, and optimization [48], [49].	Identify a problem that needs to. Be solved related to a project.
		Generate multiple ideas to solve the identified problem when working on a project.
		Analyze the constraints of potential solutions when working on a project.
		Evaluate the feasibility of ideas generated when working on a project.
		Optimize your solution(s) when working on a project.
Business & management principles	Engineering students' development of skills related to executing tasks to meet the priorities established by management, translating to the ability to manage financial, human resources, and time appropriately, demonstrate basic knowledge of the laws and regulations associated with the engineering design process and products, understand various stakeholders' needs, and analyze future needs that might emerge from stakeholders and the market [50], [51].	Plan the order of completing tasks based on stakeholders' priorities when working on a project.
		Manage available financial resources when working on a project.
		Consider possible legal constraints (e.g., laws, regulations, etc.) when working on a project.
		Evaluate whether different stakeholder needs are satisfied when working on a project.
		Anticipate possible future stakeholder needs when working on a project.
Ethics and professional responsibilities	Engineering students' development of personal awareness of ethical and professional obligations to their organization, customers, and society (i.e., mindfulness of reputation and their impacts, and accountability for long-term results) and social considerations during the engineering problem-solving process, translating to the ability to analyze social issues from professional	Consider the impacts of your professional conducts.
		Reflect how your decisions can impact your organization's reputation.
		Consider possible negative consequences of your design.

	perspectives and engage in professional activities objectively and truthfully [41], [42].	Report undesirable results truthfully.

Note. The question stem for all items is "How often in your undergraduate engineering experience did you…" The response options are seven frequency options, with 1 = Not at all and 7 = Very frequently.

V. Conclusion

This paper aims to answer two research questions. We asked to what extent did the PSO survey align with the theoretical model and found that a five-factor model closely aligned. The professional skills in the five-factor model are: shared leadership, communication, problem-solving, business and management principles, and ethics and professional responsibilities. We found that teamwork and leadership items seemed to be representing a dynamic and collaborative mode of leadership, rather than two separate factors. Based on this finding, we considered the literature and created a new factor of shared leadership, instead of assessing teamwork and leadership separately as the theoretical model suggested originally. Next, we asked what are the necessary revisions based on the EFA results. We refined our item pool and deleted a few items from each factor that do not load as intended. We proposed revisions to the scale based on these findings. Future research should consider the factor structure of the resulting instrument. In addition, future research should also consider other aspects of validity.

VI. Implication & Future Work

Professional skills are crucial for engineering students because they help students to become well-rounded professionals. Assessing professional skills is a real challenge due to their broad scales and intricate interrelationships. Our approach is focused on a developmental understanding of how professional skills are learned. Professional skill development takes longer time and can happen under different settings. Therefore, we developed and presented the initial evidence of validity of an assessment focused on students' professional skill development opportunities. The results of our study show promise that the PSO assesses the opportunities students have had to acquire and practice different professional skills. The limitation of this study is that we only performed an EFA study to evaluate the validity of the PSO survey. In the future, we will conduct additional validation studies such as a confirmatory factor analysis using data collected from a broader setting to examine the validity and application of the instrument further.

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References

[1] Association of American Colleges & Universities, "Falling short ? College learning and career success," 2015.

[2] Accreditation Board for Engineering and Technology, "ABET Engineeirng Acceditation Commission," 2021.

[3] L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The ABET 'professional skills' — Can they be taught? Can they be assessed?," *Journal of Engineering Education*, vol. 94, no. 1, pp. 41–55, 2005.

[4] J. S. Russell and J. T. P. Yao, "Education Conference Delivers Initiatives," *Journal of Management in Engineering*, vol. 12, no. 6, pp. 17–26, 1996.

[5] T. J. Siller, A. Rosales, J. Haines, and A. Benally, "Development of undergraduate students professional skills," *Journal of Professional Issues in Engineering Education and Practice*, vol. 135, no. 3, pp. 102–108, 2009, doi: 10.1061/(ASCE)1052-3928(2009)135:3(102).

[6] S. D. Garrett, J. P. Martin, and S. G. Adams, "Developing nontechnical professional skills in African American engineering majors through co-curricular activities," *IEEE Transactions on Education*, 2021, doi: 10.1109/TE.2021.3120210.

[7] A. Mohan, D. Merle, C. Jackson, J. Lannin, and S. S. Nair, "Professional skills in the engineering curriculum," *IEEE Transactions on Education*, vol. 53, no. 4, pp. 562–571, 2010, doi: 10.1109/TE.2009.2033041.

[8] M. E. Simmons, *The essential interpersonal skills for junior engineers and engineering managers.* The Union Institute, 1999.

[9] E. Seat, J. R. Parsons, and W. A. Poppen, "Enabling engineering performance skills: A program to teach communication, leadership, and teamwork.," *Journal of Engineering Education*, vol. 90, no. 1, pp. 7–12, 2001.

[10] A. Nylén and A. Pear, "Professional communication skills for engineering professionals," 2013.

[11] B. Jesiek, Q. Zhu, S. E. Woo, J. Thompson, and A. Mazzurco, "Global engineering competenciy in context: Situation and behaviors," *Online Journal for Global Engineering Education*, vol. 8, no. 1, p. 1, 2014.

[12] Q. Zhu, C. B. Zoltowski, M. K. Feister, P. M. Buzzanell, W. C. Oakes, and A. D. Mead, "The development of an instrument for assessing individual ethical decisionmaking in project-based design teams: Integrating quantitative and qualitative methods.," 2014.

[13] M. W. Ohland, M. L. Loughry, D. J. Woehr, and L. G. Bullard, "The comprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self- and peer evaluation," *Academy of Management Learning & Education*, vol. 11, no. 4, pp. 609–630, 2012.

[14] A. Mazzurco, B. Jesiek, and A. Godwin, "Development of Global Engineering Competency Scale: Exploratory and confirmatory

factor analysis," *Journal of Civil Engineering Education*, vol. 146, no. 2, 2020.

[15] E. A. Holloway, K. A. Douglas, D. F. Radcliffe, and W. C. Oakes, "Research experiences instrument: Validation evidence for an instrument to assess the research experiences of engineering PhD students' professional practice opportunities," *Journal of Engineering Education*, vol. 111, no. 2, pp. 420–445, 2022.

[16] D. Dunning, "Chapter five - The Dunning–Kruger effect: On being ignorant of one's own ignorance," *Adavances in Experimental Social Psychology*, vol. 44, pp. 247–296, 2011.

[17] K. A. Douglas, T. M. Fernandez, M. Fosmire, A. S. Van Epps, and Ş. Purzer, "Self-directed information literacy scale: A comprehensive validation study," *Journal of Engineering Education*, vol. 109, no. 4, pp. 685–703, 2020.

[18] E. A. Holloway, "Development and validation of an assessment of engineering Ph.D. students' research experirences," Purdue University, 2020.

[19] J. P. Martin, "The invisible hand of social capital: Narratives of first generation college students in engineering," *International Journal of Engineering Education*, vol. 31, no. 5, pp. 1170–1181, 2015.

[20] D. F. Carter, H. K. Ro, B. Alcott, and L. R. Lattuca, "Co-curricular connections: The role of undergraduate research experiences in promoting engineering students' communication, teamwork, and leadership skills.," *Research in Higher Education*, vol. 57, no. 3, pp. 363–393, 2016.

[21] M. E. Simmons, *The essential interpersonal skills for junior engineers and engineering managers.* The Union Institute, 1999.

[22] L. Compton-Young *et al.*, "Engineering leadership development programs a look at what is needed and what is being done," *Journal of STEM Education*, vol. 11, no. 3 & 4, pp. 11–21, 2015, doi: 10.1109/emr.2015.7059373.

[23] E. Seat, J. R. Parsons, and W. A. Poppen, "Enabling engineering performance skills: A program to teach communication, leadership, and teamwork.," *Journal of Engineering Education*, vol. 90, no. 1, pp. 7–12, 2001.

[24] D. Wang, D. A. Waldman, and Z. Zhang, "A meta-analysis of shared leadership and team effectiveness.," *Journal of Applied Psychology*, vol. 99, no. 2, pp. 181–198, 2014.

[25] A. C. Johnston, K. A. Douglas, J. P. Martin, T. Short, and R. Alexander, "Promoting student support in an online fundamental of electricnics course," *IEEE Transactions on Education*, 2022.

[26] L. J. Cronbach and P. E. Meehl, "Construct validity in psychological tests," *Psychological Bulletin*, vol. 52, no. 4, pp. 281–302, 1955.

[27] G. Dall'Alba, "Learning professional ways of being: Ambiguities of becoming," *Educational Philosophy and Theory*, vol. 41, no. 1, pp. 34–45, 2009.

[28] R. G. Netemeyer, W. O. Bearden, and S. Sharma, *Scaling procedures: Issues and applications*. Sage Publications, 2003.

[29] T. Li, E. A. Holloway, V. Bill, K. A. Douglas, and J. P. Martin, "WIP: Think-aloud interviews for assessment of engineering students' opportunities to practice professional skills," 2022.

[30] M. W. Watkins, "Exploratory factor analysis: A guide to best practice," *Journal of Black Psychology*, vol. 44, no. 3, pp. 219–246, 2018, doi: 10.1177/0095798418771807.

[31] P. J. Curran, S. G. West, and J. F. Finch, "The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis," *Psychological Methods*, vol. 1, no. 1, pp. 16–29, 1996.

[32] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 7th ed. New York, NY: Pearson, 2010.

[33] B. Thompson, *Exploratory and Confirmatory Factor Analysis*. Washington, DC: American Psychological Association, 2004.

[34] L. Hu and P. M. Bentler, "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives.," *Structural Equation Modeling*, vol. 6, no. 1, pp. 1–55, 1999.

[35] A. S. Beavers, J. W. Lounsbury, J. K. Richards, S. W. Huck, G. J. Skolits, and S. L. Esquivel, "Practical considerations for using exploratory factor analysis in educational research.," *Practical Assessment Research and Evaluation*, vol. 18, no. 1, 2013.

[36] L. J. Cronbach, "Coefficient alpha and the internal structure of tests," *Psychometrika*, vol. 16, no. 3, pp. 297–334, 1951.

[37] J. C. Nunnally, *Psychometric theory*, 2nd ed. New York: McGraw-Hill, 1978.

[38] J. F. Cox, C. L. Pearce, and M. L. Perry, "Toward a model of shared leadership and distributed influence in the innovation process: How shared leadership can enhance new product development team dynamics and effectiveness.," in *Shared leadership: Reframing the hows and whys of leadership*, C. L. Pearce and J. A. Conger, Eds. Thousand Oaks, CA: Sage Publications, 2003, pp. 48–76.

[39] D. Wang, D. A. Waldman, and Z. Zhang, "A meta-analysis of shared leadership and team effectiveness.," *Journal of Applied Psychology*, vol. 99, no. 2, pp. 181–198, 2014.

[40] J. F. Cox, C. L. Pearce, and M. L. Perry, "Toward a model of shared leadership and distributed influence in the innovation process: How shared leadership can enhance new product development team dynamics and effectiveness.," in *Shared leadership: Reframing the hows and whys of leadership*, C. L. Pearce and J. A. Conger, Eds. Thousand Oaks, CA: Sage Publications, 2003, pp. 48–76.

[41] N. E. Canney and A. R. Bielefeldt, "Validity and reliability evidence of the engineering

professional responsibility assessment tool," *Journal of Engineering Education*, vol. 105, no. 3, pp. 452–477, 2016.
[42] National Society of Professional Engineers, "Code of Ethics," 2022.
[43] S. Özgen, O. Sánchez-Galofré, J. R. Alabart, M. Medir, and F. Giralt, "Assessment of engineering students' leadership competencies.," *Leadership and Management in Engineering*, vol. 13, no. 2, pp. 65–75, 2013.
[44] J. Wang, P. K. Imbrie, and J. J. Lin, "Work in progress - A feedback system for peer evaluation of engineering student teams to enhance team effectiveness.," 2011.
[45] D. J. Cegala, M. T. Coleman, and J. W. Turner, "The development and partial assessment of the medical communication competence scale.," *Health Commun*, vol. 10, no. 3, pp. 261–288, 1998.
[46] E. Suter, J. Arndt, N. Arthur, J. Parboosingh, E. Taylor, and S. Deutschlander, "Role understanding and effective communication as core competencies for collaborative practice.," *Journal of Interprofessional Care*, vol. 23, no. 1, pp. 41–51, 2009.
[47] S. C. Kim, D. Boren, and S. L. Solem, "The Kim Alliance Scale: Development and preliminary testing.," *Clin Nurs Res*, vol. 10, no. 3, pp. 314–331, 2001.
[48] C. Charyton and J. A. Merrill, "Assessing general creativity and creative engineering design in first year engineering students.," *Journal of Engineering Education*, vol. 98, no. 2, pp. 145–156, 2009.
[49] M. Basadur and G. Gelade, "Using the creative problem solving profile (CPSP) for diagnosing and solving real-world problems.," *Emergence*, vol. 5, no. 3, pp. 22–47, 2003.
[50] M. E. Loades *et al.*, "Rapid Systematic Review: The Impact of Social Isolation and Loneliness on the Mental Health of Children and Adolescents in the Context of COVID-19," *J Am Acad Child Adolesc Psychiatry*, vol. 59, no. 11, pp. 1218-1239.e3, Nov. 2020, doi: 10.1016/j.jaac.2020.05.009.
[51] T. Mejtoft, "Integrating business skills in engineering education: Enhancing learning using a CDIO approach.," in *12th International CDIO Conference*, 2016, pp. 12–16.