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An investigation into perceptions, expectations, and development of professional skills in engineering students

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Upon graduation from an undergraduate institution, engineering graduates are expected to have a baselevel skill in technical skills related to their discipline. Teaching technical skills comes naturally to engineering programs as the conceptual understanding of the material form the foundation of engineering ability. However, engineering graduates also are expected to have a baselevel of professional skills, which are more subjective in nature and do not have a standardized approach for teaching or assessing them at the undergraduate level. An investigation into current perceptions of professional skills by relevant parties is an initial step in providing more structure to professional skills education in engineering departments and courses.

This dissertation explored the perceptions of engineering students, engineering faculty, and practicing engineers when it comes to professional skills. Eight professional skills were investigated: collaboration, communication, ethical considerations, inclusivity, leadership, professional judgment, task management, and teamwork. Surveys were administered and interviews were conducted with students. Statistical analysis on survey data indicated that how students rate their peers' abilities aligns with the perceptions that practicing engineers have of student abilities with both groups' means for each skill be lower than how the students rated their own ability to a significant level ($p < 0.001$ for six of eight skills).

Student interviews yielded potential operational definitions for professional skills, which can be validated in future work. Interviews also gave insight into how various student experiences aid in professional skills development. Recommendations for methods to improve professional skills education in engineering curricula were provided for each professional skill.

DEDICATION

To every younger version of myself that felt discouraged, unqualified, and too quiet to make an impact – this is for you. So many times you defined success based on someone else's misguided and unfair metric. Thanks for hanging in there and pushing forward to this day.

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In the fall of 2013, I sat in Carpenter 112 and listened to Dr. Alta Knizley tell my Introduction to Mechanical Engineering course all about mechanical engineering and the opportunities that awaited us in the profession. Dr. Knizley seemed like someone who knew what she was talking about. It was obvious from the beginning that she held her students to high standards. My intuition told me that Dr. Knizley was someone who could take me places, so I made a mental note that I needed to get on her good side. It didn't take long for me to do that. It also didn't take long for Dr. Knizley to start the "you need to go to grad school" campaign. Freshman Morgan said, "nope, not for me." Sophomore Morgan said, "I don't know, but probably not." Junior Morgan said, "I'm so tired can I just sleep for a couple of years straight please?" And finally, senior Morgan said, "so I think I want to go to grad school."

And so, Alta, you were right. I did need to go to grad school. In the end I dragged you along with me through it, and it's been a journey of ups and downs and quarantines and changes that made us both stronger and probably a little crazier (or a lot, depending on who you ask). Thanks for guiding, building, shaping, and supporting me through all ten of my years in school at Mississippi State University. Thanks for paving the way and showing me how to succeed at a career I was always meant to pursue. And, hey, I was right too. You did take me places. Can I sleep for a couple of years straight now?

Thank you to Dr. Lesley Strawderman for her constant support and encouragement as I discovered the wonderful, wonderful world of engineering education. Thank you as well to my other committee members, Dr. Dana Franz and Dr. Aaron Smith. Brandon Miller and Bailey Jose were a great help in gathering information and processing data for this dissertation, and I cannot thank you enough for the time you saved me.

A million thanks to the person who would definitely say Alta and I are a lot crazier these days, Emily McCabe. It was always the most convenient when we took turns being the burnt out, stressed grad student, but of course that is rarely how these things work and we spent a lot of doing so simultaneously. Thanks for your patience and kindness even when I was whiney and too often pretty hangry. Thanks for cheering me on through all of the successes and cheering me up through all of the failures. Thanks for not letting me give up on finishing this degree.

To my parents, grandparents, and other family members who were probably the least surprised that I was going to take this school thing all the way, thank you for always supporting and pushing me even when the math got way over your heads. Thanks for letting me dig through recycling bins and build and create and try new things. Thanks for letting and encouraging me to love STEM. You have made many a drive to Starkville, and the fact that know your way down Hwy 45 so well shows me how much you care.

I've been teaching quite a while, actually. Thanks is due to my first co-teacher and favorite sister, Savannah. She and I ran a tight ship of a classroom at the experienced ages of 6 and 8. Thanks is also due to my first student and favorite brother, Addison, even though he probably rolled his eyes when he just read that. I'm glad that going to grad school meant I got to share in his four years in Starkville.

There are so many more people to thank for making Starkville the special place that it is to me, and to them I say thanks for the memories. From shutting down the world to hiding from tornados in an apartment bathroom to playing a resounding Long Hail State after a Bulldog touchdown, y'all have been there through it all. The list of people that have left an impact on me during the past ten years is incredibly long.

I would be amiss if I failed to acknowledge my furry companions who never say much but give all of the love and support they have. Our Queen, Tali, was just the cat I needed to join me as I finished out undergrad and started grad school. My six years with her were full of snuggles and smiles. These days the Captain carries on the torch of being my four-legged friend, and I am happy for the snuggles and laughs he supplies even if he does sometimes like to be the biggest curmudgeon on the planet.

As I've worked on this PhD the past four years, I have had the distinct honor to work as a faculty member in the department that raised me from a baby engineer, getting to teaching students who sit in the same seats I sat in. Among a number of other courses, I got teach the "holy trinity" of thermal-fluids courses (Thermodynamics I, Thermodynamics II, and Heat Transfer) in the same semester in my third year as an Instructor. I dreamed of teaching those courses at the very least individually, and in my wildest dreams did I get to teach them all together, much less so early in my career. Thanks is due to Alta once again for supporting me every step of the way that semester by providing notes, advice on how to teach the courses effectively, and everything in-between. Thanks to the colleagues and mentors across campus who help me grow in my teaching abilities. By far, however, the best part of my job is interacting with the students in any capacity. Thank you to all of those precious souls who have been patient with me as I settle into my teaching style. Thank you to all of them who have referred to me as "Morgan" no matter how many times I have said I prefer "Ms. Green," thus coincidentally motivating me to finish my PhD so I can correct them to say "Dr. Green," which

is just so cool. Thank you to the students who constantly come by my office for no other reason than to say hello and decompress.

Finishing this PhD is only the start to what is going to be an exciting ride. Thanks to everyone who has followed along thus far. I can't wait to see what's next.

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CHAPTER I

ENGINEERING STUDENT PERSPECTIVES OF THE RELATIVE IMPORTANCE OF PROFESSIONAL SKILLS

Introduction

Numerous studies show that engineering employers are seeking to hire students that demonstrate proficient professional skills (Carter, 2011; Hynes & Swenson, 2013; Kumar & Hsiao, 2007b; Mohan et al., 2010; Pastel et al., 2015; Pulko & Parikh, 2003; Rao, 2015; Robles, 2012; Sambamurthy & Cox, 2016; Schulz, 2008; Shakir, 2009; Skipper et al., 2017; Walther et al., 2017). These professional skills include communication, initiative, teamwork, and organization, among others. As the engineering field becomes more global, proficiency in these skills will be paramount (Walther et al., 2017). However, in many cases students are learning these skills after graduation has already occurred. They learn "soft skills the hard way" on the job (Kumar & Hsiao, 2007). There is a need to find efficient ways to effectively teach these skills at the undergraduate level.

Additionally, there is not a clear consensus on the operational definitions of the skills, making fair and consistent assessment difficult (Heckman & Kautz, 2012; Sambamurthy & Cox, 2016). Because of the subjective nature of professional skills perceptions and assessment, a starting point in obtaining these operational definitions is investigating the current state of professional skills abilities and perceptions for engineering students. Understanding that these current perceptions may be deep-rooted, initial work will investigate the possibility of slightly adjusting the perceptions of the constituents as opposed to aligning them to set of ideals that may not be close to current perceptions.

Background

Engineering departments across the country require their students to complete many hours of courses to cover all of the required course material specific to their field (Kumar & Hsiao, 2007a). In STEM majors such as engineering, a need for a strong technical background is evident as members of the public expect engineers to design infrastructure and products that are safe to use (Schulz, 2008). However, numerous universities in recent years have found that employers are asking for more professional skills from their recent graduates in addition to sound technical knowledge (Carter, 2011; Grugulis & Vincent, 2009; Hynes & Swenson, 2013; Pulko & Parikh, 2003; Robles, 2012; Sambamurthy & Cox, 2016; Shakir, 2009; Skipper et al., 2017). Various studies and surveys show that there are a number of professional skills with which many employers wish their employees were proficient. (Carter, 2011; Hynes & Swenson, 2013; Kumar & Hsiao, 2007a; Mohan et al., 2010; Pastel et al., 2015; Pulko & Parikh, 2003; Rao, 2015; Robles, 2012; Sambamurthy & Cox, 2016; Schulz, 2008; Shakir, 2009; Skipper et al., 2017; Walther et al., 2017; Woods, Donald et al., 2013). These professional skills, also called interpersonal skills, are intangibles such as communication, initiative, teamwork, and organization. Mohan argues that such skills allow students to demonstrate their technical skills more effectively (Mohan et al., 2010). Walther et al. (Walther et al., 2017) discuss how as the world becomes more globalized, engineers must become more adept at these skills in order to be competitive in the global market. In addition, the authors say such skills may help engineers be more successful in the workplace as they allow individuals to be more prepared to encounter people from different cultures and backgrounds.

The College Experience

A student's time in college will undoubtedly provide numerous opportunities for growth in a variety of areas. Some of this growth occurs as a direct result of what happens in the classroom; however, many experiences outside of the classroom contribute to a student's overall experience as well. Reason et al. presented a conceptual model of the college experience (Reason et al., 2006). Shown in Figure 1.1, this model relates a student's various college experiences and how they correspond to overall student outcomes.

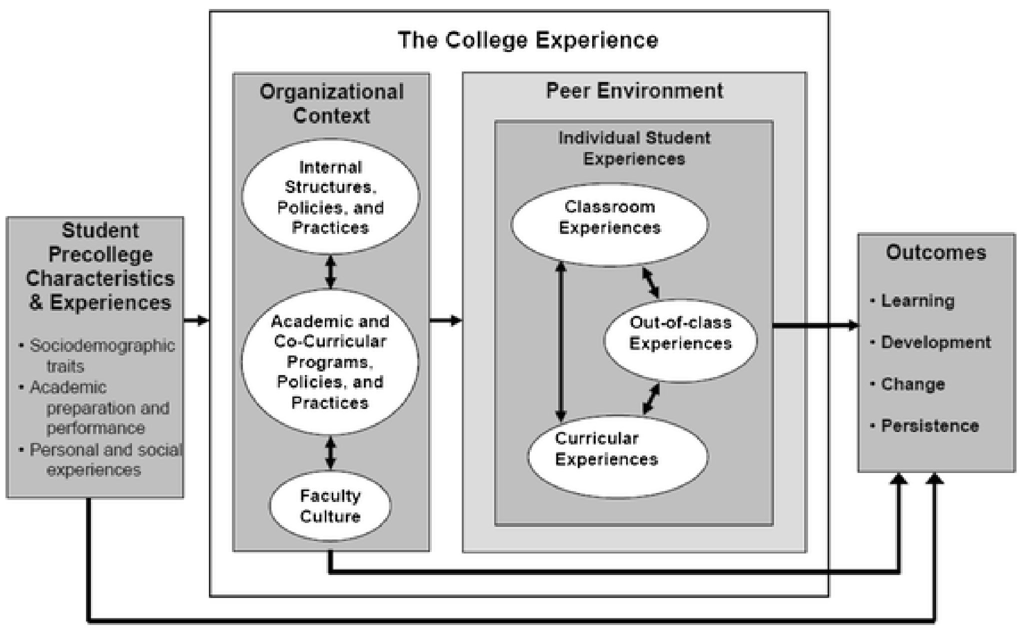

Figure 1.1 Terenzini and Reason's College Impact Model

(Reason et al., 2006. Page 154)

Professional skills are included throughout this model. In student precollege characteristics and experiences, professional skills contribute to the college experience through personal and social experiences such as extracurricular activities, after-school jobs, and school projects. In college, professional skills education and practice may be found in academic and co-curricular programs, policies, and practices; classroom experiences; out-of-class experiences; and curricular experiences. The combination of class projects, student organizations, and student life (i.e. resident hall communities) add to student experiences with professional skills. While there are multiple areas that provide the potential for professional skills education, it is worth investigating which of these areas are affecting professional skills development the most, along with which of these areas students think are contributing to their professional skills education the most and if they find value in that contribution.

Emotional Intelligence and Self-Efficacy

Skipper et al. investigated emotional intelligence of civil engineering versus electrical engineering students. They hypothesized that civil engineering students would have a higher level of emotional intelligence than electrical engineering students. They administered the TalentSmart Emotional Intelligence Appraisal® and found that civil engineering students improved in emotional intelligence from freshman to senior year at a higher rate than electrical engineering students. They found a positive correlation between work experience and increased emotional intelligence (Skipper et al., 2017).

When administering self- and peer-evaluations, it is important to understand implicit bias of the student group completing the evaluation. Wagner et al. (2011) compared faculty, self-, and peer-ratings on an assignment in a pharmacy course. Students rated their own abilities and their peer abilities in two courses: advanced pharmacy practice experience (APPE) and seminar presentation courses. Faculty also rated the students. They found that student self-ratings were lower than faculty ratings overall and for APPE. The two groups had the same rating for the seminar course. For both APPE and the seminar course, students rated their peers' skills higher than faculty rated their skills. Thus, students always rated their peers' skills higher than their own. In education, a study found that students rate their peers higher as well (Kilic, 2016). In the study, pre-service teachers gave presentations. The teachers rated the students, students rated themselves, and the students rated their peers. They found that the peer-assessment scores were higher than both the student and teacher-assessment scores by a statistically significant difference.

In an engineering technology capstone course, faculty introduced CATME software in an effort to improve accuracy of self- and peer-ratings (Berry et al., 2022). The issue they faced is that when presented a Likert scale to rate themselves and their peers with “3” indicating “average,” students regularly rated themselves with a “5” and expected the same of the peer ratings they received. The goal of this study was to introduce an intervention to help students adjust to give more accurate “average” ratings and understand that “5” does not indicate “average” on the scale. The hypothesis of the study was that the intervention would cause the frequency of lower number ratings to go up over time. They were correct; regardless, even with the score correction over time, students still rated their own ability higher than that of their peers on average. While engineering technology and engineering are not the same field, they are closely related and most likely share students with a similar level of self-efficacy. McAnear et al. (2000) did conduct a study with engineering students and found a statistically significant difference between how students rated themselves and how their team members rated them. Students expected higher scores than they received. Pulko and Parikh (2003) discussed how in their first year, male engineering students “report a high level of confidence in their own ability in both ‘academic’ and ‘soft’ subjects.”

Compared to students in other fields, engineering student are more likely to rate their own skills higher than those of their peers.

Which professional skills are the most important to employers?

Literature shows that professional skills are necessary for engineering graduates, but there is less agreement on how those skills rank or, many times, even what to call them. To gather data on student perceptions of top professional skills, a concise list is needed.

One study asked employers to list skills that they want in potential hires and rate the importance of the skills on a scale of 1-5, with 1 being the lowest and 5 being the highest. The responses included both hard (technical) and soft (professional) skills. The technical skills that were listed averaged an importance rating of 3.3, and the professional skills that were listed averaged an importance rating of 4.5 (Carter, 2011). If this statistic holds true for most STEM employers, then the need for curriculums that teach professional skills is evident. In addition to employers asking for professional skills, the skill sets as given by the engineering accreditation body ABET include professional skills such as professional judgement, team work, leadership, collaboration, inclusivity, task management, ethical considerations, and communication (ABET 2022).. Leadership and management positions in industry require a working knowledge and proper utilization of professional skills, and engineers may find themselves overlooked for these positions when compared to employees with degrees where teaching professional skills is naturally a part of the curriculum, such as business and the social sciences. (Schulz, 2008).

Woods et al. created a survey that combined the skills listed most frequently in professional skills literature. They took a list of twenty-three skills and asked employers (from all backgrounds, engineering included) to assign a level of importance to each skill and a frequency of use. Both scales were Likert scales ranging from 1 (not very important) to 6 (very important). They found that the ratings for importance and frequency were similar overall, so the top eleven skills given are a combination of the two ratings. They are, listed from highest score to lowest: verbal communication, written communication, time management, problem solving, decision making, teamwork, critical thinking, self-confidence, initiative, trust, and stress management. The rankings of the remaining 12 skills are: social awareness and skill, self-awareness, leadership, life-long learning, analysis, empathy, creativity, self-assessment, intercultural-understanding, research, change management, and chairperson skills (Woods, Donald et al., 2013).

Which professional skills are students utilizing?

In their study, Picard et al. administered a survey to students completing a team project in an undergraduate engineering class and in a graduate engineering class. The undergraduate project was an in-course engineering project. The graduate project was a capstone project. Both projects ran the length of the semester. The first part of the survey was the Interprofessional Project Management Questionnaire (IPMQ). The IPMQ score included a self-efficacy score in five areas in addition to the overall score: planning, risk assessment, ethical sensitivity, communication, and interprofessional competence. The pre-test was administered prior to the completion of the project, and the post-test was administered after the completion of the project. For the pre-test results, the researchers compared scores of undergraduates, graduates, and professionals. The professionals scored higher in all areas except for communication. The undergraduates and graduates were on par with each other except in risk assessment, where graduates were higher. Post-test results included students only. For the post-test results, researchers compared pre- and post-test scores for the undergraduates and graduates. They saw improvement in the scores of both groups in all areas after the completion of the team project. The undergraduate students' survey also included three open-ended questions for them to answer. One question asked for "the three most important non-technical things [the student] learned while carrying out the team project.” They presented responses that had more than four occurrences. The top five were (1) communicate, share information; (2) organize, coordinate, manage work; (3) manage time and workload; (4) split and distribute tasks; and (5) interpersonal attitude. The undergraduate students were also asked for the “two biggest challenges [they] encountered during the realization of the team project.” The top five responses were (1) mechanical engineering design methodology; (2) manage time and workload; (3) split and distribute tasks; (4) team up, get along; and (5) organize, coordinate, manage work (Picard et al., 2022). The results of this study show that in team projects, students are utilizing logistical skills to organize and complete tasks. The team project also, on average, improved professional skill levels of the students.

A study exploring student perceptions toward top-rated professional skills would close gaps in literature. There is a need to see how students perceive the importance of various professional skills as well as investigate what environment has fostered the growth (or lack thereof) of professional skills thus far in students’ lives.

Research Objectives

This study aims to investigate student perceptions of the importance of, their ability with, their peers’ ability with, proficiency of education of, and opportunities for the development of various professional skills. The results can inform next steps in developing consistent teaching and assessment methods of professional skills in undergraduate engineering programs. Of particular interest in this study are how student self-efficacy compares to an assessment of their peers’ skills and to what extent previous work experience influences professional skills development.

Research Questions

The following research questions will guide this study.

1. What are student perceptions of professional skills' importance?
2. How do student perceptions of their own professional skills compare to their perceptions of their peers' abilities with professional skills?
3. How well do students believe they have been taught professional skills in their engineering curriculum?
4. Does having previous work experience result in a higher self-efficacy in professional skills?
5. Which environments (e.g. courses, experiential learning, student organizations) are perceived by students to have the largest impact on students' professional skills development?

Statement of Hypotheses

It is hypothesized that students will place higher importance on teamwork and communication. In general, it is expected that students will think more highly of their personal abilities of professional skills compared to the abilities of their peers. Students will likely have an average to low opinion of how well they have been taught professional skills in their engineering curriculum. Previous work experience will result in an improved self-efficacy for multiple professional skills. It is expected that the environments perceived to be most important for developing professional skills will be co-op/internship, undergraduate research, and student organizations (both engineering and non-engineering).

Contributions

The results of this study can lead to a greater understanding of the current state of student perceptions of the professional skills of engineering students. Understanding where perceptions do and do not line up among students, professionals, and faculty can aid engineering educators in teaching professional skills. Particularly, a difference in self-efficacy versus how students perceive the skills of their peers could show a disconnect in a particular professional skill's importance or definition. Any differences can hinder consistent teaching and assessment.

This study will ask students to provide the scenarios/experiences they believe have contributed to their professional skills education. Responses will be analyzed to look for overlap in the skills learned and/or assessed as a result of the scenarios/experiences. Potentially, it is possible to synthesize the same learning experience in the classroom by replicating the aspects of the scenario/experience that made it beneficial to the participant's professional skills development. By replicating the educational aspect of the scenario/experience, more students can be exposed to an effective method for teaching professional skills.

Methods

Design

This study utilized surveys to evaluate engineering students' perceptions of professional skills of and for engineering students. It also investigated engineering students' perceptions of how well they and their peers exhibit these skills as well as what course, involvement, and/or instruction contributed to the development of their professional skills.

Participants

The participants of this study were undergraduate engineering students currently enrolled in ABET accredited programs in the Southeastern United States of America. This region was selected as the focus of this study due to the broad implied cultural similarities of the students' university experience. Students from all undergraduate student classifications (freshman, sophomore, junior, senior) were recruited for the study to provide perspectives of students at all levels in a program.

Students were recruited from ABET-accredited engineering programs in the Southeastern United States. This includes students from universities in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.

Students represented ten universities and nine engineering majors, as seen in Table 1.1 and Table 1.2.

Table 1.1 Universities Represented in Student Survey Responses

University	Frequency	Percent
N/A (response left blank)	5	3.4
Emory University	1	0.7
Florida Institute of Technology	31	21.2
Louisiana State University	2	1.4
Mississippi State University	87	59.6
North Carolina State University	3	2.1
University of Alabama at Huntsville	4	2.8
University of Arkansas	3	2.1
University of Louisiana at Lafayette	7	4.8
University of North Carolina	2	1.4
University of Southern Mississippi	1	0.7
Total	146	100

Table 1.2 Majors Represented in Student Survey Responses

Major	Frequency	Percent
Aerospace engineering	18	12.3
Biomedical/biological engineering	14	9.6
Chemical engineering	14	9.6
Civil/environmental engineering	21	14.4
Computer/software engineering	11	7.5
Electrical engineering	10	6.8
Industrial/systems engineering	6	4.1
Mechanical Engineering	48	32.9
Ocean Engineering	4	2.7
Total	146	100

All classifications of students were represented in student survey responses, with upper-level students (juniors, seniors, and 5th+ year seniors) comprising the highest percentage. The distribution is shown in Table 1.3.

Table 1.3 Classifications Represented in Student Survey Responses

Classification	Frequency	Percent
Freshman	20	13.7
Sophomore	21	14.4
Junior	38	26.0
Senior	48	32.9
5th+ year senior	19	13.0
Total	146	100

The breakdown of gender representation in the student survey responses is shown in Table 1.4.

Table 1.4 Genders Represented in Student Survey Responses

Gender	Frequency	Percent
Male	83	56.8
Female	59	40.4
Non-binary / third gender	3	2.1
N/A	1	0.7
Total	146	100

Ethnicity representation of student survey responses is shown in Table 1.5.

Table 1.5 Ethnicities Represented in Student Survey Responses

Ethnicity	Frequency	Percent
Asian	13	8.07
Black	12	7.45
First Nations	1	0.62
Latino/Hispanic	15	9.32
Native American	1	0.62
Pacific Islander	2	1.24
White	112	69.57
Unknown	2	1.24
Other	3	1.86
Total	161	100

Multiple demographic question responses are presented in Table 1.6. These questions include student type (traditional or non-traditional student; first in family to attend college; engineers in family), transfer status (freshman enrollee or transfer student), and whether or not participants had previous work experience.

Table 1.6 Student Types Represented in Student Survey Responses

Demographic	Yes	No
Traditional Student	121	25
First Generation College Student	26	120
Engineer in Family	55	91
Junior College Transfer	32	113
Previous Work Experience	140	6

Descriptives of the ages of survey respondents are shown in Table 1.7. It should be noted that 30 respondents did not provide their age.

Table 1.7 Age Descriptive Statistics for Student Survey Responses

N	Minimum	Maximum	Mean	Standard Deviation
116	18	43	21.26	3.37

Sample Size

Studies discussed in previous sections typically involve sample sizes of 50 or fewer. For this study, a sample size of 100+ allowed for more representative sampling than in previous studies.

Survey Instrument

The survey instrument aimed to capture student perceptions of the importance of top-ranked professional skills and their experience with how these skills have been/are being developed. The list of professional skills were taken from the ABET Criterion 3: Student Outcomes (Criteria for Accrediting Engineering Programs, 2022). The eight skills listed in the survey were:

1. Collaboration
2. Communication
3. Ethical Considerations
4. Inclusivity
5. Leadership
6. Professional Judgment
7. Task Management
8. Teamwork

The Student Outcomes from *Criteria for Accrediting Engineering Programs* (ABET, 2022) are provided below. The list of professional skills presented by Woods et al. (2013) and Picard et al. (2022) were cross-referenced with the ABET Student Outcomes to create the list of eight professional skills included in this study. Professional skill(s) contributing to the formulation of outcomes are listed below the outcome as relevant.

1. An ability to identity, 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.
    a. Ethical considerations; professional judgment
3. An ability to communicate effectively with a range of audiences.
    a. Communication
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.
    a. Ethical considerations; professional judgment

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.

    a. Collaboration; inclusivity; leadership; task management; teamwork

6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

    a. Professional judgment

7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Participants were asked to rate the importance of: their own abilities with, their peers' abilities with, and the level of instruction in the university setting of each of the eight professional skills via a slider scale. Additionally, for each professional skill participants were provided a list of environments and asked which environment(s) they believe contributed to their development of that skill. These environments were non-engineering courses, engineering courses, co-op/internship, undergraduate research, non-engineering student organization, engineering student organization, off-campus involvement, pre-college involvement, and upbringing. The full list of questions comprising the survey is found in Appendix A.

The following demographic information was collected: current major, age, gender, ethnicity, student classification, student type (traditional or non-traditional student; first in family to attend college; engineers in family), transfer status (freshman enrollee or transfer student), and whether or not participants had previous work experience.

The survey was administered online through Qualtrics.

Survey Reliability and Validity

Since this survey did not measure constructs, evidence of survey reliability and validation was not necessary.

Procedure

A solicitation was sent via email to department heads of ABET-accredited engineering programs in the selected southeastern states. The department heads were asked to share the survey with students in their department. The solicitation included:

- Link to the survey
- Description and motivation of the study
- IRB approval number
- Description for the incentive for participation

A solicitation was posted on LinkedIn, Facebook, and Twitter. Upon accessing the survey, participants could access the consent document which included:

- Description and motivation of the study
- IRB approval number
- Description for the incentive for participation

At the conclusion of the survey, participants were asked if they are willing to participate in an interview to further investigate their responses. These interviews are discussed in Chapter III.

Analysis

To complete analysis, Statistical Package for Social Sciences software (SPSS) (*IBM SPSS Statistics for Windows*, 2021) was used. Participants responded to each question along the scale, and while no numerical distinctions were provided to participants, the scale ranged from 0 to 100. Anchors of “lowest” and “highest” were provided for each scale response question. This scale is more akin to a continuous scale than typical Likert scales, allowing for greater expression from participants for the responses.

Inferential Analysis

One-way repeated measures analysis of variance (ANOVA), correlation, and frequency analysis were completed. For all ANOVA, the significance level (α) was set to 0.05. Thus, any occurrence with a p-value less than 0.05 led to a rejected null hypothesis. When presenting results, further distinction is provided to show when p-values were less than 0.05, less than 0.01, and less than 0.001 in order to show the reduced likelihood of a Type I error.

To investigate how students rated the professional skills for each category, one-way repeated-measures ANOVA was completed for professional skill (independent variable) and mean rating (dependent variable). The results of this analysis showed if there was any statistically significant difference between the mean rating of the professional skills for importance, self-ability, peer-ability, and level of instruction in university setting. Tukey post-hoc analysis was utilized for further investigation where one-way ANOVA produced significant results.

An additional one-way repeated measures ANOVA was completed to compare mean ratings across categories for each of the professional skills. Tukey post-hoc analysis was utilized for further investigation where one-way ANOVA produced significant results.

Correlation tests were conducted for level of instruction in university setting versus both self-ability and peer-ability to determine if level of instruction in university setting was related to the mean reported student ability for self- and/or peer-ratings. The tests were run for each professional skill.

A paired t-test was completed to investigate if there was a significant difference in mean rating if a student reported previous work experience. This analysis was completed for self-ability rating and peer-ability rating for each professional skill.

For environments which students believed contributed to their professional skills development, three steps were taken for analysis. First, frequency analysis was completed to see how often environments were selected and for which professional skills. Next, one-way repeated measures ANOVA was completed for environment (independent variable) and self-ability (dependent variable) for each environment and each professional skill. One-way ANOVA was also completed for environment (independent variable) and peer-ability (dependent variable) for each environment and each professional skill. Tukey post-hoc analysis was utilized for further investigation where one-way ANOVA produced significant results.

Results

Survey results were downloaded from Qualtrics as an SPSS statistics data document. After incomplete responses (lower than 70% completion percentage) were removed, the responses for analysis included 146 students.

Overall Student Perceptions of Professional Skills for Each Category

Figure 1.2 provides a visualization of how the mean rated values vary amongst the categories across all professional skills. Standard error is indicated for each mean rating.

The means and standard deviation of the rated value for each professional skill and category are shown in Table 1.8.

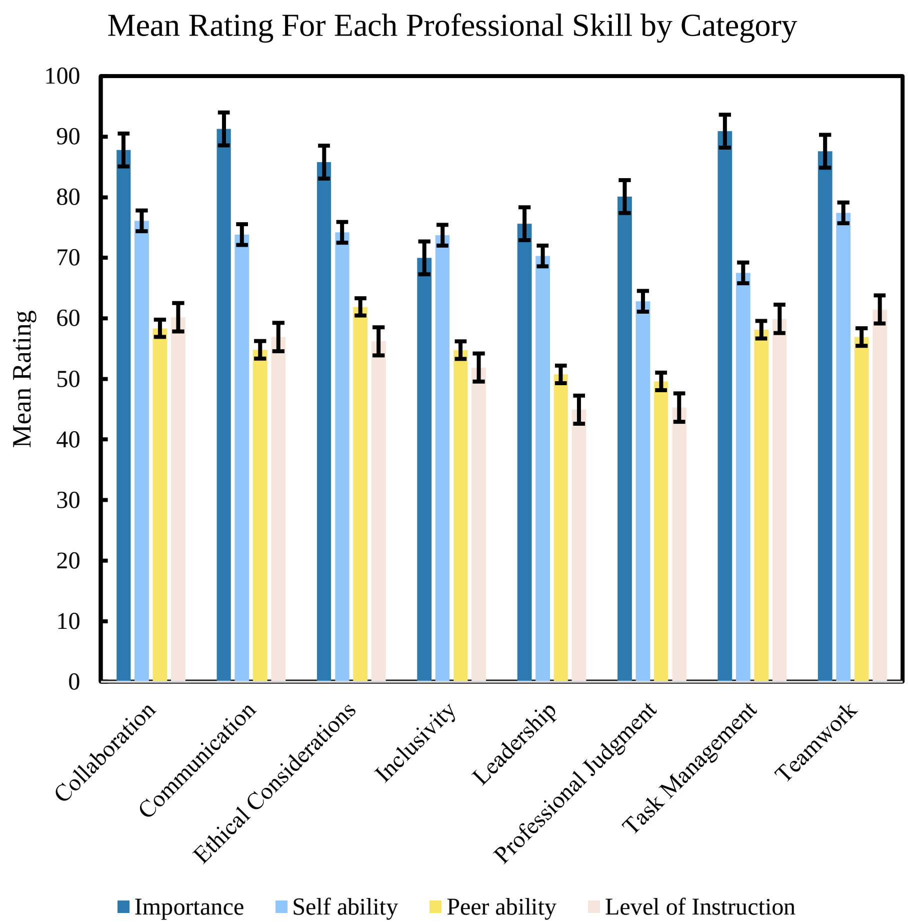

Figure 1.2 Mean Response for Each Skill and Rating Question

Table 1.8 Means and Standard Deviations of Rating for Each Professional Skill and Category

Skill	Importance			Self-ability			Peer-ability			Level of Instruction		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Collaboration	144	**87.80**	16.28	145	76.11	17.29	145	58.37	18.86	143	60.18	24.19
Communication	135	<u>**91.28**</u>	12.46	135	73.81	19.11	135	54.79	19.57	131	56.92	24.58
Ethical Considerations	136	**85.79**	18.21	136	74.19	20.64	136	<u>61.90</u>	22.01	136	56.22	29.04
Inclusivity	143	69.99	28.08	143	**73.71**	22.41	143	54.75	22.63	141	51.87	28.89
Leadership	145	**75.61**	19.93	145	70.31	20.13	145	50.74	18.84	141	44.94	25.77
Professional Judgment	145	**80.11**	17.05	144	62.84	18.72	144	49.60	16.21	143	45.27	24.37
Task Management	140	**90.90**	12.05	139	67.52	22.37	140	58.14	19.66	136	59.92	25.78
Teamwork	145	**87.60**	17.18	145	<u>77.44</u>	19.23	145	56.91	18.61	143	<u>61.47</u>	24.29

Note. Highest value within a skill is bolded. Highest value within a category is underlined.

On average, students indicated a high importance for all skills, with all averaging approximately 70.00 or higher. The average response decreased across the categories, with students rating their own abilities at 77.44 or lower, their peers' abilities at 61.90 or lower, and their level of instruction in the university setting at 61.47 or lower.

Communication appears to be clearly perceived by students as the most important professional skill, with its mean rating being the highest out of the eight professional skills. The mean importance rating of 91.28 is almost 20 points higher than the mean self-ability rating (73.81) and almost 40 points higher than the peer-ability and level of instruction in university setting mean ratings (54.79 and 56.92, respectfully).

The top four rated skills were communication, task management, collaboration, and teamwork. These results align with those found by Picard et al (2022). The five top responses to their free response map to the eight professional skills in this study as see in Table 1.9.

Table 1.9 Mapping Professional Skills from Picard et al. to the Eight Professional Skills

Picard et al.	This study
Communicate, share information	Communication
Organize, coordinate, manage work	Task management
Manage time and workload	Task management
Split and distribute tasks	Collaboration, teamwork
Interpersonal attitude	Teamwork

The order of importance that Picard et al. found in their study directly correlate with the mean ratings of the survey results. This correlation helps to validate the results of the two studies.

Comparing Mean Ratings for Professional Skills Within Each Category

One-way repeated-measures ANOVA was completed to compare mean rated responses for each professional skill for each category. The null hypothesis was that the mean ratings for each professional skill within the same category are the same. Results showed if there was any statistically significant difference between the mean ratings of the professional skills, thus leading to a ranking of the professional skills within each category. Numerical results of the analysis are shown in Table 1.10.

Table 1.10 ANOVA Table for Comparison of Mean Ratings for each Professional Skill within each Category

Category	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Importance	Between groups	58448.32	7	8349.76	24.90***	0.13
	Within groups	377227.26	1125	335.31		
	Total	435675.58	1132			
Self-ability	Between groups	23544.69	7	3363.53	8.37***	0.05
	Within groups	451588.12	1124	401.77		
	Total	475132.80	1131			
Peer-ability	Between groups	16464.30	7	2352.04	6.11***	0.04
	Within groups	432860.97	1125	384.77		
	Total	449325.27	1132			
Level of Instruction	Between groups	42783.10	7	6111.87	9.10***	0.05
	Within groups	743158.48	1106	671.93		
	Total	785941.58	1113			

***$p < .001$.

The results of the four ANOVA tests were all statistically significant ($p < 0.001$). The null hypothesis was rejected for every category. Within each category, there is a statistically significant difference in the mean rating for one or more pairs of professional skills. Therefore, a preliminary ranking of professional skills can be created for each category.

The eta squared value shows what percentage of variability between the mean ratings is explained by the difference in professional skill. The eta squared value for Importance (η^2 =

13%) shows a medium effect, showing that the particular professional skill accounts for 13% of the variability in mean ratings in the Importance category. While not a large effect, this result shows there will be a somewhat clear ranking to the professional skills within the Importance category. The other three categories had small effects (5%, 4%, and 5% for Self-ability, Peer-ability, and Level of Instruction, respectively), and thus rankings of professional skills within those categories are less decisive with multiple professional skills falling within the same subset of mean ratings.

Tukey post-hoc analysis showed which professional skills have statistically significantly different mean ratings within each category. Statistically significant results including mean difference and 95% confidence intervals from the Tukey post-hoc analyses are shown in Appendix B in Table B.1.

All of the one-way repeated-measures ANOVA results yield a preliminary ranking of professional skills within each category. Post-hoc analysis provided a summary table for each category with subsets to assist in ranking the professional skills. There is not data to support a clear ranking of professional skills within the same subset. If a professional skill is in a higher-numbered subset than another professional skill (and neither professional skill is in both subsets), then data supports that the professional skill in the higher-numbered subset ranks higher than the professional skill in the lower-numbered subset. The subsets and rankings for Importance are shown in Table 1.11. The subsets and rankings for Self-ability are shown in Table 1.12. The subsets and rankings for Peer-ability are shown in Table 1.13. The subsets and rankings for Level of Instruction are shown in Table 1.14.

Table 1.11 Subsets and Rankings for Mean Ratings for Professional Skills in the Importance Category

Professional Skill	N	1	2	3	4
Inclusivity	143	69.99			
Leadership	145	75.61	75.61		
Professional Judgment	145		80.11	80.11	
Ethical Considerations	136			85.79	85.79
Teamwork	145				87.60
Collaboration	144				87.80
Task Management	140				90.90
Communication	135				91.28

Table 1.12 Subsets and Rankings for Mean Ratings for Professional Skills in the Self-ability Category

Professional Skill	N	1	2	3
Professional Judgment	144	62.84		
Task Management	139	67.52	67.52	
Leadership	145		70.31	70.31
Inclusivity	143		73.71	73.71
Communication	135		73.81	73.81
Ethical Considerations	136		74.19	74.19
Collaboration	145			76.11
Teamwork	145			77.44

Table 1.13 Subsets and Rankings for Mean Ratings for Professional Skills in the Peer-ability Category

Professional Skill	N	1	2	3	4
Professional Judgment	144	49.60			
Leadership	145	50.74	50.74		
Inclusivity	143	54.75	54.75	54.75	
Communication	135	54.79	54.79	54.79	
Teamwork	145		56.91	56.91	56.91
Task Management	140			58.14	58.14
Collaboration	145			58.37	58.37
Ethical Considerations	136				61.90

Table 1.14 Subsets and Rankings for Mean Ratings for Professional Skills in the Level of Instruction Category

Professional Skill	N	1	2	3
Leadership	141	44.94		
Professional Judgment	143	45.27		
Inclusivity	141	51.87	51.87	
Ethical Considerations	136		56.22	56.22
Communication	131		56.92	56.92
Task Management	136		59.92	59.92
Collaboration	143		60.18	60.18
Teamwork	143			61.47

The practical significance of these results is concerning the Importance category. As indicated by the eta squared value ($\eta^2 = 13\%$), the Importance category had the most definitive ranking of the professional skills, meaning the clusters of professional skills that could not be definitively ranked were smaller than those in the other three categories. The results put inclusivity in the bottom subset, with it unable to reach an overall ranking higher than seventh. Communication, teamwork, collaboration, task management, and ethical considerations comprise the top five professional skills, but no definitive placement can be assigned.

For the Self-ability category, professional judgment is the bottom skill, unable to rank above seventh. The top six skills have no statistically significant difference between their means, thus a clear order cannot be established. The Peer-ability results are similar. Professional judgment is at the bottom, and the top four skills cannot be ordered.

When it comes to how well professional skills have been taught in the university setting, professional judgment and leadership fill the bottom two spots and teamwork is at the top of the list. Professional judgment fell in the bottom subset for all three of these categories. Thus, students do not perceive the level of instruction concerning professional judgment in the university setting to be high, which is reflected by the low mean ratings for both self- and peer-ability. The practical significance of the results from the Self-ability, Peer-ability, and Level of Instruction categories is that professional judgment is not perceived to be taught well, and this low perception is reflected in how students perceive both their own and their peers' abilities with the professional skill.

The clearer rankings of importance compared to the less clear ones for the other three categories is promising when considering professional skills education at the university level. Arguably, rated Self-ability, Peer-ability, and Level of Instruction are more variable and subject to change more easily than rated importance.

Comparing Mean Ratings Across Categories for Each Professional Skill

To determine if it can be said the mean ratings for each professional skill decreased from Importance to Self-ability to Peer-ability to Level of Instruction, one-way repeated-measures

ANOVA was completed for each professional skill to determine if there is a statistically significant difference in the mean ratings for each category within the professional skill. The null hypothesis was that across categories the mean rating for each professional skill is the same. Numerical results from the analysis are shown in Table 1.15.

Table 1.15 ANOVA Table for Comparison of Mean Ratings for each Category within each Professional Skill

Category	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Collaboration	Between groups	84221.58	3	28073.86	74.72***	0.28
	Within groups	215302.230	573	375.75		
	Total	299523.88	576			
Communication	Between groups	116485.07	3	38828.36	103.49***	0.37
	Within groups	199593.94	532	375.18		
	Total	316079.01	535			
Ethical Considerations	Between groups	70911.90	3	23637.30	45.35***	0.20
	Within groups	281455.79	540	521.21		
	Total	352367.69	543			
Inclusivity	Between groups	50482.58	3	16827.53	25.55***	0.12
	Within groups	372814.28	566	658.68		
	Total	423296.86	569			
Leadership	Between groups	95050.10	3	31683.37	69.79***	0.27
	Within groups	259669.87	572	453.97		
	Total	354719.97	575			
Professional Judgment	Between Groups	106295.79	3	35431.93	94.77***	0.33
	Within Groups	213862.10	572	373.89		
	Total	320157.89	575			
Task Management	Between groups	95148.58	3	31716.19	75.09***	0.29

Table 1.15 (Continued)

Category	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Task Management	Within groups	232716.56	551	422.35		
	Total	327865.14	554			
Teamwork	Between groups	87741.70	3	29247.23	73.18***	0.28
	Within groups	229420.00	574	399.69		
	Total	317161.69	577			

***$p < .001$.

The results of the four ANOVA tests were all statistically significant ($p < 0.001$). The null hypothesis was rejected for all eight professional skills. Within each professional skill, there is a statistically significant difference in the mean rating for one or more pairs of categories.

Six of the eight professional skills had a large effect size ($\eta^2 > 25\%$). The two professional skills that did not, ethical considerations ($\eta^2 = 20\%$) and inclusivity ($\eta^2 = 12\%$), still had medium effect sizes. Thus, the category explained a large portion of the variability in mean ratings within three-fourths of the professional skills. Neither of the skills with medium effect sizes had high rankings in the previous ANOVA, but only one ever fell in the bottom subset (inclusivity: Importance, Peer-ability, and Level of Instruction).

Tukey post-hoc analysis showed which categories have statistically significantly different mean ratings within professional skill. Every statistically significant result had a p value less than 0.001. Peer-ability and Level of Instruction did not have a statistically significant difference of means for any professional skill, thus it can be concluded that the mean ratings are comparable for the two categories. Students rate their peers' average ability with each of the professional skills at the same level they rate the level of instruction in the university setting.

Statistically significant results including mean difference and 95% confidence intervals from the Tukey post-hoc analyses are shown in Appendix B in Table B.2. For all professional skills except inclusivity and leadership, the mean difference between Importance and the other three categories was statistically significant ($p < 0.001$) with the mean rating for Importance being higher than those of all three categories. For inclusivity and leadership, the mean rating for Importance was determined to be greater than that of Peer-ability and Level of Instruction to a statistically significant level ($p < 0.001$). Thus, it was concluded that on average, students rate the importance of professional skills higher on a scale of 0 to 100 than they rank peer-ability and the level of instruction. The same can be said for self-ability for six of the eight professional skills.

For all eight professional skills, there is a statistically significant difference between the mean ratings for Self-ability and Peer-ability ($p < 0.001$). In every instance, students ranked their own abilities higher than those of their peers to a statistically significant level, and all but one had a mean difference greater than 10. Illusory superiority may be at play here, as students appear to overestimate their own abilities. However, as a part of the design of this study, no definition for each professional skill was provided. Thus, interpretation was left to the student of what proficient ability with each skill looked like. This subjective bias conflicts with clear assessment. Regardless, this difference is an important point to address in efforts to improve professional skills education. A lack of operational definitions for the professional skills may contribute to the issue. When combating illusory superiority, accountability and transparency is key.

Additionally, other issues in professional skills education may arise because of the apparent inflated self-ability ratings or deflated peer-ability ratings. If it is true that the self-ability scores are inflated, then it follows that faculty may have a difficult time in reaching students when attempting to teach and/or assess professional skills in the classroom. A student may be inclined not to invest as much time or effort into such assignments if they perceived they have mastered the skill or at least are pleased with their level of proficiency. Issues may arise because, in the faculty member's perspective, more development may be useful contrary to the perception of the student.

The analysis completed in Chapter II should give insight into whether the inflation or deflation is the accurate assessment. In Chapter II, student ability ratings from faculty and practicing engineers will be compared to the self- and peer-ability ratings presented in this chapter.

Implications

Research Question One asked, "What are student perceptions of professional skills' importance?" One-way repeated-measures ANOVA results yielded four subsets to categorize the mean ratings for each of the professional skills in the Importance category. Four professional skills fell only in the top subset (communication, task management, collaboration, and teamwork), signifying that students value these four skills highly. No statistically significant difference was found in the means between any pairing arrangements of these top four skills, thus a ranking of first through fourth place cannot be determined based on the data available. Inclusivity and leadership were the bottom two professional skills.

Concerning Importance, it was hypothesized that students would rank teamwork over communication. This hypothesis was incorrect as no statistically significant difference was found between the mean ratings for teamwork and communication. While communication had a higher mean rating (91.28) than teamwork (90.90), results do not support that the difference in means did not happen by chance. These results mean that based on data available, it can be assumed that students value these professional skills at approximately the same level.

Research Question Two asked, “How do student perceptions of their own professional skills compare to their perceptions of their peers’ abilities with professional skills?” For every professional skill, there was a statistically significant difference in the mean ratings between Self-ability and Peer-ability, with Self-ability always being the higher of the two. On average, students think more highly of their own skills than those of their peers. These results agree with those of Berry et al. (2022) and McAnear et al. (2000). A limitation of this study to consider is that the question prompted students to rate the average engineering students’ skills with each professional skill. If the overall ability of the respondents leaned more toward above average, then any assessment of the “average” ability of all other students would result in a higher assessment of personal ability compared to the assessment of the average ability of other students.

Perceptions of Professional Skills Instruction at the University Level

A Pearson correlation coefficient was computed to assess the linear relationship between Rated ability (self and peer) and Level of Instruction in University Setting for each professional skill. A strong correlation would show that students rate their own/their peers’ ability with a professional skill higher as they rate the Level of Instruction in University Setting of the skill higher. The results of the analysis are shown in Table 1.16.

Table 1.16 Pearson Correlation Coefficients for Self-ability and Level of Instruction in University Setting

Skill	df		Pearson's r		Δ
	Self-ability	Peer-ability	Self-ability	Peer-ability	
Collaboration	141	141	.38***	.56***	.18
Communication	129	129	.37***	.48***	.11
Ethical Considerations	134	134	.50***	.59***	.09
Inclusivity	139	139	.32***	.58***	.26
Leadership	139	139	.23**	.51***	.28
Professional Judgment	141	141	.32***	.35***	.03
Task Management	133	134	.30***	.34***	.03
Teamwork	141	141	.28***	.37***	.08

**p < .01. ***p < .001.

All correlations were positive and statistically significant. Ethical considerations had a moderate correlation for both pairs. For Self-ability, all other professional skills had weak correlations. For Peer-ability, four professional skills had positive, moderate correlations (collaboration, ethical considerations, inclusivity, and leadership). The remaining four skills had positive, weak correlations (communication, professional judgment, task management, and teamwork). Communication was close to having a moderate correlation.

Overall, there are stronger correlations between Peer-ability and Level of Instruction in University Setting than Self-ability. For every professional skill, the Pearson Correlation Coefficient was higher for Peer-ability than Self-ability. Thus, as students rate the level of instruction of professional skills in the university setting higher, they are likely to rate the average level of other students with professional skills higher. This increase may contribute towards closing the gap between self- and peer-ratings.

Implications

Research Question Three asked, “how well do students believe they have been taught professional skills in their engineering curriculum?” The results of the previously conducted one-way repeated-measures ANOVAs and the above correlation test show that on average, students do not think highly of the level of instruction of professional skills in the university setting. The mean rating for Level of Instruction was the lowest for half of the professional skills, and the Tukey post-hoc analysis presented in Table B.2 placed Level of Instruction in the bottom subset for every professional skill. On average, students rated Importance and Self-ability higher on a scale from 0 to 100. While these results may be disheartening to engineering educators, the high Importance mean ratings show a level of receptiveness to professional skills education. Current student perceptions of professional skills education at the university level are low, but improvement is highly feasible.

Impact of Previous Work Experience on Self-efficacy

One-way repeated-means ANOVA was completed for each professional skill to investigate if previous work experience had an effect on self-efficacy. The results are shown in Table 1.17.

Table 1.17 ANOVA Table for Comparison of Mean Ratings for each Category within each Professional Skill

Category	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Collaboration	Between groups	86.75	1	86.75	0.29	0.002
	Within groups	42979.48	143	300.56		
	Total	43066.23	144			
Communication	Between groups	101.40	1	101.40	0.28	0.002
	Within groups	48822.97	133	367.09		
	Total	48924.37	134			
Ethical Considerations	Between groups	180.89	1	180.19	0.42	0.003
	Within groups	57312.84	134	427.71		
	Total	57493.03	135			
Inclusivity	Between groups	2.46	1	2.46	0.01	0.000
	Within groups	71291.20	141	505.61		
	Total	71293.66	142			
Leadership	Between groups	109.87	1	109.87	0.27	0.002
	Within groups	58245.17	143	407.31		
	Total	58355.03	144			
Professional Judgment	Between Groups	506.35	1	506.35	1.45	0.010
	Within Groups	49626.98	142	349.49		
	Total	50133.33	143			
Task Management	Between groups	1139.79	1	1139.79	2.30	0.017

Table 1.17 (Continued)

Category	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Task Management	Within groups	67916.92	137	495.74		
	Total	69056.71	138			
Teamwork	Between groups	12.13	1	12.13	0.03	0.000
	Within groups	53253.63	143	372.40		
	Total	53265.75	144			

No results were statistically significant. For every professional skill, the null hypothesis is not rejected. Previous work experience was not shown to lead to a higher self-efficacy concerning the professional skills. A limitation of this analysis is that previous work experience is combined into one category. Of the 146 survey respondents, 140 indicated that they had previous work experience. While ANOVA does control for differences in sample sizes, the small sample size for the “no previous work experience” group is most likely not representative of the population of students without previous work experience. Future work that asked about which kinds of work experience students had would allow for further exploration into the impact of previous work experience on self-efficacy regarding professional skills.

Implications

Research Question Four asked, “Does having previous work experience result in a higher self-efficacy in professional skills?” The results of the study were inconclusive. While the one-way repeated-measures ANOVA did not yield any statistically significant results, the small sample size of the “no previous work experience” group (N = 6) is a cause for concern. A greater sample size is necessary to draw more concrete conclusions about the impact of previous work experience on self-efficacy regarding professional skills.

Analysis of How Environments Contribute to Perceived Professional Skills Development

Respondents were asked to select which environment(s) they believed contributed to their development of each professional skill. The frequencies of the responses are shown in Table 1.18. The leftmost column lists the environments. They are ordered by highest to lowest frequency from top to bottom. The topmost row lists the professional skills. They are ordered by highest frequency to lowest frequency from left to right.

Table 1.18 Frequency for Environments Indicated as Contributing to Professional Skills Development

Environment	COM	TEAM	TASK	COL	LEAD	PJ	INC	EC	Total	M	SD
Engineering course	84	**105**	**114**	**108**	62	**96**	57	**99**	725	89.43	22.61
Upbringing	**86**	70	75	69	**93**	93	**85**	77	648	81.57	10.23
Pre-college involvement	66	72	65	64	79	43	58	45	492	63.86	11.33
Non-engineering course	77	61	69	54	47	40	69	50	467	59.57	13.26
Co-op/internship	58	53	54	54	46	65	28	30	388	51.14	11.70
Engineering student organization	48	51	40	52	49	44	43	33	360	46.71	4.46
Off-campus involvement	52	47	40	45	61	40	45	29	359	47.14	7.38
Non-engineering student organization	49	45	34	43	55	29	56	31	342	44.43	10.13
Undergraduate research	31	28	35	33	24	32	17	17	217	28.57	6.24
Total	551	532	526	522	516	482	458	411	3998		

Abbreviations. COM (communication), TEAM (teamwork), TASK (task management), COL (collaboration), LEAD (leadership), PJ (professional judgment), INC (inclusivity), and EC (ethical considerations).
Note. Environment with the highest count for each professional skill is bolded.

Engineering courses and upbringing were attributed the most for contributing to students' development of professional skills. These high frequencies are not surprising because they are two environments that all participants have in common. The demographic questions inquiring about previous work experience only asked if students had previous work experience or not. It is unknown how many students have previous experience in the various environments. The frequency counts only tell how often a student thought their experience in that environment affected their development in a particular professional skill. Descriptive statistics, specifically the standard deviation, can show a potential higher possibility that students thought a particular environment affected their development in multiple professional skills. Such environments could potentially be high-impact, and future work should investigate this hypothesis. Engineering student organizations (SD = 4.46), undergraduate research (SD = 6.24), and off-campus involvement (SD = 7.38) all had standard deviation values lower than 10.00. These three environments may have a high-impact on professional skills development in that they may help improve multiple skills to a level that students notice the effect.

One-way ANOVA was completed to investigate how indicated experience in an environment contributed to rated self-ability and peer-ability for each professional skill. The purpose of this analysis was to determine if there was a significant difference in the mean reported values for ability for those students that indicated experience in an environment and those without. The investigation was to see if the perceived effectiveness of an environment by students influenced how students perceived their own ability and their peers'. The investigation is not to see if experience in an environment affects perceptions of ability.

Sample size, means, standard deviations, and F values from the analysis for self- and peer-ability for collaboration are shown in Table 1.19. Values for communication are shown in

Table 1.20. Values for ethical considerations are shown in Table 1.21. Values for inclusivity are shown in Table 1.22. Values for leadership are shown in Table 1.23. Values for professional judgment are shown in Table 1.24. Values for task management are shown in Table 1.25. Values for teamwork are shown in Table 1.26.

Table 1.19 Sample Size, Means, Standard Deviation, and One-way ANOVA Results for Collaboration Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	91	74.01	18.44	54	79.65	14.65	3.67
	Peer	91	57.35	20.17	54	60.07	16.46	0.71
Engineering Courses	Self	37	72.54	19.56	108	77.33	16.37	2.13
	Peer	37	49.32	21.71	108	61.46	16.80	**12.31*** **
Engineering Student Organization	Self	94	74.97	18.31	51	78.22	15.19	1.17
	Peer	94	57.32	19.50	51	60.29	17.65	0.82
Non-engineering Courses	Self	91	75.43	16.41	54	77.26	18.80	0.38
	Peer	91	57.60	19.18	54	59.65	18.42	0.40
Non-engineering Student Organization	Self	102	75.71	17.79	43	77.07	16.22	0.19
	Peer	102	57.45	18.58	43	60.53	19.57	0.81
Off-campus Involvement	Self	100	74.64	17.17	45	79.38	17.31	2.35
	Peer	100	58.14	17.59	45	58.87	21.63	0.05
Pre-college Involvement	Self	81	75.42	17.05	64	76.98	17.69	0.29
	Peer	81	59.83	18.10	64	56.52	19.78	1.10
Undergraduate Research	Self	112	75.35	17.36	33	78.70	17.06	0.96
	Peer	112	58.29	19.28	33	58.61	17.66	0.01
Upbringing	Self	76	74.18	17.87	69	78.23	16.50	2.00
	Peer	76	59.00	18.99	69	57.67	18.83	0.18

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table 1.20 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Communication Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	77	74.17	19.72	58	73.34	18.42	0.06
	Peer	77	53.23	21.11	58	56.86	17.27	1.14
Engineering Courses	Self	51	69.02	19.91	84	76.73	18.11	**5.33***
	Peer	51	46.35	18.32	84	59.92	18.59	**17.08*****
Engineering Student Organization	Self	88	73.16	19.87	47	75.04	17.74	0.30
	Peer	88	54.61	20.73	47	55.13	17.40	0.02
Non-engineering Courses	Self	58	74.57	18.85	77	73.25	19.41	0.16
	Peer	58	53.53	20.09	77	55.74	19.25	0.42
Non-engineering Student Organization	Self	86	71.55	19.51	49	77.80	17.88	3.40
	Peer	86	55.34	19.61	49	53.84	19.66	0.18
Off-campus Involvement	Self	83	73.18	18.43	52	74.83	20.28	0.24
	Peer	83	55.54	18.16	52	53.60	21.76	0.32
Pre-college Involvement	Self	69	70.81	19.64	66	76.95	18.16	3.55
	Peer	69	58.97	18.64	66	50.42	19.70	**6.71***
Undergraduate Research	Self	104	74.04	19.94	31	73.06	16.26	0.06
	Peer	104	55.88	19.98	31	51.13	17.95	1.42
Upbringing	Self	49	71.43	19.56	86	75.17	18.83	1.20
	Peer	49	54.65	20.60	86	54.87	19.08	0.00

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded

Table 1.21 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Ethical Considerations Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	106	72.53	20.93	30	80.07	18.72	3.17
	Peer	106	60.55	21.68	30	66.67	22.84	1.82
Engineering Courses	Self	37	70.49	22.82	99	75.58	19.70	1.65
	Peer	37	52.97	24.28	99	65.23	20.23	**8.85****
Engineering Student Organization	Self	104	72.86	20.85	32	78.53	19.61	1.86
	Peer	104	59.30	22.41	32	70.34	18.54	**6.41***
Non-engineering Courses	Self	86	71.51	21.57	50	78.80	18.22	**4.03***
	Peer	86	60.31	21.31	50	64.62	23.12	1.21
Non-engineering Student Organization	Self	105	72.64	20.33	31	79.45	21.14	2.64
	Peer	105	60.28	21.80	31	67.39	22.15	2.53
Off-campus Involvement	Self	107	72.71	20.94	29	79.66	18.80	2.62
	Peer	107	62.91	20.48	29	58.17	26.99	1.06
Pre-college Involvement	Self	91	71.54	20.44	45	79.56	20.19	**4.67***
	Peer	91	60.67	21.51	45	64.38	23.02	0.85
Undergraduate Research	Self	119	73.53	20.85	17	78.82	18.98	0.98
	Peer	119	62.09	22.58	17	60.53	17.96	0.08
Upbringing	Self	59	72.98	21.64	77	75.12	19.93	0.36
	Peer	59	62.02	23.21	77	61.81	21.19	0.00

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table 1.22 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Inclusivity Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	115	72.47	23.00	28	78.79	19.32	1.80
	Peer	115	54.48	22.46	28	55.86	23.67	0.08
Engineering Courses	Self	86	70.91	22.12	57	77.93	22.37	3.43
	Peer	86	49.27	20.94	57	63.02	22.73	**13.80*** **
Engineering Student Organization	Self	100	72.10	23.13	43	77.44	20.38	1.72
	Peer	100	54.05	21.87	43	56.37	24.48	0.32
Non-engineering Courses	Self	74	71.43	23.14	69	76.14	21.50	1.59
	Peer	74	54.03	23.54	69	55.52	21.74	0.16
Non-engineering Student Organization	Self	87	68.48	23.35	56	81.82	18.26	**13.10*** **
	Peer	87	51.63	22.73	56	59.59	21.79	**4.31***
Off-campus Involvement	Self	98	71.03	22.21	45	79.53	21.97	**4.55***
	Peer	98	53.06	20.91	45	58.42	25.85	1.74
Pre-college Involvement	Self	85	68.42	23.49	58	81.45	18.31	**12.60*** **
	Peer	85	51.27	21.23	58	59.84	23.80	**5.09***
Undergraduate Research	Self	126	72.75	22.37	17	80.82	22.05	1.96
	Peer	126	53.37	22.65	17	64.94	20.25	**4.00***
Upbringing	Self	58	64.78	24.87	85	79.80	18.34	**17.28*** **
	Peer	58	51.07	22.20	85	57.26	22.70	2.61

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table 1.23 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Leadership Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	99	69.75	21.00	46	71.52	18.29	0.24
	Peer	99	49.45	19.49	46	53.50	17.24	1.45
Engineering Courses	Self	84	67.79	21.07	61	73.79	18.37	3.19
	Peer	84	47.08	18.46	61	55.77	18.33	**7.87****
Engineering Student Organization	Self	96	69.64	21.42	49	71.63	17.47	0.32
	Peer	96	48.96	19.29	49	54.22	17.59	2.56
Non-engineering Courses	Self	98	69.58	21.08	47	71.83	18.12	0.40
	Peer	98	50.23	19.14	47	51.79	18.35	0.22
Non-engineering Student Organization	Self	90	68.26	21.74	55	73.67	16.83	2.50
	Peer	90	51.29	19.27	55	49.84	18.25	0.20
Off-campus Involvement	Self	84	66.57	20.83	61	75.46	18.04	**7.18****
	Peer	84	54.43	17.06	61	45.66	20.10	**8.04****
Pre-college Involvement	Self	66	66.21	21.71	79	73.73	18.14	**5.17***
	Peer	66	52.42	20.76	79	49.33	17.08	0.97
Undergraduate Research	Self	121	69.92	20.93	24	72.29	15.72	0.28
	Peer	121	50.30	18.37	24	52.96	21.31	0.40
Upbringing	Self	52	71.96	20.50	93	69.39	19.97	0.54
	Peer	52	52.02	22.47	93	50.02	16.56	0.37

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table 1.24 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Professional Judgment Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	79	61.44	17.99	65	64.54	19.59	0.97
	Peer	79	50.94	14.45	65	47.97	18.10	1.20
Engineering Courses	Self	49	64.39	21.96	95	62.04	16.89	0.51
	Peer	49	43.98	17.05	95	52.49	15.04	**9.45****
Engineering Student Organization	Self	101	60.36	19.11	43	68.67	16.56	**6.17***
	Peer	101	49.22	16.54	43	50.49	15.55	0.18
Non-engineering Courses	Self	105	63.63	18.24	39	60.72	20.06	0.69
	Peer	105	48.11	15.67	39	53.59	17.13	3.30
Non-engineering Student Organization	Self	116	61.32	19.13	28	69.14	15.73	**4.02***
	Peer	116	48.16	15.83	28	55.54	16.66	**4.79***
Off-campus Involvement	Self	104	61.06	18.93	40	67.48	17.58	3.45
	Peer	104	49.41	15.84	40	50.08	17.32	0.05
Pre-college Involvement	Self	101	60.83	19.12	43	67.56	17.05	**3.97***
	Peer	101	48.60	16.37	43	51.93	15.77	1.27
Undergraduate Research	Self	112	61.15	19.66	32	68.75	13.69	**4.19***
	Peer	112	50.32	16.63	32	47.06	14.57	1.01
Upbringing	Self	51	61.27	18.85	93	63.70	18.70	0.55
	Peer	51	50.98	16.98	93	48.84	15.81	0.57

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table 1.25 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Task Management Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	85	68.01	22.58	54	66.74	22.23	0.11
	Peer	86	59.17	20.25	54	56.50	18.74	0.61
Engineering Courses	Self	26	63.08	24.00	113	68.54	21.96	1.26
	Peer	26	49.52	20.44	113	60.20	18.98	**6.70***
Engineering Student Organization	Self	100	66.22	21.95	39	70.85	23.38	1.20
	Peer	100	56.51	19.61	39	62.23	19.43	2.44
Non-engineering Courses	Self	70	66.20	23.16	69	68.86	21.63	0.49
	Peer	71	55.27	20.75	69	61.10	18.15	3.13
Non-engineering Student Organization	Self	105	64.59	22.78	34	76.56	18.60	**7.71****
	Peer	106	56.17	19.62	34	64.29	18.77	**4.51***
Off-campus Involvement	Self	100	66.53	21.46	39	70.05	24.66	0.69
	Peer	100	55.88	19.85	40	63.80	18.21	**4.76***
Pre-college Involvement	Self	75	64.89	22.35	64	70.59	22.17	2.26
	Peer	75	58.89	19.48	65	57.28	19.98	0.23
Undergraduate Research	Self	104	69.13	21.66	35	62.74	24.04	2.15
	Peer	105	58.22	20.43	35	57.91	17.42	0.01
Upbringing	Self	65	64.88	21.36	74	69.84	23.11	1.71
	Peer	65	56.20	20.95	75	59.83	18.45	1.19

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table 1.26 Sample Size, Means, Standard Deviation and One-Way ANOVA Results for Teamwork Split by If Environment was Marked No or Yes

Environment		No			Yes			F
		N	M	SD	N	M	SD	
Co-op/Internship	Self	93	77.48	20.60	52	77.37	16.70	0.00
	Peer	93	55.63	19.36	52	59.19	17.14	1.22
Engineering Courses	Self	40	69.88	22.37	105	80.32	17.15	**9.03****
	Peer	40	47.23	17.17	105	60.60	17.87	**16.58*****
Engineering Student Organization	Self	94	77.03	19.16	51	78.20	19.53	0.12
	Peer	94	56.27	18.02	51	58.10	19.78	0.32
Non-engineering Courses	Self	84	76.17	18.36	61	79.20	20.39	0.88
	Peer	84	55.08	18.18	61	59.43	19.05	1.94
Non-engineering Student Organization	Self	100	75.71	20.64	45	81.29	15.18	2.64
	Peer	100	54.67	19.24	45	61.89	16.24	**4.79***
Off-campus Involvement	Self	98	75.34	19.82	47	81.83	17.33	3.69
	Peer	98	55.12	18.29	47	60.64	18.91	2.83
Pre-college Involvement	Self	73	74.05	19.96	72	80.88	17.95	**4.68***
	Peer	73	56.58	18.31	72	57.25	19.03	0.05
Undergraduate Research	Self	117	77.48	19.94	28	77.29	16.25	0.00
	Peer	117	57.03	19.32	28	56.39	15.62	0.03
Upbringing	Self	75	71.52	21.47	70	83.79	14.10	**16.29*****
	Peer	75	56.89	18.34	70	56.93	19.03	0.00

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Full results of the one-way ANOVA regrouped by environment for self-ability are found in Appendix C Table C.1 and for peer-ability in Appendix C in Table C.2 A list of significant results from data presented in Table C.1 is shown below in Table 1.27. A list of significant data presented in Table C.2 is shown below in Table 1.28.

Table 1.27 Significant Results for One-way ANOVA of Environment and Self-ability for Each Professional Skill

Environment	Professional Skill	F
Engineering Courses	Communication	5.33*
	Teamwork	9.03**
Engineering Student Organization	Professional Judgment	6.17*
Non-engineering Courses	Ethical Considerations	4.03*
Non-engineering Student Organization	Inclusivity	13.10***
	Professional Judgment	4.02*
	Task Management	7.71**
Off-campus Involvement	Inclusivity	4.55*
	Leadership	7.18**
Pre-college Involvement	Ethical Considerations	4.67*
	Inclusivity	12.60***
	Leadership	5.17*
	Professional Judgment	3.97*
	Teamwork	4.68*
Undergraduate Research	Professional Judgment	4.19*
Upbringing	Inclusivity	17.28***
	Teamwork	16.29***

*p < .05. **p < .01. ***p < .001.

Table 1.28 Significant Results for One-way ANOVA of Environment and Peer-ability for Each Professional Skill

Environment	Professional Skill	F
Engineering Courses	Collaboration	12.31***
	Communication	17.08***
	Ethical Considerations	8.85**
	Inclusivity	13.80***
	Leadership	7.87**
	Professional Judgment	9.45**
	Task Management	6.70*
	Teamwork	16.58***
Engineering Student Organization	Ethical Considerations	6.41*
Non-engineering Student Organization	Inclusivity	4.31*
	Professional Judgment	4.79*
	Task Management	4.51*
	Teamwork	4.79*
Off-Campus Involvement	Leadership	8.04**
	Task Management	4.76*
Pre-College Involvement	Communication	6.71*
	Inclusivity	5.09*
Undergraduate Research	Inclusivity	4.00*

*$p < .05$. **$p < .01$. ***$p < .001$.

Even after splitting mean ratings for self- and peer-ability based on if the student attributed their development in a skill to a certain environment, students still rated their own ability higher than that of their peers on average.

For self-ability, there were 18 instances where experience in an environment led to an increase in mean rated ability to a significant level. Most notable is pre-college experience, where when attributed to skill development, mean rating of self-ability increased for five professional skills (ethical considerations, inclusivity, leadership, professional judgment, and teamwork). For instance, when comparing the overall mean rating for self-ability for inclusivity and the mean rating that only includes those who attribute pre-college experience to their development of their skills in inclusivity, the mean increases from 73.71 to 81.45, a 7.74-point jump and the highest of the five skills.

For peer-ability, there were 16 instances where experience in an environment led to an increase in mean rated ability to a significant level.

The mean rating for peer-ability increased to a statistically significant level for every professional skill when students attributed their development in a particular professional skill to their engineering courses. This is an interesting phenomenon and is worth further investigation. These results seem to imply that students that can see the value in their education and how the classroom can help develop professional skills (whether purposefully or not purposefully by the instructor, such a distinction is unclear)to a degree that students think more highly of their peers' skills. Further investigation into these results and additional studies may have a good contribution to engineering student self-efficacy research.

There were two instances where experience in an environment led to a decrease in mean rated peer-ability to a significant level. Those environment/professional skills pairs were pre-college involvement/communication and off-campus involvement/leadership. Students who attributed their personal development in communication to pre-college involvement rated their peers' ability with communication lower on average than those students who did not attribute pre-college involvement to their development in communication. Pre-college involvement implies experience in high school or before for the average student. No conclusive reasoning can be drawn from these results, but one hypothesis is that development of communication at an earlier age (and recognizing that development) leads to an individual holding higher standards for others once they are of the typical college age (early 20s). Providing measurable metrics for effective communication may help curb this misaligned perception. Another skill that saw a decline for experience in environment was leadership. Students that attributed their development in leadership to off-campus involvement rated their peers lower on average in leadership than students that did not attribute off-campus involvement to their development. Off-campus involvement was left to the interpretation of the student responding to the survey, so it could include several things such as off-campus jobs (not degree-related), community service, or church/religious involvement. Thus, no conclusive reasoning can be drawn from these results as well. However, in the types of off-campus involvement listed above, there are multiple opportunities for leadership roles, and it could be argued that there are more opportunities for clearly defined leadership roles. Students may have held the position of manager, coordinator, or small group leader, for example. A hypothesis is that students that attribute their off-campus involvement to the development of their leadership skills have either seen or demonstrated examples of good or bad leadership frequently, and the perception of what leadership includes is different for those students. Future work could investigate how frequent such opportunities are available to students compared to degree-related experience.

Limitations

Participant Limitations

The quality of student was not controlled for in this study. Participation in the study was limited to students who (1) saw the solicitation and (2) were motivated to take the time to complete the survey. Those students may or may not include a range of below average to above average students. It is anticipated that the participants are weighted more towards the above average rating since they took the time to respond to an optional survey. Future work should include repeating survey administration with a similar or larger sample size and running the same analysis to determine if the statistically significant difference in means between self- and peer-ability are representative of the entire student population or just of “above average” students.

It is assumed that students enrolled in Southeastern United States universities will share cultural similarities. This regional selection does not account for out-of-state students from different regions in the country which may have cultural experiences that do not align with those of the Southeastern United States. The survey did not ask for participants’ home state.

The author of this dissertation is currently a member of the mechanical engineering faculty at Mississippi State University. As such, a large portion of survey respondents attend Mississippi State University, and of those respondents, a large portion are mechanical engineering students. The author may have interacted with the survey respondents in the classroom or in another environment due to their role as a faculty member. As part of the survey solicitation, the link was posted on the author’s social media accounts. The Mississippi State University community comprises a large part of the audience of these accounts.

Conclusions

This work gave insight into current engineering student perceptions of professional skills. Survey respondents (N = 146) rated the importance, their self-efficacy, the average students’ abilities, and the level of instruction of professional skills in the university setting each on a scale of 0 to 100 for eight professional skills. These professional skills included collaboration, communication, ethical considerations, inclusivity, leadership, professional judgment, task management, and teamwork.

One-way repeated-measures ANOVA and Tukey post-hoc results yielded preliminary rankings for the professional skills according to mean rating. The category of Importance had most distinct rankings due to its effect size ($\eta^2 = 13\%$). Inclusivity was clearly ranked as the least important skill (even though the mean rating of 69.99 was higher than the highest mean rating for any professional skill in the Peer-ability and Level of Instruction Categories). Four professional skills were placed solely in the top subset (communication, task management, collaboration, and teamwork). These four skills comprised the top four in the rankings, but no statistically significant difference was found between their mean ratings, thus no decisive ranking can be produced. Rankings for the other three categories (Self-ability, Peer-ability, and Level of Instruction) were less decisive and demonstrate room for improvement in professional skills education in engineering education.

When comparing the mean ratings across categories for each professional skill, a statistically significant difference in mean rating was found for every professional skill when comparing Self-ability to Peer-ability ($p < 0.001$). Engineering students think more highly of their own professional skills ability than that of their peers. This discrepancy shows a need for clear, measurable, and actionable items to evaluate when assessing professional skills abilities, and such definitions should be provided to students. When it comes to the correlation of how well students believe they have been taught professional skills in a university setting and how they rate the abilities of themselves and their peers, the correlations are majority weak with some moderate correlations. There is not a clear positive correlation between the variables.

There were no statistically significant results when investigating if previous work experience resulted in higher self-efficacy concerning professional skills. Of the 146 respondents, 140 indicated they had previous work experience, leaving 6 without. Additional analysis with a larger sample size is necessary before drawing any conclusions about this relationship.

Pre-college experience was the environment that resulted in a higher mean rating for self-ability for the most professional skills. For peer-ability ratings, students that attributed their engineering courses as a source of professional skills development rated their peers higher than those who did not for every professional skill. Theories to explain these occurrences were provided, but further work is necessary to explain them more definitively.

The discrepancy between how students rate themselves and their peers will need to be addressed if any kind of peer assessment is to be used in engineering courses. The results showed that students rated their own skills higher than they rated their peers to a significant level for every professional skill. Steps to address the discrepancy may include providing operational definitions for the professional skills, which will be discussed in Chapter III.

CHAPTER II

A STUDY OF ENGINEERING FACULTY, PRACTICING ENGINEER, AND STUDENT PERCEPTIONS OF PROFESSIONAL SKILLS TO DETERMINE WHERE THE GROUPS ALIGN AND DIFFER IN THEIR PERCEPTIONS

Introduction

Across the nation, engineers go to work in environments where they must utilize professional skills. Whether it is giving a presentation, working in a team, or sending a summary of a project, engineers are using a skillset of abilities outside of the typical "hard" technical skills that encompass an engineering curriculum. However, there is not a clear consensus among students, engineering faculty, and practicing engineers on what it means to be good at various professional skills that engineers need or how to properly assess them. According to current literature, there is a need to evaluate the current perceptions of the top-rated professional skills of these constituents.

Background

For a successful integration of professional skills into a curriculum, constituents should have a similar understanding of the importance of developing these types of skills. These parties include students, faculty, and industry professionals. Carter provides data that shows employers', students', and faculty's opinions towards professional skills (Carter, 2011).

For the employers' data, job descriptions for postings for software engineers on Monster.com were evaluated. Out of the 50 descriptions evaluated, 43 of them listed various professional skills as requirements. The requirements were grouped into twelve skills categories, and four skills were at or above about a 50% response rate, meaning that at least 50% of the 43 companies listed that skill. The top four skills were written communication (34 responses), verbal communication (33 responses), teamwork (22 responses), and self-motivation/learning (20 responses). Written and verbal communication combined for about 75% of responses (Carter, 2011). Hirudayaraj surveyed over 450 practicing engineers and found that the rated importance outranked the rated proficiency for 24 of the 26 professional skills surveyed. ANOVA showed there was a statistically significant difference in the means of importance and proficiency for the 24 skills where importance was rated higher ($p \leq 0.001$ for 23, $p < 0.05$ for 1). The two skills where proficiency was rated higher than importance were global and cultural awareness and social responsibility (Hirudayaraj et al., 2021).

To evaluate students' opinions of professional skills, students at Point Loma Nazarene University (PLNU) were given ten professional skills and asked to rank their importance on a 1-5 scale (with 5 being the highest). These skills were similar to those from the employer's study. The responses (which included 27 students) all averaged over 2.5, with four skills averaging over 4. Those skills were communication, teamwork, professional attitude, and self-motivation/learning. Work across disciplines, passion for work, efficient/deadline conscious, problem solving/creativity, and organization were all at 3 or above but less than 4. The only skill rated below 3 was leadership (Carter, 2011).

Interviews conducted with faculty in a technical public university show a faculty awareness for the necessity of developing professional skills (Matusovich et al., 2009). The faculty gave four skills categories in which they believe students should be competent by graduation: technical, interpersonal, self-regulatory, and social responsibility. They give examples of how they attempt to integrate professional skills education in their classrooms and give examples of where the integration needs improvement. The selection of faculty interviewed was designed to include a large range of faculty backgrounds, but the authors state that further interviews should be conducted to verify if the results from the interviews are echoed by faculty in other universities.

Kabicher et al. administered a survey to investigate the importance that employers and faculty placed on various professional skills. This study did show similar perceptions by the two groups of the skills; however, this study is limited in that the number of surveys completed by employers and faculty were 35 and 17, respectively (Kabicher et al., 2009). A greater sample size is needed to more adequately compare perceptions of the constituents.

Overall, these studies show that students, faculty, and practicing engineers alike understand the need for employees to be proficient in professional skills, primarily communication, teamwork, and initiative. The skills studied in literature are all valid professional skills, and many studies investigate the same or similar ones, but investigating skills directly tied to ABET Student Outcomes would be beneficial to the research area. Unifying both the skillset and the approach to assessing the perceptions and abilities of students, faculty, and practicing engineers will also be beneficial as results can be directly compared.

Literature is lacking a comparison of the perceptions of students, faculty, and practicing engineers. Once an understanding of current perceptions is understood, approaches can be created and perfected to align these perceptions.

Research Objectives

This study aims to investigate faculty and practicing engineers' perceptions of the importance of, student ability with, and student education in various professional skills. These perceptions will be compared to those of students using data presented in Chapter I, and the results of the three groups will be compared to see what overlap, if any, occurs. Explanations will be offered as to why responses align or differ. These results will help to identify areas where goals and approaches to professional skills education may need realigned.

The following research questions will guide this study.

1. What are faculty and practicing engineers' perceptions of professional skills' importance, and how do they compare to student perceptions?
2. How do faculty and practicing engineers rate the ability of engineering graduates with top professional skills, and how do these ratings compare to those of students?
3. How well do faculty and practicing engineers believe professional skills are being taught, and how do these perceptions compare to those of students?

It is hypothesized that overall faculty and practicing engineers will give a greater importance to professional skills than students. They will place higher importance on communication and task management. Practicing engineers will indicate that students have lower ability of the professional skills. Overall, faculty will have average opinion of the ability and education level of the students' abilities.

Contributions

The purpose of this study is to investigate the similarities and differences that students, educators, and employers have in their perceptions of various levels of professional skills proficiency. Ultimately, the results from this study will help inform future work to strengthen professional skills education in undergraduate engineering students. The perceptions of the three constituents and how they compare can assist engineering educators in re-aligning goals in teaching and assessing professional skills in engineering students, aiming to close the gap between any differences in perceptions.

Methods

Design

This study utilized surveys to evaluate engineering faculty members' and practicing engineers' perception of the importance of top-rated professional skills and how well engineering students, recent graduates, and experienced engineers exhibit these skills. Responses to the questions from all three groups were compared to assess agreements and disagreements in the perception and development of professional skills in engineering students.

Participants

The participants of this study consisted of two groups: engineering faculty and practicing engineers.

Engineering faculty were recruited from the same universities as the students from Chapter I. This included faculty from universities in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. To aid in a higher response rate, responses from faculty from universities in other states were retained.

Practicing engineers in industry were recruited from companies that hire students from the universities of students from Chapter I.

Faculty members represented nine universities and ten engineering. University and department demographic information is provided in Tables 2.1 and 2.2, respectively. Areas represented in the practicing engineer survey responses are shown in Table 2.3.

Table 2.1 Universities Represented in Faculty Survey Responses

University	Frequency	Percent
Mississippi State University	12	48
Tennessee Tech University	1	4
University of Alabama	1	4
University of Alabama at Huntsville	1	4
University of Arkansas	6	24
University of Florida	1	4
University of Kentucky	1	4
University of North Carolina Wilmington	1	4
University of Wisconsin-Madison	1	4
Total	25	100

Table 2.2 Departments Represented in Faculty Survey Responses

Department	Frequency	Percent
Agricultural and Biological Engineering	3	12
Center for Advanced Vehicular Systems	1	4
Chemical Engineering	5	20
Civil and Environmental Engineering	1	4
Computer Science	2	8
Computer Science and Engineering	1	4
Engineering Professional Development	1	4
Industrial and Systems Engineering	1	4
Mechanical Engineering	2	8
N/A	8	32
Total	25	100

Table 2.3 Engineering Areas Represented in Practicing Engineer Survey Responses

Area	Frequency	Percent
Aerospace	6	8
Agricultural	1	1
Appliance	1	1
Automotive	7	9
Civil and Environmental	2	3
Commercial Equipment	2	3
Consulting	3	4
Defense	8	11
Energy	3	4
Engine filtration	1	1
Government	2	3
HVAC	1	1
Logistics/Automation	1	1
Manufacturing	6	8
Military Research	1	1
Neuroscience	1	1
Nuclear Power	1	1
Oil and Gas	2	3
Orthopedic Medical Devices	1	1
Packaging	1	1
Paper	1	1
Petrochemical	2	3
Pipe Stress	1	1
Power Generation	1	1
Power Systems	1	1
Research	4	5
Shipbuilding	1	1
Space	1	1
Specialty Catalysts	1	1
Steel Industry	3	4
Telecommunications	1	1
Transportation and Logistics	1	1
Utilities	5	7

Together, the faculty and practicing engineers represented eleven undergraduate engineering majors, which is shown in Table 2.4.

Table 2.4 Undergraduate Majors Represented in Faculty and Practicing Engineer Survey Responses

Undergraduate Major	Faculty	Practicing Engineers
Aerospace Engineering	1	2
Biomedical/biological Engineering	4	1
Chemical Engineering	6	10
Civil/environmental Engineering	2	4
Computer Science	1	0
Computer/software Engineering	2	1
Electrical Engineering	2	1
Industrial/systems Engineering	1	5
Materials Engineering	1	0
Mechanical Engineering	3	51
Petroleum Engineering	1	0
N/A	1	0
Total	25	75

Undergraduate graduation years for both groups collectively spanned five decades. The frequency of respondents per decade is shown in Table 2.5.

Table 2.5 Undergraduate Graduation Year for Faculty and Practicing Engineers

Graduation Year	Faculty	Practicing Engineers
1980s	6	2
1990s	6	1
2000s	7	12
2010s	6	35
2020s	0	25
Total	25	75

The breakdown of genders represented in the faculty and practicing engineer survey responses are shown in Table 2.6.

Table 2.6 Genders Represented in Faculty and Practicing Engineer Survey Responses

Gender	Faculty		Practicing Engineers	
	Frequency	Percent	Frequency	Percent
Male	16	64	56	75
Female	9	36	19	25
Total	25	100	75	100

A total of five ethnicities were represented in faculty and practicing engineer survey responses. The breakdown is shown in Table 2.7.

Table 2.7 Ethnicities Represented in Faculty and Practicing Engineer Survey Responses

Ethnicity	Faculty		Practicing Engineers	
	Frequency	Percent	Frequency	Percent
Asian	4	16	5	7
Black	0	0	2	3
Latino/Hispanic	0	0	2	3
White	19	76	68	91
Other	2	8	0	0
Total	25	100	75	100

On average, the mean age of the practicing engineers was lower than that of faculty. Descriptive statistics of the age of the survey respondents is shown in Table 2.8.

Table 2.8 Age Descriptive Statistics for Faculty and Practicing Engineer Survey Responses

Group	N	Min	Max	M	SD
Faculty	23	26	65	45.04	11.57
Practicing Engineers	61	22	60	30.15	8.35

Sample Size

Studies discussed in previous sections typically involve sample sizes of 50 or less. This study aimed to meet the threshold of 50 from each group (faculty and practicing engineers). This threshold was met for practicing engineers but was not attained for faculty.

Survey Instrument

The survey instrument had the same format as that of Chapter I. The same list of eight professional skills was used. Changes were made to the wording of the questions to ask participants to assess engineering student skills and not their own. Participants were asked to rate the importance of, current engineering students'/recent graduates' skills with, and level of instruction in university setting of the eight professional skills via a slider scale. The questions comprising the survey are found in Appendix C.

The following demographic information was collected: current industry area/engineering department, undergraduate college major, age, gender, ethnicity, and year of graduation with a bachelor's of science in engineering degree.

The survey was administered through Qualtrics.

Survey Reliability and Validity

Since this survey did not measure constructs, evidence of survey reliability and validation was not necessary.

Procedure

A solicitation was sent via email to department heads of the engineering departments from the selected universities as well as directly to faculty members. The department heads were asked to share the survey with faculty members in their department. The solicitation included:

- Link to the survey
- Description and motivation of the study
- IRB approval number
- Description for the incentive for participation

A solicitation was posted on LinkedIn, Facebook, and Twitter. Upon accessing the survey, participants could access the consent document which included:

- Description and motivation of the study

- IRB approval number
- Description for the incentive for participation

Analysis

To complete analysis, Statistical Package for Social Sciences software (SPSS) (*IBM SPSS Statistics for Windows*, 2021) was used. Participants responded to each question along the scale, and while no numerical distinctions were provided to participants, the scale ranged from 0 to 100. Appropriate anchors for the question were provided. This scale is more akin to a continuous scale than typical Likert scales, allowing for greater expression from participants for the responses.

Inferential Analysis

One-way repeated-measures analyses of variance (ANOVA) was completed based on group (Faculty, Practicing Engineers, and Students) for all professional skills. Student data presented in Chapter I was also used in analysis. For all ANOVA, the significance level (α) was set to 0.05. Thus, any occurrence with a p-value less than 0.05 led to a rejected null hypothesis. When presenting results, further distinction is provided to show when p-values were less than 0.05, less than 0.01, and less than 0.001 in order to show the reduced likelihood of a Type I error.

To investigate Faculty and Practicing Engineers' perceptions of professional skills and how they compare to Student perceptions, two one-way repeated-measures ANOVAs were completed for each research question (RQ1: importance; RQ 2: student skill; RQ3: level of instruction at university level).

The first ANOVA determined if there was a statistically significant difference in mean ratings across the groups for a particular professional skill. The results of this analysis showed if the groups had the same perception of the level of importance, level of student ability, and level of instruction in university setting.

The second ANOVA determined if there was a statistically significant difference in mean ratings across the professional skills for a particular group. The ANOVA was repeated for each group.

Tukey post-hoc analysis was utilized for further investigation where one-way repeated-measures ANOVA produced significant results.

Results

Survey results were downloaded from Qualtrics as an SPSS statistics data document. After incomplete responses (70% or lower completion percentage) were removed, the responses for analysis included 25 Faculty and 75 Practicing Engineers.

Perceptions of Importance of Professional Skills

The responses to the survey question, "how important is [professional skill] for engineering students and graduates," were analyzed in order to answer Research Question 1. The question was, "What are faculty and practicing engineers' perceptions of professional skills' importance, and how do they compare to student perceptions?" The hypothesis was that faculty and practicing engineers would give a greater importance to the professional skills than students.

Descriptive and Inferential Statistical Analysis Results and Discussion

Figure 2.1 below provides a visualization of how each group rated the importance of each professional skill on average. Standard error is indicated for each mean rating. One-way ANOVA was completed to compare Faculty, Practicing Engineers, and Student perceptions of the importance of each professional skill. The null hypothesis was that the mean ratings for the importance of a professional skill were the same for each group. Results showed if there was any statistically significant difference between the mean ratings for the importance of the professional skills across each group. The numerical results of the analysis along with the means standard deviations for each group and professional skill are shown in Table 2.9.

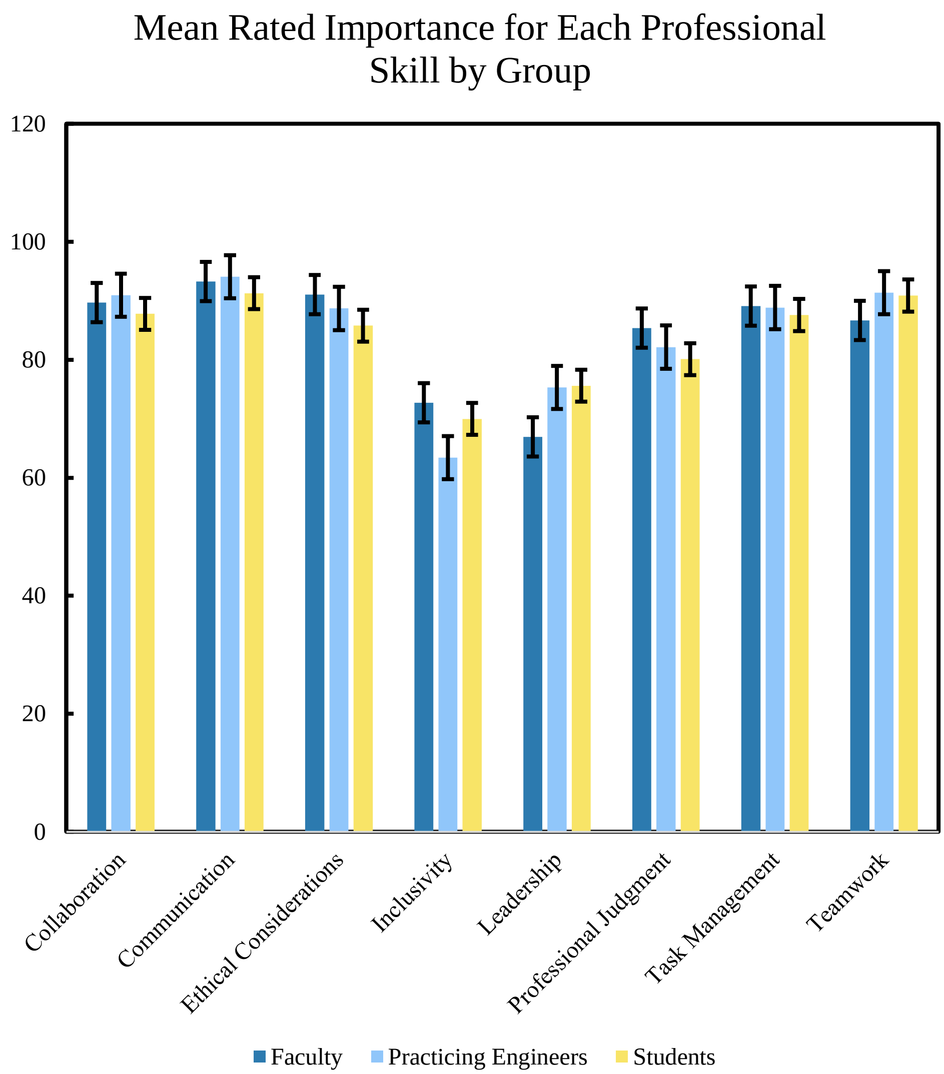

Figure 2.1 Mean Rated Importance for Each Professional Skill by Group

Table 2.9 Means, Standard Deviations, and One-Way ANOVA of Group and Rated Importance Each Professional Skill

Skill	Faculty			Practicing Engineers			Students			F	η^2
	N	M	SD	N	M	SD	N	M	SD		
Collaboration	25	89.68	13.32	75	**90.96**	12.22	144	87.80	16.28	1.15	0.009
Communication	25	93.28	10.84	70	**94.07**	11.20	135	91.28	12.46	1.35	0.012
Ethical Considerations	25	**91.04**	11.38	70	88.71	19.67	136	85.79	18.21	1.22	0.011
Inclusivity	25	**72.72**	23.29	69	63.42	31.73	143	69.99	28.08	1.53	0.013
Leadership	25	66.96	18.82	69	75.32	19.27	145	**75.61**	19.93	2.14	0.017
Professional Judgment	25	**85.36**	14.08	69	82.15	18.55	145	80.11	17.05	1.13	0.009
Task Management	25	86.68	13.92	72	**91.39**	11.08	140	90.90	12.05	1.54	0.013
Teamwork	25	**89.12**	12.80	75	88.85	16.46	145	87.60	17.18	0.19	0.002
Mean	25	84.36	14.81	71	84.36	17.52	142	83.64	17.66		

*p < .05. **p < .01. ***p < .001.
Note. Highest mean for each skill is bolded. Highest skill within a group is underlined.

On average, the three groups appear to agree on the level of importance for all skills. The mean of the three groups' means is 84.12 and the standard deviation is 0.42. The difference in mean ratings for inclusivity and leadership are slightly greater than the other professional skills. However, the one-way repeated-measures ANOVA produced no statistically significant results. All three groups have a comparable perception of the importance of each of the professional skills. Thus, the null hypothesis was not rejected for any professional skill. In fact, from highest to lowest mean for the skill, the Practicing Engineers and Students had the same order of skills. For the Faculty, two pairs of skills were switched. On average, all three groups rated communication as the most important professional skill. Each group had mean rating for all professional skills except inclusivity and leadership at 80.00 or higher. The ranges of the mean ratings were 30.65 (Practicing Engineers), 26.32 (Faculty), and 21.30 (Students).

All eight professional skills had an effect size of 0.017 or less, leading to the conclusion that no Type II error has occurred.

These results agree with those presented by Carter (2011). Top skills requested by employers, when mapped to the eight professional skills used in this study, were communication and teamwork. When asked to rate the importance of various professional skills on a scale of 1 to 5, students had communication and teamwork rated highly. In this study, communication had the highest mean rating of importance for both Practicing Engineers and Students, and teamwork had a high rating as well.

One-way repeated-measures ANOVA was completed to compare mean rated importance for each professional skill within each group. The null hypothesis was that the mean ratings for each professional skill within the same group are the same. Results showed if there was any statistically significant difference between the mean ratings of the professional skills, thus leading to a ranking of the professional skills' importance within each group. Numerical results of the analysis are shown in Table 2.10.

Table 2.10 One-Way ANOVA of Professional Skill and Rated Importance for Each Group

Group	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Faculty	Between groups	15494.52	7	2213.50	9.44***	0.26
	Within groups	45041.28	192	234.59		
	Total	60535.80	199			
Practicing Engineers	Between groups	53016.54	7	7573.79	22.08***	0.21
	Within groups	196552.83	573	343.02		
	Total	249569.37	580			
Students	Between groups	58448.32	7	8349.76	24.90***	0.13
	Within groups	377227.26	1125	335.31		
	Total	435675.58	1132			

***$p < .001$.

The results of the three ANOVA tests were all statistically significant ($p < 0.001$). The null hypothesis was rejected for each group. There is a statistically significant difference between the mean ratings of one or more pairs of professional skills for each group.

The eta squared value shows what percentage of variability between the mean ratings is explained by the difference in professional skill. The eta squared value for Faculty ($\eta^2 = 26\%$) and Practicing Engineers ($\eta^2 = 21\%$) show a large effect, showing that the particular profession skill accounts for 26% and 21%, respectively, of the variability in mean ratings for importance. For students, the eta squared was calculated to be 13%, which is a medium effect.

Tukey post-hoc analysis shows interactions between significantly different skills for each group. Statistically significant results including mean difference and 95% confidence intervals from the Tukey post-hoc analysis are shown in Appendix E in Table E.1.

All of the ANOVA results yield a preliminary ranking of professional skills within each group. Post-hoc analysis provided a summary table for each category with subsets to assist in ranking the professional skills using the same basis as discussed in Chapter I. The subsets and rankings for Faculty are shown in Table 2.10. The subsets and rankings for Practicing Engineers are shown in Table 2.11. The subsets and rankings for Students are shown in Table 2.12.

Table 2.11 Subsets and Rankings for Mean Ratings of Importance for Faculty

Professional Skill	N	1	2	3
Leadership	25	66.96		
Inclusivity	25	72.72	72.72	
Professional Judgment	25		85.36	85.36
Task Management	25			86.68
Teamwork	25			89.12
Collaboration	25			89.68
Ethical Considerations	25			91.04
Communication	25			93.28

Table 2.12 Subsets and Rankings for Mean Ratings of Importance for Practicing Engineers

Professional Skill	N	1	2	3	4
Inclusivity	69	63.42			
Leadership	75		75.32		
Professional Judgment	75		82.15	82.15	
Ethical Considerations	70			88.71	88.71
Teamwork	75			88.85	88.85
Collaboration	75			90.96	90.96
Task Management	72			91.39	91.39
Communication	70				94.07

Table 2.13 Subsets and Rankings for Mean Ratings of Importance for Students

Professional Skill	N	1	2	3	4
Inclusivity	143	69.99			
Leadership	75	75.61	75.61		
Professional Judgment	75		80.11	80.11	
Ethical Considerations	70			85.79	85.79
Teamwork	75				87.60
Collaboration	75				87.80
Task Management	72				90.90
Communication	70				91.28

For Faculty, leadership is significantly lower than all skills except for inclusivity. Communication, ethical considerations, collaboration, teamwork, and task management are all significantly higher than professional judgment, inclusivity, and leadership, but the five skills are not significantly different from each other. There is no clear “winner” of what Faculty consider to be the most important professional skill.

Results do support that inclusivity is considered the least important professional skill by Practicing Engineers, as it is significantly lower than all other professional skills. Communication is significantly higher than professional judgment, leadership, and inclusivity, but it is not significantly different from task management, collaboration, teamwork, and ethical considerations.

The results for the Student ratings are similar. Inclusivity is significantly lower than every skill but leadership. There are four professional skills that are significantly higher than the other skills but not significantly different from each other: communication, task management, collaboration, and teamwork.

For all three groups, communication had the highest mean rating for importance. For Practicing Engineers, communication is the only professional skill clearly in the top subset, showing the high value Practicing Engineers place on the skill in comparison to the other professional skills (both Faculty and Students had multiple professional skills only in the top subset). The Practicing Engineers and Students had the same order of professional skills when arranged from highest to lowest mean rating. The results of the Tukey post-hoc analysis are not identical, however, signifying there are some differences in the perceptions of the professional skills within the two groups, even if the ANOVA comparing mean ratings between pairs of groups (results presented in Table 2.9) produced no statistically significant results.

Implications

All three groups have the same perceived importance of each of the professional skills. The mean ratings for every group and skill were all higher than 70.00 except for Student rating of inclusivity (69.99), Faculty rating of leadership (66.96), and Practicing Engineers rating of inclusivity (63.42). The overall means for each group were close to one another with the mean of the means for each group at 84.12 and the standard deviation at 0.42. The similarities in how the three groups rated the importance of the professional skills were seen further in the results of the one-way repeated-measures ANOVA. The results yielded no statistically significant results for any professional skill. Thus, the hypothesis was wrong, and it can be concluded that Faculty, Practicing Engineers, and Students all place the same value on the various professional skills. In fact, when the mean ratings of the professional skills are arranged from highest to lowest, the professional skills are in the same order for both Practicing Engineers and Students, and the Faculty order is similar.

There were some statistically significant differences when comparing mean ratings of the professional skills within each group. These results show some subtleties in how each group perceives the professional skills. Future work could explore the source of the slight differences. All three groups have communication, task management, collaboration, teamwork, and ethical considerations in the top subset of skills. These can be considered the most important professional skills.

This overall alignment in perception of the importance of the professional skills is promising when it comes to professional skills education for engineers. Educational practices can then focus on ensuring students have high ability with the most important skills.

Perceptions of Student Abilities with Professional Skills

The responses to the survey question asking participants to rate student ability (for students, this was their own and their peers) were analyzed to answer Research Question 2. The question was, “How do faculty and practicing engineers rate the ability of engineering graduates with top professional skills, and how do these ratings compare to those of students?” The hypothesis was that practicing engineers will indicate lower ability and faculty will indicate average ability.

Descriptive and Inferential Statistical Analysis Results and Discussion

Figure 2.2 below provides a visualization of how each group rated student ability of each professional skill on average. Standard error is indicated for all mean ratings. Both Self-ability and Peer-ability ratings were included for the Students. One-way repeated-measures ANOVA was completed to compare Faculty, Practicing Engineers, and Student perceptions of abilities of students for each professional skill. The null hypothesis was that the mean ratings for the student ability with a professional skill were the same for each group. Results showed if there was any statistically significant difference between the mean ratings for the student ability with the professional skills across each group. The numerical results of the analysis along with the means and standard deviations for each group and professional skill are shown in Table 2.14.

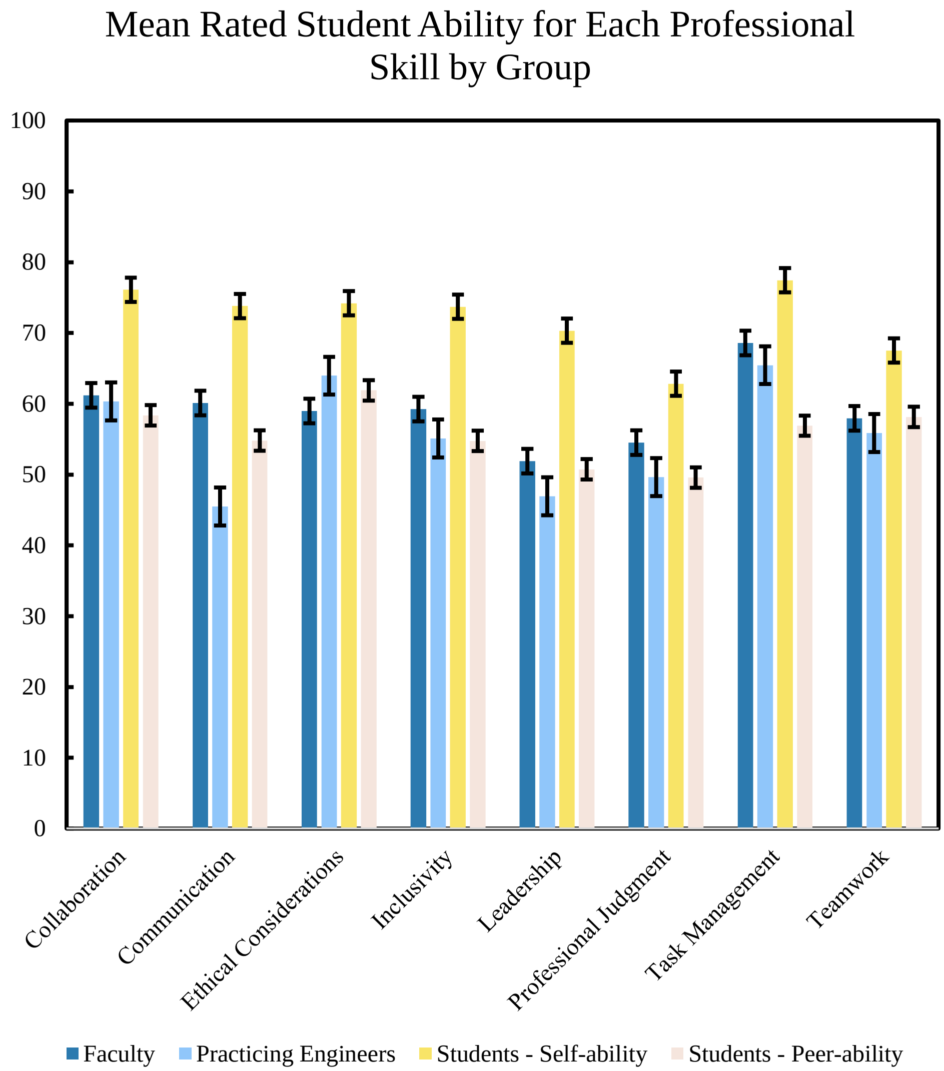

Figure 2.2 Mean Rated Student Ability for Each Professional Skill by Group

Table 2.14 Means, Standard Deviations, and One-Way Analyses of Variance of Group and Rated Student Ability for Each Professional Skill

Skill	Faculty			Practicing Engineers			Student Self-ability			Student Peer-ability			F	η^2
	N	M	SD	N	M	SD	N	M	SD	N	M	SD		
Collaboration	25	61.20	16.44	75	60.33	19.86	145	**76.11**	17.29	145	58.37	18.86	25.91***	0.17
Communication	25	60.12	22.27	70	45.50	21.77	135	**73.81**	19.11	135	54.79	19.57	36.63***	0.23
Ethical Considerations	25	59.00	22.77	70	63.97	22.92	136	**74.19**	20.64	136	61.90	22.01	9.01***	0.07
Inclusivity	25	59.24	23.29	69	55.12	23.84	143	**73.71**	22.41	143	54.75	22.63	19.57***	0.14
Leadership	25	51.92	16.93	69	46.95	17.48	145	**70.31**	20.13	145	50.74	18.84	36.51***	0.22
Professional Judgment	25	54.52	19.86	69	49.64	17.65	144	**62.84**	18.72	144	49.60	16.21	16.19***	0.11
Task Management	25	57.96	17.69	75	55.89	21.70	139	**67.52**	22.37	140	58.14	19.66	29.68***	0.19
Teamwork	25	68.60	13.97	72	65.45	18.65	145	**77.44**	19.23	145	56.91	18.61	6.93***	0.05
Mean	25	59.07	19.15	71	55.36	20.48	142	71.99	19.99	142	55.65	19.55		

***$p < .001$.

Note. Highest mean for each skill is bolded. Highest skill within a group is underlined.

The mean of the three groups' means is 60.52 and the standard deviation is 7.83. The results of the eight ANOVA tests were all statistically significant ($p < 0.001$). The null hypothesis was rejected for each professional skill. There is a statistically significant difference in the mean ratings of student ability for one or more groups for each professional skill. Communication had the largest range (28.31), with the highest mean rating belonging to Student Self-ability and the lowest to Practicing Engineers. Interestingly, while both groups are in agreement about the importance of communication, how well the skill is executed by students is not. Another large range was leadership (23.36) once again for Student Self-ability and Practicing Engineers. Overall, all of the mean ratings that Students assigned to their own ability except for one skill (professional judgment) are numerically higher than the highest mean rating of the Professional Engineers.

Unsurprisingly, communication and leadership had the highest effect sizes ($\eta^2 = 23\%$ and 22%, respectively), which was expected because of the clear discrepancy in student ability for the skills. Both of these skills had the largest differences between the highest and lowest mean rating between the groups. Other professional skills with high effect sizes were task management ($\eta^2 = 19\%$), collaboration ($\eta^2 = 17\%$), and inclusivity ($\eta^2 = 14\%$).

Based on the descriptive statistical results, it was expected for the Student Self-ability mean ratings to be higher than one or more groups' mean ratings for all of the professional skills to a statistically significant level. For every professional skill, the highest mean rating belonged to Student Self-ability. Tukey post-hoc analysis was utilized to investigate which groups had statistically significantly different mean ratings. Statistically significant results including mean difference and 95% confidence intervals from the Tukey post-hoc analysis are shown in Appendix E in Table E.2.

Student Self-ability had a statistically significant, positive mean difference between every group for every professional skill except for faculty for the professional skills of professional judgment, task management, and teamwork. Thus, it can be said that students think more highly of their own abilities than they think of their peers' abilities to a statistically significant level for every professional skill. Similarly, students think more highly of their own abilities than practicing engineers think of the students' abilities to a statistically significant level for every professional skill. As discussed in the limitations of Chapter I, the quality of the students who responded to the survey may have an effect on these results. Students and Practicing Engineers were asked to rate the average engineering student's ability with each professional skill, thus the similarities between those two groups are encouraging (only two professional skills, communication and teamwork, had mean differences at a statistically significant level). However, if the sample of students is an average representation of the student population, there will be discrepancies between self- and peer-ratings due to illusory superiority. The quality of student cannot be determined, but this consideration should still be made when looking at the results of the analysis.

Even though all groups agree on the importance of communication, they disagree on how well students execute the skill. The only pair where the null hypothesis (means are the same) was not rejected was Faculty and Student Peer-ability.

These results both agree and disagree with those presented by Hirudayaraj et al (2021). In their survey to Practicing Engineers, the mean rating for importance was higher than that of rated proficiency to statistically significant difference for 24 of the 26 skills provided. For all but the comparison of Student rated importance and self-ability for inclusivity, the mean rating for importance was higher than the mean rating for student ability for every professional skill and group.

The subsets produced from the Tukey post-hoc results are shown below: collaboration (Table 2.15), communication (Table 2.16), ethical considerations (Table 2.17), inclusivity (Table 2.18), leadership (Table 2.19), professional judgment (Table 2.20), task management (Table 2.21), and teamwork (Table 2.22).

Table 2.15 Subsets and Rankings for Mean Ratings of Student Ability for Collaboration

Group	N	1	2
Student Peer-ability	145	58.37	
Practicing Engineers	75	60.33	
Faculty	25	61.20	
Student Self-ability	145		76.11

Table 2.16 Subsets and Rankings for Mean Ratings of Student Ability for Communication

Group	N	1	2	3
Practicing Engineers	70	45.50		
Student - Peer-ability	135	54.79	54.79	
Faculty	25		60.12	
Student - Self-ability	135			73.81

Table 2.17 Subsets and Rankings for Mean Ratings of Student Ability for Ethical Considerations

Group	N	1	2
Faculty	25	59.00	
Student - Peer-ability	136	61.90	
Practicing Engineers	70	63.97	63.97
Student - Self-ability	136		74.19

Table 2.18 Subsets and Rankings for Mean Ratings of Student Ability for Inclusivity

Group	N	1	2
Student - Peer-ability	143	54.75	
Practicing Engineers	69	55.12	
Faculty	25	59.24	
Student - Self-ability	143		73.71

Table 2.19 Subsets and Rankings for Mean Ratings of Student Ability for Leadership

Group	N	1	2
Practicing Engineers	74	46.95	
Student - Peer-ability	145	50.74	
Faculty	25	51.92	
Student - Self-ability	145		70.31

Table 2.20 Subsets and Rankings for Mean Ratings of Student Ability for Professional Judgment

Group	N	1	2	3
Practicing Engineers	70	45.50		
Student - Peer-ability	135	54.79	54.79	
Faculty	25		60.12	
Student - Self-ability	135			73.81

Table 2.21 Subsets and Rankings for Mean Ratings of Student Ability for Task Management

Group	N	1	2
Practicing Engineers	72	55.89	
Faculty	25	57.96	57.96
Student - Peer-ability	140	58.14	58.14
Student - Self-ability	139		67.52

Table 2.22 Subsets and Rankings for Mean Ratings of Student Ability for Teamwork

Group	N	1	2	3
Student - Peer-ability	145	56.91		
Practicing Engineers	75	65.45	65.45	
Faculty	25		68.60	
Student - Self-ability	145			77.44

Student Self-ability is significantly higher than all other groups for all professional skills except ethical considerations and task management. For all professional skills, no group is significantly lower than all other groups. For collaboration, inclusivity, and leadership, Student Self-ability is significantly the highest, but there is no significant difference between the other groups. Students think highly of their own abilities (McAnear et al., 2003), and while this confidence can be beneficial to the learning process, caution should be taking for the negative effect it may have on students' willingness to participate in classroom activities where a professional skill is being taught that they believe they have high proficiency in.

The results for communication, and professional judgment are interesting. Student Self-ability, Faculty, and Practicing Engineers are all significantly different from each other, with Faculty perception in the middle of the three groups. There is no significant difference in the Practicing Engineers/Student Peer-ability and Student Peer-ability/Faculty pairs. Teamwork has similar results, except the order is Student Self-ability, Faculty, and Student Peer-ability. There is no significant difference in the Student Peer-ability/Practicing Engineers and Practicing Engineers/Faculty pairs. Thus, Student Self-ability is higher than Faculty, which is higher than Practicing Engineers. There is a clear discrepancy concerning student ability of a professional skill that all groups value highly.

Practicing Engineers and Student Peer-ability generally always fall in the bottom subset (Practicing Engineers all but one professional skill, Student Peer-ability all but two professional skills), showing how much lower the mean ratings are for these groups are compared to those of Student Self-ability. It also shows how these groups' mean ratings for ability are comparable across the professional skills.

Faculty had the second highest mean rating for every professional skill except for ethical considerations and task management, but it never was the sole professional skill in a subset. Thus, there was always one or more group that Faculty was not significantly different from. Faculty was always significantly lower than Student Self-ability except for task management. There was no significant difference between Faculty and Practicing Engineers for all professional skills except communication and professional judgment.

One-way repeated-measures ANOVA was completed to compare mean rated student ability for each professional skill within each group. The null hypothesis was that the mean ratings for each professional skill within the same group are the same. Results showed if there was any statistically significant difference between the mean ratings of the professional skills, thus leading to a ranking of the perceived student ability with the professional skills within each group. Numerical results of the analysis are shown in Table 2.23.

Table 2.23 One-Way ANOVA of Professional Skill and Rated Student Ability for Each Group

Group	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Faculty	Between groups	4238.78	7	605.54	1.61	0.06
	Within groups	72388.24	192	377.02		
	Total	76627.02	199			
Practicing Engineers	Between groups	29208.85	7	4172.69	9.89***	0.11
	Within groups	241273.90	572	421.81		
	Total	270482.80	579			
Student Self-ability	Between groups	23544.69	7	3363.53	8.37***	0.05
	Within groups	451588.10	1124	401.77		
	Total	475132.80	1131			
Student Peer-ability	Between groups	16464.30	7	2352.04	6.11***	0.04
	Within groups	432861.00	1125	384.77		
	Total	449325.30	1132			

***$p < .001$.

The results of the four ANOVA tests produced statistically significant results ($p < 0.001$) for every group except Faculty. The null hypothesis was not rejected for the Faculty group but was rejected for Practicing Engineers, Student Self-ability, and Student Peer-ability. There is a statistically significant difference between the mean ratings of one or more pairs of professional skills for the latter three groups.

The largest eta squared value was for Practicing Engineers (η^2 = 11%), which is still a medium effect. Regardless, this value shows that Practicing Engineers had the largest variability within the mean ratings for the professional skills.

Tukey post-hoc analysis shows interactions between significantly different skills for each group. Statistically significant results including mean difference and 95% confidence intervals from the Tukey post-hoc analysis are shown in Appendix E in Table E.3.

Three of the four ANOVA results yield a preliminary ranking of professional skills within each group. Post-hoc analysis provided a summary table for each category with subsets to assist in ranking the professional skills using the same basis as discussed in Chapter I. The subsets and rankings for Practicing Engineers are shown in Table 2.24. The subsets and rankings for Student Self-ability are shown in Table 2.25. The subsets and rankings for Student Peer-ability are shown in Table 2.26.

Table 2.24 Subsets and Rankings for Mean Ratings of Student Ability for Practicing Engineers

Professional Skill	N	1	2	3
Communication	70	45.50		
Leadership	74	46.95	46.95	
Professional Judgment	75	49.64	49.64	
Inclusivity	69	55.12	55.12	55.12
Task Management	72		55.89	55.89
Collaboration	75			60.33
Ethical Considerations	70			63.97
Teamwork	75			65.45

Table 2.25 Subsets and Rankings for Mean Ratings of Student Ability for Student Self-ability

Professional Skill	N	1	2	3
Professional Judgment	144	62.84		
Task Management	139	67.52	67.52	
Leadership	145		70.31	70.31
Inclusivity	143		73.71	73.71
Communication	135		73.81	73.81
Ethical Considerations	136		74.19	74.19
Collaboration	145			76.11
Teamwork	145			77.44

Table 2.26 Subsets and Rankings for Mean Ratings of Student Ability for Student Peer-ability

Professional Skill	N	1	2	3	4
Professional Judgment	144	49.60			
Leadership	145	50.74	50.74		
Inclusivity	143	54.75	54.75	54.75	
Communication	135	54.79	54.79	54.79	
Teamwork	145		56.91	56.91	56.91
Task Management	140			58.14	58.14
Collaboration	145			58.37	58.37
Ethical Considerations	136				61.90

These results show that Practicing Engineers think relatively poorly of students' communication ability. Communication is significantly lower for every skill but leadership, professional judgment, and inclusivity. The Student Peer-ability results were the same for communication. These results are in juxtaposition to the Student Self-ability results, where communication is significantly higher than professional judgment and significantly lower than only teamwork and collaboration (there was no significant difference found among ethical considerations, communication, inclusivity, leadership, and task management).

Students' perception of their own abilities with professional judgment is significantly lower than all professional skills except for task management. Teamwork and collaboration are both significantly higher than task management and professional judgment.

Implications

The perceived student ability varies across the groups. The mean of the of the means for each group was 60.52 and the standard deviation was 7.83, showing there is a difference in how the groups rate student ability. One-way repeated-measures ANOVA to investigate if there was a statistically significant difference in any of the means for the group for a particular professional skill produced statistically significant results for each professional skill. For all but ethical considerations and task management, Student Self-ability was significantly higher than every other group. The only time there was not a significant difference between Practicing Engineers and Students was for ethical considerations. There was also only one instance where there was not a significant difference between Faculty and Student Self-ability, and that was for task management. When looking at Practicing Engineers compared to Faculty, Faculty was found to be significantly higher than Practicing Engineers for communication and professional judgment. For all six other professional skills, there was no significant difference between the two groups. The answer to the Research Question is that practicing engineers do indicate student ability at a lower level than students indicate their own ability. Faculty think slightly higher of student ability than practicing engineers.

Results show that students likely think highly of their own abilities with professional skills, but the perception is perhaps misguided. For every professional skill, the highest mean rating was for Student Self-ability. For all but one professional skill (ethical considerations), there was a significant difference in mean rated student ability for Student Self-ability and Practicing Engineers. A conclusion can be drawn that engineering students/graduates are likely entering the workforce with an inflated perception of their abilities with professional skills despite the fact that both groups agree on the rated importance of the eight skills. Further studies could investigate if this inflated perception affects engineering students'/recent graduates' attitude towards training in these skills.

As discussed in Chapter I, Student Self-ability mean rated student skill was found to be significantly higher than those of Student Peer-ability for all professional skills except teamwork. For all but one professional skill (task management), there was a significant difference in mean rated student ability for Student Self-ability and Faculty. A conclusion can be drawn that while faculty may believe students need more development in certain professional skills, students may view themselves as proficient or better. This may lead to students not fully investing their time and efforts into assignments designed to give practice with professional skills. Future work should focus on clear, objective definitions for what it means to be proficient at each professional skill to avoid discrepancies and help curb illusory superiority.

Perceptions of Level of Instruction in University Setting of Professional Skills

The responses to the survey question asking participants to rate the level of instruction in the university setting were analyzed to answer Research Question 3. The question was, "How well do faculty and practicing engineers believe professional skills are being taught, and how do these perceptions compare to those of students?"

Descriptive and Inferential Statistical Analysis Results and Discussion

Figure 2.3 below provides a visualization of how each group rated level of instruction in university setting of each professional skill on average. Standard error is indicated for each mean rating. One-way repeated-measures ANOVA was completed to compare Faculty, Practicing Engineers, and Student perceptions of level of instruction in the university setting for each professional skill. The null hypothesis was that the mean ratings for the level of instruction for a professional skill were the same for each group. Results showed if there was any statistically significant difference between the mean ratings for the level of instruction of the professional skills across each group. The numerical values of analysis along with the means and standard deviations for each group and professional skill can be seen in Table 2.27.

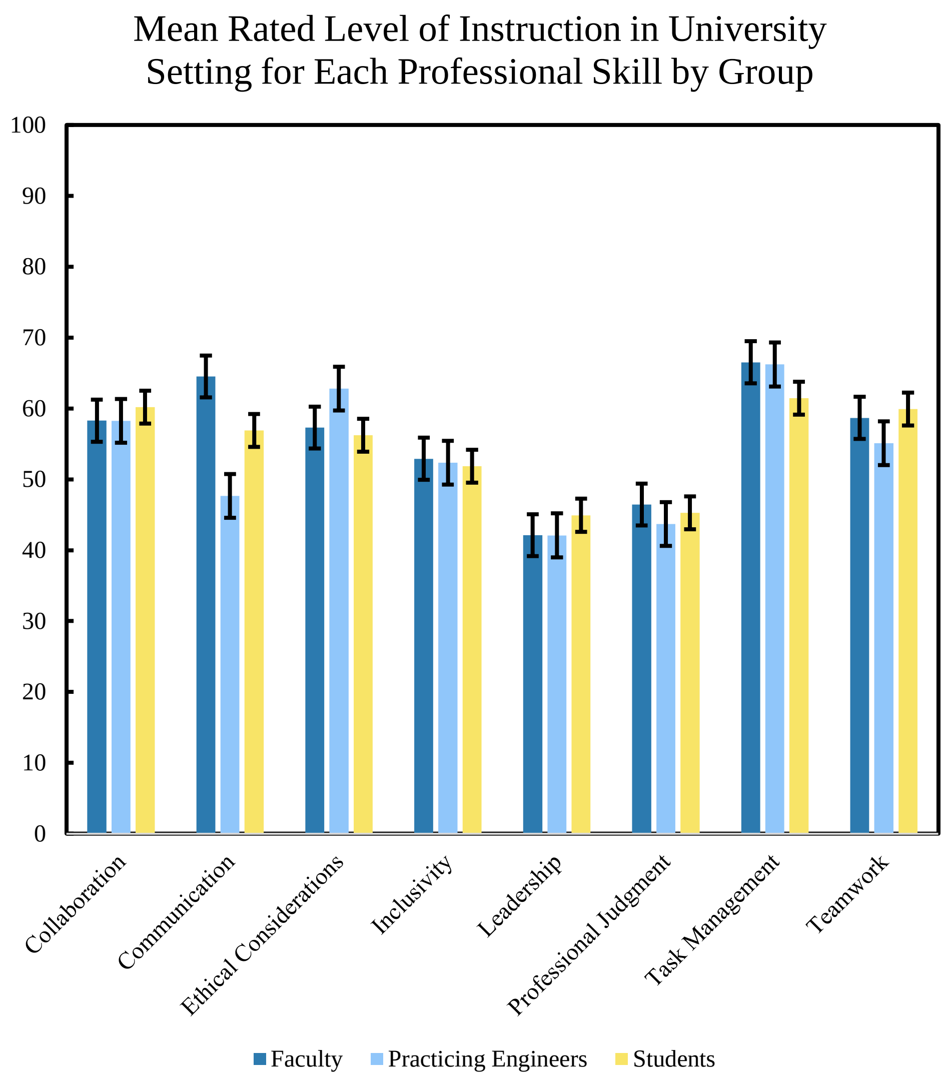

Figure 2.3 Mean Rated Level of Instruction in University Setting for Each Skill by Group

Table 2.27 Means, Standard Deviations, and One-Way ANOVA of Group and Rated Level of Instruction in University Setting for Each Professional Skill

Skill	Faculty			Practicing Engineers			Students			F	η^2
	N	M	SD	N	M	SD	N	M	SD		
Collaboration	25	58.28	20.86	75	58.25	22.75	143	**60.18**	24.19	0.198	0.002
Communication	25	**64.52**	18.77	68	47.65	23.24	131	56.92	24.58	5.762**	0.050
Ethical Considerations	25	57.32	24.12	68	**62.82**	25.84	136	56.22	29.04	1.312	0.011
Inclusivity	25	**52.91**	22.27	68	52.37	29.09	141	51.87	28.89	0.016	0.000
Leadership	25	42.12	21.80	68	42.10	21.62	141	**44.94**	25.77	0.397	0.003
Professional Judgment	25	**46.44**	19.45	68	43.71	21.21	143	45.27	24.37	0.172	0.001
Task Management	25	58.68	21.21	75	55.11	24.28	143	**59.92**	25.78	0.864	0.008
Teamwork	25	<u>**66.52**</u>	18.31	70	<u>66.21</u>	19.91	136	<u>61.47</u>	24.29	1.357	0.011
Mean	25	55.85	20.85	70	53.53	23.49	139	54.60	25.86		

**p < .01.
Note. Highest mean for each skill is bolded. Highest skill within a group is underlined.

The mean of the three groups' means is 54.66 and the standard deviation is 1.16. The one statistically significant result in the one-way ANOVA for level of instruction for was for communication. The professional skill had a small effect size ($\eta^2 = 5\%$), but it was close to medium ($\eta^2 > 6\%$). Again, a discrepancy is seen in perceptions of the different groups with regards to communication. All groups rated it as the most important professional skill on average; students think they have high ability with communication, and practicing engineers think they have low ability with it. Post-hoc analysis will reveal where the differences are among the groups when it comes to level of instruction of communication.

Tukey post-hoc analysis revealed that the means were statistically significantly different for Practicing Engineers (47.65 ± 23.24) who rated the preparation lower than both Faculty (64.52 ± 18.77, $p = 0.007$) and students (56.92 ± 24.58, $p = 0.025$). The rankings are visualized in Table 2.28.

Table 2.28 Subsets and Rankings for Mean Ratings of Level of Instruction in University Setting of Communication

Group	N	1	2
Practicing Engineer	68	47.65	
Student	131	56.92	56.92
Faculty	25		64.52

Thus, it is concluded that Practicing Engineers have the lowest perception of how well communication is taught at the university setting, and Students and Faculty have a similar perception. This disconnect is important to acknowledge when it comes to resolving the discrepancies found throughout the results of the study when it comes to communication.

One-way repeated-measures ANOVA was completed to compare mean rated level of instruction for each professional skill within each group. The null hypothesis was that the mean ratings for each professional skill within the same group are the same. Results showed if there was any statistically significant difference between the mean ratings of the professional skills, thus leading to a ranking of rated level of instruction with the professional skills within each group. Numerical results of the analysis are shown in Table 2.29.

Table 2.29 One-Way ANOVA of Professional Skill and Rated Level of Instruction in University Setting for Each Group

Group	Source of Variability	Sum of Squares	df	Mean Square	F	η^2
Faculty	Between groups	12243.743	7	1749.106	4.00***	0.26
	Within groups	82595.018	189	437.011		
	Total	94838.761	196			
Practicing Engineers	Between groups	38811.984	7	5544.569	9.99***	0.21
	Within groups	311984.367	562	555.132		
	Total	350796.351	569			
Students	Between groups	42783.104	7	6111.872	9.10***	0.13
	Within groups	743158.48	1106	671.934		
	Total	785941.583	1113			

***$p < .001$.

The results of the three ANOVA tests all produced statistically significant results ($p < 0.001$). The null hypothesis was rejected for every group. There is a statistically significant difference between the mean ratings for one or more pairs of professional skills for each group.

Faculty had the largest variability within the mean ratings for the professional skills with an eta squared value of 13%.

Tukey post-hoc analysis shows interactions between significantly different skills for each group. Statistically significant results including mean difference and 95% confidence intervals from the Tukey post-hoc analysis are shown in Appendix E in Table E.4.

The four ANOVA results yield a preliminary ranking of professional skills within each group. Post-hoc analysis provided a summary table for each category with subsets to assist in ranking the professional skills using the same basis as discussed in Chapter I. The subsets and rankings for Faculty are shown in Table 2.30. The subsets and rankings for Practicing Engineers are shown in Table 2.31. The subsets and rankings for Student Self-ability are shown in Table 2.32.

Table 2.30 Subsets and Rankings for Mean Ratings of Level of Instruction for Faculty

Professional Skill	N	1	2	3
Leadership	25	42.12		
Professional Judgment	25	46.44	46.44	
Inclusivity	22	52.91	52.91	52.90
Ethical Considerations	25	57.32	57.32	57.32
Collaboration	25	58.28	58.28	58.28
Task Management	25	58.68	58.68	58.68
Communication	25		64.52	64.52
Teamwork	25			66.52

Table 2.31 Subsets and Rankings for Mean Ratings of Level of Instruction for Practicing Engineers

Professional Skill	N	1	2	3	4	5
Leadership	73	42.10				
Professional Judgment	73	43.71	43.71			
Communication	68	47.65	47.65	47.65		
Inclusivity	68	52.37	52.37	52.37	52.37	
Task Management	70		55.11	55.11	55.11	55.11
Collaboration	75			58.25	58.25	58.25
Ethical Considerations	68				62.82	62.82
Teamwork	75					66.21

Table 2.32 Subsets and Rankings for Mean Ratings of Level of Instruction for Students

Professional Skill	N	1	2	3
Leadership	141	44.94		
Professional Judgment	143	45.27		
Inclusivity	141	51.87	51.87	
Ethical Considerations	136		56.22	56.22
Communication	131		56.92	56.92
Task Management	136		59.92	59.92
Collaboration	143		60.18	60.18
Teamwork	143			61.47

For Faculty, teamwork is significantly higher than professional judgment and leadership. For Practicing Engineers, teamwork is significantly higher than inclusivity, communication, professional judgment, and leadership. For Students, teamwork is higher than inclusivity, professional judgment, and leadership. Overall, all groups have level of instruction of professional judgement and leadership lower than teamwork.

While Professional Engineers have communication as significantly lower than teamwork, Faculty and Students have no significant difference among communication and multiple other skills: teamwork, task management, collaborations, and ethical considerations (and Faculty add inclusivity). This discrepancy in perceived level of instruction of communication was seen previously, as communication was the only professional skill that produced a statistically significant result for the ANOVA investigating if there was any statistically significant difference the mean rating for a professional skill depending on the group.

Implications

Perceived level of instruction in the university setting varied between the groups for one professional skill: communication. For all other professional skills, there was no statistical significance in means when comparing the mean rating for a professional skill across the groups. However, on average the mean ratings for all groups and all skills were lower than those of importance and student ability. With the mean of the three means being 54.66 and the standard deviation being 1.16, all three groups have a lower perception of the education of these professional skills compared to both the perceived importance and student ability.

The general alignment in perception of level of instruction for all professional skills is encouraging for education’s sake, showing that improved pedagogy for teaching professional skills would hopefully increase the mean rating of level of instruction across all groups. The professional skill to start with should be communication as it had the highest discrepancies between groups.

Limitations

The small sample size of Faculty (25) when compared to Practicing Engineers (75) and Students (146) may have introduced unintended error. While ANOVA does control for differences in sample size, that control is assuming that while small, the sample is representative of the population. It cannot be concluded that the sample of faculty is representative of the greater engineering faculty. Future work with a larger sample size of faculty may yield different conclusions.

The author of this dissertation is currently a member of the mechanical engineering faculty at Mississippi State University. As such, a large portion of survey respondents are most likely alumni of Mississippi State University, and of those respondents, a large portion mechanical engineering alumni. The author may have interacted with the survey respondents in the classroom or in another environment due to their role as a faculty member. As part of the survey solicitation, the link was posted on the author's social media accounts. The Mississippi State University community comprises a large part of the audience of these accounts.

The demographics do not include the respondent's years of experience in their position/field. Generational differences in the groups are not controlled for. The younger mean age of the practicing engineers should be considered. These practicing engineers may lack the perspective and experience that comes with years of experience in the field. However, these younger practicing engineers may have a more accurate understanding of the abilities of recent engineering graduates since they are more likely to be in lower-level positions working more closely with recent engineering graduates. Upper-management practicing engineers may not have enough direct interaction with recent engineering graduates to assess the current state of their abilities and education. For faculty, demographics do not include faculty rank. Faculty rank (assistant professor, associate professor, professor) indicates years of experience in academia. Similarly to the practicing engineers, faculty in lower ranks may have different perceptions than those in higher ranks. Additionally, it was not distinguished if faculty were primarily research- or teaching-focused. Faculty with a primary teaching appointment may have different perceptions than those with a higher research appointment. It is assumed that faculty more inclined to have an interest in effective pedagogy would take the time to respond to a survey regarding engineering pedagogy. Thus, the sample's perception of importance, student ability, and level of instruction in the university setting may be different (either higher or lower) than the average faculty member's perception.

Conclusions

This work confirmed many anecdotal assumptions of the perceptions of professional skills when it comes to Faculty, Practicing Engineers, and Students. While students thought highly of their own abilities, Faculty and Practicing Engineers rated student abilities comparably between each other, with communication being one of the two professional skills (the second being professional judgment) where the mean rated student ability was found to be significantly different between the two groups. For all but two professional skills (ethical considerations and task management), Student Self-ability was significantly higher than both Faculty and Practicing Engineers when it comes to perception of student ability with the professional skills.

The alignment of the rated importance of the skills was a surprising result yet has positive implications on the potential to improve professional skills education for engineering students. Future work should aim to clearly define what it means to be proficient at each of the professional skills, which can potentially help align the student ability ratings. Clear definitions may lead to an increased and improved education of professional skills at the university level.

Communication was rated on average as the most important skill on the list for all three groups (faculty, practicing engineers, and students), but it was not found to be significantly higher than all other professional skills for any group. Regardless, there was not a significant difference found between each group's mean rating for communication, thus all have the same perception of importance of the skill. However, for student ability, Student Self-ability was significantly higher than Faculty, which was significantly higher than Practicing Engineers. There is a clear discrepancy in what the skill level of students is when it comes to communication. The agreement in importance of communication is a positive in addressing the differences in perceived student ability. All groups should likely be receptive to improved communication education, assuming they all think it is currently at a low level. However, results show that Practicing Engineers have a low perception of communication instruction. Faculty and Students have a similar and higher perception of communication instruction. There is a disconnect in what it means to excel at communication. Future work to improve professional skills pedagogy in engineering should focus on communication, as the results show this to be an important skill that is falling short of its expected results.

Another interesting result is that the mean ratings drop for each question. Importance had the highest mean (84.12), followed by student ability (60.52), and then level of instruction (54.66). Future work could explore what caused the overall poor perception of both student ability with professional skills and professional skills education in the university compared to importance.

The results of this study help to outline next steps in professional skills education of engineering students. First, standardization of definitions of the professional skills and what "good, average, and bad" looks like can lead to changes in perceived student ability with the professional skills. If all groups are assessing the student ability using the same metric, then a more accurate understanding can be achieved. From there, educators can take advantage of the aligned importance perceptions and work to ensure students have high ability in the most important professional skills. Presumably, an improved perception of student ability will result in an improved perception of the level of instruction in the university setting.

CHAPTER III

UTILIZING STUDENT INTERVIEWS TO IMPROVE UNDERSTANDING OF ENGINEERING STUDENT PERCEPTIONS OF PROFESSIONAL SKILLS AND EDUCATION

Introduction

Employers across engineering have stated their desire for their employees to demonstrate various professional skills (Carter, 2011; Grugulis & Vincent, 2009; Hynes & Swenson, 2013; Idrus & Dahan, 2009; Kumar & Hsiao, 2007a; Pulko & Parikh, 2003; Robles, 2012; Schulz, 2008; Shakir, 2009; Skipper et al., 2017), and so it is not a question of "is professional skills education necessary," but instead "how do we teach professional skills effectively?" An obstacle that undergraduate faculty face in building students' professional skills is where to place the training in the curriculum. While it is tempting to believe that professional skills can be developed in general education classes where a certain skill is used frequently (i.e. writing in composition courses or presenting in speech classes), students do not learn these skills in the context of their major. STEM students need to be able to effectively communicate their technical knowledge in their field (Carter, 2011). Based on literature, courses dedicated solely to the development of professional skills are a step in the right direction but do not always produce the best results. In addition to adding more courses to already time-consuming curriculums, students are likely to view the course material as mundane and a waste of time (Carter, 2011; Kumar and Hsiao, 2007; Pulko and Parikh, 2003; Skipper et al., 2017). Pulko goes on to say that professional skills focused courses are perhaps the least popular with first year students, as they may hold the opinion that they have covered the material prior to college and would rather get into their STEM material. There is not a clear consensus on how to give students the opportunity to practice and develop professional skills.

A search of literature shows a lack of operational definitions for professional skills in the engineering field. There is no shortage of faculty, students, and employers expressing the importance of professional skills, but they call for "good" communication, teamwork, etc. many times without defining what it means to be good at those skills. There is also a lack of explanation of how these skills are developed before students arrive in a college classroom. Students bring with them implicit bias and/or proficiency in any number of professional skills, and the literature is lacking in how such preconceived notions come to be and how they affect a student's ability to improve in professional skills education. Bias continues to be present at the college level, which impacts the professional skills education of the students. Schmidt et al. created a standard engineering curricula named Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS). They ran the program with students from four institutions, and they found that institutional differences affect the students' performance in the program. The prestige of a university may increase the relative competitiveness of its students, and thus there is an even greater desire to perform well GPA-wise as opposed to less prestigious institutions. Culture and instructor dynamics also played a role in perceptions of professional skills (Schmidt et al., 2000).

The aim of this study is to understand the phenomenon of professional skills development through student experiences and perspectives. Student operational definitions of professional skills will be investigated as well as what areas/opportunities encourage growth in various professional skills.

Background

Professional Skills Development in Non-STEM Curriculums

A review of how professional skills are being taught in non-STEM curriculums was conducted. Some programs acknowledge the need for professional skills development and have programs in place to teach them. Others, like STEM programs, recognize the need and are working to develop a method to incorporate professional skills education.

Business Communication at the University of North Georgia

Anthony discusses a method to teach professional skills that was integrated into a business communication course (Anthony & Garner, 2016). Five assignments were given to the students: a self-evaluation of their professional skills proficiency, an interview with a boss or manager, a guest speaker, a journal article reading and class discussion, and a short video and class discussion. A student survey administered after the assignments found that students found the guest speaker to be the more beneficial. Overall, the survey results showed that students find assignments with a practical application to be the most helpful and interesting. This finding aligns with results from similar studies in STEM subjects (Pulko & Parikh, 2003).

Tuck School of Business at Dartmouth College

At the Tuck School of Business at Dartmouth College, Master of Business Administration (MBA) students have access to resources for improving their professional skills (Dvorak, 2007). Students work in teams on various exercises and give feedback on team members' skills and those that need more work. In addition, faculty members serve as coaches.

They assess students' skills and give them techniques to put into practice to improve their skills. Overall, students find the approach helpful as it shows their areas of weakness and gives them a plan for how to improve them.

The Hospitality Industry

Contrary to those in STEM areas, individuals in the hospitality industry put the greatest importance on professional skills as opposed to technical skills. Sisson gives five areas where competency is needed in the hospitality industry: conceptual/creative, leadership, interpersonal, administrative, and technical. The importance of professional skills can be seen as four of the five are professional skills. Hospitality programs include courses that cover the technical skills, but they also include courses that cover professional skills such as courses in meetings, events, conventions, and festivals. Similar to STEM subjects, the hospitality industry recognizes the need to adapt to the globalizing market and increasing technology (Sisson & Adams, 2013).

Accounting Education at Canisius College

Similar to the recent attitudes towards professional skills as those in STEM fields, Kermis discusses how technical skills are no longer sufficient enough for a successful career in the accounting field. Kermis goes on to describe a laboratory experience that was integrated into the accounting curriculum at Canisius College. The required laboratories were added to two existing courses and were designed to develop professional skills without leaving behind the theory and technical topics. The laboratories included a panel discussion with professionals from various levels in the accounting industry. The instructor also led a lecture on emotional intelligence including an introduction to the Myer Briggs assessment tool. To help develop their verbal communication, students delivered verbal resumes to the class accompanied by a question and answer session. Students also participate in a five-week professional development program through the college's Career Planning and Job Placement Office. This program covers topics such as resume and interview preparation (Kermis & Kermis, 2011).

Obstacles in Implementation in STEM Programs

One of the main obstacles to undergraduate professional skills competency is the nature of professional skills. When compared to technical skills, professional skills are often viewed as intangible and biased (Grugulis & Vincent, 2009; Hynes & Swenson, 2013; Robles, 2012; Shakir, 2009). While the need for professional skills development is recognized, literature does not provide a good method for teaching them (Walther et al., 2017). A defining characteristic of many STEM majors is the nature of the material: the solution is correct or incorrect, the bridge will succeed or fail. Teaching and assessing professional skills goes against the basis for many STEM curricula. Assessing hard/technical skills can more easily be standardized. Professional skills, however, are more situational, depending on factors such as personal background, environment, and the task at hand (Heckman & Kautz, 2012). To assess professional skills, some have taken a survey approach. Surveys administered to students ask the students to describe their own abilities or shortcomings. While this method does give feedback about the general state of the students and/or an attempt to teach professional skills, it cannot be easily standardized due to the individual bias of each student. This kind of assessment cannot easily prevent a student's overconfidence in his abilities or over criticism of his shortcomings (Shelby et al., 2013; Skipper et al., 2017).

Having a professor or potential employer assess a student's professional skills with a rubric or similar method also introduces bias. When discussing the assessment of potential hires' professional skills, Sambamurthy states that the evaluators will introduce their own level of bias due to their background and the definitions and importance of various professional skills (Sambamurthy & Cox, 2016). Theygo on further to state that this kind of bias affects both new hires and employees seeking promotions. The values of the company can be stated, but they are not always fully defined and are left up to the discretion of each employee. For instance, in a group each person may interpret the trait "assertive" differently. What one person defines as assertive, another person may define as aggressive. These kinds of inconsistencies provide an obstacle to college faculty trying to develop a certain professional skill in a class of students of varying backgrounds. A discussion about these inconsistencies and their controlling factors, such as body language and tone of voice, may help faculty establish a consistent idea of the professional skills they are trying to develop.

Another obstacle that undergraduate faculty face in building students' professional skills is where to place the training in the curriculum. While it is tempting to believe that professional skills can be developed in general education classes where a certain skill is used frequently (i.e. writing in composition courses or presenting in speech classes), students do not learn these skills in the context of their major. STEM students need to be able to effectively communicate their technical knowledge in their field (Carter, 2011). Based on literature, courses dedicated solely to the development of professional skills are a step in the right direction but do not always produce the best results. In addition to adding more courses to already time-intensive curricula, students are likely to view the course material as mundane and a waste of time (Carter, 2011; Kumar & Hsiao, 2007a; Pulko & Parikh, 2003; Skipper et al., 2017). Pulko goes on to say that professional skills-focused courses are perhaps the least popular with first-year students, as they may hold the opinion that they have covered the material prior to college and would rather get into their STEM material. Research also shows that courses that involve active and collaborative learning can be more beneficial than traditional courses (Pendergrass et al., 2001). Aji discusses that using project or problem-based learning to create an active learning environment can shift the course from deductive to inductive learning (Aji & Khan, 2017).

Methods for Teaching Professional Skills in STEM Programs

STEM faculty at various universities have employed different methods to integrate professional skills education into the curriculum. Literature shows that one method for teaching professional skills that has shown success is integrating the instruction into a service learning or capstone course (Ansari et al., 2013; Carter, 2011; Kumar & Hsiao, 2007a; Shakir, 2009; Shelby et al., 2013). Kumar and Hsiao discuss how they restructured their courses to more effectively improve students' professional skills (Kumar & Hsiao, 2007a). Schulz suggests the same idea (Schulz, 2008). Rao proposes the use of a Training and Placement Officer (TPO) to serve as a liaison between university persons (students and faculty) and industry professionals (Rao, 2015). A civil engineering course at the Citadel called Engineering Management has been restructured to include active learning techniques (Ghanat & Brown, 2017). Programs across the Southeast are implementing professional skills development into their curriculums.

Teaching Professional Skills through Service Learning or Capstone Opportunities

Various STEM programs at universities have attempted to improve professional skills through service-learning courses. The University of California at Berkeley implemented a freshmen-level multidisciplinary course titled Engineering Design and Analysis. The course is divided into multiple modules that cover various branches of engineering, and students select two modules to take during the semester. A recent addition has been a leadership module. Leadership strategies are discussed in the module and put into practice through a service-learning project. The students were divided into teams and each team worked to create an interactive exhibit for children in conjunction with a local science museum. Students then develop a proposal to present to the science museum that included a report and presentation. This project format allows students to improve their communication as they must talk with children to gauge what is desired in an exhibit and present their project to peers and faculty (Shelby et al., 2013). A follow up study surveyed the students after they had reached the third year of the engineering curriculum. The survey was administered to all students that took the course and aimed to assess the success of the leadership module. Overall, the feedback was beneficial and gave suggestions for improving the course (Ansari et al., 2013).

The computer science department at PLNU has set up a service-learning course to simulate a business experience. Students work in groups on a project for their client. The teams progress through their project throughout the year. In addition to working on the technical content of the project, students have the opportunity to improve various professional skills. Students can improve their communication through status and data analysis reports written throughout the project, through presentations, and through communicating with their client. The project also leads to developing skills such as efficiency, initiative, and organization as teams work independently from other teams and the instructor. The course is yearlong, and after the first semester a dinner is held for the students and clients where the teams display their progress and share it with other teams and clients. The paper includes some discussion of feedback from students and clients for improving the class model, but it does not mention any quantitative assessment being administered (Carter, 2011).

In the aerospace engineering department at Embry-Riddle Aeronautical University, the team structure for the undergraduate capstone project encompasses professional skills education.

The project is divided into four components: design, project, stress, and material/manufacturing. Each component has a designated lead, and the remaining team members work under the direction of the lead for that component of the project. If a team has more than four members, one or more components are split into unique roles, creating two independent leads for a component. Surveys administered to the students show that this format was successful. Seventy percent of students agreed that splitting the project into engineering roles helped to improve their engineering skills. Seventy percent also agreed that the split helped improve their ability to communicate with and work as a team. The engineering roles added depth to a problem based learning scenario, and it helped to prevent students from not doing their share of the work for the project (Namilae, 2018).

The University of West Florida established a mechanical engineering program in August of 2016. The structure of the program is based off of recommendations from the ASME Vision 2030 document. Two recommendations of ASME Vision 2030 are more project-based learning and more professional skills education. The mechanical engineering program at the University of West Florida encompasses these recommendations through an expansion of the common capstone course. The enterprise program includes six design-based courses culminating in two capstone courses that are similar to those of other programs. The six courses span three years and therefore include students from different points in the program. Students selected one of seven projects to join. Each team is responsible for creating the structure for the team, creating presentations and reports, and ensuring all deadlines are met. Senior students function as managers who both supervise the other students and meet with faculty about the status of their group's project. Some projects last more than one year, allowing students the opportunity to invest in a project for all three years. The paper includes a vision for growing and improving the program (Reynolds, 2018).

Stanford et. al (Stanford et al., 2013) describe a change made to the capstone course in the civil engineering department. Instead of student teams working on separate projects, they implemented a jigsaw format where the class worked on one project with multiple parts. This new course ran simultaneously as a capstone course in the traditional form. Student feedback showed that the students in the jigsaw capstone enjoyed and benefited from the teamwork and diversity present in the format. Students acknowledged that the format allowed them to practice their teamwork skills and that those are not skills that can typically be learned from a textbook. In addition, the project for the new course was designed to be an open-ended and real-world application. The project was not idealized for ease of calculations. Students spend the first part of the project researching previous solutions to a similar issue and putting together designs. One student commented on the amount of organization and planning that went into the first part of the project. Overall, students and faculty involved in the new capstone course spent more time on the coursework than those involved in the traditional course (27 hours/student versus 6 hours/student). The authors state that this discrepancy is one aspect of the new course that needs improved because it is not sustainable. However, based on student response, the new course design was engaging and considered practicable for their future jobs in civil engineering.

The capstone course in the mechanical engineering department at the University of Wisconsin is designed to offer students real-world team-based projects through industry partnerships (Ravikumar, 2015). Ravikumar discusses a robust design that allows for the capstone course to be administered for multiple semesters and cover the same topics. The course has eight defined objectives that cover topics from time management to considering all ways the design will affect others (environmentally, financially, ethically, etc.). Students must complete reports throughout the semester and follow the given process for completing the project. Surveys and assessments are used to assess the success of the course, and there is a positive trend for overall student success in the course from the first year of the format to the most recent at the paper's publication.

Restructuring Traditional Lecture Courses to Teach Professional Skills

While service-learning and capstone courses can be beneficial to teaching professional skills, students can benefit more if more than two courses acknowledge the development of these skills (Kumar & Hsiao, 2007a). Kumar and Hsiao discuss the integration of problem based learning (PBL) into their courses at Southern Illinois University at Carbondale (SIUC). They describe one course, "Geotechnical Engineering in Professional Practice," which addresses both technical and professional skills. In this course, groups work on multiple projects modeled after real engineering designs. The course is structured to offer technical content needed to complete the projects. After giving the initial technical content, the instructor aides groups when problems arise, but the groups work more independently. The instructor evaluates the group's work as a whole, and each member of the group evaluates the efforts of the other group members. Feedback from students has been positive, with one student attributing his successful job search (eight interviews and eight offers) to the course. Schulz states that a restructuring of current courses would be helpful but requires careful planning and cooperation from faculty (Schulz, 2008).

At North Carolina (NC) State University, the statics classes are flipped classrooms. Class time is spent working through examples and discussing the material in more depth. In the statics classes, students work in teams of three. Teams are assigned by the instructor and are changed after each of three midterms. There are three roles, and team members change roles for each class meeting. The recorder is in charge of the white-board and does not use a calculator. He/she relies on the other team members to use their calculators as needed. The manager ensures everyone stays on task. The skeptic's role is to question the steps taken when solving a problem. Each team member has a symbol assigned to them (each team of three contains the same symbols). After each class meeting, the instructor asks all team members to rate the performance of one team member by choosing one of the three symbols. A multiple choice question is given as a means for evaluating team member contribution. Students receive the compiled data after the midterm. This system has been successful in multiple ways. It allows the instructor to assess the teams in a large class (100+ students). The class also includes a final project with student selected teams. It is common that these teams contain students who were on the same team in a previous team rotation (Howard & Zellweger, 2018). Overall, this approach helps to show students productive team structure and attempts to erase previous opinions about teamwork (i.e. some team members will not contribute to the team's efforts but will still receive credit for the work).

Using a Training and Placement Officer to Improve Professional Skills Education

In addition to implementing service-learning and/or capstone classes and restructuring other courses in the curriculum, Rao states that a Training and Placement Officer (TPO) would be a useful tool for connecting faculty and students to industry professionals. The TPO's responsibilities include training faculty to effectively teach professional skills and arranging opportunities for students to hear from industry professionals. The TPO plays an important role in integrating professional skills education into the existing curriculum (Rao, 2015).

Teaching Professional Skills in a Professional Development Course

Electrical and Computer Engineering faculty at the University of Missouri saw that their graduate students had a lack of professional skills and created a two-semester course to cover professional skills and prepare them for a future as faculty and professionals (Mohan et al., 2010). Originally only for graduate students, the courses were later opened to senior undergraduate students chosen by faculty. Between the two courses, students covered three books that discussed learning styles, successful habits, and global trends. Classwork included class discussions and presentations of the material. A large focus of the semester course was studying and learning how to write effective proposals. While the two courses proved beneficial to the students, scheduling the two courses was challenging. Because of this, the two courses were designed to be stand-alone yet complementary courses. Survey results showed that students who took both courses showed better growth in professional skills competence.

At the Citadel, the Engineering Management course in the civil engineering department aims to improve students' professional skills (which includes professional skills) by using active learning techniques to improve student engagement (Ghanat & Brown, 2017). The required course includes several active learning techniques. Throughout the semester, each student teaches a lesson on one of the topics covered in class. In-class debates promote growth in communication skills as well as a competency of the topics. Team-based ethical arguments are used. Teams must compose their argument for an ethical issue and be able to explain it effectively. A class project allows students to practice teamwork and management skills while using their civil engineering knowledge. Questionnaires administered before and after the course show growth in technical and professional skills knowledge.

Developing Extra-Curricular Activities to Cover Professional Skills

At Middle Tennessee State University (MTSU), the school's chapters of the American Society of Mechanical Engineers (ASME) and the Society of Automotive Engineers (SAE) joined resources to create the Experimental Vehicles Program (EVP). The multi-disciplinary student group is divided into teams that compete in separate vehicle competitions. Students in officer positions get the opportunity to develop leadership and management skills. The competition nature of the projects helps to teach time management and give it a real-world application. Students also practice teamwork and communication as they build their vehicle. Through industry partnerships, students get to learn from industry professionals and receive advice on their projects (Foroudastan & Kelley, 2018). The structure of this extra-curricular group could be applied to a course with a project component.

Research Objectives

This study aimed to investigate survey responses from Chapters I and II on a phenomenological level. It aimed to show what similarities, if any, exist among students in professional skills development and perceptions and even if the opportunities and abilities differ. The main contributors to professional skills education were explored and the various experiences of the participants were compared to find any commonalities in the methods by which professional skills are effectively learned.

Contributions

The findings of this study will contribute to the understanding of the phenomenon of professional skills development in engineering students. The results will allow engineering educators to get a picture of where these skills are currently being developed, which methods are working well, and use new understanding to improve the ways these skills are taught and assessed at the undergraduate level.

Additionally, the results of this study can make good contributions toward creating operational definitions of “good,” and “bad” exhibitions of top professional skills. Well-defined operational definitions would help remove the bias and subjectivity currently in teaching and assessing professional skills. With clearly defined definitions, students can work towards meeting specific milestones in their professional skills education, preparing them for success in the workforce.

Suggestions for engineering educators for enhancing professional skills education will be discussed. Strategies from literature will be presented in light of findings of the study.

Methods

Design

Through interviews with a semi-structured and structured portion, this study was a continuation of the work from Chapters I and II. The aim of this study was to dive deeper into student perceptions of professional skills. Interview questions asked participants to elaborate on how they feel their professional skills have been developed and in what environment(s). Participants also provided personal definitions for a list of professional skills.

The interview was divided into two parts. Part I was semi-structured. Participants were asked about their professional skills experiences and development. Participants were not provided a set list of professional skills to refer to when describing their experiences. The interviewer had a set of pre-determined questions, but additional questions were allowed based on the direction of the conversation. These questions could ask participants to elaborate on a point they brought up or ask for clarification on something shared.

Part II was structured. Participants were provided a list of professional skills and were asked to define each professional skill and give a good and bad example and/or description of each. The eight professional skills from the surveys presented in Chapters I and II comprised this list of professional skills. This list of professional skills will be referred to as the Control List throughout the remainder of the study. The professional skills were:

- Collaboration
- Communication
- Ethical Considerations
- Inclusivity
- Leadership
- Professional Judgment
- Task Management
- Teamwork

Participants

The participants of this study were selected from the pool of survey respondents who consented to participating in an interview as part of the survey in Chapter I. At the conclusion of the survey, respondents were asked to enter their email address to be entered in a drawing for a gift card. They were also asked to indicate "yes" or "no" if the researchers could contact them about participating in an interview about the subject matter of the survey. The "yes" responses were narrowed down to only include email addresses from an official university account. This decision was made to protect the integrity of the study by ensuring interviews were only conducted with current undergraduate engineering students. From this reduced pool of potential participants, stratified sampling was utilized to select students at random that represented a variety of engineering majors. The selected students were then emailed and invited to participate in an interview. If they agreed to be a part of the study, they signed up for an interview timeslot and were sent the consent documentation.

Participant Exclusion Criteria

The author of this dissertation is currently a member of the mechanical engineering faculty at Mississippi State University. In recruiting interview participants, interviewer bias was reduced by excluding students with whom the author has an established relationship.

As discussed previously, the pool of potential interview participants was narrowed down to only include those who provided an email address from an official university account.

Instrument

Interviews each with a semi-structured and structured portion were utilized to explore engineering student experience with professional skills development as well as operational definitions of good and bad for the various skills. Prepared questions are provided in Appendix F. Due to the nature of semi-structured interviews, there was the opportunity for participants to elaborate on areas of interest, which in some interviews prompted additional questions from the researcher.

Procedure

Interviews lasted between thirty minutes and one hour. They were held via virtual meetings, and audio was recorded for aid in data analysis. Practice interviews were conducted prior to administering interviews to study participants to test the interview questions and overall design.

Before the interview began, participants were presented with research documentation which included IRB approval and an overview of the study and its goals. In addition, methods for protecting participants' identities were discussed. Nine interviews were conducted, and all participants received an Amazon gift card as compensation for their time in completing the interview.

Analysis

Transcription Preparation and Coding

Audio was transcribed using Otter.ai. Comparison to recorded files ensured transcription was completed properly. Participant identities were stripped from data before it was uploaded to MAXQDA (VERBI Software, 2020) for coding.

Each specific mention by name of a professional skill or discussion of a professional skill from the Control List was coded. In the Part I discussions, the name of the professional skill was sometimes explicitly stated by the student, but not always. Additionally, sometimes a different term was used to describe a skill from the Control List. Interpretation of when a professional skill was discussed without explicit mention of the name or with a different name was at the discretion of the researchers. To help reduce bias in interpretation of which professional skills were discussed, definitions for each professional skill were gathered from Merriam-Webster (Merriam-Webster, n.d.) and served as a reference during coding. Multi-word professional skills were defined through synthesis of the definitions of the separate words. For full definitions of some skills, definitions of derivatives of the word were defined.

The definitions as provided by Merriam-Webster are:

- Collaboration: to work jointly with others or together especially in an intellectual endeavor

- Communication: a process by which information is exchanged between individuals through a common system of symbols, signs, or behavior

- Ethical considerations (synthesized): continuous and careful thought of moral values and principles of conduct; taking matters of morals and principles of conduct into consideration when formulating an opinion or plan

    - Ethics: a set of moral principles; a theory or system of moral values; the principles of conduct governing an individual or a group

    - Considerations: continuous and careful thought; a matter weighed or taken into account when formulating an opinion or plan

- Inclusivity: the quality or state of being inclusive

    - Inclusive: including everyone; especially allowing and accommodating people who have historically been excluded (as because of their race, gender, sexuality, or ability)

- Leadership: the office or position of a leader; capacity to lead; the act or an instance of leading

    - Leader: a person who leads such as a person who has commanding authority or influence

    - Lead: to direct on a course or in a direction; to direct the operations, activity, or performance of

    - Leading: exercising leadership; providing direction or guidance

- Professional Judgment (synthesized): the process of conforming to the technical or ethical standards of a profession by discerning and comparing

    - Professional: characterized by or conforming to the technical or ethical standards of a profession

    - Judgment: the process or forming an opinion or evaluation by discerning and comparing

- Task Management (synthesized): judicious use of means to finish a piece of work within a certain time

    - Task: a usually assigned piece of work often to be finished within a certain time

    - Management: judicious use of means to accomplish an end

- Teamwork: work done by several associates with each doing a part but all subordinating personal prominence to the efficiency of the whole

Transcripts were coded based on the adjectives good/bad, helpful/unhelpful, important/unimportant. Discussion of applied experience was coded, and where relevant, the specific environment of the applied experience was coded. Only environments from which participants discussed experiences were coded. The environments coded are shown in Table 3.1

Table 3.1 Environments Coded in Transcripts

Category	Environment
Work Experience	Co-op
	Internship
	Undergraduate Research
	Full-time Work (non-engineering)
	Part-time Work (engineering)
	Part-time Work (non-engineering)
	Teaching Assistant
Upbringing	Upbringing
Student Organizations	Student Organization (engineering)
	Student Organization (non-engineering)
Course	Course-related (engineering)
	Course-related (non-engineering)

Codes for Part I were evaluated to see which professional skills from the Control List the participants discussed throughout their responses. The percentages were then calculated for how much of material coded for the professional skills each professional skill represented. It was hypothesized that this percentage is positively correlated to the students' mean rating for importance from the survey data in Chapters I and II. Using MAXQDA's code coverage feature and looking at only portions of Part I that were coded for professional skills, the percentage was found that represents how often each particular professional skill was discussed when only considering discussions about the professional skills.

In the analysis, the development and perception of each professional skill was compared amongst students. Discussion of applied experience was the main sources of information for development analysis. In discussing the development of each professional skill, coded segments from both Part I and Part II were utilized. Even though the main goal of Part II was to get each participant's operational definition of each professional skill, in numerous cases participants gave operational definitions through telling the story of their applied experience. Discussion is provided for each professional skill broken down by experience. Only professional skills and experiences with intersecting codes were discussed in the results section of this work.

Perception analysis was completed separately for Parts I and II. The unaffected perception of professional skills was the focus, so only coded segments from Part I were used in analysis. These segments do not include any discussion of professional skills as specifically prompted by the researcher. Part of the perception analysis was investigating which professional skills students perceived as the most important, relevant, and practiced. It was assumed that bringing up a professional skill in discussion implied value to the student.

The second part of perception analysis looked at the operational definitions provided in Part II along with the descriptions of good and bad exhibition of each professional skill.

Additional themes were analyzed for when discussion involved overlapping professional skills. These themes included additional classroom discussion, receiving feedback, experiences with group work, and other general observations of interest.

Results

Overview of Interview Participants

Nine interviews were conducted. What follows are brief introductions to the interview participants.

Adam

Adam is a male senior mechanical engineering student. He completed a co-op rotation with a company, has completed an internship, and has worked as a teaching assistant for a faculty member. Additionally, Adam has held a leadership position on an engineering student competition team.

Ben

Ben is a male junior mechanical engineering student. He is a non-traditional student and has full-time work experience at an engineering consulting firm in a non-engineering role for the past nine years. It is a technical role that has interactions with engineers of various disciplines.

Carson

Carson is a non-binary junior chemical engineering student. They have engineering on-campus work experience and non-engineering undergraduate research experience. They are also involved in multiple engineering and non-engineering extracurricular activities.

David

David is a male senior aerospace engineering student. He has undergraduate research experience as well as student government and alumni-relations experience.

Emily

Emily is a female senior biomedical engineering student. She has completed an internship and has worked as an undergraduate researcher. She also has experience serving in a college recruitment organization and in student government. She is involved in an MBA prep program which involves taking business courses and is part of her university's honors college. Additionally, she is a member of a sorority.

Frances

Frances is a female senior chemical engineering major. She has extensive engineering extracurricular experience with multiple instances of leadership experience. She has participated in undergraduate research at her university and has participated in a summer research program at another university.

Grace

Grace is a female senior chemical engineering major. She has completed a co-op rotation and internship. She also has undergraduate research experience.

Henry

Henry is a male freshman mechanical engineering student. He has non-engineering part-time work experience and non-engineering extracurricular involvement.

Isabelle

Isabelle is a female junior computer engineering student. She has co-op experience as well as both engineering and non-engineering extracurricular experience, including a leadership role. She also has part-time work experience in a non-engineering role. She has been involved in a college recruitment organization.

Work and Involvement Summary

The work and involvement of the participants are summarized in Table 3.2. Leadership experience is indicated where appropriate.

Table 3.2 Summary of Work and Involvement Experiences of Interview Participants

Experience	Adam	Ben	Carson	David	Emily	Frances	Grace	Henry	Isabelle
Co-op	X						X		X
Internship	X				X		X		
Undergraduate Research			X	X	X	X	X		
Full-time Work (non-engineering)		X*							
Part-time Work (engineering)									X
Part-time (non- engineering)								X	
Teaching Assistant/Facilitator	X								X
Student Organization (engineering)	X*		X		X*	X*			X*
Student Organization (non-engineering)			X	X	X			X	X

* indicates leadership experience

Frequencies of Discussions of Professional Skills in the Semi-Structured Portion

In the semi-structured portion of the interview, participants were asked to share their experiences in developing professional skills. As no list of professional skills was provided for participants to refer to, any discussion of a particular professional skill implied that it held some level of importance to the participant. Table 3.3 shows the results of the MAXQDA Code Coverage analysis for the professional skills codes. If a student did not discuss a particular professional skill, no value is shown.

Table 3.3 Percentage of Coded Text Only Considering Professional Skills Codes in Part I

	Adam	Ben	Carson	David	Emily	Frances	Grace	Henry	Isabelle	Total
Collaboration	7%	11%	5%	27%	33%	23%	4%	21%	23%	17%
Communication	48%	58%	26%	53%	21%	39%	68%	53%	48%	45%
Ethical Considerations	7%			7%		7%				2%
Inclusivity		5%		10%	6%	7%	3%			4%
Leadership	3%	24%		23%		16%		35%	10%	11%
Professional Judgment	42%	29%	16%		31%	27%	30%	14%	15%	22%
Task Management	13%	3%	20%		4%		18%		8%	8%
Teamwork	62%	19%	63%	48%	44%	43%	14%	54%	31%	40%

Note. The percentages will total to a number greater than 100% if the codes overlap at one or more point. Zero values are left blank.

In the semi-structured portion, no participant discussed all eight professional skills, but Adam, Ben, and Frances discussed seven of the eight. Every student discussed collaboration, communication, and teamwork. These three skills were in the top subset for mean importance rating for Students, Faculty, and Practicing Engineers (data presented in Chapter II). Thus, the results seen in the interviews align with those seen from the surveys. This agreeance helps to affirm that the sample represented in the survey results is representative of the population and validate the results of the analysis. Because of this, the results are appropriate to inform decisions about changes to professional skills education for engineering students.

It is unsurprising that communication had the highest total percentage for code coverage (45%). Survey results showed that Students value communication. Code relations show that in Part I across the nine interviews, communication was discussed simultaneously with every skill. The discrepancy with communication lies in what the students perceive to be good communication. The analysis of the perceptions of communication will explore this discrepancy.

Another professional skill discussed frequently was teamwork (40%). It should be considered, however, that many of the applied experiences that students have had in their professional skills has occurred in a team, whether that be in their courses, on the job, or in student organizations. In talking about their applied experiences, they by default commonly discussed teamwork. This high percentage may say more about the environments where students are developing professional skills than it provides an idea of how much a student values teamwork.

Development of Collaboration

Non-engineering Student Organization Involvement

David described how important collaboration has been in his involvement in different organizations. Across these different organizations, David has had to move and amend legislation, set up a camp for 1700 incoming freshmen students, and network with alumni. In these experiences, multiple parties worked together to produce the final product, with collaborative feedback occurring throughout the process. The collaboration is in contrast to David's experience in group projects. He shared how the work is typically divided amongst the group members, and the tasks are completed in isolation.

Engineering Student Organization Involvement

Adam has been involved with the Formula Society of Automotive Engineers (SAE) team for multiple years and discussed how he has gotten practice with collaboration. The Formula SAE team is divided into multiple sub-teams, with each sub-team responsible for a different area of the car. In order to have a functional car, the sub-teams must collaborate and work together to ensure their respective designs will work will with those of the other sub-teams. Adam's description of collaboration on the Formula SAE aligns with the Merriam-Webster definition of collaboration. The sub-teams must work together and not in isolation for team to be successful.

Undergraduate Research Work Experience

Emily works with her research professor, other professors, graduate students, and undergraduate students across multiple engineering disciplines. As part of this research experience, Emily has been able to network with professionals at her home university and at other institutions.

Other Work Experience

Ben has nine years of experience working at an engineering consulting firm (in a non-engineering position). He described how in projects at his job he has to collaborate with others, for instance with Professional Engineers (PEs) who approve the designs.

Working alongside other staff members at a restaurant has given Henry the opportunity to practice collaboration. The restaurant staff consists of people with various roles that are all important for the restaurant to run effectively.

Engineering Courses

When it comes to classes, Emily has had a good experience with her senior design project and team. The team is working with a doctor who gives good feedback on the team's device design. The team values this doctor's expertise in the area. The team is also working with a professor for 3D printing needs for the project. Emily shared that both of these individuals have been a great help for the project and have provided good mentorship. There has been good collaboration throughout the project as all team members work together and bring in expertise from outside sources.

Perceptions of Collaboration – Part I

To Isabelle, collaboration happens when everyone leans into their own strengths to cover the needs of a project. They are focused on the group success instead of individual success. Frances agrees with this idea. Collaboration helps to lighten the load of the team overall.

Henry and Emily agree that collaboration involves people working together throughout the process instead of being isolated. David shared how in group class assignments, it is common for students to divide the project evenly, piecing together everything at the end. This observation is in contrast to his experience in student organizations where people are working together and communicating throughout the process.

Two other important components of collaboration to David are accountability and open-mindedness. Ben touched on accountability and open-mindedness in collaboration when he discussed how people have to be prepared for handling situations with difficult individuals. He believes students are introduced to how to handle those situations in school.

Ben also discussed the benefit of personality styles assessment when it comes to collaboration, saying, “If I can identify their style…I kind of cater my approach to them.”

Based on student discussion, effective collaboration is focused on the individual members of a team working closely throughout a project. Frequent updates and feedback keep the focus on the success of the overall project and not the individual.

Perceptions of Collaboration – Part II

Each student was asked to define collaboration.

- Adam: “Collaboration is really important…being able to identify the strengths and weaknesses of other people and then work with those people to use those effectively. That is really, really important.”

- Ben: “First, having that open channel of communication is questions, making sure that everybody who’s involved is comfortable with asking any back and forth questions or everybody’s comfortable with that open channel of communication.”

- Carson: “[An] extended project that may have more parts, various things for people to do. Collaboration would be more of an individual task that needs multiple people to work together to get it done.”

- David: “It’s similar to teamwork in the sense that when you collaborate you have to work with other people…collaboration, like teamwork, is goal oriented, but in collaboration, definitely not everyone is working on the same thing at the exact same time, because when you collaborate, I would say you leverage peoples’ expertise.”

- Emily: “Collaboration, I guess within a team would be working with other teams or with another person bringing someone into your team, maybe just to kind of help for things…but collaboration doesn’t mean someone else does all the work for you. You just kind of bring them in to kind of help.”

- Frances: “In my head, collaboration and teamwork go hand-in-hand. I feel like [they’re] more like synonyms of one another than actually distinct.”

- Grace: “To me, collaboration is how do you integrate the skills of different people to produce a product or an end goal? Teamwork can be a lot of separate ideas coming together. Separate deliverables that you combine.

- Henry: “So obviously, collaboration is kind of similar to teamwork, where you’re working with a team to achieve a common goal…you have…different teams that are all working on different things to achieve this one thing. And I think that part is collaboration, where like the individual teams are like teamwork, but it’s all kind of hand-in-hand.”

- Isabelle: “Collaboration, like, I guess it’s more focused on the aspect of everyone has a strength and everyone has a weakness. Let’s band together and kind of like, even up those stats, you know?”

All of the students understand that collaboration means working with a group of people. It is goal oriented and plays to the strengths of the people involved.

Students were then asked to provide good and bad definitions of collaboration. Responses were analyzed for words and phrases that represented a greater theme. Tables 3.4 and 3.5 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.4 Themes of Good Definitions of Collaboration

Equal input; fair share David, Isabelle	**Maximizing strengths; Leveraging expertise** Adam, Ben, Carson, David, Emily, Frances, Grace, Henry, Isabelle	**Communication** Ben, Carson, Henry
Respectful of others; conflict resolution Adam, Carson, Grace	**Working together** Carson	

Table 3.5 Themes of Bad Definitions of Collaboration

Unclear when explaining; poor communication Ben, Isabelle	**Not contributing** David, Emily, Frances, Henry	**Toxic superiority; taking over** Adam, Frances, Grace
Not holding people accountable David	**Not working together** Carson	

Every student said that good collaboration means maximizing the strengths of the people on the team. Other popular themes were communication and being respectful of others. The general definition of collaboration then, based on these students' responses, is maximizing efficiency of the team by assigning tasks to the person with the most expertise in the area. Many students tie collaboration and teamwork together. After analyzing teamwork, a conclusion will be made if they are distinctly different or not.

The dictionary definition of collaboration was, “to work jointly with others or together especially in an intellectual endeavor.” The perceptions of the students do align with this definition, with their overall definition being more applied in nature. The student definition for collaboration includes actionable items, which can be beneficial when it comes to teaching this professional skill. Actionable items can be more easily taught and assessed than non-actionable items.

Recommendations for Improving Collaboration Education in Engineering

A major discussion of collaboration was how it maximizes strengths. Exercises that help students identify their strengths would be good practice in building a foundation of collaboration skills. More involved work could include a project designed like that discussed by Stanford et. al. The project was designed where groups worked on separate portions of a greater project (Stanford et. al., 2013). Collaboration is required because no one group can achieve the final goal without the others.

Development of Communication

Non-engineering Student Organization Involvement

A large part of effective communication is being able to share ideas with people that both do and do not share in your experience and expertise. It is not enough to be good at one or the other. David, Emily, Henry, and Isabelle shared how their experiences in their non-engineering student organizations helped develop this skill. David has been a part of multiple non-engineering student organizations all with a different purpose including student government, a new student camp, and an alumni relations group. He specifically discussed the skillset of being able to shift your approach in communicating depending on both the group you are working with and the goal of the group. He spoke very positively about these experiences and the successes that have come out of them. Emily has also been involved in multiple non-engineering student organizations. She discussed how even though she does not interact with engineers all of the time in these spaces, the communication skills she develops are still relevant when applied in an engineering setting. Henry is a member of his university's marching band. In that organization, communication is helpful when learning drill and making sure everyone is in the right place on the field. Isabelle works as a supplemental instruction leader, and in this role she leads study sessions for students in a course. She discussed that not only does she have to explain material in a way that the students can understand, but she also works to reach the freshmen students who, in addition to taking challenging courses, are trying to adjust to college life. All four students saw value in their non-engineering student organization involvement and how it has helped to develop their communication skills. In non-student organization, effective communication lends to better teamwork and collaboration as all parties can find a common ground.

Engineering Student Organization Involvement

Adam, Frances, Emily, and Isabelle shared about developing communication through their involvement in engineering student organizations. Adam has served as the lead chassis designer for the Formula SAE team for two years. He discussed how the role has involved communicating with the other students on the team and also with sponsors. He said that includes activities like writing a well-composed email and teaching another team member how to machine something, how to design something, and even how to effectively communicate with others on the team. Through this experience, Adam has developed his communication skills in working with multiple groups that are motivated by different outcomes and by teaching others new skills. As president of the American Institute of Chemical Engineers (AICE) chapter at her university, Frances has gained valuable experience in communicating with different groups of people. She shared how she communicates with students at other chapters, professors, and industry professionals when working to plan events. She has learned a lot about corresponding with others through this experience. Emily and Isabelle are both part of a student recruitment group for their engineering college. They both shared how when giving tours they have to explain things in a way that both the prospective students and their parents can understand, even if neither has any background in engineering. The experiences of students in engineering student organizations when it comes to communication is mixed. Depending on the organization, they may interact with non-engineers. Many times the students interact with other engineers, and in those cases the effective communication most often includes helping all parties be on the same page and oriented toward the goal. Sometimes it includes teaching technical skills to others. In engineering student organizations, common ground is more naturally established due to both shared interests and experience, thus effective communication lends to better task management as all parties can understand plans and deadlines.

Co-op/Internship Work Experience

Isabelle’s work experience includes a co-op rotation. Communication was the most frequently utilized professional skill as Isabelle had to work with both internal coworkers and engineers from a branch in another state.

On the job, Adam had to communicate with coworkers in other departments, which required a different approach in communication compared to presenting themselves to supervisors, especially “when they did not have any experience with the issue that I was describing.” His internship was at a smaller company, which led to more freedom in project decisions without the bureaucracy that is not unusual in larger companies. Adam got practice writing memos and other such documents to explain decisions.

Grace’s first work experience was at an internship working for a contractor that worked under the Department of Energy (DOE). Grace was a part of the team tasked with cleaning up a cesium 127 spill in a building. Record keeping was very important in that job because of the government regulations involved with the process.

Undergraduate Research Work Experience

Carson shared how important communication has been in their work environments. They have experience in a research lab and in a position where they worked with laser cutters and 3D printers. In both experiences, Carson was working alongside other students who all reported to a supervising faculty member. The day-to-day activities was usually just the students, and they had to develop plans of action for tasks that needed to be completed as well as timelines. They coordinated who would manage certain tasks.

Through her experience in undergraduate research, Grace has gotten to practice her communication skills through poster and technical presentations.

Other Work Experience

On-campus, Adam works as a teaching assistant for a professor. He shared how in this role he communicates with the professor to discuss course needs and grading criteria, and with a different approach he communicates with students to help them with course material.

Henry attributes his work experience in the restaurant industry to the development of his communication skills. Effective communication with the other restaurant staff is crucial to things running smoothly.

On the job, Ben practices a lot of cross-disciplinary communication. He has had to communicate with electrical and civil engineering teams to help projects run smoothly.

Engineering Courses

Ben mentioned an informal classroom experience that had an impact on him. The professor told the class to be conscientious about using filler words such as “um” when speaking. Upon self-reflection, Ben realized he is guilty of saying “um” frequently. He has been working on improving his communication when it comes to reducing filler words.

A skill that Emily thinks will translate over well to the medical field from engineering training is communicating with groups of people that have different knowledge and experience. Through their technical writing course, Emily learned how engineering terms need to be explained in layman terms, which is similar to how medical terms need to be explained.

Perceptions of Communication – Part I

In Part I, communication was discussed frequently. Of the material coded for a professional skill, 45% of the total coded material was for communication. All students discussed communication multiple times throughout their responses.

In discussing communication, David gave examples of how part of communicating is being able to get ideas across to groups of people with different experiences and backgrounds. It includes “presenting and summarizing” information so that others can understand the work you do or the work you would like someone else to do. Good documentation skills are another part of effective communication. Clear, thorough documentation is a great resource for someone who needs to review work another person (or even themselves) has completed previously. When it comes to his development of documentation skills specifically, David attributes this development to his experiences at the university. Overall, David described communication as a "two-way street," requiring at least two parties who take turns actively listening and speaking, allowing for live feedback. He gave the consideration that when communicating, the parties have to be using the same level of language. All parties should be familiar with the topic of conversation and the vocabulary used.

Similarly, Emily talked about how communication involves being able to speak with people on different levels as yourself, even if it may be hard to do sometimes.

> …like with [student recruitment group], we'll do tours. And we'll be talking to high school students about the classes we take and it seems so intimidating to them and be like, Oh, no, it's not that bad. Like getting into it there. It's a bunch of big words but like, it really is like in this class, all you're doing is just like learning equations and how water flows. Like it's not that scary. And so like trying to explain things to them, that's a little bit harder.

Emily went on to emphasize the importance of communicating effectively with people on the same level. She said that effective communication is, "such a vital part of getting anything done." Grace agrees that good communication is important for completing work. She shared what can go wrong when good communication is not present and how it hinders progress.

> In terms of specifically engineering students, the need for precise and explicit communication skills are what make certain it, it's what allows timelines to be met appropriately and for proper coordination, especially if you're working in plant sites where there's a lot of red tape to get through…You're either going to get lost in the red tape or miscommunicate so bad that it causes other people to have to make up in the long run.

Ben and Grace agree that communication can be enhanced by useful and productive questions. Ben spoke multiple times about how good communication means encouraging discussion and open-ended questions. To Ben, good communication leads to good collaboration. Having been in a full-time technical position for nine years, Ben has worked in multiple team scenarios and frequently communicates with coworkers (both domestic and international) and clients.

> … communication…asking good questions. As an engineer, I think that it's important to look for. Uh. I don't know how to word this, so you don't want to go into any conversation really with the mindset that you had the answers for everything. You need to encourage open thought and, uh, I guess consultation with your peers and subordinates and superiors by asking those types of questions. You need to have group discussions and encourage other people's thoughts on topics and I think by realizing the importance of asking those kinds of questions as is, is where that would apply."

Based on the experiences of the interview participants, effective communication is precise and clear, and it encourages feedback from others involved in a project or scenario. Effective communication is key to successful outcomes and makes working with others easier. It involves being able to work with people from varying backgrounds and express plans, topics, etc. in a manner that everyone involved can understand.

Perceptions of Communication – Part II

Each student was asked to define communication.

- Adam: "Biggest overall skills you can have as well as the like judgment just because communication is much more power when you have to communicate over e-mail when you can't hear somebody's, like, underlying like tones in their voice. It also is really beneficial when maybe you have a deadline, you're coming up on fast and the other person has been, has not done what they need to do, so being able to communicate that, hey, I expect this out of you. What can I do to help you? That makes a huge, huge difference in the outcome of the situation."

- Ben: “So yeah, just making sure that all necessary members or you know, project team members are in the loop. No items are left out in the open, there's no open-ended questions that aren't closed. And, just making sure that everybody is up to speed with where things are…And that that, that goes, that goes, that's bi-directional, right, there's not, I mentioned earlier stuff not being centralized. Uh. And decentralize in that communication so that you're completely sure that nobody else, not just you on your project team or in your cohort, have questions and then they should feel comfortable… this is an environment that everybody could get any questions that they have out there.”

- Carson: “communication is being able to talk or message between people working together in order to establish what needs to be done if there's a problem, be able to discuss it, explain that there is a problem and hopefully find a way to solve the problem… And any sort of talking between people as far as making sure that things are understood and sharing knowledge I guess.”

- David: “Communication, being able to communication is a two-way street. You need a receiver and you need someone who sends the information. I cannot think about the word opposite for receiver. But you need a receiver and someone who sends the information and in communication I would say is actively listening and actively getting the information and also in communication, it's important to have live feedback. It's not just I talk, and I talk, and you listen, you listen. We alternate, you're the receiver and then I'm the receiver. You told me all about it and then I can stop you halfway through and be like, yes, that's a fantastic idea. And then I know about this other guy, that or I know about this other guy, all that it's doing the same thing. So we should bring on board. So it's interactive process. Communication is definitely an active process. Not a passive process and an all important thing about communication is that the language has to be the same, so if you're speaking in simple terms, keep it in simple terms… So an active process in which you have a receiver and you have someone that gives the information, but there's live feedback and it's important to have the same language level.”

- Emily: “So communication for me, is talking not only with people on the same level as me, but people above me and below me. And with my experiences, I have learned how to talk about a lot of things with people on my level…But when it comes to communicating with others on the same level as me, that goes to like just talking about projects, being open with things, being honest. I feel like that’s a big part of communication and keeping to your word. Because communication is such a vital part of getting anything done, a lot of work in engineering or most other occupations. So communication with others on the same level as you is very important to get work done.”

- Frances: “The ability to get across your ideas and points.”

- Grace: "I would say communication is relaying relevant information to the appropriate parties, and appropriate parties being the people who are impacted by that information and the people who can act appropriately to that information."

- Henry: "It's how you express yourself to other people, like express your ideas and all that."

- Isabelle: "Essentially keeping everyone who needs to be in the loop and making sure you're consistent, and you cover all your bases when it comes to telling people certain things, because I know if you don't cover, like, if you don't CC, like, certain people in an email, that could come back to you , and like it would suck, especially, on like, a business aspect or whatever. Just because not only is communication for other people, but it's for yourself."

Students were then asked to provide good and bad definitions of communication. Responses were analyzed for words and phrases that represented a greater theme. Tables 3.6 and 3.7 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.6 Themes of Good Definitions of Communication

Gives all relevant details Adam, Grace	**Bi-directional; active participation from all participants** Ben, Carson, David	**Asking good questions** Ben
Conflict resolution; open; honest Carson, Emily	**Clear expectations; easy to understand** Carson, David, Emily, Frances, Henry	**Efficient; precise** Grace, Henry
Involving all relevant parties Isabelle		

Table 3.7 Themes of Bad Definitions of Communication

Short; not thorough; not responding Adam, Carson, Emily	**Spam; information overload** Ben	**Closed loop; leaving people out** Ben, Carson, Isabelle
Hard to understand; not specific Carson, Frances, Grace, Henry	**Not bi-directional** David	

The definitions of good and bad communication cover a lot of different areas. Communication is a broad skill with a lot of interworking facets. At the center is being able to set clear expectations and being easy to understand. The other themes of good communication seem to be secondary methods to strengthen the main goal of communication. Students also shared how good communication incudes a back-and-forth between parties and not a one-sided lecture.

The most frequent theme for bad communication was being hard to understand or not specific, which is the opposite of the most important theme of good communication. Thus, focusing on clarity is the top priority in communication.

A proposed framework for communication is shown in Figure 3.1. In the framework, the main goal of communication is shown as having clear expectations and being easy to understand. Branching off from the main goal are six enhancements to education. The framework could be validated through future work.

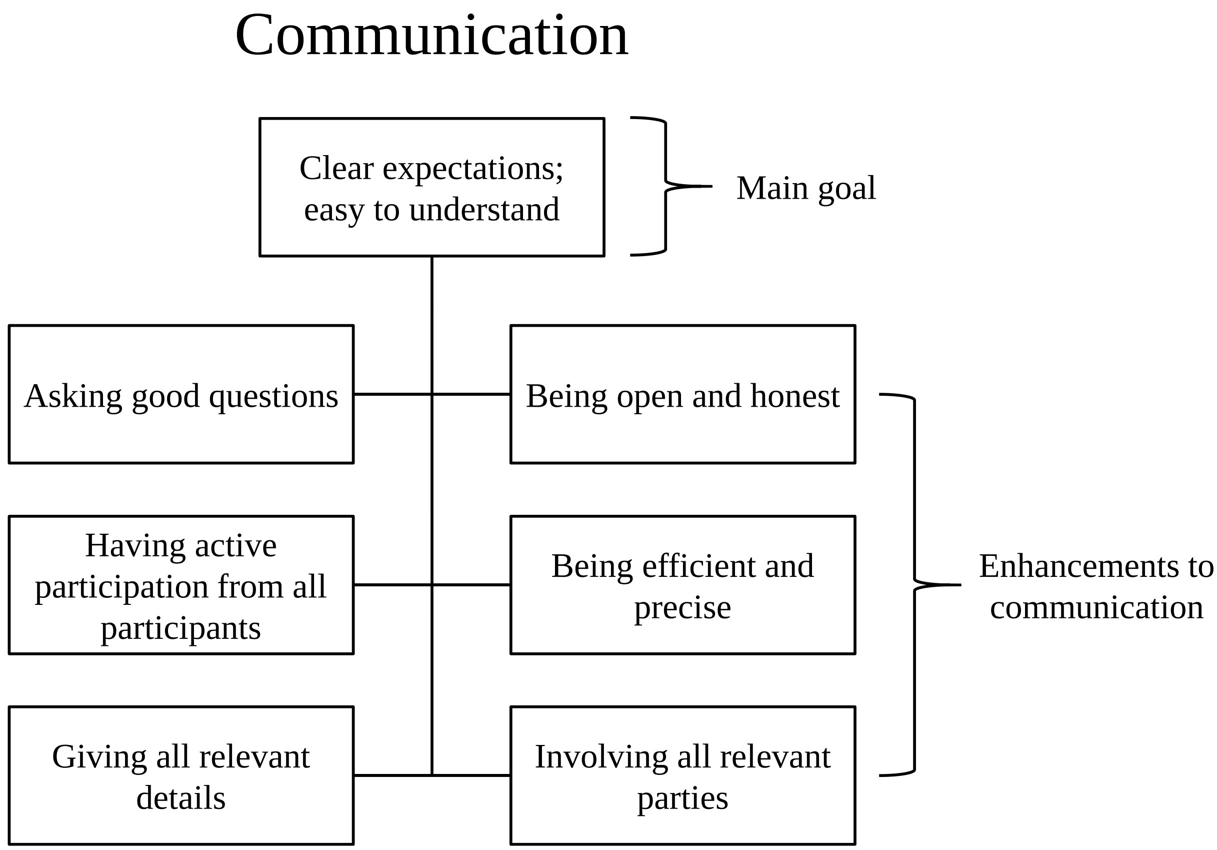

Figure 3.1 Proposed Framework for Communication

Recommendations for Improving Communication Education in Engineering

Framing communication as a multi-tiered skill may help students have a better grasp on this expansive professional skill. The first tier is the goal: be able to express expectations clearly and to be easy to understand. The second tier is then a list of methods that students can utilize to enhance the success of meeting the goal. In the classroom, this could include going over best practices in composing and formatting emails and holding workshops on conflict resolution. As a result of improving their abilities in the methods, students will see improvement in overall clarity when communicating.

Students spoke highly of their communications development that occurred through non-engineering student organizations and how they learned to communicate with different kinds of people. The opportunity to work with students in other colleges, including non-STEM colleges, is a good opportunity for engineering students to improve their ability to communicate with a wide variety of audiences as called for in ABET Student Outcome 3 (Criteria for Accrediting Engineering Programs, 2021), which is, "An ability to communicate effectively with a range of audiences." Engineering educators can encourage students to pursue involvement in non-engineering student organizations, but this involvement cannot be guaranteed. One method to implement that may give some of the same benefits would be inter-disciplinary projects with students from course outside of engineering. In practice, engineers work with both engineers and non-engineers, so simulating that at the university level could be beneficial to all parties.

Development of Ethical Considerations

Co-op/Internship Work Experience

Grace's work at a PVC production chemical site involves practicing ethical considerations ensure that projects are executed safely for the operators, the environment, and anyone else impacted. Grace described the American Institute of Chemical Engineers (AICHE)'s code of ethics and how it provides a set of standards for chemical engineers to follow when making decisions.

Other Work Experience

In his job as a Teaching Assistant for a professor, Adam helps students with assignments and answers questions. He understands the importance of maintaining rigor in the learning process, and so he works with students to help them learn without giving them all of the answers.

Engineering Courses

Grace shared a story where ethical considerations had a big impact. She had a professor whose research expertise is in biofuels. The professor suggested using grass as a biofuel source, suggesting to plant the grass along highways and along airport runways in open areas that did not seem to have a big impact on peoples' day-to-day lives. However, when an ecologist assessed the plan, they shared the potential harm to the environment that this project could pose. The grass might increase the number of animals grazing along the roadways, which could lead to an increase in roadkill and dangers for both drivers and animals. The grass also would invite insects and pests which could have a significant ecological impact. Because this knowledge is outside of the professor's field, these considerations were not made originally. The professor was willing to listen to the ecologist and reevaluate the plan based on the ecologist's input and knowledge. Grace expressed learning about this experience was a good lesson ethical considerations.

Perceptions of Ethical Considerations – Part I

David combines the impact of ethical considerations and inclusivity into a feeling of "being a better human." He is able to consider other people and their background. Frances mentioned the importance of emotional intelligence.

Perceptions of Ethical Considerations – Part II

Each student was asked to define ethical considerations.

- Adam: "I don't think I feel ethical considerations are super important. I mean obviously it depends if you're what industry you're working on, I think, but for the most part, when you're working as far as a group, the ethical considerations are usually limited as you're not working on something that's going to, not usually a weapon or something."

- Ben: “Ethical considerations. Making sure that nothing you're doing is, I'm very careful not to use the word moral cause I guess there's a lot of subjectiveness to that too, right? As a, I'm going to use it, it's just it is subjective. Making sure that you're doing is, morally and professionally, uh, sustainable.”

- Carson: “Ethical considerations. There's a lot of aspects of that, a big one I would say, is environmental considerations. Umm, as well as impact to the workers, for example, it's pretty widely known that Amazon is not a great place to work because of the conditions that the workers are put under, and so ethical consideration would be, you know, making sure that you can minimize negative environmental impacts as well as putting a safe and healthy working environment for anyone to work in, even if that might have negative economic effects.”

- David: “Ethical considerations. I would describe ethical considerations as taking into consideration the right thing to do, and the truth about that is that ethics and values vary from person to person. But from culture to culture as well,…you have to look into what project you're looking at and what kind of people are working on it. Maybe the best way to work with that is, is assign some ethics to the project, or as an engineering disciplines have it, no matter where you're from, there's an ethics, there's ethics and values for aerospace disciplines. There's ethics and values for the chemistry department or chemical engineering. So no matter where you're from or what do you believe in things Considerations you have to look into what project you're looking at and what kind of people are working on it. Maybe the best way to work with that is, is assign some ethics to the project, or as an engineering disciplines have it, no matter where you're from, there's an ethics, there's ethics and values for aerospace disciplines. There's ethics and values for the chemistry department or chemical engineering. So no matter where you're from or what do you believe in [these are] things that are hold everyone together.”

- Emily: “This is a big one and I really wish we were required to take an ethics class in college, because a lot of projects that engineers do, there are some sort of ethical things that you need to consider when building it whether that be defense projects or like with biomedical engineering, you're going to be working with humans, implanting things into humans. And so ethical considerations is taking into account that you're, that people are people and the environment is the environment. And like all of these things have a purpose. And your project needs to recognize that.”

- Frances: “When making a decision knowing what would morally and legally be accepted by society”

- Grace: “This is very important. Ethical consideration is about understanding the impacts of your actions and the actions of wherever you work on the people around you whether it be your coworkers, your boss, the people who live around the area, the work, the area that you work, the people who you live around in your life and it's founded on a respect for all the like the things around you, not only living things, the people but the world around you. Ethical considerations. It's all about recognizing the fact that all of those things deserve respect. And just because you have a goal that you need to get done, doesn't mean you can just do it anyway you want to.”

- Henry: “So that's, I would define that as being able to consider like, if I perform this action, how's it gonna affect other people or the company or something?”

- Isabelle: “Um, I've never really thought about this one. Oh, boy. Think it's about thinking about like the well being of a team, but then also thinking about the well being of the environment, if that makes sense.”

Students were then asked to provide good and bad definitions of ethical considerations. Responses were analyzed for words and phrases that represented a greater theme. Tables 3.8 and 3.9 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.8 Themes of Good Definitions of Ethical Considerations

Considering environmental impact Adam, Carson, Emily, Grace, Isabelle	**Considering impact on people** Adam, Carson, David, Emily, Frances, Grace, Henry, Isabelle	**Balancing all factors** Carson, David, Emily, Frances, Grace, Henry, Isabelle
Following laws, regulations, and standards Carson, Frances, Grace	**Considering safety** David	**Not only considering economics** Adam, Carson
Acknowledging errors in designs/calculations and making corrections Ben		

Table 3.9 Themes of Bad Definitions of Ethical Consideration

Not considering the environment Adam, Carson, Emily, Grace, Isabelle	**Not considering impact on people** Adam, Carson, Emily, Frances, Grace, Henry, Isabelle	**Not balancing all factors** Ben, Carson, David, Emily, Frances, Grace, Henry, Isabelle
Not following laws, regulations, and standards Carson, Frances, Grace	**Valuing profit over people; valuing personal gain over other areas** Adam, Carson, Emily, Frances, Grace	**Not considering safety** Carson, David

There is an agreeance among the students that practicing good ethical considerations includes balancing all factors, including effects on people and the environment. Interestingly, many of the students had a lot to say about ethical considerations. They gave specific examples of various situations and companies that practice what they consider to be either good or bad ethical considerations.

Ben did not have much to say, and his shorter discussion might could be attributed to generational differences between him and the other students. Ethical consideration appears to be a professional skill that may find new meaning and value with upcoming generations. Educators will need to pay attention to this trend and structure their approach to teaching ethical considerations accordingly.

Recommendations for Improving Ethical Considerations Education in Engineering

Because students explained ethical considerations using anecdotes, utilizing case studies in class can be a good method to improve skills with ethical considerations. The subjectivity of ethical considerations makes it one of the harder professional skills to teach. Grace referred to the American Institute for Chemical Engineers (AICE) code of ethics. Other engineering disciplines have their own codes of ethics, and there is an overall engineering code of ethics as well (Code of Ethics, NSPE). Utilizing these codes when reviewing case studies and instructing students to use the code of ethics to justify their reasoning could be an effective method to remove subjectivity.

Development of Inclusivity

Engineering Student Organization Involvement

Frances said her experience as president of the American Institute of Chemical Engineers (AICE) chapter was great for learning how to include everyone's ideas in the planning and execution of events.

Co-op/Internship Work Experience

Grace recalls how her first internship was the first opportunity she had to interact with a lot of different people that were different from her. She said it was an interesting experience.

Engineering Courses

Up until her senior design project, group projects for Emily usually meant being in a group with people she had worked with previously. For the senior design project, she is working with people she has never worked with before. She has enjoyed the experience of coming together despite everyone's differences to work on the project. The inclusivity of the group led to greater collaboration.

Perceptions of Inclusivity – Part I

For Frances, inclusivity includes taking everyone's ideas into account. For Emily, it means being able to accept other peoples' opinions and being able to work with people both above and below you in a hierarchy. People come from different backgrounds, and those differences can be used as a strength of the group. Ben agrees with this idea, sharing the benefit of welcoming conversations that encourage others to share their thoughts freely.

David specifically stated that inclusion is an important professional skill. For him, part of inclusivity is understanding that people may perceive information differently due to their background, and this perception should be considered when working with people.

Perceptions of Inclusivity – Part II

Each student was asked to define inclusivity.

- Adam: "I would say that's pretty important. Everybody has a very different experience. For when it comes to. Really anything in their professional lives? Having somebody who. They're on the team, for instance, we have. Parts of where I'm a structures guy, I don't really understand much about our powertrain side, but maybe I, but there's times where I can look at something and say, hey. This little like tab or bracket you made to attach here. That's not very stiff. That's gonna fail under like high vibratory vibration loads and such. Or maybe they can look at something I've designed said hey, we have this part that needs to go inside of here the engine mainly AMP but if you put two peer or a tab here we can't actively work on the engine or take it out."

- Ben: "We just discussed this recently at work and how we are implementing this into our EDI approach (Equity, Diversion and Inclusion)…a definition would be including all individuals, regardless of race, gender, etc."

- Carson: "Inclusivity. So I think inclusivity is something that has various, it goes in various ways. So one major aspect of inclusivity I would say is definitely, uh, diversity type of inclusivity. So having members from various racial ethnic backgrounds as well as perhaps different gender identities, sexualities, and making sure that everyone feels equally welcome and a member there, but also inclusivity can be more on an individual basis of making sure that no one feels ostracized from the team. For example, if you have a new member on it. If there is, you know a well-established connections between everyone else, inclusivity would be making sure that the new person doesn't feel left out and can become established with the rest of the team."

- David: "Inclusivity. So inclusivity would make it would be making sure that everyone is getting what they need to work period or to work in a project, or to do what they want to do. So everyone has different things going in life. So inclusivity would mean, hey, I might be able to afford this sticker cost of the school, but maybe someone else's not, meant then I might complain about. "Hey, where's my scholarship?" But then [it might be] said it would be that person needs a lot more because thankfully I can afford it. But they cannot. And who knows, maybe that person is gonna be a better engineer that I ever will be. Maybe they'll be my boss one day."

- Emily: “Inclusivity is a big one. And I know people always talk about diversity and things with gender and that is a really big thing but also with people around you like what we were just saying with leadership. Taking into account people below you aren't, like you're not better than anyone, accepting everyone for who they are. And I feel like [University] does do a decent job of that whole, like we have, it's a very [family-like] atmosphere here. Um, I think just going into the workspace with an open mind not assuming judgment on anyone and just listening to what they have to say to get done. I feel like that's a really good one.”

- Frances: “Making sure to incorporate everyone regardless of any ethnicity nationality, color, sexual orientation and gender identity and you're that kind, just taking them for who they are as a person rather than specifications.”

- Grace: “Inclusivity is all about ensuring that different people of different backgrounds have input, and real input not just your president in the meeting but an actual chance for impact and input on regular opportunities in the project or in the in the workforce.”

- Henry: “So that's just I guess it's just like being inclusive, like letting other different kinds of people you know, from like, different backgrounds or whatever, like, participate in something that you're working on.”

- Isabelle: “Recognizing that everyone has their strengths and weaknesses, and then also that everyone has like had experiences doing whatever like you won't know because like, they won't tell you unless you know, and just like, being nice to everyone and try not to discriminate, or like don't discriminate, because discriminating sucks. And just be aware of like what you say because especially being like a woman in the engineering field, you get like micro aggressions, and I'm not gonna lie that's, that sets me off. Like I have yelled at people because they said certain things and I'm just like, I don't fly with that.”

Students were then asked to provide good and bad definitions of inclusivity. Responses were analyzed for words and phrases that represented a greater theme. Tables 3.10 and 3.11 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.10 Themes of Good Definitions of Inclusivity

Seeking advice from others Adam, Grace, Isabelle	**Including all individuals regardless of background** Ben, Carson, David, Frances, Grace, Henry, Isabelle	**Educating others about various identities; being receptive to learning about various identities** Carson, Emily, Henry
Selecting people based on merit and not on bias Carson, Emily	**Being welcoming to new people** Carson, Grace	**Practicing equity; meeting peoples' needs** David
Being accepting of others even when they are different from you Emily, Frances, Grace, Isabelle		

Table 3.11 Themes of Bad Definitions of Inclusivity

Not seeking advice from others Adam, Grace, Isabelle	**Selecting people based on bias and not on merit** Carson, Emily	**Now being welcome to new people** Carson, Grace
Not being equitable; not meeting peoples' needs David	**Discriminating based on background** Carson, Frances, Grace, Henry, Isabelle	

Overall, students said that in practicing good inclusivity, students include all individuals regardless of background. Some spoke about generally accepting everyone, and others gave examples of specifics such as gender identity, sexual orientation, and ethnicity. Someone that practices bad inclusivity discriminates against those groups and other differences. Three students mentioned how part of practicing good inclusivity means being open to learning more about people who are different from you.

Interestingly, the four students who said that good inclusivity means being accepting of others even when they are different from you was the four females who were interviewed. Perhaps experience as a female in a male-dominated field has established this belief. Future investigations into this phenomenon would be interesting.

Students spoke highly of inclusivity, and there was not a sense of obligation from the majority of them. Based on their discussions, the students appear to consider good inclusivity as the default behavior for interacting with people.

Recommendations for Improving Inclusivity Education in Engineering

In the education space, inclusivity instruction could include a focus on exposing students to different cultures and people groups. Assignments where students work in groups of people they don't know as well can also be a good tool for teaching inclusivity.

Development of Leadership

Non-engineering Student Organization Involvement

High school leadership experiences in band were very beneficial for Henry. As a freshman member in the band in college with no established leadership position, Henry still practices leadership in assisting fellow band members who were struggling. Henry recognized that not all of the college band members had the same previous marching experience as him and were behind in their skills. Henry took it upon himself to assist these other band members. Isabelle practices leadership when she leads supplemental instruction sessions. She must motivate the group of students to work to understand the material while listening to their needs and adjusting accordingly.

Engineering Student Organization Involvement

With Frances's leadership position came experience in managing large organizations operations and involving the members decisions of the direction of the organization. Of these experiences, Frances said the biggest takeaway was the skills developed while planning and advertising events. She had to be able to pitch ideas in a short amount of time while attempting to induce interest. Isabelle has served as president of her university's chapter of Institute of Electrical and Electronics Engineers (IEEE). This role has involved managing people and coordinating events.

Other Work Experience

Ben has benefitted from leadership experience on the job. Early in his time at the company, Ben described being "thrust into a lead design position." He worked with groups in multiple disciplines such as structural, electrical, and civil and across multiple consulting firms to complete the project. The project was to design and build a 160 mile, 36 inch transmission line. After the design phase, the proposal was sent to the client, and after approval it went to the contractor. While the build is happening, Ben's team had to cross-reference the designs with how things were actually built and update drawings and models accordingly. When it came to the actual build, Ben shared that there were little to no updates needed to the drawings and models, which means the original designs were clear and feasible for being built as designed. Ben saw this as a great success and thinks highly of their leadership experience in that project.

In high school, experience working as a lifeguard showed Isabelle what examples of bad leadership looked like. She was put into a management position at 16 years old. She described her bosses as bad managers.

Perceptions of Leadership – Part I

Ben discussed how effective leadership requires the good delegation and using delegation opportunities to mentor others and help them grow. Leadership also includes having difficult conversations in order to resolve conflict. Henry spoke on how good leaders help others improve. As Isabelle said, leaders help bring people together.

Leading has two parts: taking action and listening to others. According to David, effective leaders can take in and process information to make decisions. Frances also discussed how leading involves listening to others.

Perceptions of Leadership – Part II

Each student was asked to define leadership.

- Adam: “That's really important. Being able to think not only manage people, but being able to point them in the direction and then know how to use those people to accomplish a similar goal, that is…I would say, one of the most beneficial things somebody can do.”
- Ben: “I think leadership is the ability to direct and get people to achieve what you need them to achieve what you need them to accomplish. I know the word manipulate has bad connotations with it, but in a sense very tactfully and professionally, in a sense, that's what you're trying to do is get someone to achieve something that you need done.”

- Carson: “So leadership is rather than I guess, teamwork and collaboration where everyone is working on the same level, leadership would be having typically one person in particular who is responsible for managing, organizing the work of others. Umm. And also I would say checking in and ensuring that everyone is doing their part and getting things done on time and that there are no issues even if people aren't, you know, reporting that on their own. A team with a leader would be benefited by having a leader that is able to check in and make sure there are no problems that even if people aren't checking in on with their own regard.”

- David: “Leadership would be just a skill of, in a very simple, simple way leading a project or a group of people towards a goal that could be a shared goal, or that could even be the goal of the leader, because the leader you know assembled his own team for his own product or her own product or their own project. Umm, but leadership? Then becomes a matter of. Uh. Kind of brings back all these other skills that we talked about…you have communication, you have leading which is holding people accountable but also holding yourself accountable. And I don't know, it's very difficult word to define.”

- Emily: “Leadership is a big one. Personally, I am more introverted, so it is sometimes harder for me to take that leadership role but leadership is rolling is you're in charge and you're dictating which you need to do get done for everyone else while you also do work. So I guess it's just taking control in a sense.”

- Frances: “The ability to bring out the best in a large group of people and the ability to delegate tasks throughout that group.”

- Grace: “Leadership to me is about enhancing the skills of the people who you are assisting. I think ideally, leadership should be helping. It shouldn't be a credit role. It should be a way that someone who is more experienced can help those beneath them perform better, and providing a way to hold those people accountable for their actions and preventing long term like damage in the case of like bad actions.”

- Henry: “So I define leadership as yeah being, like, taking a role to help teach other people how to how to be a better version of themselves.”

- Isabelle: “Think probably being able to pick up on the small things of like, like people give it like, okay, there's gonna be so many like vibes written down on your notes because I keep saying vibes, but like, it's the trying to pick up on the vibe of everyone and kind of getting all those vibes in sync.”

Students were then asked to provide good and bad definitions of leadership. Responses were analyzed for words and phrases that represented a greater theme. Tables 3.12 and 3.13

(good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.12 Themes of Good Definitions of Leadership

Managing people and tasks effectively Adam, Carson, Emily, Frances, Isabelle	**Teaching; assisting; investing in people's success and growth** Adam, Ben, Carson, David, Grace	**Giving recognition where due** Ben, Grace
Setting a good example Ben, Henry	**Good communication** Carson, David, Frances, Henry	**Good conflict resolution skills** Carson, Henry, Isabelle
Good inclusivity David	**Being involved in the work; not making everyone else complete tasks only** Emily, Grace	

Table 3.13 Themes of Bad Definitions of Leadership

Dictator; controlling Adam, David, Emily	**Unhelpful; ignoring people** Adam, Ben, David, Henry, Isabelle	**Not giving recognition where due** Ben, Grace
Setting a poor example Ben	**Having unrealistic expectations** Carson	**Inequitable task distribution** Carson, Frances
Bad conflict resolution skills Carson	**Bad communication** David, Frances, Henry	**Not holding people accountable** Grace

Based on responses, students expect good leaders to be proficient at a number of other professional skills such as collaboration, communication, inclusivity, task management, and teamwork. Most notably, students value leaders who invest in the success and growth of the people they are leading. Effective task management is also valued. Students discussed that the role of a leader is to guide and assist the team; the leader is not there to control everyone. Emily and Grace value leaders who work alongside those they lead.

Recommendations for Improving Leadership Education in Engineering

As effective leadership is perceived to be the application and demonstration of a combination of professional skills, a first step teaching leadership is to provide methods to improve in the other professional skills. The students also seemed to develop in their leadership skills through working under a bad leader. Looking at case studies of poor leadership may be helpful. Role-playing exercises where students practice both good and bad leadership could lead to productive discussion about what worked well and what did not.

Development of Professional Judgment

Engineering Student Organization Involvement

In his experience on the Formula SAE team, Adam has had to practice professional judgment. Decisions must be made concerning the design of the car, ensuring that all of the deliverables of the various sub-teams work properly together.

Co-op/Internship Work Experience

The small size of the company Adam worked at provided him the opportunity to exercise his professional judgment skills. He described an instance where he was given a brief description of a task from a superior who said, “I’m trusting you to be able to figure it out.”

Other Work Experience

Ben discussed an experience in running a failure analysis for a client. His team was tasked in identifying where and why the design failed. He described the scenario of a piping system with a blow-off valve. Ben shared that the original design would have worked well without issue, but during construction the contractor veered from the plans, installing an elbow in the piping system. Ben’s team was able to analyze and show the forces exhibited on this elbow, which caused the failure in the system. From Ben’s description of the experience, it seems to be a good application of professional judgment.

Henry shared a story from working a restaurant where he practiced professional judgment. After failed attempts at dealing with a difficult customer, Henry and his coworkers stepped away from the situation so that the manager could handle it.

Engineering Courses

Emily plans to attend medical school after completing her biomedical engineering degree. She shared why she chose to stay in a rigorous major before going to medical school. In her opinion, engineering allowed her the opportunity to exercise logic and judgment as opposed to a major such as biology that has a lot of memorization. She felt that the skills learned while in an engineering program would be translatable to work in the medical field. She described a hypothetical scenario of walking into a patient's room where she is provided surface-level information about the patient and their conditions. As a medical provider, she would be tasked with taking in the known information, synthesizing it with previous knowledge, and figuring out what is wrong with the patient based on limited information and test results. Emily went on to discuss how she is experiencing this open-ended way of approaching problems and exercising professional judgment in her engineering classrooms.

Perceptions of Professional Judgment – Part I

Isabelle discussed how planning events involves making decisions to ensure everything goes smoothly.

Being able to exercise good professional judgment makes dealing with regulatory organizations easier according to Grace. She also shared how good professional judgment leads to more effective task management. Engineers practice professional judgment when troubleshooting issues. Similarly to this idea, Emily described the process of utilizing professional judgment when interacting with medical patients. With limited information, doctors have to assess the information at hand to make a judgment call about what is going on with the patient. As someone who plans to attend medical school after finishing her engineering degree, Emily values the translatability of skills she learns in the engineering space to her future experiences in the medical field.

On a different note, part of Ben's perception of professional judgment includes being able to form and ask useful questions. The wording of a question depends on the audience and the purpose of the conversation, and being able to navigate that skill is useful to networking. He went on to share that leaders practice professional judgment when deciding how to delegate tasks and who to delegate them to. Similarly, Adam mentioned the professional judgment involved when reading body language and the sub-text of emails. That interpretation can be key to an effective interaction with someone.

Perceptions of Professional Judgment – Part II

Each student was asked to define professional judgment.

- Adam: "I think professional judgement is something that takes forever to develop. It's really, really, really handy once you have developed the skill. Just because you can usually apply it to not only work or anything you do, but pretty much anything outside of as well."
- Ben: "Identifying and knowing when, I'm almost getting to ethics here, but when you can make a like a change from an approved design."
- Carson: "Professional judgment so, I would say that this is kind of a skill where you would use your technical knowledge about any specific item of concern and determine what's the best way to go about it, whether you know, that's material selection for some sort of process. It would be, I would say using, both your technical knowledge and maybe other things like economic knowledge, ideas of how things should be timed, you know how long is it gonna take for this to get here and determining what's the best course of option to go from there."

- David: "So professional judgment would be, being able to judge, discern, going back to what I was saying at the at the beginning, there's too much noise, too many things, but that doesn't mean that every idea's gonna be right. That doesn't mean that every decision is gonna be right, obviously. So you have to judge all the ideas, you have to judge everything that's coming in and look at what's the possible outcome. It's hard to know what the outcome is going to be most of the time because you know, things might not have been invented. Things might not be done right now, so it's difficult to judge if you don't know exactly what's gonna happen. But professional judgment…the word that I would use a synonym with is discerning, discerning what's going on."

- Emily: "So professional judgment to me is someone above me giving me…feedback or letting me know how I'm doing, whether that be through a grade or through a conversation after I present like, with research…every week, one of us has to present and then my professor will give us feedback on it based on like, Oh, this is what you need to improve in your research or what you can't do, but I feel like that's the biggest part of professional judgment is just someone above you telling you to, I don't know if it's so much as an opinion as it is a fact."

- Frances: "Professional judgments, I would define it as the ability to determine what choice would be more ethical or moral when presented with a certain scenario."

- Grace: "I would say they are always recording explanations for their decision. If they're making a decision that is going to impact anyone else at the plant, there needs to be a clear logic behind it that they can explain. And also if it is a long term decision, they need to be recording it through the proper channels. And that may be that will depend on the company and their methods in place."

- Henry: "So I would say that's like being able to see a situation and know what the best way to approach it is like being able to figure out what the best approach of it is."

- Isabelle: "So professional judgment can also like for me, it means like, either figuring out, something comes up and you need to figure out what to do to solve it kind of be quick on your toes when it comes to like solving those issues."

Students were then asked to provide good and bad definitions of professional judgment. Responses were analyzed for words and phrases that represented a greater theme. Tables 3.14 and 3.15 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.14 Common Themes of Good Definitions of Professional Judgment

Seeking input from others Adam, Ben, David, Isabelle	**Calm mannerism; level-headed** Adam, Frances, Henry	**Considering problems from multiple points of view** Adam, Ben, Carson, David, Grace, Henry
Assessing the best way to handle a situation Ben, Carson, David, Frances, Grace, Henry	**Justifying decisions/actions** Grace	**Adhering to laws and regulations** Ben, Grace
Honesty Emily	**Giving helpful feedback** Emily	**Goal-oriented** David

Table 3.15 Common Themes of Bad Definitions of Professional Judgment

Not seeking input from others David, Isabelle	**Accepting failure; reluctance to act** Ben, Grace, Henry	**Dishonesty; hiding bad results from others** Grace
Selfish; making decisions for personal benefit Frances	**Harsh; unhelpful** Emily	**Not considering the big picture** Carson, David
Single-minded decision making; quick to act Adam, Carson		

When describing good professional judgment, students mentioned seeking input from others and considering problems from multiple points of view in assessing the best way to handle a situation. They shared that people who are good at professional judgment are level-headed.

Emily's description of professional judgment did not align with the other students'. Her discussion focused on giving/receiving feedback. While a relevant topic, she did not appear to have a grasp on an accurate definition of professional judgment. Multiple students may share in this misunderstanding, and engineering educators need to be adamant to offer a clear explanation of what is expected for professional judgment.

Recommendations for Improving Professional Judgment Education in Engineering

Professional judgment is a skill that is learned by doing. Open-ended projects can help students practice professional judgment. Creating a suggested process of steps in evaluating a problem and sharing that with students is something educators could do.

Development of Task Management

Engineering Student Organization Involvement

Through his involvement in Formula SAE, Adam has gotten practice with task management. As a sub-team lead, he has had to coordinate the sub-teams activities and help make sure they do not slow down the progress of the entire team. Isabelle has served as president of IEEE, which involves managing different groups and coordinating events.

Co-op/Internship Work Experience

Through a year-long co-op experience, Grace has gained perspective that can help with task management in the future.

> “a lot of co-ops are structured as a semester on semester off, so about three to four months, and then you're back to school and then you're back [to work]. I'm doing a year straight May to May. That gives me a lot more time to learn the ropes of the job and get like really good at like daily stuff but also like set long term personal goals and project goals, but I have my personal goals of things I want to work on as well. So I would say that has really helped me get a grasp of how to really, what does a year feel like working on something...this will be the longest time I've held a job straight in terms of like without a semester blocking. So that's really valuable to understand what does the year feel like, what's possible in a year. What is reasonable for me to do in a year. And how do you get through shifts in a job space? How do you get through the busy and the slow times without getting lost in the middle of it?”

Perceptions of Task Management – Part I

Carson emphasized the role that being at a university plays in developing task management skills. They shared how it is not like high school, and now there are responsibilities coming from every direction that need organized and addressed. Also unlike high school, there is not as much structure and supervision, so students have more personal responsibility to manage everything. When effective task management occurs, projects run smoother because things are addressed without the added pressure of approaching deadlines. They also shared that in the university setting, it can be difficult to navigate courses when a group member does not have good task management skills.

Grace’s discussion of task management was along the same lines. For Grace, the lessons learned in the classroom regarding task management are translatable to scenarios outside of class. She mentioned the role that setting deadlines and data keeping play in effective task management. Prioritizing information well and understanding the best way to ask for help are good skills associated with task management as well. Ben also mentioned how part of task management is understanding when to ask for help with something.

Isabelle has had a stressful experience at times when it comes to task management. Last minute changes can make holding events difficult. In a leadership role, task management involves handling issues behind the scenes.

Perceptions of Task Management – Part II

Each student was asked to provide their definition of task management.

- Adam: “There’s too many things [to do] as a person throughout 24 hours that if you are not managing this, your every, not every task, but managing most of your tasks, nothing will get done efficiently or effectively.”
- Ben: “I think a good definition for that would be or the way I view it is being able to recognize first off, what’s urgent and what's important. Just because something's urgent doesn't mean it's important. So that kind of goes into prioritizing and if you can do that. If there's, if there's things that you need to delegate being able to know and recognize who you can delegate it to.”

- Carson: “So task management would be I guess organization and distribution of tasks, so understanding what's needed for a task, understanding how much time and effort is needed for tasks, and then whether that's on just one person doing the tasks, deciding what order to do the tasks and what timing to do the tasks for. For task management within a group of people distributing the tasks to different people in a way that. You know they have an equitable amount of things to get done.”

- David: “Task management is able to manage all your tasks obviously, but more so than that is being able to assign the right amount of time and the right amount of power, whether that's brain power, physical power to those tasks.”

- Emily: “Task Management. That's kind of been a struggle for me like entering the college of engineering that was really hard. Because balancing classes, extracurriculars, and then all the chores like doing your laundry and launching it you're like no one's telling you to do anything so that was really hard for me to learn coming in. But it's very necessary to get your stuff done to remain on task would be to have everything organized, get everything done on due dates, showing up on time for things and then just giving it your all and not halfway doing things.”

- Frances: “The ability to juggle multiple tasks and complete them in a time efficient manner.”

- Grace: “I think task management is all about understanding the priorities and the parts of a deliverable. You have to know how to break it down into tasks. You have to understand what those tasks entail and you have to understand what order to do those tasks and whether to whether to move toward the angle or rather just time priorities.”

- Henry: “So, I would define that as being able to understand the tasks that you have too... that you have at hand, and how to, how to divvy them up, and how to order them from level of importance, to least important.”

- Isabelle: “I think every, like anyone can prioritize tasks. But I think being able to shift priority is task management.”

Students were then asked to provide good and bad definitions of task management Responses were analyzed for words and phrases that represented a greater theme. Tables 3.16 and 3.17 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.16 Themes of Good Definitions of Task Management

Characterizing tasks by priority Adam, Carson, Emily, Grace, Henry, Isabelle	**Delegating effectively** Ben, Carson, David, Henry	**Recognizing what is important** Ben, Grace, Henry
Establishing a reasonable timeline Carson, David, Frances, Grace, Henry		

Table 3.17 Themes of Bad Definitions of Task Management

Not characterizing tasks by priority Adam, Carson, Grace, Henry	**Not delegating effectively** Ben, Carson, David, Henry	**Treating every task as high priority** Ben
Missing deadlines; procrastinating Carson, Emily, Frances, Grace, Henry	**Fixated on one task** Isabelle	

The big focus of task management discussions was in prioritizing tasks and establishing a reasonable timeline. Students also mentioned how knowing when to delegate can help alleviate the burden of completing a task. Bad task management has a direct consequence of missing deadlines, which can negatively affect a person's standing in a group or company.

Recommendations for Improving Task Management Education in Engineering

Students are currently practicing task management in their engineering programs, or they are at least attempting it. Part of the perceived issue with task management at the university level is it is not always easy for students to discern which tasks are high priority. Priority is determined by due date, which is an arbitrary metric. Faculty may set unrealistic expectations that cause students to treat every task as high priority. Improving task management education in engineering may require a culture change among faculty.

Development of Teamwork

Undergraduate Research Work Experience

In Carson's experience with undergraduate research, they have been able to work on what they consider to be an effective team. The group of undergraduate workers in the laboratory worked together to coordinate plans and schedules. Overall, Carson was pleased with the working environment. They felt as if all of the students wanted to be involved in the work, thus they were motivated to do well and put in an effort.

Grace described her experiences working on proposals with her research team as good experience with teamwork.

Engineering Courses

Emily speaks highly of the teamwork that occurs with her senior design project. The team members themselves work well together, and they have been working with experts in various areas to help guide their project.

Perceptions of Teamwork – Part I

For Grace, teamwork involves managing the short term deliverables together and interacting with each other throughout that process. Isabelle agrees teamwork is bigger than the individual. Adam discussed how teamwork involves relying on others and using each other's strength and weaknesses to the team's advantage.

Henry was pessimistic at times about others' abilities with teamwork.

> …some people just aren't going to want to participate. And they are not going to want to pitch in, and, you know, work with you. And sometimes you might have to pick up their slack or sometimes you'll have to…kind of give them a nudge to start going. But that's just going to be part of it. And there's nothing really you can do about it except, accept it as it is and move on.

When working in teams, Frances has learned that identifying both personal strengths and weaknesses and the strengths and weaknesses of team members can improve teamwork. Frances has found that teamwork has gotten easier in group projects the further she gets into the curriculum. Ben's experience in an introduction to engineering course aligns with this perception. He had a bad experience with a team that did not want to assume leadership and responsibility. In general, Carson says teamwork has been easier at the university level than in high school because people are likely more dedicated to school. This observation would explain Frances' improved teamwork experiences at higher levels in the curriculum since students who stay longer in an engineering program are typically more dedicated to finishing the degree.

Emily has had both positive and negative experiences in groups, and the presence of lack of teamwork has been a contributing factor to that perception. In the positive scenarios, team members have exhibited other professional skills such as communication and collaboration, and that has helped the group work well together and all strive toward a common goal. David discussed similar issues in group projects, where many times the culprit is the fact that students want to divide up the work for a project and work independently until it is time to combine the sections into one submission. Teamwork includes accountability and patience for David. For Carson, teamwork includes effective communication. It is “important to communicate your expectations, communicate well for everyone to determine a timeline for things to get done, and set deadlines, and then if that’s not being met, to communicate with people.”

Perceptions of Teamwork – Part II

Each student was asked to provide their definition of teamwork.

- Adam: “Teamwork is something you get after you’ve had good communication, good judgment. I think because you have to build up, you have to build the teamwork.”

- Ben: “Teamwork, just actively working towards the same goal, right? Well, we all want to succeed and whatever, whatever goal we’re working towards, be it a deliverable, a classroom assignment, what have you, I think it’s just a collaborative effort to succeed toward a uniform goal would be my definition.”

- Carson: “It definitely involves a lot of communication…communicate and distribute work in a way that makes things get done effectively.”

- David: “Teamwork. That’s a hard one to describe, because to a certain extent, most people have participated in teamwork, if you think about it. Since we’re kids, teamwork, you know, hide and seek. Well, maybe not hard to see, but if you play soccer or if you play the…baseball as a kid or softball, there’s teamwork going over there. But I guess that speaking up on that, I would say that teamwork happens, or is the action of getting people together. So a team and working towards a mutual goal.”

- Emily: “Teamwork is working with others, whether they be on your level or not. And that does involve a lot of communication…someone needs to be in charge of directing everything and then assigning roles to everyone so that everyone is actively involved. I feel like that’s teamwork, to get something done to some sort of purpose.”

- Frances: “The ability to collaborate with others to achieve a goal.”

- Grace: “The ability to produce a deliverable or a long-term project with other individuals, whether they be peers, people above or below in you in the corporate ladder, or with people [through] interdisciplinary work.”

- Henry: “Working to achieve a common goal with a group of people.”
- Isabelle: “Teamwork is being able to collaborate with others, but also being able to, like, understand that, like other people have different strengths than you and you have different strengths than other people.”

These general definitions show an emphasis on communication and collaboration. Additionally, students share that it is important to include all group members, playing to everyone’s strengths. Teamwork is working toward a common goal.

Students were then asked to provide good and bad definitions of teamwork. Responses were analyzed for words and phrases that represented a greater theme. Tables 1.3 and 1.4 (good and bad, respectively) show the themes that came out of the analysis with each student mapped to the theme(s) from their definitions.

Table 3.18 Themes of Good Definitions of Teamwork

Communication Adam, Ben, Carson, David	**Playing to others' strengths** Adam, Frances	**Inclusivity** David, Grace, Isabelle
Reasonable expectations Carson	**Collaboration** Ben, David, Isabelle	**Active contribution from all members; take responsibility** Emily, Grace
Efficiency Henry	**Low conflict; compromise** Frances, Henry	**Supporting each other** Isabelle

Table 3.19 Themes of Bad Definitions of Teamwork

Dictator; taking over Adam, Carson, David, Frances	**Lack of leadership** Ben	**Lack of initiative; not contributing; procrastination** Ben, Carson, David, Frances, Grace, Henry
Lack of communication David, Grace, Henry	**Disagreements; conflict** Emily, Henry	**Insecurities hinder progress** Isabelle

The themes agreed upon the most for good teamwork are communication, inclusivity, and collaboration. It is interesting that these are all professional skills. Thus, teamwork is perhaps not a specific professional skill but more an application of others.

For bad teamwork, a lack of contribution was a popular theme with 75% of students sharing that perception. Taking over a project and a lack of communication were also common responses. The themes of bad teamwork exhibit the lack of the themes present in good teamwork: communication, inclusivity, and collaboration. When bad teamwork occurs, most students agree that people either cut others out of the work or do not contribute. The question then is, when bad teamwork occurs, what is the root cause? The relationship of teamwork ability and intrinsic vs extrinsic motivation is an important relationship.

Recommendations for Improving Teamwork Education in Engineering

As teamwork is the application of the other professional skills, methods to improve other professional skills will have a positive impact on teamwork education. Previously discussed methods should be referred to.

Operational Definitions for the Professional Skills

Based on the definitions and descriptions of good examples of the eight professional skills, operational definitions were created for the professional skills.

- Collaboration: Maximizing efficiency of the team by assigning tasks to the person with the most expertise in the area
- Communication: Easy to understand and setting clear expectations by giving all relevant details, encouraging active participation from all participants, asking good questions, being open and honest, being efficient and precise, and/or involving all relevant parties

- Ethical Considerations: Balancing all factors while considering the effects that decisions have on people, safety, and the environment and not only considering economics
- Inclusivity: Including all individuals regardless of background; being accepting of others even when they are different from you; being receptive to learning about various identities
- Leadership: Managing people and tasks effectively while practicing good communication and investing in the success and growth of the individual team members
- Professional Judgment: Considering problems from multiple points of view to assess the best way to handle a situation while considering the input of others and adhering to relevant laws and regulations
- Task Management: Characterizing tasks by priority and establishing a reasonable timeline
- Teamwork: The application of communication, inclusivity, and collaboration to work as a team towards a common goal

The Conundrum of Professional Skills Education in the Classroom

Multiple participants specifically shared how they believe the bulk of their professional skills education happened outside of the classroom, some even saying they do not believe the classroom has had an impact at all on their professional skills.

In their initial definition of professional skills, Henry discussed how most professional skills development happens outside of the classroom.

> "So I would say those are like skills that you're…not necessarily taught like in the classroom, but like, as you gain from like experience like in other jobs and stuff, and you may learn in the classroom with like, collaborations on projects and talking to teachers and stuff. Like it's not something that they can like, sit down and really teach you, you just gotta experience it."

When Adam was asked to rate the professional skills education in his classes, he shared that out-of-class experiences contribute more to student development.

> “I would say moderate in terms of classes, it's. On the lower end, in terms of extracurriculars, it's on the higher end.”

Frances was not optimistic about being able to get proficient professional skills development in the classroom.

> “I feel like the way my university goes about it, you have to be very involved with your professors and outside organizations and outside the courses in order to fully develop properly.”

Isabelle went so far as to say that the university setting has not done much for developing her professional skills.

> “Honestly, I don't really think I've gotten any of like my professional skills or like anything directly from the university. I feel like a lot of the times I've had a kind of like trial and error it myself I mean, I know there are there are resources out there like at the Career Center and stuff, but I've never really utilized them. Honestly, until like, last semester. I never really used them. But yeah, for me personally trial and error.”

Carson had a more positive outlook on their professional skills experience in the classroom; however, the lessons are indirect and not typically explicitly covered as part of the course. The focus shifted to opportunities for professional skills development provided through on-campus organizations.

> “I would say it's been great. I mean with courses. They definitely have a lot of various options. As far as just what courses will teach you, not necessarily as the focus of the course, but as something that the course also goes over and helps you work on. But then we also have a ton of various workshops and that kind of thing offered as extracurricular like I know that Theta Tau had a professional attire workshop last week. And then I think. I don't remember what organization did it, but there's been like resume workshops and various things around campus as well that aren't particularly part of a course. But they’re something that anyone can go to.”

David discussed how most of his professional skills development has happened outside of the classroom and through his upbringing. David declared that professional skills education in the classroom is not as effective because students are motivated by finishing the course, and thus students do not show initiative in developing their skills past what is required for the grade or course.

> "…I've learned or gained a lot of professional skills through academics and also involvement on campus and off campus, but also my upbringing personally, there's many things that are not taught in the classroom but are taught in life…I would say that most of them have happened or I've picked up these skills outside the classroom. I by all means don't have all the skills necessary to lead a country or, you know, be the next Bill Gates or someone like that. But I feel like I've, being able to recollect a lot of professional skills outside of class that in class there's not much more room for me…a lot of my professional skills have come just from outside, outside class environment. Still on campus though, just…different organizations that I've been through and also the research that I've done for three years you know talked to my PI, my principal advisor, or presenting at our research symposium…I think that some classes do challenge people to come out of their shell and learn some skills, but people will not do it in a class environment because they just know that they just have to go through that class and then that's all, it's over. Whatever skills they thought they were gonna acquire there, they probably don't care, because again, they just need to get through it."

Grace has had experience in all three major undergraduate engineering student work environments: co-op, internship, and undergraduate research. She shared that a commonality among the three is communication, record keeping, and setting deadlines. She has seen these skills translate to the classroom.

These results align with the literature that says students do not have good perceptions of professional skills education in the classroom (Carter, 2011; Kumar and Hsiao, 2007; Pulko and Parikh, 2003; Skipper et al., 2017). The challenge to engineering educators then is to design professional skills instruction that easily demonstrates its inherent value to students. Bringing in outside sources, such as practicing engineers, to work with students may be a good start.

Feedback on Professional Skills Abilities

When considering feedback, instances of positive and helpful feedback experiences involved an individual giving direct, measurable feedback to a participant. Henry discussed how specific discussion of areas of improvement are helpful and desired.

> "I've only really gotten like, compliments on it. I've never had constructive criticism, which I think I would prefer more constructive criticism. Because like, that's how you get better. You don't get better from like, compliments, like they're really good. Like, you know, affirm, I'm doing well but like, I'm gonna get better. I need like, constructive feedback."

Multiple participants discussed feedback while on the job. Emily's experience was at a summer internship.

> "Yeah, so at the end of my summer internship, I did have, I was working with someone in the [health institute] and she like, would make me practice the in my presentation over and over again, and she would tell me what I was doing wrong. And she's like, Oh, that's awkward. Don't say that. Talk slower. All that type of stuff. And that's like, as far as presenting to people, that's probably the most help I've ever gotten was with her."

Adam discussed a similar experience during one of his co-op rotations. Specifically, he benefitted from a mental checklist developed after speaking with supervisors.

> "The one stands out the most is in my third term at [Company]. When I was giving weekly presentation updates. It came from one of my managers, the at the end of presentation, we would stay on for an extra 5 minutes and we had he would actually write down things he saw that did good things that I saw that were not great and things that I need to absolutely change and. They will get feedback to me and just kind of a list order and with a little bit of discussion to hash out so next time as I was prepping for a presentation, making a presentation. And giving the presentation, I would have that kind of checklist in my head about, OK. Did what I said here and how I said it. Is that better communication than what I did last week?"

Grace discussed an evaluation administered by their university's career center to co-op students.

"You know, I think the only time I've been explicitly given I do have evaluations with my co op. And in those evaluations, there are skills like communication, time management, prioritization, and this evaluation is provided by [university]. We have a career center. They sent out this evaluation for employers to fill out, and I've been lucky enough that my direct supervisor, the one who filled it out, she sat me down and she was like, she went through it with me so I can get actual feedback. Um, so that was really nice. It was a verbal exchange. of uh...skills evaluation is ranked one to five it's by being bad and or one being bad five being really, really good. So just going through that with a bunch of different skills on top of STEM specific skills, so experimental design, research. Um, that's, that's one of the only times I've had explicitly discussion about professional skills and what that encapsulates and also the expectations of a good overall worker."

Grace implied that they did not consider the one-on-one meeting with their supervisor concerning this assessment to be the default and were glad to have the opportunity to discuss their progress. The explicit conversation seems to be of high value to Grace.

David works as an undergraduate researcher, and they discussed the benefit of having a Principal Investigator (PI) and graduate students for guidance.

"I usually receive it from my PI, my principal advisor, or in my research group. I'm an undergraduate student, so in a way I look up to the master students and the PhD students. So they always give me a lot of feedback, not only in my projects that I'm working on, but also how to succeed. And again, those steps can be translated not only from academia…to life."

Frances appreciates that their feedback typically comes in one-on-one meetings so that they can focus on communicating with the person giving the feedback and not fear that another person is listening in on the conversation.

"Usually, when I do get feedback, it's usually on our one-on-one meeting. Because a lot of my professors are someone who would give me feedback like that. They're big proponents of what's it called? It's like praise in person, but criticize or give feedback in private is the methodology…normally when I do receive feedback, it's a one-on-one so it's not other people listening to like other negatives about how I performed or anything, which I really appreciate…"

As a non-traditional student, Ben benefits from a more experienced perspective on receiving and seeking out feedback.

> "…there's a development course at my company called [course name] that I'm currently in…it's a way for your peers, subordinates and superiors to…assess you where you are …and I basically sent this this survey out to I think it was like eight of my people that I work with and ask for their feedback and respect with respect to all of these areas on the professional side, what are some areas I could improve them? What do I do good at? And for the most part, my feedback was really good. One of the things…that was brought to my attention that was like a really good hey…they're not wrong about this, was I tend to be a perfectionist. And you know, a lot of times people hear that they're like, oh, that's great. Well, it is a good thing to, to be very attentive to detail. But perfectionists can also…if you're too big of a perfectionist, it can hinder your productivity. You can get really hung up in the weeds. So in regards to receiving that feedback, I do pretty well at receiving it. I mean, you can be as open as you want to with me in in regards to anything my workflow, my, my professional skills and I look for that feedback actively, I seek it. And. Yeah, I'll oftentimes also go to some of our higher ups that have been in the company for a while…and I'll lean on those guys a lot for, how in even going into [a difficult conversation with a direct report]…I kind of did a dry run, if you will, on like a scenario of a mock discussion with him before, before I had that actual discussion."

Ben was able to use a tool provided to him by his company to receive specific feedback about relevant skills. He were able to take constructive criticism well and justify why the criticism was valid. He also shared about his initiative to seek out feedback from supervisors and specifically shared about how a supervisor was able to help him prepare for a difficult situation with a direct report.

Ben shared about an experience working with a difficult coworker. He had a new subordinate that had been abrasive and difficult to work with. This coworker was much older than Ben, and he wonders if the age gap contributed to the hostility. Ben shared how he prepared for this coworker's performance review. Ben wanted to have a productive conversation, so he prepared by asking for advice from his supervisors. The conversation went well, and both parties were able to get insight into how to have a better relationship.

Emily completed a summer internship at a health institution. There were weekly seminars on professional skills development from doctors and CEOs of hospitals. Emily found these seminars to be very helpful in learning about networking, interviews, and general professionalism.

Emily served as an officer in a student recruitment organization and was part of the interview panel for potential incoming members. Being on the interviewer side of the process gave Emily good insight into good and bad things to do in an interview.

Student Experiences with Groupwork

When describing experiences in group projects, Adam alluded to effective collaboration and teamwork making the experiences positive. A lack of communication was evident in a bad experience shared.

Carson did not speak highly of a certain group project experience. The group of four had one member that barely contributed to group efforts. Poor communication created tension between this member and the other members of the group. After a lot of back and forth, the three members of the group ended up having to pick up the slack on the due date of the assignment.

In contrast, Carson enjoyed an experience on a design project for a course. Carson's description of the project best encapsulates the experience.

> "So I would say in well, one really good example of that would be in the class transfer processes that I took last semester. We had a project where we designed a pipeline to carry particular chemicals at a certain distance and we had to then look at the numbers, look at how much things cost, how often things need to be maintained, replaced, what installation costs look like, what yearly taxes look like. And choose. You know what kind of pump are we gonna use? What materials? How big should the pipe be? So it was a combination of doing math about. The actual flow of the liquid itself and of. Considering economic considerations and functionality and weighing what's more important."

Ben shared about a group project experience in an engineering course. Because Ben gets experience leading teams in his every-day work experience, he offered the opportunity to lead the project to another student, explaining it would be a good opportunity for them to develop leadership, communication, and task management skills. Unfortunately, the other student did not rise to the occasion, and Ben describes how poor the overall group experience was.

Henry has had a mixed experience in groupwork in university courses. A group project did not go well due to a low level of communication and collaboration in the group. He has had good experience in his chemistry laboratory where he and his lab partner work well together and completed laboratory assignments efficiently in order to finish the laboratory faster.

Other Observations

Because of his extensive previous work experience, Ben believes he is ahead of the other students in his classes when it comes to professional development. Ben's responses and attitude throughout the interview demonstrated good emotional intelligence, so this personal assessment may be true. Thinking back to the results of Chapter I and how students rated their self-ability higher than that of their peers, the higher self-ability rating may be justified for non-traditional students as many times they have had more applied professional skills experience in a work environment than traditional students.

A lot can be learned from Ben's experience in engineering-related work experience. It would be beneficial to ask practicing engineers about their experiences in their work and which ones give practical experience in practicing professional skills. Being more familiar with these environments and expectations may help engineering faculty design group projects in their courses where the task at hand and expectations align better with real-world scenarios.

Grace is currently in a full-year co-op rotation, so she will spend a full straight year with the company. Because of the length of the experience, Grace believes it has resembled what the day-to-day would look like if this was her full-time job. She described practice with the "day-to-day mundanity of professional skills" such as writing clear, effective emails and prioritizing information. Grace shared that the structure of this co-op rotation has taught her about long-term goal setting.

Further Recommendations for Improving Teamwork Education in Engineering

Overall, students agree that bad teamwork involves one or more members either taking over a project or not contributing. In fact, more likely than not, stories about a time when a student experienced bad teamwork was due to a group member not contributing. Students shared that they have been in a lot of teams in their courses, and they have had mixed success. The trouble with teaching teamwork in the classroom is the influence of grades. A high-performing group member that thinks lesser of their peers' abilities may take over the project to protect their grade in the course. Within the same team, poor students may take advantage of the high-performing student and contribute less because they know the high-performing student will pick up the slack. In this case, the idea of teamwork being "working toward a common goal" is not the case. With the current state of engineering education, the final grade will be a goal that may or may not be shared among all members of the team. As an educator, it is misguided to believe every student will be capable of achieving or aiming for a perfect score. The goal for educators should then be either to form to assist students in forming groups where goals are aligned, specifically grade expectations.

Conclusions

As part of this study, nine undergraduate engineering students were interviewed and asked about their experiences developing professional skills. They were also asked to provide definitions and good/bad examples for a list of eight professional skills from the Student

Outcomes of the Accreditation Board for Engineering and Technology (ABET) (Criteria for Accrediting Engineering Programs, 2021).

The nine students represented five engineering majors and collectively had applied experience through a co-op, internship, undergraduate research, full-time work (non-engineering), part-time work (non-engineering), teaching assistant/facilitator, and student organizations (engineering and non-engineering).

Part I of the interview was semi-structured, and students were prompted to share about their professional skills development. In Part II, students were provided the list of eight professional skills and were asked to define each one and to provide an example of good/bad demonstrations of each professional skill.

Overall in Part I, the students discussed every one of the eight professional skills, even though the list was not made available to the students at the time. The fact that a professional skill was brought up implied the student valued the skill. Three students discussed seven of the eight skills. Three professional skills were discussed by every student: collaboration, communication, and teamwork. The high frequency of teamwork discussion was expected, as it was central to most of the applied experience. A consideration to make is that students had previously seen the list of professional skills through completing the survey, Approximately two weeks passed between survey completion and the interviews. The eight professional skills may have been at the forefront of their memory, but they still chose which ones to discuss and which ones not to discuss in Part I.

Communication was discussed frequently by all the students, being discussed on its own and in conjunction with other professional skills. Across the nine interviews, it was discussed simultaneously with all eight professional skills. Student discussion leads to the conclusion that practice of effective communication enhances other professional skills. These results align with the ones from Chapters I and II where communication had the highest mean rating for faculty, practicing engineers, and students. A framework for communication was proposed, which can be validated through future work.

Interview participants spoke frequently about experiences with professional skills outside of the classroom. In most instances, they enjoyed the opportunity to use their professional skills in a practical and applied environment. Applied experience is important to overall professional skills development because it allows the skills to be situated in a realistic and relevant environment.

The interview participants had a wide variety of experiences with degree-related work experience and on-campus involvement among other things. Seemingly different experiences allowed different students to practice and develop the same professional skills (most frequently communication).

Even though perceptions about professional skills may not be perfectly aligned, the interviews showed that students recognize environments that contribute to their professional skills development. They can also identify experiences where poor professional skills ability is present from one or more parties.

While it is good that there are multiple opportunities for students to develop their professional skills in an applied setting, the idea that the majority of the development of professional skills, which results from Chapter II show are important for engineering graduates, happens outside of the classroom brings concerns of issues with diversity, equity, and inclusion. Out-of-class opportunities vary by student, and not all may be based on merit alone. The level of involvement among undergraduate students is not consistent. As a result, there are engineering graduates that are entering the workforce at a disadvantage compared to some of their peers because of the lack of consistency of professional skills development in the classroom.

The discussions of how feedback on professional skills is best given and received can help inform educators on potential practices for giving feedback on professional skills in an educational setting. A common theme among the participants was for feedback to be measurable and relevant. Specific goals or areas of improvement help guide students in their next steps. Participants also valued intentional feedback from supervisors where support was evident. While providing individual experiences for students in large classes can be difficult, strategies to help created intentional feedback experiences for students can be a good motivator for students. It is also recommended for professional skills development in the classroom to provide a low-stakes environment for students to get exposure to various professional skills.

Future Work

The next steps in this work on professional skills development is forming agreed-upon definitions for the eight professional skills, with the starting point being the definitions synthesized using the themes found among students' good examples for the professional skills.

CHAPTER IV

CONCLUSIONS

Overview of Study Methods

Two surveys were administered, one to current undergraduate engineering students, and second to engineering faculty and practicing engineers. These surveys asked respondents to give their perceptions of the importance of, student ability with, and level of instruction in the university setting of eight professional skills. The eight professional skills were taken from the Accreditation Board for Engineering and Technology (ABET) Criteria for Accrediting Engineering Programs Student Outcomes (ABET, 2022). They were collaboration, communication, ethical considerations, inclusivity, leadership, professional judgment, task management, and teamwork. A selection of student survey respondents was invited to participate in an interview, where they were asked to describe the development of their professional skills. They were also prompted to provide a definition and examples of good and bad demonstrations of each of the eight professional skills.

Unified Perceptions of Professional Skills' Importance

Faculty, practicing engineers, and students alike all showed that on average they value the eight professional skills investigated in this work. One-way repeated means analysis of variance (ANOVA) yielded no statistically significant difference in the means ratings of any of the groups for any of the professional skills. Thus, the perceived importance of a professional skill is not a result of which group is rating it.

Discrepancies in Perceptions of Student Abilities with Professional Skills

Students thought more highly of their own abilities than faculty and practicing engineers thought of their skills to a statistically significant level for all professional skills except ethical considerations and task management. A conclusion can be drawn that engineering students/graduates are likely entering the workforce with an inflated perception of their abilities with professional skills despite the fact that both groups agree on the rated importance of the eight skills. Further studies could investigate if this inflated perception affects engineering students'/recent graduates' attitude towards training in these skills.

Low Perception of How Well Professional Skills are Taught in the University Setting

Communication was the one professional skill where there was a statistically significant difference in how faculty, practicing engineers, and students perceived the level of instruction of the professional skill in the university setting.

The general alignment in perception of level of instruction for all professional skills is encouraging for education's sake, showing that improved pedagogy for teaching professional skills would hopefully increase the mean rating of level of instruction across all groups. The professional skill to start with should be communication as it had the highest discrepancies between groups.

Communication: The Epicenter of Professional Skills

The results of Chapter II showed that Faculty, Practicing Engineers, and Students all value communication. It had the highest mean rating for importance for all three groups, and Tukey post-hoc analysis placed it in the top subset for each group. Student interviews gave insight into why communication was rated so highly. Every student discussed communication more than once, many times alongside other professional skills. When giving good examples of other professional skills, effective communication or a derivation was given as a characteristic of good collaboration, leadership, professional judgment, and teamwork. Communication is key to successful execution of these other professional skills. It is no surprise then that it was rated so highly. Without communication, other professional skills would not be nearly as effective.

Lessons learned from the student interviews give insight into potential causes of the discrepancies in student ability and level of instruction mean ratings for communication. The central theme of good communication was having clear expectations and being easy to understand. Five students described good communication in that way. There were eight other themes of good communication, with most coming from only one or two students. These other eight themes, “gives all relevant details,” “having active participation from all participants,” “asking good questions,” “conflict resolution; open; honest,” “efficient; precise,” and “involving all relevant parties,” seem to serve to strengthen the primary goal of communication.

A framework for communication (Figure 3.1) was proposed with the overall goal of “having clear expectations and being easy to understand” at the top. Branching off from the overall goal were six themes seen in the student descriptions of good education. The author argues that while incorporating all six of the themes into one’s communication practices may yield to maximum communication ability, the effect of having just one or two is still significant. The dictionary definition of communication only mentions an information exchange. It does not specify how the information is exchanged and to what extent. Confusion may arise when assessing student ability with and level of instruction of communication if an individual believes good communication requires someone to exercise all the facets of communication. The surveys from Chapters I and II most likely had a mix of respondents who had varying levels of how much was required for it to count as good communication.

For future work, a good next step would be to investigate receptiveness of faculty, practicing engineers, and students to modeling communication as a multi-tiered professional skill through validation of the proposed framework (Figure 3.1).

Operational Definitions of Professional Skills

Based on the definitions and descriptions of good examples of the professional skills gathered from the interviews, operational definitions were created.

- Collaboration: Maximizing efficiency of the team by assigning tasks to the person with the most expertise in the area
- Communication: Easy to understand and setting clear expectations by giving all relevant details, encouraging active participation from all participants, asking good questions, being open and honest, being efficient and precise, and/or involving all relevant parties
- Ethical Considerations: Balancing all factors while considering the effects that decisions have on people, safety, and the environment and not only considering economics
- Inclusivity: Including all individuals regardless of background; being accepting of others even when they are different from you; being receptive to learning about various identities
- Leadership: Managing people and tasks effectively while practicing good communication and investing in the success and growth of the individual team members
- Professional Judgment: Considering problems from multiple points of view to assess the best way to handle a situation while considering the input of others and adhering to relevant laws and regulations
- Task Management: Characterizing tasks by priority and establishing a reasonable timeline
- Teamwork: The application of communication, inclusivity, and collaboration to work as a team towards a common goal

Charges to Engineering Educators

The results of the surveys combined with the perceptions expressed by the students in the interviews show that current methods for teaching professional skills in engineering programs are not as effective as they could be and as faculty, students, and practicing engineers expect them to be. The practice of engineering involves continuous improvement, thus applying this practice to educational methods is key if perceptions of professional skills by the engineering community are to be improved.

The recommendations of methods to implement in the classroom range from low- to high-involvement. This list aims to be inclusive of the wide range of engineering teachers who have a similarly wide range of training in engineering pedagogy. The focus of the recommendations is practical application. Pulko and Parikh (2003) show the need for assignments where students see the practical application of the professional skills. Results from the interviews aligned with these findings.

Giving Feedback

Interview analysis concluded that students want and benefit from feedback that is measurable, relevant, and intentional. They value the spirit of improvement and support over a correction-focused mindset. Formative feedback opportunities are beneficial to students. Low-stakes presentations or written reports can be a good tool for providing feedback on these skills. The opportunity to demonstrate improvement should be provided to the students.

Providing Clear Definitions and Expectations of Professional Skills and Their Application

Part of the discrepancies in the perception of professional skills by the engineering community is attributed to a lack operational definitions for the professional skills. Explicit instruction in expectations of the various professional skills, for example when assigning a group project, will help align student perceptions of the skills.

Methods Focused on Inter-personal Skills

Within the good examples of each of the professional skills, six of the eight had something to do with inter-personal skills, which involve interacting with others. Part of being good at collaboration, communication, ethical considerations, inclusivity, leadership, and teamwork all require proficiency with inter-personal skills. The unifying idea is that people perform best when they understand the strengths and weaknesses of those they work with, and they welcome different perspectives.

Two common personality assessment tools are the DISC and Myers-Briggs assessments. It is recommended that engineering instructors employ these or similar assessments to help identify their strengths and weaknesses. Discussion and exercises about the different personality types expressed would be helpful to show students how others operate. Clear and specific discussion how the different types work together is important.

Exposure to people of different backgrounds and experiences is a key factor to fostering good inclusivity. Engineering educators are encouraged to take this into consideration when inviting guest speakers to their courses, student organizations, or programs. Being conscious of having a variety of ethnicities, genders, backgrounds, and fields of expertise, among other considerations, can expose students to people both the same as and different from them.

A high-involvement method to integrate inter-personal skills education into the classroom is implementing a project in the style that Stanford et al. did (Stanford et al., 2013). The class had one collective project, and individual teams worked on a portion of the project. An initial exercise could be for students to read the project description and list where their strengths lie in completing it. This assessment would be a factor in deciding the individual teams. An additional exercise would be having students discuss the contribution that each individual teams add to the greater class project.

Case Studies and Role-Playing Exercises

Educators may find success in partnering case studies with role-playing exercises. Students might review a case study and then act out the events of the study as a class. This active learning exercise can give a simulation of applied experience for the professional skills.

CHAPTER V

SUGGESTIONS FOR FUTURE WORK

Further studies into the environments that engineering students are involved in can deepen the understanding of the role that these opportunities play in professional skills education. Comparing the effects of various environments on perceptions of professional skills would fill gaps in the understanding of professional skills education in engineering.

Three environments were attributed to student development in the eight professional skills and had a relatively low standard deviation when averaging the number of students selecting the environment for each professional skill. These environments, engineering student organizations, undergraduate research, and off-campus involvement, may be high-impact environments that are rich in professional skills development opportunities. Future work could explore this hypothesis. If it is found to be true, educators could either increase how much they recommend these opportunities to students or try to replicate the educational opportunities in the classroom, or a combination of the two.

The results presented in Chapters I and II could be validated by readministering the surveys. Specifically, quality of student was not controlled for in student surveys. The sample size of the faculty responding was 25, which is small and may or may not be reflective of the population of engineering faculty. Additionally, the faculty and practicing engineers who responded to the survey may have responded because they have a higher interest in new methods to improve engineering education. Their perspectives may or may not be reflective of the greater populations.

ANOVA results showed no statistically significant difference among mean ratings of importance for communication, task management, collaboration, and teamwork for faculty, practicing engineers, and students. Future work could investigate any minor differences in the perceptions of the skills, if any exist.

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APPENDIX A

STUDENT SURVEY QUESTIONS

Consent Information

Per IRB regulations, the consent information will be provided first. Participants must consent to the terms of the study to continue with the survey.

Demographic Questions

The following demographic information will be collected:

- University name
- Current degree major
- Concentration/specialization, if any
- Age
- Gender
    - Woman
    - Man
    - Transgender/Trans woman
    - Transgender/Trans man
    - Non-binary
    - Other
    - Prefer not to reply
- Ethnicity
    - Asian
    - Black
    - First Nations
    - Latino or Hispanic
    - Native American

- Pacific Islander
- White
- Other
- Unknown

- Current classification (by progress in degree major):
  - Freshman
  - Sophomore
  - Junior
  - Senior
  - 5^{th}+ year senior

- Are you the first member of your family to pursue a college degree?
  - Yes
  - No

- Which type of student are you?
  - Traditional (began university at 18 with continuous enrollment)
  - Non-traditional (some interruption in enrollment or started university later than 18)

- Did you transfer to this university from a community or junior college?
  - Yes
  - No

- Did you transfer to this university from another 4-year institution?
  - Yes
  - No

- Are any of your family members engineers?
    - Yes
    - No
- Do you have any previous work experience? Select all that apply.
    - High-school level employment
    - Degree-related experience
        - Co-op
        - Internship
        - Undergraduate Research
    - On-campus job/work-study
    - Off-campus job (while enrolled in college)

Professional Skills Questions

The following list of professional skills will fill in the blank for each of questions to follow.

- Professional judgement
- Teamwork
- Leadership
- Collaboration
- Inclusivity
- Task management
- Ethical considerations
- Communication

The first four questions provided will have a sliding scale response option with one side being negative and the other being positive. The fifth question will have checkboxes that allows for multiple selections.

- How important is _____ for engineering graduates?
- How you would rate your skills with _____?
- How would you rate the average engineering students' skills with _____?
- How well have you been taught _____ in the university setting?
- Select the area(s) that you feel contributed to your development of _____
    - Non-engineering courses
    - Engineering courses
    - Co-op/internship
    - Undergraduate research
    - Non-engineering student organizations
    - Engineering student organizations
    - Off-campus involvement
    - Pre-college involvement
    - Upbringing (homelife)

The professional skills were presented in the following order

APPENDIX B

TUKEY POST-HOC TABLES FOR CHAPTER I

Table B.1 Statistically Significant Tukey Post-Hoc Results for One-way Repeated-measures ANOVA of Professional Skill within each Category

Category	(I) Skill	(J) Skill	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Importance	Collaboration	Inclusivity	17.813***	11.25	24.38
Importance	Collaboration	Leadership	12.185***	5.64	18.73
Importance	Collaboration	Professional Judgment	7.688**	1.15	14.23
Importance	Communication	Inclusivity	21.295***	14.62	27.97
Importance	Communication	Leadership	15.668***	9.02	22.32
Importance	Communication	Professional Judgment	11.171***	4.52	17.82
Importance	Ethical Considerations	Inclusivity	15.801***	9.14	22.46
Importance	Ethical Considerations	Leadership	10.173***	3.54	16.81
Importance	Professional Judgment	Inclusivity	10.124***	3.57	16.68
Importance	Task Management	Inclusivity	20.914***	14.3	27.53
Importance	Task Management	Leadership	15.286***	8.7	21.87
Importance	Task Management	Professional Judgment	10.790***	4.2	17.38

Table B.1 (Continued)

Importance	Teamwork	Inclusivity	17.614***	11.06	24.17
Importance	Teamwork	Leadership	11.986***	5.46	18.52
Importance	Teamwork	Professional Judgment	7.490*	0.96	14.02
Self-ability	Collaboration	Professional Judgment	13.270***	6.11	20.43
Self-ability	Collaboration	Task Management	8.592**	1.37	15.82
Self-ability	Communication	Professional Judgment	10.975***	3.68	18.27
Self-ability	Ethical Considerations	Professional Judgment	11.351***	4.07	18.63
Self-ability	Inclusivity	Professional Judgment	10.866***	3.68	18.05
Self-ability	Leadership	Professional Judgment	7.470*	0.31	14.63
Self-ability	Teamwork	Professional Judgment	14.601***	7.44	21.76
Self-ability	Teamwork	Task Management	9.923***	2.7	17.15
Peer-ability	Collaboration	Leadership	7.628*	0.63	14.62
Peer-ability	Collaboration	Professional Judgment	8.768**	1.76	15.78
Peer-ability	Ethical Considerations	Inclusivity	7.149*	0.01	14.28
Peer-ability	Ethical Considerations	Leadership	11.159***	4.05	18.27

Table B.1 (Continued)

Peer-ability	Ethical Considerations	Professional Judgment	12.300***	5.18	19.42
Peer-ability	Task Management	Leadership	7.405*	0.35	14.46
Peer-ability	Task Management	Professional Judgment	8.546**	1.48	15.62
Peer-ability	Teamwork	Professional Judgment	7.313*	0.31	14.32
Level of Instruction	Collaboration	Leadership	15.246***	5.9	24.59
Level of Instruction	Collaboration	Professional Judgment	14.916***	5.61	24.23
Level of Instruction	Communication	Leadership	11.980**	2.43	21.53
Level of Instruction	Communication	Professional Judgment	11.650**	2.13	21.17
Level of Instruction	Ethical Considerations	Leadership	11.284**	1.82	20.75
Level of Instruction	Ethical Considerations	Professional Judgment	10.955*	1.53	20.38
Level of Instruction	Task Management	Leadership	14.983***	5.52	24.44
Level of Instruction	Task Management	Professional Judgment	14.653***	5.23	24.08
Level of Instruction	Teamwork	Inclusivity	9.596*	0.25	18.94
Level of Instruction	Teamwork	Leadership	16.532***	7.19	25.87
Level of Instruction	Teamwork	Professional Judgment	16.203***	6.89	25.51

*p < .05. **p < .01. ***p < .001.

Table B.2 Statistically Significant Tukey Post-Hoc Results for One-way ANOVA of Category within each Professional Skill

Category	(I) Skill	(J) Skill	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Collaboration	Importance	Level of Instruction	27.62***	21.72	33.51
	Importance	Peer-ability	29.43***	23.56	35.31
	Importance	Self-ability	11.69***	5.81	17.56
	Self-ability	Level of Instruction	15.93***	10.04	21.81
	Self-ability	Peer-ability	17.74***	11.88	23.61
Communication	Importance	Level of Instruction	34.37***	28.24	40.49
	Importance	Peer-ability	36.49***	30.41	42.56
	Importance	Self-ability	17.47***	11.39	23.54
	Self-ability	Level of Instruction	16.90***	10.78	23.02
	Self-ability	Peer-ability	19.02***	12.95	25.10
Ethical Considerations	Importance	Level of Instruction	29.57***	22.43	36.70
	Importance	Peer-ability	23.89***	16.76	31.02
	Importance	Self-ability	11.60***	4.46	18.73

Table B.2 (Continued)

Ethical Considerations	Self-ability	Level of Instruction	17.97***	10.84	25.11
	Self-ability	Peer-ability	12.29***	5.16	19.43
Inclusivity	Importance	Level of Instruction	18.11***	10.27	25.96
	Importance	Peer-ability	15.24***	7.42	23.06
	Self-ability	Level of Instruction	21.83***	13.99	29.68
	Self-ability	Peer-ability	18.96***	11.14	26.78
Leadership	Importance	Level of Instruction	30.68***	24.18	37.17
	Importance	Peer-ability	24.88***	18.43	31.32
	Self-ability	Level of Instruction	25.37***	18.88	31.87
	Self-ability	Peer-ability	19.57***	13.12	26.02
Professional Judgment	Importance	Level of Instruction	34.84***	28.97	40.72
	Importance	Peer-ability	30.51***	24.65	36.37
	Importance	Self-ability	17.27***	11.41	23.13
	Self-ability	Level of Instruction	17.57***	11.69	23.46
	Self-ability	Peer-ability	13.24***	7.37	19.11

Table B.2 (Continued)

Task Management	Importance	Level of Instruction	30.98***	24.60	37.36
	Importance	Peer-ability	32.76***	26.43	39.09
	Importance	Self-ability	23.38***	17.04	29.72
	Self-ability	Peer-ability	9.38***	3.03	15.72
Teamwork	Importance	Level of Instruction	26.13***	20.06	32.20
	Importance	Peer-ability	30.69***	24.64	36.74
	Importance	Self-ability	10.16***	4.11	16.21
	Self-ability	Level of Instruction	15.97***	9.90	22.04
	Self-ability	Peer-ability	20.53***	14.48	26.58

***$p < .001$.

APPENDIX C

ONE-WAY ANOVA RESULTS FOR ENVIRONMENT AND PROFESSIONAL SKILL FOR CHAPTER I

Table C.1 Student Self-ability One-way ANOVA Results for Environment and Professional Skill

Environment	Professional Skill	F
Co-op/Internship	Collaboration	3.67
	Communication	0.06
	Ethical Considerations	3.17
	Inclusivity	1.80
	Leadership	0.24
	Professional Judgment	0.97
	Task Management	0.11
	Teamwork	0.00
Engineering Courses	Collaboration	2.13
	Communication	**5.33***
	Ethical Considerations	1.65
	Inclusivity	3.43
	Leadership	3.19
	Professional Judgment	0.51
	Task Management	1.26
	Teamwork	**9.03****
Engineering Student Organization	Collaboration	1.17
	Communication	0.30
	Ethical Considerations	1.86
	Inclusivity	1.72
	Leadership	0.32

Table C.1 (Continued)

Environment	Professional Skill	F
Engineering Student Organization	Professional Judgment	**6.17***
	Task Management	1.20
	Teamwork	0.12
Non-engineering Courses	Collaboration	0.38
	Communication	0.16
	Ethical Considerations	**4.03***
	Inclusivity	1.59
	Leadership	0.40
	Professional Judgment	0.69
	Task Management	0.49
	Teamwork	0.88
Non-engineering Student Organization	Collaboration	0.19
	Communication	3.40
	Ethical Considerations	2.64
	Inclusivity	**13.10*****
	Leadership	2.50
	Professional Judgment	**4.02***
	Task Management	**7.71****
	Teamwork	2.64
Off-Campus Involvement	Collaboration	2.35
	Communication	0.24
	Ethical Considerations	2.62

Table C.1 (Continued)

Environment	Professional Skill	F
Off-Campus Involvement	Inclusivity	**4.55***
	Leadership	**7.18****
	Professional Judgment	3.45
	Task Management	0.69
	Teamwork	3.69
Pre-College Involvement	Collaboration	0.29
	Communication	3.55
	Ethical Considerations	**4.67***
	Inclusivity	**12.60*****
	Leadership	**5.17***
	Professional Judgment	**3.97***
	Task Management	2.26
	Teamwork	**4.68***
Undergraduate Research	Collaboration	0.96
	Communication	0.06
	Ethical Considerations	0.98
	Inclusivity	1.96
	Leadership	0.28
	Professional Judgment	**4.19***
	Task Management	2.15
	Teamwork	0.00
Upbringing	Collaboration	2.00
	Communication	1.20

Table C.1 (Continued)

Environment	Professional Skill	F
Upbringing	Ethical Considerations	0.36
	Inclusivity	**17.28*** **
	Leadership	0.54
	Professional Judgment	0.55
	Task Management	1.71
	Teamwork	**16.29*** **

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

Table C.2 Student Peer-ability One-way ANOVA Results for Environment and Professional Skill

Environment	Professional Skill	F
Co-op/Internship	Collaboration	0.71
	Communication	1.14
	Ethical Considerations	1.82
	Inclusivity	0.08
	Leadership	1.45
	Professional Judgment	1.20
	Task Management	0.61
	Teamwork	1.22
Engineering Courses	Collaboration	**12.31*** **
	Communication	**17.08*** **
	Ethical Considerations	**8.85** **
	Inclusivity	**13.80*** **
	Leadership	**7.87** **
	Professional Judgment	**9.45** **
	Task Management	**6.70* **
	Teamwork	**16.58*** **
Engineering Student Organization	Collaboration	0.82
	Communication	0.02
	Ethical Considerations	**6.41* **
	Inclusivity	0.32
	Leadership	2.56
	Professional Judgment	0.18

Table C.2 (Continued)

Environment	Professional Skill	F
Engineering Student Organization	Task Management	2.44
	Teamwork	0.32
Non-engineering Courses	Collaboration	0.40
	Communication	0.42
	Ethical Considerations	1.21
	Inclusivity	0.16
	Leadership	0.22
	Professional Judgment	3.30
	Task Management	3.13
	Teamwork	1.94
Non-engineering Student Organization	Collaboration	0.81
	Communication	0.18
	Ethical Considerations	2.53
	Inclusivity	**4.31***
	Leadership	0.20
	Professional Judgment	**4.79***
	Task Management	**4.51***
	Teamwork	**4.79***
Off-Campus Involvement	Collaboration	0.05
	Communication	0.32
	Ethical Considerations	1.06
	Inclusivity	1.74

Table C.2 (Continued)

Environment	Professional Skill	F
Off-Campus Involvement	Leadership	**8.04****
	Professional Judgment	0.05
	Task Management	**4.76***
	Teamwork	2.83
Pre-College Involvement	Collaboration	1.10
	Communication	**6.71***
	Ethical Considerations	0.85
	Inclusivity	**5.09***
	Leadership	0.97
	Professional Judgment	1.27
	Task Management	0.23
	Teamwork	0.05
Undergraduate Research	Collaboration	0.01
	Communication	1.42
	Ethical Considerations	0.08
	Inclusivity	**4.00***
	Leadership	0.40
	Professional Judgment	1.01
	Task Management	0.01
	Teamwork	0.03
Upbringing	Collaboration	0.18
	Communication	0.00
	Ethical Considerations	0.00

Table C.2 (Continued)

Environment	Professional Skill	F
	Inclusivity	2.61
	Leadership	0.37
Upbringing	Professional Judgment	0.57
	Task Management	1.19
	Teamwork	0.00

*p < .05. **p < .01. ***p < .001.
Note. Significant F values are bolded.

APPENDIX D

ENGINEERING FACULTY AND PRACTICING ENGINEERS SURVEY QUESTIONS

Consent Information

Per IRB regulations, the consent information will be provided first. Participants must consent to the terms of the study to continue with the survey.

Demographic Questions

The following demographic information will be collected:

- Current industry/college department
- Undergraduate degree major
- Concentration/specialization, if any
- Year of graduation with undergraduate degree
- Age
- Gender
  - Woman
  - Man
  - Transgender/Trans woman
  - Transgender/Trans man
  - Non-binary
  - Other
  - Prefer not to reply

- Ethnicity
    - Asian
    - Black
    - First Nations
    - Latino or Hispanic
    - Native American
    - Pacific Islander
    - White
    - Other
    - Unknown
    - No

Professional Skills Questions

The following list of professional skills will fill in the blank for each of questions to follow.

- Professional judgement
- Teamwork
- Leadership
- Collaboration
- Inclusivity
- Task management
- Ethical considerations
- Communication

APPENDIX E

QUESTIONS FOR SURVEY IN CHAPTER II

The questions provided will have a sliding scale response option with one side being negative and the other being positive.

- How important is _____ for engineering students and graduates?
- Of current engineering students and engineering graduates within the past 5-10 years, how would you rate the average engineering student's skills with _____?
- Of current engineering students and engineering graduates within the past 5-10 years, how well do you believe they have been taught _____ in the university setting?

APPENDIX F

TUKEY POST-HOC RESULTS FOR CHAPTER II

Table F.1 Statistically Significant Tukey Post-Hoc Multiple Comparison Results for One-Way Repeated-Measures ANOVA of Professional Skill and Rated Importance for Each Group

Group	(I) Skill	(J) Skill	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Faculty	Task Management	Inclusivity	13.96**	0.68	27.24
Faculty	Teamwork	Inclusivity	16.40*	3.12	29.68
Faculty	Collaboration	Inclusivity	16.96*	3.68	30.24
Faculty	Ethical Considerations	Inclusivity	18.32***	5.04	31.60
Faculty	Professional Judgment	Leadership	18.40***	5.12	31.68
Faculty	Task Management	Leadership	19.72***	6.44	33.00
Faculty	Communication	Inclusivity	20.56***	7.28	33.84
Faculty	Teamwork	Leadership	22.16***	8.88	35.44
Faculty	Collaboration	Leadership	22.72***	9.44	36.00
Faculty	Ethical Considerations	Leadership	24.08***	10.80	37.36
Faculty	Communication	Leadership	26.32***	13.04	39.60
Practicing Engineer	Leadership	Inclusivity	11.90*	2.50	21.30
Practicing Engineer	Communication	Professional Judgment	11.92*	2.56	21.29

Table F.1 (Continued)

Group	(I) Skill	(J) Skill	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Practicing Engineer	Ethical Considerations	Leadership	13.39***	4.03	22.76
Practicing Engineer	Teamwork	Leadership	13.53***	4.33	22.73
Practicing Engineer	Collaboration	Leadership	15.64***	6.44	24.84
Practicing Engineer	Task Management	Leadership	16.07***	6.77	25.37
Practicing Engineer	Professional Judgment	Inclusivity	18.73***	9.33	28.13
Practicing Engineer	Communication	Leadership	18.75***	9.39	28.12
Practicing Engineer	Ethical Considerations	Inclusivity	25.29***	15.74	34.85
Practicing Engineer	Teamwork	Inclusivity	25.43***	16.03	34.83
Practicing Engineer	Collaboration	Inclusivity	27.54***	18.14	36.94
Practicing Engineer	Task Management	Inclusivity	27.97***	18.48	37.46
Practicing Engineer	Communication	Inclusivity	30.65***	21.09	40.21
Student	Professional Judgment	Inclusivity	10.12***	3.57	16.68
Student	Ethical Considerations	Leadership	10.17***	3.54	16.81
Student	Task Management	Professional Judgment	10.79***	4.20	17.38

Table F.1 (Continued)

Group	(I) Skill	(J) Skill	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Student	Communication	Professional Judgment	11.17***	4.52	17.82
Student	Teamwork	Leadership	11.99***	5.46	18.52
Student	Collaboration	Leadership	12.18***	5.64	18.73
Student	Task Management	Leadership	15.29***	8.70	21.87
Student	Communication	Leadership	15.67***	9.02	22.32
Student	Ethical Considerations	Inclusivity	15.80***	9.14	22.46
Student	Teamwork	Inclusivity	17.61***	11.06	24.17
Student	Collaboration	Inclusivity	17.81***	11.25	24.38
Student	Task Management	Inclusivity	20.91****	14.30	27.53
Student	Communication	Inclusivity	21.30****	14.62	27.97
Student	Teamwork	Professional Judgment	7.49**	0.96	14.02
Student	Collaboration	Professional Judgment	7.69*	1.15	14.23

*p < .05. **p < .01. ***p < .001. ****p = 0.

Table F.2 Statistically Significant Tukey Post-Hoc Multiple Comparison Results for One-Way Repeated-Measures ANOVA of Group and Rated Student Ability for Each Professional Skill

Professional Skill	(I) Group	(J) Group	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Collaboration	Student - Self-ability	Faculty	14.91**	4.66	25.16
Collaboration	Student - Self-ability	Practicing Engineers	15.78***	9.04	22.51
Collaboration	Student - Self-ability	Student - Peer-ability	17.74***	12.18	23.31
Communication	Student - Peer-ability	Practicing Engineers	9.29*	1.68	16.91
Communication	Student - Self-ability	Faculty	13.69*	2.44	24.95
Communication	Student - Self-ability	Practicing Engineers	28.31***	20.70	35.93
Communication	Student - Self-ability	Student - Peer-ability	19.02***	12.73	25.31
Ethical Considerations	Student - Self-ability	Faculty	15.19**	2.98	27.40
Ethical Considerations	Student - Self-ability	Practicing Engineers	10.22**	1.97	18.47
Ethical Considerations	Student - Self-ability	Student - Peer-ability	12.29***	5.49	19.10
Inclusivity	Student - Self-ability	Faculty	14.47*	1.71	27.23
Inclusivity	Student - Self-ability	Practicing Engineers	18.59***	9.96	27.22
Inclusivity	Student - Self-ability	Student - Peer-ability	18.96***	12.00	25.92

Table F.2 (Continued)

Professional Skill	(I) Group	(J) Group	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Leadership	Student - Self-ability	Faculty	18.39***	7.79	28.99
Leadership	Student - Self-ability	Practicing Engineers	23.36***	16.37	30.36
Leadership	Student - Self-ability	Student - Peer-ability	19.57***	13.82	25.32
Professional Judgment	Student - Self-ability	Practicing Engineers	13.20***	6.70	19.70
Professional Judgment	Student - Self-ability	Student - Peer-ability	13.24***	7.86	18.62
Task Management	Student - Self-ability	Practicing Engineers	11.63***	3.77	19.49
Task Management	Student - Self-ability	Student - Peer-ability	9.38**	2.89	15.86
Teamwork	Practicing Engineers	Student - Peer-ability	8.54**	1.72	15.37
Teamwork	Student - Self-ability	Practicing Engineers	11.99***	5.16	18.82
Teamwork	Student - Self-ability	Student - Peer-ability	20.53***	14.89	26.17

*p < .05. **p < .01. ***p < .001.

Table F.3 Statistically Significant Tukey Post-Hoc Multiple Comparison Results for One-Way Repeated-Measures ANOVA of Professional Skill and Rated Student Ability for Each Group

Group	(I) Skill	(J) Skill	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Practicing Engineers	Collaboration	Professional Judgment	10.69**	0.49	20.90
Practicing Engineers	Collaboration	Leadership	13.39*	3.15	23.62
Student - Peer-ability	Ethical Considerations	Inclusivity	7.15**	0.01	14.28
Student - Peer-ability	Teamwork	Professional Judgment	7.31**	0.31	14.32
Student - Peer-ability	Task Management	Leadership	7.40**	0.35	14.46
Student - Peer-ability	Collaboration	Leadership	7.63**	0.63	14.62
Student - Peer-ability	Task Management	Professional Judgment	8.55*	1.48	15.62
Student - Peer-ability	Collaboration	Professional Judgment	15.19**	2.98	27.40
Student - Self-ability	Leadership	Professional Judgment	7.47**	0.31	14.63
Student - Self-ability	Collaboration	Task Management	8.59*	1.37	15.82

*p < .05. **p < .01.

Table F.4 Statistically Significant Tukey Post-Hoc Multiple Comparison Results for One-Way Repeated-Measures ANOVA of Professional Skill and Rated Level of Instruction in University Setting

Professional Skill	(I) Group	(J) Group	Mean Difference (I-J)	95% Confidence Interval	
				Lower	Upper
Faculty	Communication	Leadership	22.40*	4.28	40.52
Faculty	Teamwork	Leadership	24.40*	6.28	42.52
Faculty	Teamwork	Professional Judgment	20.08**	1.96	38.20
Practicing Engineers	Collaboration	Professional Judgment	14.54*	2.76	26.33
Practicing Engineers	Ethical Considerations	Communication	15.18*	2.88	27.47
Practicing Engineers	Task Management	Leadership	13.02**	1.03	25.01
Practicing Engineers	Teamwork	Inclusivity	13.85**	1.84	25.85
Students	Communication	Professional Judgment	11.65*	2.13	21.17
Students	Communication	Leadership	11.98*	2.43	21.53
Students	Ethical Considerations	Professional Judgment	10.95**	1.53	20.38
Students	Ethical Considerations	Leadership	11.28*	1.82	20.75
Students	Teamwork	Inclusivity	9.60**	0.25	18.94

*p < .05. **p < .01.

APPENDIX G

QUESTIONS ASKED IN INTERVIEWS

The following questions were asked of participants in the semi-structured portion of the interview (Part I).

1. How do you describe professional skills, also known as soft skills?
2. What purpose to professional skills serve for engineering students?
3. How would you describe how the development of your professional skills has gone throughout your lifetime?
4. Can you list what you consider to be professional skills?
5. What is your experience with professional skills being taught at the university level? How would you evaluate this education?
6. Describe any extracurricular involvement and/or work experience you have had in high school and college and what professional skills you saw demonstrated by someone else or developed and/or practiced yourself.
7. What does it look like when you receive feedback on your professional skills abilities? Who have you received feedback from?
8. Can you describe your experiences with group projects? What have been the outcomes?
9. What lessons have you learned from completing group projects?

The following questions were asked of participants in the structured portion of the interview (Part II).

1. Can you define and describe _____?
2. What is a good example of _____?
3. What is a bad example of _____?

Questions 1-3 were repeated for each of the following professional skills:

- Collaboration
- Communication
- Ethical Considerations
- Inclusivity

- Leadership
- Professional Judgment
- Task Management
- Teamwork