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Understanding How Engineering Faculty Provide Engineering Students Opportunities to Develop Professional Skills In Technical Courses

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Abstract

Many researchers fear that engineering students are not adequately developing creativity, entrepreneurial mindset, and cultural competency, which leaves them ill-prepared to solve 21st-century problems. Researchers indicate that these professional skills are not specifically included in the ABET student learning outcomes and are not assessed in engineering curricula. There is an overarching concern that curricula favor technical skills over professional skills. This qualitative research study explores how engineering faculty currently provide engineering students with opportunities to develop professional skills. Three semi-structured interviews and one focus group were conducted to capture the knowledge and perceptions of engineering faculty in a mechanical engineering department. Major findings include the engineering faculty's lack of familiarity with non-ABET professional skills, like entrepreneurial mindset and cultural agility, the difficulty of making changes in technical classes, and the limitations in assessing professional skills. The researcher aims for the recommendations derived from this pilot study to raise awareness of professional skill development within engineering curricula, fostering collaboration with industry, and stimulating further research into enhancing the engineering curriculum with a focus on these essential skills.

Introduction

To succeed in the 21st-century workplace, engineering graduates need more than technical skills or risk losing their jobs to automation [1, 2]. Professional skills complement a technical education and are part of the accreditation process for engineering programs. ABET, the leading accreditation body for engineering programs, has four professional skills and three technical skills used in program evaluation that were developed with academic and industry partners. ABET includes communication, professional responsibility, professional growth, and collaboration as professional skills. Most definitions of 21st-century skills have the technical and professional skills mandated by ABET but also include creativity, cultural competency, and entrepreneurial mindset, which ABET does not currently require [3,4]. Entrepreneurial thinking has become very popular in the engineering curriculum due to the efforts of KEEN and the Engineering Unleashed network. Their partnership of colleges and universities "fosters collaboration among administration, faculty, and institutions to implement entrepreneurially minded learning in a variety of contexts" [5].

ABET accreditation is essential to engineering programs to recruit and attract top engineering students and provide a path toward licensure. Regrettably, the predominant emphasis on meeting ABET criteria within engineering curricula often sidelines opportunities for fostering supplementary professional skill sets. Technical content invariably takes precedence, sometimes at the expense of broader skill cultivation.

Given the limitations described above within technical courses, this qualitative pilot study describes how engineering faculty in a mechanical engineering program currently provide engineering students with opportunities to develop professional skills. This research will help identify opportunities for faculty to improve professional skills development within engineering curricula. This study provides valuable insight into the attitudes of engineering faculty regarding the development of professional skills and can be utilized alongside research from industry and student perspectives to enhance the development of these crucial skills.

Research Questions

The research questions guiding this pilot study are:

1. How do engineering faculty view professional skill development?
2. How do engineering faculty provide opportunities for students to develop professional skills, including creativity, EM, and cultural competency, throughout the engineering curriculum?

Research Methodology

The researcher employed a descriptive qualitative methodology to describe and explore how engineering faculty provide opportunities to develop professional skills in technical courses offered by the mechanical engineering department. A descriptive method is commonly used in qualitative research to provide a detailed account of phenomena under study. The researcher utilized two data collection methods: one-on-one semi-structured interviews and a focus group. A qualitative approach was selected to "uncover participants' understandings of their experiences" and is particularly useful in an educational context [6].

Site

The study site is a private four-year university in the mid-Atlantic region that focuses on technology education. The School of Engineering at the university has nearly 200 faculty members, of which 20% are female. The School of Engineering offers nine departments and 11 engineering programs, and it is committed to providing a multidisciplinary, design-based education that prepares the next generation of technology leaders. It is important to note that this university is not part of the KEEN network of schools.

Population

Three engineering faculty members with similar teaching experience from the site's Mechanical Engineering department participated in the study. The researcher has previous working relationships with the invited participants, and these same three faculty members participated in the focus group.

Research Methods

The researcher performed three in-depth, semi-structured one-on-one interviews, each 30 minutes, to obtain a detailed description of the faculty's perception of professional skills and how they are incorporated into their courses. These interviews were conducted via Zoom and were scheduled at convenient dates and times for the participants. The researcher followed a semi-structured protocol to encourage dialogue and allow flexibility in the conversation. The initial questions focused on the participant's opinions on the importance of professional skill development, and additional questions focused on opportunities for professional development. Interview participants were selected as instructors with at least five years of experience in courses with professional skills associated with the course learning outcomes. After completing the semi-structured interviews, the researcher held a 45-minute focus group with the same three participants for "data validation and refinement purposes" [7]. The researcher disseminated early information on themes and categories and requested feedback on the findings using the same participants.

Invitation and Consent

This work was part of a qualitative research methods class and received approval from an instructor before starting the study; it did not go through formal IRB approval. After receiving approval for the Pilot Study, the researcher emailed three targeted participants. The researcher emailed prospective candidates using the "Invitation to Participate in a Pilot Study" document provided in Appendix A. This email explained the research study and requested a one-to-one 30-minute interview and a 45-minute focus group. The participants were also requested to provide information such as sample assignments or course syllabi to supplement the interviews and focus group data collection if needed.

Stages of Data Collection

The researcher recorded each interview and the focus group using Zoom's built-in recording capability and recorded the audio using her cell phone. The researcher saved the recordings on her hard drive computer, not the cloud, to ensure privacy. Names and identifiers were removed, and initials were used instead on the recorded file names to maintain confidentiality for the participants.

The first round of data collection was through one-on-one semi-structured interviews using the attached protocol in Appendix B. These questions allowed for open-ended responses, and sub-questions prompted discussions if specific topics were not mentioned. The questions started with background information about professional skills required by ABET and their importance. Then, the researcher asked the participants to describe the challenges of providing students with opportunities to improve their professional skill development. The participants were asked to give examples of opportunities for professional skill development in their coursework. In the focus group, the researcher compared "one segment of data with another to determine similarities and differences" with the individual interviews [6].

The focus group took place after the one-on-one interviews. The researcher used the focus group to get feedback on the previous data collection and presented some summary data and early themes. The focus group protocol document is in Appendix C.

Ethical Considerations

In this qualitative study, privacy issues for the interview subjects were paramount. Therefore, the researcher used no names in the data, analysis, or final report. However, it may be possible to deduce who participated in the interviews based on the courses and demographics of the interview participants. However, the researcher has done everything possible to secure and protect the identity of the participants.

The researcher received appropriate approval for this pilot study through a Qualitative Methods class in an Ed.D program with a supervising professor. Permission was secured for all interview participants through written and verbal informed consent to participate in the interview phase, as seen in Appendix D. It was clarified that any involvement in the interview and follow-up focus group was voluntary, and a participant may withdraw from participating in either phase of the study. The participants were advised that the data would remain confidential with no personal identifiers, such as personal names, etc. The researcher secured all printed data in a locked filing cabinet and all digital files in a protected password folder on her personal computer.

Findings

Three engineering associate teaching professors agreed to participate in the semi-structured interview and focus group pilot study. These participants will be referenced by the following initials: AB, CD, and EF. These participants are all at the same rank and in the mechanical engineering department. They all have similar teaching experience and have taught design courses and capstone design. This information is summarized in Table I below:

TABLE I
PARTICIPANT OVERVIEW

	Participant 1	**Participant 2**	**Participant 3**
Pseudonym	AB	CD	EF
Scheduled Date and Time of Interview	11/23/2021 3:30 p.m. - 4:00 p.m.	11/30/2021 12:30 p.m.-1:00 p.m.	12/2/2021 12:00 p.m. - 12:30 p.m.
Scheduled Date and Time of Focus Group	12/7/2021 3:15 p.m. - 4:00 p.m.	12/7/2021 3:15 p.m. - 4:00 p.m.	12/7/2021 3:15 p.m. - 4:00 p.m.
Department	Mechanical Engineering	Mechanical Engineering	Mechanical Engineering
Rank	Teaching Associate Professor	Teaching Associate Professor	Teaching Associate Professor
Sex	Male	Female	Male
Degree (year earned)	PhD	PhD	PhD
Experience at Stevens	7 years	7 years	9 Years
Total Experience	7 years	11 Years	10 Years

Research Focus	Engineering Education, Combustion Science	Engineering Pedagogy, Increasing Diversity, Biomechanics	Control Systems, Robotics, Mechatronics, Automation
Courses Taught	Design, Thermodynamics, Statics, Automotive Engineering	Design, Engineering Graphics, Statics, Dynamics	Design, Dynamics, Control Systems, Mechatronics/Robotics

The researcher transcribed all interviews using Microsoft Office dictation software, ensuring accuracy by cross-referencing with Zoom recordings to capture contextual gestures and noises. The transcripts were reviewed for first-cycle coding. When approaching the transcripts, the researcher implemented three coding methods. The first was structural coding based on the research questions; using structural codes for question-based coding is particularly useful in semi-structured interview data collection methods [8, p. 130]. The researcher used in vivo coding to grab the engineering professors' vernacular and aid in developing theory around professional skill development [8, p. 138]. The third method was descriptive coding to capture descriptions of professional skills and development opportunities. The researcher used descriptive and in vivo coding to help ensure the participants' narratives were not lost [8, p. 134]. The researcher followed a consistent format utilizing Microsoft Word's note feature throughout the documents.

After finishing, the researcher listed all the resulting codes in an Excel document; there were 267 codes. All codes, including duplicates, were put in a website-based word cloud generator called MonkeyLearn. The website used the top 50 words to create a word cloud. The interviewees seemed more comfortable with the terminology "soft skills" rather than professional skills. This is also evidenced in the word cloud, as seen in Fig. 1. Other top keywords from the word cloud were soft skills (terminology of engineering faculty), cultural agility, 21st-century skills, Professional Skills, and then curriculum flaws.

Fig. 1. World cloud of first cycle codes.

To develop themes, the researcher then organized the codes into columns in Excel with temporary categories. Codes were placed in these initial categories, and sub-categories and new categories emerged. Then all categories were grouped into three main themes: “curriculum”, “skills and mindsets”, and “courses.” The themes are represented below in the gray boxes in Figure 2. The blue boxes represent the categories, and the green boxes represent sub-categories.

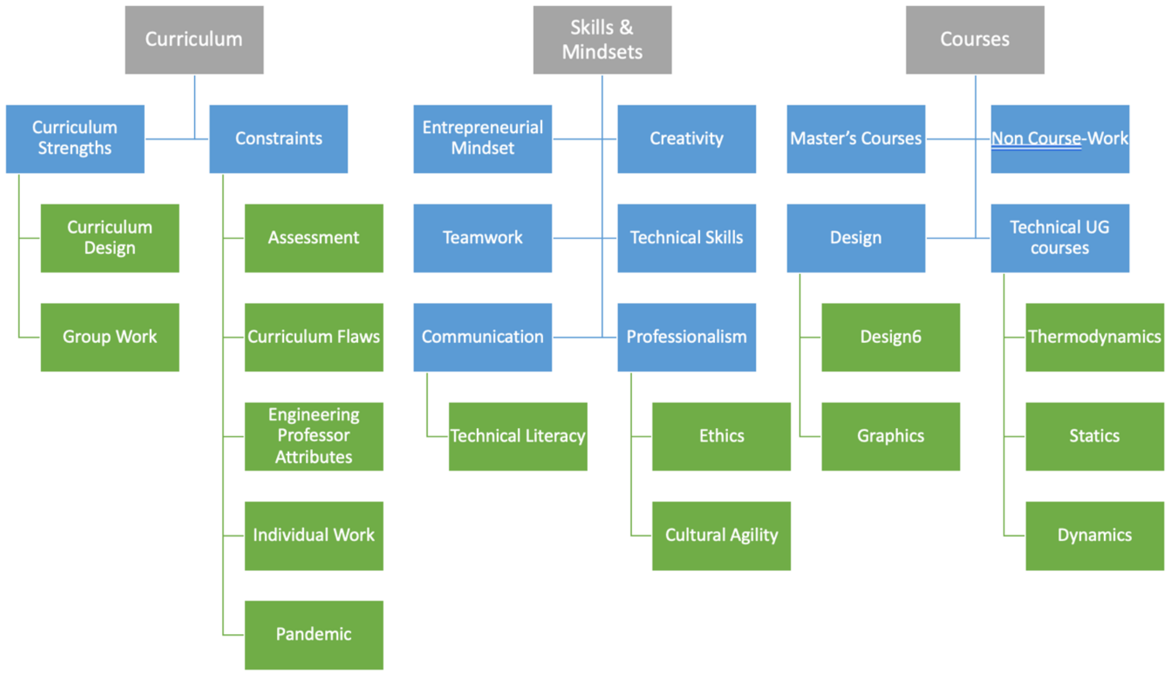

Fig. 2. Themes and categories of codes

Skills and Mindsets

The first few interview questions focused on familiarity with ABET professional skills and the importance of each skill. The subsequent questions were about other professional skills needed for engineering graduates and, lastly, if any 21st-century skills came to mind that would be useful for engineering graduates. The interview participants preferred "soft skills" rather than professional skills. The researcher prepared Table II, which indicates how faculty members would classify each skill.

TABLE II
ENGINEERING FACULTY DEFINITIONS OF PROFESSIONAL SKILLS

	ABET	Soft Skills	21st-century
Communication	X	X	X
Life-Long learning	X	X	X
Teamwork / Leadership	X	X	X
Professionalism	X	X	
Adaptability			X
Creativity*			X
Critical Thinking		X	X
Ethics		X	
Feedback & Criticism		X	X

Life Skills		X	X
Listening Skills		X	
Logic		X	X
Portable Skills		X	X
Cultural Agility*		X	
Entrepreneurial mindset*			

All three faculty mentioned communication, teamwork, and life-long learning. Equally important was that none of the faculty mentioned entrepreneurial mindset and cultural agility as professional skills. One participant later clarified that when speaking about professionalism, she was referring to aspects of cultural agility. Later in the conversation, when the topics of cultural agility and entrepreneurial mindset were introduced with semi-structured questions, the participants were familiar with those topics. However, it did not come to mind when talking about ABET professional skills, soft skills, or 21st-century skills.

While the researcher allowed the conversation to flow on all types of professional skills, the researcher was particularly interested in the interview participants' views on three identified skills not mandated by ABET, including cultural agility, creativity, and entrepreneurial mindset.

Cultural agility was a particularly lengthy conversation with each participant and again in the focus group and accounted for over 10% of the codes. The main topic of discussion was understanding how an engineering professor would define and measure cultural agility. A participant noted, "If we can't agree on how to define it, there's no way we can assess it." Other descriptions of cultural agility in the engineering faculty voices include "(understanding) different ways of doing things," "acting professionally," "mutual respect," and "working with other people." The participants also noted that many other skills are embedded in cultural agility, including communication, teamwork, professionalism, problem-solving, and work ethic. Table II indicates that participants did not explicitly mention cultural agility when embedding professional skills into existing courses.

In the sub-theme of creativity, all three participants mentioned that "Creativity was embedded in design" and that creativity is the same as problem-solving. They noted that many engineering students may not see themselves as creative due to the "social stigma of creativity" and that creativity is only "associated with the arts." The participants identified that students might need a broader definition of creativity.

Theme Courses

The interview questions focused on how faculty can embed professional skill development opportunities into existing courses. The researcher separated these courses into two categories, design courses, and technical courses, and categorized where faculty felt these skills were a good fit. The results can be seen in Table III. One of the participants mentioned that design courses have a more "natural fit" for professional skill development than technical courses. In Table III, if a skill is marked with a Y, it was specifically mentioned as an opportunity to work on a specific professional skill. If it was marked with an N, it was noted that it was not a good opportunity to embed professional skill development. If the table is blank, it means it was not mentioned at all in discussing current professional skill development opportunities.

TABLE III
PROFESSIONAL SKILLS ASSOCIATED WITH UNDERGRADUATE COURSES

	Design Courses	Technical Courses UG
Communication	Y	N
Creativity	Y	Y
Ethics	Y	
Feedback & Criticism	Y	
Professionalism	Y	
Teamwork / Leadership	Y	N
Life-long learning		Y
Adaptability		
Critical Thinking		
Cultural Agility*		
Entrepreneurial mindset*	N	
Life Skills		
Listening Skills		
Logic		Y
Portable Skills		

As indicated in Table III, the participants felt there was room for students to develop creativity in design and technical courses. However, it was mentioned that they were not cultivating an entrepreneurial mindset in design courses, as indicated in Table III. The engineering faculty indicated they were unfamiliar with entrepreneurial mindset. AB noted, “I don’t know a lot about it,” and CD noted that entrepreneurial mindset was “not something I gained (in my education).” They indicated that they felt it was a mindset, not a skill, but thought it was easier to measure than cultural competency.

Once again, Table III revealed that cultural agility was not addressed in either design or technical classes. Numerous skills essential for both disciplines were overlooked. Although faculty recognized these skills' significance, they faced limitations in integrating them into their teaching.

Theme Curriculum

The “curriculum” theme combines both positive and negative forces that act within the curriculum, affecting the opportunities for professional skills development. These forces are illustrated in Fig. 3.

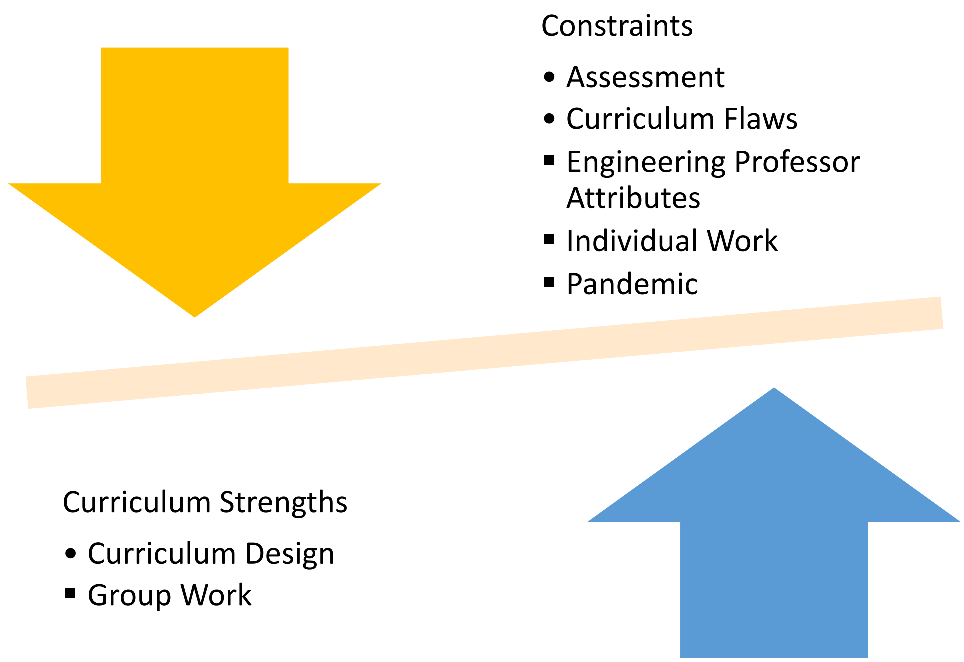

Fig. 3: Curriculum Theme

Some of the strengths of the curriculum, which include group work and curriculum design, are counterbalanced by constraints including assessments, curriculum flaws, engineering professor attributes, individual work and the pandemic. One participant noted that professional skills were “outside of their comfort zone” and that engineering curricula are “heavily weighted towards the technical.”

One of the main curriculum flaws noted by the research participants included the assessment of professional skills. One participant commented, “Technical (assessment) is easier,” and another noted, “You can tell why we all become engineers.” They indicated that soft skills assessment is “subjective” and “less verifiable.” There was doubt surrounding the efficacy of teaching professional skills and skill transference, with a participant asking, “Does teaching ethics work?” and is there “meaningful evidence of results.”

Results and Interpretation

Result One: Engineering faculty are more familiar with ABET Student Outcomes containing professional skills than other professional skills not mandated by ABET.

It was very clear that the faculty have the most familiarity with the ABET professional skills, and these skills have found their way into design and some technical classes. ABET is the leading accreditation body for engineering programs, and universities must accredit each one of their engineering programs every five years through a self-study report that focuses on many criteria, including the assessment of student outcomes known as Criteria 3 [9]. The site went through its most recent ABET review in 2021. Many faculty members are involved with student learning outcomes in their courses and contribute to the ABET self-study report.

The student outcomes were recently shifted to what students learn instead of what is taught for the 2019-2020 cycle [10]. This resulted from years of working with stakeholders, developing a task force, and a comprehensive literature review looking at the desired attributes of engineering graduates [11]. The original 11 criteria were reduced to 7 and are shown side-by-side here in Table IV reprinted from ABET to show the recent changes in student outcomes.

TABLE IV
CHANGES IN CRITERION 3 – STUDENT OUTCOMES

Current Language **EAC Criteria effective 2017-18 and 2018-19 Cycles**	**New Language** **Approved by the EAD October 20, 2017** **Applicable beginning in the 2019-20 cycle**
Criterion 3. Student Outcomes The program must have documented student outcomes that prepare graduates to attain the program educational objectives. Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.	**Criterion 3. Student Outcomes** The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.
(a) an ability to apply knowledge of mathematics, science, and engineering (e) an ability to identify, formulate, and solve engineering problems	1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	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
(d) an ability to function on multidisciplinary teams	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
(f) an understanding of professional and ethical responsibility (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (j) a knowledge of contemporary issues	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
(g) an ability to communicate effectively	3. an ability to communicate effectively with a range of audiences
(i) a recognition of the need for, and an ability to engage in life-long learning	7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Implied in 1, 2, and 6

The engineering faculty most often use the former names rather than the new names, as they were embedded in the university's assessment system. A few specifically mentioned “life-long learning,” which is (i) from pre-2019, rather than (7) from the newest language, which describes an “ability to acquire and apply new knowledge as needed using appropriate learning strategies.”

When looking at Tables II and III, it is clear the faculty were familiar with the four ABET professional skills, communication, professional responsibility, professional growth, and collaboration, and were able to embed these skills mostly in their design courses and some in their technical courses. Group work was seen as a curriculum strength by all the participants, and this is directly related to the ABET collaboration professional development skill.

Result Two: Engineering faculty feel it is important to embed professional skills in their courses, but feel it is easier in Design Courses rather than Technical Courses.

All three engineering faculty noted they thought professional skills were important for students to obtain. AB emphasized:

> But I think we also need to take advantage of the university experience and these other things that we can add that folks wouldn't get from just reading a textbook, right? So, I do think some of my job is teaching some of those other skills, right, which I think is sometimes even more important and then I'm gonna use one of your terms. I think you just have to be creative with how you do it right (laughs). Like, you don't just have to set homework; you can set the homework that could be in the form of a presentation. Or it could be in the form of some activity that forces the students to exercise some of these skills.

When looking at Table III, the data suggest that design courses offer more opportunities to embed professional skills than technical courses. The interview participants indicated that professional skills are a more "natural fit" in design courses. CD emphasizes, "Well, some of them are easier to incorporate than others. So, for the design courses or project work courses, those easily encompass teamwork, leadership, and creativity." This is supported by research that suggests that problem-based learning, which is used in design courses, allows for simultaneous professional and technical skill development [12]. One of the participants noted how coupled the skills can be together and hard to assess them separately. EF added:

> So I think that those (communication) are some of the more important soft skills that are a little bit difficult to assess. And I find that they're difficult to assess because they're difficult to decouple from the technical content. Meaning if someone is going to do a great job presenting awful technical work, it's very difficult to decouple how well they are presenting versus how good is the quality of the technical work.

This supports a shift in the literature that suggests a more integrated skills development and advocates for programs to adopt problem-based learning pedagogy with professional skill integration [12]. It is important to note that the participants specifically noted the difficulty of including professional skills in technical classes. CD noted:

> This one (Statics) is also highly technical, it's similar to dynamics in that sense and we try to incorporate some of what we call a design challenge in it or design problems. But, I would say that it's still very structured, so I would say that we don't get to do a lot of professional skills in that course. We don't do a very good job putting skills in.

EF continued along the same lines and noted the inflexibility of technical courses' learning outcomes:

> There's really no flexibility in me hitting all the technical content I need to hit it and if I can't do that efficiently, then I'm not doing what I need to do at the end of the day even if I want to bring in something else; it's like something's gotta give. So being efficient, I can't always get as far with the soft skills as I wish I could, but then I can't even assess the soft skills as well as I wish I could.

Result Three: Professional skills assessment is difficult for engineering professors who prefer quantitative assessment measurements.

Engineering faculty indicated that they would prefer to avoid professional skill assessment. Engineering faculty prefer quantitative assessment methodology, which aligns more with technical skills. CD stated:

> First and foremost, how do you assess and secondarily, is the assessment going to really mean anything in the long run? Because oftentimes we find ourselves concocting methods to assess these things, which may not be founded, and it's not because we have ill will, it's just that we aren't aware of an efficient, effective way to make certain assessments. Certain assessments need to be made over extremely long periods of time.

Professional skill development may align more with qualitative assessment or measuring intention or attitudes than actual ability. The engineering faculty didn't have knowledge of student attitudes assessment methods or how the Theory of Planned Behavior (TPB) might be used in assessing professional skill development [13].

Result Four: Engineering faculty feel that cultural agility is an important professional skill; however, it is not currently taught or assessed in the curriculum.

The engineering faculty indicated that cultural agility is important for engineering students but admitted that they do not embed opportunities to develop cultural competency in design or technical courses. AB stated:

> I would say in terms of like the cultural competences. I would imagine at [our university] we do next to nothing, international, at least. You know we do a lot of stuff, with kind of teamwork, communication. We frankly probably try and fail to teach any kind of ethical responsibility.

It is important to note that ABET does not specify cultural competence as a student outcome but does suggest that engineers acquire the ability to consider global and societal factors in their professions. While ABET uses *global* and *societal* words in ABET outcomes 2 and 6, Jesiek et al. [14] argue this is vague and difficult to address and assess. Therefore, engineering programs do not consider cultural agility a stand-alone professional skill needing assessment. In the focus group, there was a conversation about assessing cultural agility, and AB suggested:

> I'm sure there's surveys that measure students' beliefs and things like that. I would be willing to bet there are; that makes some attempt to measure some of these things, beliefs about other cultures, what it's like working with other people, that kind of try to measure students perspectives.

Result Five: Engineering professors think students can develop creativity in design and technical courses.

The interview participants think that students exhibit and learn creativity in their design classes and technical courses. They indicated that “creativity is embedded in design” and related creativity to problem-solving. EF noted:

> Through engineering design, you nurture creativity so that students can explore different ways of solving a problem while still satisfying some technical requirements. So, I would consider that a nurturing of creativity.

I found these results to be contrary to existing literature that suggests that creativity is an overlooked criterion by ABET [15,16] and that engineering students are not developing creativity but lose it during their engineering education [17,18]. Additional researchers suggest that engineering curriculums are at fault and do not adequately address creative thinking [15, 19, 20].

Result Six: Engineering professors are not currently embedding entrepreneurial mindset into their design or technical courses.

In the engineering field, the term “entrepreneurial mindset” is often used to describe the development of entrepreneurship skills without the end goal of creating a new venture [5, 20, 21]. It was clear that engineering professors do not have a background in or embed these opportunities into their courses: CD indicated:

> I want to say it’s (entrepreneurial mindset) important, although I don’t know a lot about it. I think a lot of students are interested in it and I think it’s an important skill but it’s not something that I had when I was a student and it’s not something that I really gained (laughs) during my career in academia.

It is important to note there are stand-alone courses in entrepreneurial thinking for engineering students at the site. These courses were developed by the business school, and are mostly taught by adjunct professors that are not part of the engineering school. The engineering faculty are not familiar with the content of these courses, nor are the concepts expanded upon in technical courses. The site is not part of the KEEN network.

Conclusions and Recommendations

Based on the data collected from the interviews and focus group, conclusions have been presented in the context of answers to the three research questions that directed this study.

Research Question 1: How do engineering faculty view professional skill development?

The data suggest that faculty feel most comfortable with the ABET professional skills and think that design courses, or courses with group project work, are best suited for professional skill development. ABET’s dominance over the direction of engineering curricula was evident. The faculty could name all the ABET professional skills quite readily and describe specific examples of coursework and projects that develop communication, professional responsibility, professional growth, and collaboration.

The interview participants described the assessment of professional skills as challenging and indicated they needed to be equipped to assess some areas of professional skill development. They favor assessing technical skills and have even noted it is easier to assess. Assessment is one of the main issues with professional skills, as assessment may require a more qualitative approach, in which quantitative engineering professors are unfamiliar with those methods. Additional limitations within professional skill development include questions of teaching methods' efficacy and skill transference.

Faculty have named several other professional skills, like adaptability and logic, not currently taught or assessed in the engineering curriculum. It leaves room for further research to understand where students develop skills outside their coursework.

Research Question 2: How do engineering faculty provide opportunities for students to develop professional skills, including creativity, entrepreneurial mindset, and cultural competency, throughout the engineering curriculum?

This study reveals that faculty have the most experience embedding the ABET professional skills and creativity into courses but limited expertise in cultural competency or entrepreneurial mindset. Contrary to the existing literature, engineering professors indicated they provide ample opportunities to develop creativity in both design and technical classes. The engineering professors defined creativity as problem-solving and indicated that open-ended design projects provide context for engineering students to develop creativity. The professors remarked that engineering students did not have a good definition of creativity, but it seems that professors also overestimate student’s understanding of creativity. The faculty members did not cite any creativity theories or techniques taught and did not use the term creativity in their syllabi or assess students' creative abilities.

The participants did not feel they could provide opportunities to develop cultural competency or entrepreneurial mindset in the design or technical coursework. This may be due to the crowded curriculum, assessment issues, inflexibility, and other obstacles. There are stand-alone courses in entrepreneurial thinking at the site, but not all researchers agree that stand-alone classes are effective and purport more integrated approaches [12]. Moreover, curricula typically address cultural competency through required humanities courses or optional study abroad experiences rather than embedded with technical content [23].

Recommendations

There are three main recommendations based on this research study. First, professional skills, beyond the ones required by ABET, should be included as learning outcomes of engineering programs, and embedded directly into technical engineering courses. Second, faculty should be provided with assessment instruments and other developmental support to assess professional skills in technical courses. Lastly, the author provides suggestions and ideas on how creativity, entrepreneurial mindset and cultural competency could be included in engineering programs.

In order to ensure students, develop professional skills, they should be part of the student learning outcomes of a program, as programs tend to favor technical learning outcomes. If there is no learning outcome for a professional skill in a curriculum, then it will not be addressed by faculty nor developed by students. Engineering curriculums should adopt creativity, cultural competency, and entrepreneurial mindset as required student attributes for graduation. Once required as learning outcomes, faculty would benefit from training on teaching these professional skills and assessment methodology for professional skills development.

The site has already added acquiring an entrepreneurial as a student learning outcome and teaches entrepreneurial mindset in stand-alone courses. Still, recent research suggests it should be integrated into technical content. It seems dangerous to off-load these important professional skills to be only taught outside of the engineering curriculum in either humanities or other stand-alone courses. A more integrated approach is needed. Engineering programs can consider adding entrepreneurial mindset to the engineering curriculum in two main ways: as required, stand-alone courses [26] or embedded entrepreneurial mindset into existing engineering courses. Several examples have been successful with the latter, and the KEEN organization can help provide funding to make these changes to the curriculum [25-28]. This methodology is more aligned with research by Winberg et al. [12] that calls for the coupling of technical and professional content.

It is recommended that engineering program coordinators introduce alternate assessment theories into the engineering curriculum. Examples include a scale based on the Theory of Planned Behavior [13] to assess student attitudes toward professional skills, including communication, ethical decision-making, cultural adaptability, leadership, teamwork, innovation, and civic and public engagement. The survey aimed to understand students' "attitudes towards professional skills is to predict their intention to master those skills during college and enact them after graduation" [13, p. 1430]. This recent work is focused on helping universities develop curricula that incorporate professional skill development within technical courses and seems particularly useful for engineering educators. Another option might be using the Miville-Guzman Universality-Diversity Scale—Short form (MGUDS-S) to determine their openness to and appreciation of cultural diversity [14].

Students should be taught creativity theories and methodologies in engineering design courses to increase creativity in engineering students. This deeper understanding of creativity can support initiatives with wider implications of graduating more creative individuals to solve society's wicked problems. It should also be included as a student learning outcome.

To increase the development of cultural competency, engineering programs should integrate cultural competency development opportunities into technical courses rather than rely on study abroad or humanities courses. Carberry et al. [24] found that students who participated in service-oriented projects, for example, Engineers without Borders, increased cultural competency. Service-oriented projects might be one way to increase cultural competency. If design courses focused on service-oriented projects with different communities, it could provide opportunities to understand the implications of societal factors and provide a valuable learning experience.

Future Research

Given the importance of this topic, this pilot study is just a starting point, and there are many avenues to continue research around professional skill development. One avenue is to investigate where engineering students are developing professional skills if outside their technical courses and how activities outside the classroom like sports, co-curricular and extra-curricular activities like sports, internships, Greek life and clubs play a role in professional skill development. Student perspective in learning professional skills would be paramount, as nothing will be obtained if they do not understand the value.

Another would be to investigate the theoretical underpinnings regarding the pedagogy and learning of entrepreneurial mindset in engineering, as noted by both Huang-Saad et al. [29] and Miranda et al. [30]. The main curriculum advancements have been developed due to KEEN funding, and Miranda et al. [30] note the framework created by KEEN needed to be better researched and validated. It was pointed out that nonempirical descriptions of programs outweigh empirical research of EM in engineering education [29, p. 263].

Another avenue would be to explore assessments used in professional skill development outside of engineering curriculums and lean into what is already available in social science and education research. One of the interview participants noted that engineering faculty do not have that knowledge and said, "if you're gonna teach and assess these things (professional skills) you're reaching a lot more into social sciences."

Limitations

This research's findings cannot be generalized to any engineering programs at different universities. Nonetheless, the research process of engaging with faculty can offer valuable insights into areas for enhancement and collaboration and raise awareness of curricular initiatives.

The study solely reflects faculty perspectives, given their role as gatekeepers determining syllabus content and classroom focus. However, it's crucial to incorporate industry and student perspectives into discussions on professional skill development. Integrating these viewpoints enriches the conversation and provides a more comprehensive understanding of skill needs and priorities.

Summary

In summary, this qualitative study investigated how creativity, entrepreneurial mindset, and cultural agility, three professional skills not required by ABET, are included in the engineering curricula. The researcher interviewed three engineering faculty in one-on-one interviews and a focus group format as the primary data collection method. The main findings of the research include the engineering faculty's lack of familiarity with non-ABET professional skills, the difficulty of making changes in technical classes, and the limitations in assessing professional skills. The researcher hopes this pilot study encourages engineering faculty to provide opportunities for development in creativity, entrepreneurial mindset, and cultural agility in technical courses. The researcher hopes that recommendations generated from this pilot study will draw attention to professional skill development in the engineering curriculum and encourage more research on enhancing the engineering curriculum to focus on these crucial skills.

Works Cited

[1] D. H. Pink, "Revenge of the right brain," *Public Management*, vol. 89, no. 6, pp. 10–14, Jul. 2007.

[2] J. Aoun, *Robot-Proof: Higher Education in the Age of Artificial Intelligence*. Cambridge, Massachusetts: The MIT Press, 2017.

[3] F.R. Channa, F. Bugti and P. S. Sarhandi, and H. Pathan. "Harnessing artificial intelligence in education for preparing learners for the 21st century," *Elementary Education Online*, 2021.

[4] J. Voogt and N. Roblin, "A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies," *Journal of Curriculum Studies*, vol. 44, no. 3, pp. 299–321, Jun. 2012, doi: 10.1080/00220272.2012.668938.

[5] "Entrepreneurial Mindset | Engineering Unleashed." [Online]. Available: https://engineeringunleashed.com/mindset. Accessed: Feb. 28, 2023.

[6] S.B., Merriam and E. J. Tisdell, *Qualitative Research: A Guide to Design and Implementation (4th ed.)*. San Francisco, CA: Jossey Bass, 2016.

[7] J. W. Creswell and T.C. Guetterman, *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*, 6th edition. Saddle River, NJ: Pearson, 2019.

[8] J. Saldaña, J. *The Coding Manual for Qualitative Researchers* (4^{th} ed.). Thousand Oaks, CA: Sage Publications, 2021.

[9] G. L. Heileman and C. T. Abdallah, "ABET won't let us do that!," *Change*, vol. 51, no. 3, pp. 62–66, Jun. 2019, doi: 10.1080/00091383.2019.1606613.

[10] A. C. Estes, P. A. Brady, and P. Laursen, "Adjusting to the new ABET criteria 3 and 5: It's really not very hard," presented at the 2018 ASEE Annual Conference & Exposition, Jun. 2018. Accessed: Apr. 22, 2021. [Online]. Available: https://peer.asee.org/adjusting-to-the-new-abet-criteria-3-and-5-it-s-really-not-very-hard

[11] "Rationale for Revising Criteria 3 and 5 | ABET." [Online]. Available:https://www.abet.org/rationale-for-revising-criteria-3-and-5/. Accessed: Apr. 22, 2021.

[12] C. Winberg *et al.*, "Developing employability in engineering education: A systematic review of the literature," *European Journal of Engineering Education*, vol. 45, no. 2, pp. 165–180, Mar. 2020, doi: 10.1080/03043797.2018.1534086.

[13] Z. S. Byrne, J. W. Weston, and K. Cave, "Development of a scale for measuring students' attitudes towards learning professional (i.e., soft) skills," *Research in Science Education*, vol. 50, no. 4, pp. 1417–1433, Aug. 2020, doi: 10.1007/s11165-018-9738-3.

[14] B. K. Jesiek, Y. Shen, and Y. Haller, "Cross-cultural competence: A comparative assessment of engineering students," *International Journal of Engineering Education*, vol. 28, no. 1, pp. 144-155, Jan. 2012.

[15] D. H. Cropley, "Promoting creativity and innovation in engineering education," *Psychology of Aesthetics, Creativity, and the Arts*, vol. 9, no. 2, pp. 161–171, May 2015, doi: 10.1037/aca0000008.

[16] H. J. Passow and C. H. Passow, "What competencies should undergraduate engineering programs emphasize? A systematic review," *Journal of Engineering Education*, vol. 106, no. 3, pp. 475–526, 2017, doi: https://doi.org/10.1002/jee.20171.

[17] E. Sola, R. Hoekstra, S. Fiore, and P. McCauley, "An investigation of the state of creativity and critical thinking in engineering undergraduates," *Creative Education*, vol. 08, no. 09, Jul. 2017, doi: 10.4236/ce.2017.89105.

[18] S. A. Atwood and J. E. Pretz, "Creativity as a factor in persistence and academic achievement of engineering undergraduates," *Journal of Engineering Education*, vol. 105, no. 4, pp. 540–559, 2016, doi: https://doi.org/10.1002/jee.20130.

[19] A. Valentine, I. Belski, M. Hamilton, and S. Adams, "Creativity in electrical engineering degree programs: Where is the content?," *IEEE Transactions on Education*, vol. 62, no. 4, pp. 288–296, Nov. 2019, doi: 10.1109/TE.2019.2912834.

[20] S. Zappe, I. B. Mena, and T. Litzinger, "Creativity is not a purple dragon," in *Proceedings of the NCIIA's 17th Annual Conference*, 2013, [Online]. Available: /paper/Creativity-is-Not-a-Purple-Dragon-Zappe-Mena/f117548842a8df9c9837f48e7229742240747874 Accessed: Apr. 07, 2021.

[21] S. Celis Guzman, "How intellectual movements among external and internal actors shape the college curriculum: The case of entrepreneurship education in engineering," PhD dissertation, Dept. Higher Education, Univ. of Michigan, Ann Arbor, MI, Jan. 2015.

[22] P. Shekhar and A. Huang-Saad, "Examining engineering students' participation in entrepreneurship education programs: implications for practice," *International Journal of STEM Education*, vol. 8, Jun. 2021, doi: 10.1186/s40594-021-00298-9.

[23] R. Scupin, "The concept of culture and higher education: An anthropological perspective" in *Cultural Awareness and Competency Development in Higher Education*, L. Leavitt, S. Wisdom, and K. Leavitt, Eds., Hershey, PA: IGI Global, 2017. doi: 10.4018/978-1-52 25-2145-7.ch001.

[24] A. R. Carberry, H.-S. Lee, and C. W. Swan, “Student perceptions of engineering service experiences as a source of learning technical and professional skills,” *International Journal for Service Learning in Engineering*, vol. 8, no. 1, p. 1, Spring 2013.

[25] R. S. Harichandran, M.-I. Carnasciali, N. O. Erdil, C. Q. Li, J. Nocito-Gobel, and S. D. Daniels, “Developing entrepreneurial thinking in engineering students by utilizing integrated online modules,” presented at the 2015 ASEE Annual Conference & Exposition, Jun. 2015, pp.

[26] N. O. Erdil, R. S. Harichandran, J. Nocito-Gobel, C. Q. Li, and M.-I. Carnasciali, “Impact of integrated e-learning modules in developing an entrepreneurial mindset based on deployment at 25 institutions,” presented at the 2017 ASEE Annual Conference & Exposition, Jun. 2017.

[27] A. Huang-Saad, C. Bodnar, and A. Carberry, “Examining current practice in engineering entrepreneurship education,” *Entrepreneurship Education and Pedagogy*, vol. 3, no. 1, pp. 4–13, Jan. 2020, doi: 10.1177/2515127419890828.

[28] J. Blake Hylton, D. Mikesell, J.-D. Yoder, and H. LeBlanc, “Working to instill the entrepreneurial mindset across the curriculum,” *Entrepreneurship Education and Pedagogy*, vol. 3, no. 1, pp. 86–106, Jan. 2020, doi: 10.1177/2515127419870266.

[29] A. Y. Huang-Saad, C. S. Morton, and J. C. Libarkin, “Entrepreneurship assessment in higher education: A research review for engineering education researchers,” *Journal of Engineering Education*, vol. 107, no. 2, pp. 263–290, 2018, doi: 10.1002/jee.20197.

[30] C. Miranda, J. Goñi, B. Berhane, and A. Carberry, “Seven challenges in conceptualizing and assessing entrepreneurial skills or mindsets in engineering entrepreneurship education,” *Education Sciences*, vol. 10, no. 11, Nov. 2020, doi: 10.3390/educsci10110309.

Appendix A

Invitation to Participate in a Pilot Study

November Date, 2021

Dear NAME.

I am writing to invite you to participate in a pilot that I am conducting on professional skill development within engineering education. The purpose of this study is to explore how professional skills, like creativity, entrepreneurial mindset and cultural agility are development within technical courses. This pilot study is being conducted as a requirement for a course on qualitative research taught by XX.

If you agree to participate, you will participate in a one-on-one interview lasting approximately 30 minutes and a follow-up focus group lasting approximately 45 minutes during the last two weeks of November. I may request access to course syllabi or other course assignments to supplement the interview and focus group data collection. For purpose of data collection, I ask that I be permitted to record the interview and take handwritten notes through the process. The recordings and interview transcripts will only be reviewed only by myself and the course instructor, and then only for purposes of identifying key themes, findings, and results. Participation in this study is completely voluntary, all participants will remain anonymous and will be identified only by pseudonym.

If you are available to participate, I can be reached at ZZ or by email at Email.com If you have questions, I am available to provide more information.

Thank you for your time. I look forward to your response.

Best regards,

Doctoral Student
Drexel University School of Education

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Appendix B

Semi-Structured Interview Protocol

Understanding how engineering faculty provide engineering students opportunities to develop professional skills in technical courses

Time of Interview:

Date:

Place:

Interviewer: XX

Participant:

Questions (list below):

- How familiar are you with Professional Skills required by ABET?
- Do you feel these professional skills are important? Which ones?
- Are there other professional skills that are important for engineering students in the 21^{st} Century?
- How would you define creativity?
    - Is creativity an essential professional skill?
- How would you define Entrepreneurial Mindset
    - Is entrepreneurial mindset a crucial professional skill?
- How would you define Cultural Agility?
    - Is cultural agility a critical professional skill?
- How are you able to provide professional skill development in your course, for any of the ABET or additional 21st-century Skills identified?
- What are the challenges associated with providing opportunities for development of professional skills?

Appendix C

Focus Group Protocol

Understanding how engineering faculty provide engineering students opportunities to develop professional skills in technical courses

Time of Focus Group:
Date:
Place:
Interviewer: XX
Focus Group Participants:

Questions (list below):

- After listening to the summary of the one-on-one interviews, is there anything that I presented that doesn't sound accurate?
- After listening to the summary of the one-on-one interviews is there anything you would like to go into deeper detail or to ask the other focus group participants.
- After our conversation, did anything come up that you wished you would have mentioned in our interview?
- Is there anything I missed in our one-on-one interviews that you may want to elaborate upon in the focus group?

Appendix D

Consent to Take Part in a Pilot Research Study

To be reviewed with the participant prior to commencing the interview or focus group. Verbal consent is to be obtained.

1. Title of pilot research study: Understanding how engineering faculty provide engineering students opportunities to develop professional skills in technical courses.

2. Pilot Study Researcher: XX

3. Why you are being invited to take part in a research study

You are invited to take part in a pilot research study. Your participation will deepen the researcher's understanding of his/her proposed dissertation topic through the lens of qualitative interviewing.

4. What you should know about this pilot study

- Whether or not you take part is up to you.
- You can choose not to take part.
- If you decide to not be a part of this research no one will hold it against you.
- Feel free to ask all the questions you want before you decide.

5. How many people will be studied?

Three to four people will participate in one-to-one interviews and together in a focus group.

6. What happens if I say yes, I want to be in this research?

If you agree to participate in this pilot study, you will participate in both a 30-minute semi-structured interview and a 45-minute focus group. The interviews and focus group will be scheduled between (Nov 15 and Nov 30). Interviews and the focus group will be planned at convenient times and will be performed on Zoom. Interviews and focus groups will be recorded using Zooms recording capabilities to the researcher's hard drive. You may also be asked to share documents and artifacts related to the study, including course syllabi and sample assignments. All artifacts and documents you provide will be photographed, and the originals returned to you.

7. Is there any way being in this study could be bad for me?

There are no known risks to participating in this pilot study.

8. Will being in this study help me in any way?

There are no benefits to you from your taking part in this research. Furthermore, beyond the researcher's learning through an applied experience, there are no known benefits to others from your taking part in this research.

9. What happens to the information collected?

Efforts will be made to limit access to your personal information. Your name and other identifying information is confidential; you will only be identified by a pseudonym.

10. What else do I need to know?

A Drexel University student is doing this research study for a qualitative research class.