Assessing the Effectiveness of a Professional Formation in Engineering Course Sequence within the Electrical Engineering Department via Student's Readiness for Industrial Jobs: An Undergraduate Researcher's Investigation in a PAR Project

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Abstract

Preparing "world-ready" engineers [1] and facilitating the migration of undergraduate learners from an academic setting to a job environment in industries and elsewhere demands a blend of professional and technical competencies. For example, Mcgunagle et al. [2] list the five most critical professional competencies that are ranked by companies: teamwork, self-motivation, communication, problem-solving, and being anticipatory. Industry-centered studies over the last two decades show fresh graduates have limited workplace and interpersonal skills [3]. This scenario is associated in the literature with the shortage of dedicated engineering courses to incorporate these relevant blends of competencies into students' coursework.

In this study, we explore the efficacy of a sequence of coursework and activities designed by the University of South Florida's Department of Electrical Engineering to support students' professional proficiency and technical skills development. Undergraduate students participated in a series of Professional Formation of Engineers (PFE) courses and technical courses within specialized tracks designed by the department. A sample of students who had taken the PFE courses and the technical tracks were interviewed. Interviewed students are juniors and seniors who are taking upper-level technical courses within track concentration, such as nano/ micro scale, communication systems, and wireless systems. Additionally, an alumnus who had taken the courses was also interviewed with the aim of investigating the relevance of knowledge and skills obtained from the courses to industry jobs.

This work-in-progress research is part of a larger Participatory Action Research (PAR) project aimed at understanding the role and efficacy of the RED program activities designed for and by the undergraduate students themselves. The lead author, an undergraduate EE student, uses his perspective to research and inform change within the RED program.

Preliminary analysis shows that the PFE class series helps students obtain skills, especially professional proficiency, that are hard to get outside of this class series by directly incorporating assignments and encouraging students to participate in career development activities. Notably, the skills students develop during the courses are selectively chosen and endorsed by the course designer through the department's industry board.

Introduction

The industry needs and jobs related to Electrical Engineering are expanding faster at 5% than the average job growth rate of 3% [4], which expects more than 300,000 jobs to be created by 2032.

In addition, due to many complicated social fluctuations, such as the COVID-19 pandemic that encourages a nearly $80 billion investment in the semiconductor industry [5], it is expected that Electrical Engineers will be in great demand in the near future in the US.

In light of the promising job outlook for Electrical Engineers and years of well-documented engineering educational research, it is crucial to recognize that unquestionably, apart from technical knowledge, professional competencies such as communication, teamwork, and project management are necessary to work in this industry. However, it is reported that the gap between technical skills and workplace skills continued to widen, partly because of the misalignment in the perception of needed skills between employers and curriculum designers [6]. Moreover, the ultimate goal of college education is to prepare students with the necessary skill sets to be self-reliant and ready for real-world and industry challenges. Therefore, extensive solutions to bridging this gap are vital to creating a holistic engineering curriculum in which students can effectively acquire the skills that the industry demands.

Professional Formation in Engineering (PFE) Courses

Acknowledging these necessities, the Department of Electrical Engineering at the University of South Florida designed a series of three courses called Professional Formation in Engineering (PFE), 1 credit hour each, to support students in learning and integrating professional competencies and efficiently achieving their personal goals. These courses are designed sequentially, so elements from PFE 1 will follow with the students through PFE 3, where the industry scenario is simulated and implemented. These courses also integrate different methods to incentivize students to improve professional competencies on their own through the help of qualification plans and peer feedback. For example, the courses provide opportunities for students to engage with local companies, encouraging connections and facilitating visits to their premises for face-to-face interaction with employers. Additionally, research lab visits are planned for students to gain insight into the academic side and provide potential opportunities for them to participate as undergraduate research students.

The Qualification Plan (QP; a key activity and assignment) in PFE courses is integral to preparing engineering students for their future careers. Central to this plan is students' need to proactively strategize and map out the engineering activities required to achieve their academic and professional objectives. Incorporated into an app interface, this plan leverages insights from previous successful students who have secured internships or jobs in their respective fields. By drawing from these real-world examples, current students can craft their own personalized paths, tailoring them to their unique aspirations and circumstances. The activities within the qualification plan are ranked according to their difficulty level, from which students must spread their chosen activities across a spectrum from more straightforward tasks to more challenging ones. Combined with the technical track advisory board, which consists of representatives from industry, students, and faculty of each track in the department, the overall structure hopes to

benefit the students in an unprecedented way that revolutionizes how and what skills the Electrical Engineering curriculum can teach and offer to the students.

Purpose and Author Team

The first author initiated this research as an electrical engineering undergraduate student, intending to know how PFE and the technical tracks combined support learners to prepare for industry requirements. The study described in this article is part of a larger Participatory Action Research (PAR) project at the Department of Electrical Engineering that engages students as researchers to understand departmental transformations and their impacts. The first author is an undergraduate researcher, the second author is an engineering education scholar and the PAR mentor in this study, and the third author is the principal investigator of the larger study. By actively experiencing what they also researched, the first author used the participation to ask questions relevant to the student community. With that in mind, this research was designed to address the need to assess the effectiveness of the PFE courses in achieving its goals of equipping students with professional and problem-solving competencies. We present this work-in-progress study by qualitatively investigating the experiences of current EE students and alumni who are within the industry.

Literature Review

Professional competencies are essential for the success of engineers, influencing career persistence, employability, and early career experiences. Professional skills, as emphasized by the Accreditation Board for Engineering and Technology (ABET) board [7], highlight that teamwork on multi-disciplinary teams, comprehension of ethical responsibility, and effective communication are some of the key professional skills that the engineering curriculum should integrate. In other words, the engineering curriculum should meet the goals of cultivating holistic skills that are beyond the foundational technical knowledge.

In the context of successful engineering practice, a list of 38 competencies has been identified, including those related to the behavior of engineers and the skills and attributes important for successful job performance [8]. Additionally, self-efficacy in subject matter expertise and career fitness have been crucial for engagement and achievement in engineering majors and the engineering workforce [9]. The significance of professional competence as a critical factor in improving the quality of future engineer training has been underscored widely [10]. Studies have also noted the integration and achievement of specific professional competencies. For example, fostering teamwork skills in engineering design education has been identified as essential to developing social competencies in professional engineering [11]. Furthermore, an interdisciplinary competence profile for AI in engineering has been proposed, emphasizing the need for skilled, methodical, social, and self-competencies in future roles of AI in engineering [12].

There are many college courses and research on incorporating methodologies into a technical class to help students develop professional competencies. [13] examines active learning (AL) –a teaching methodology- in Math courses to enhance leadership skills, working under pressure, and solving conflicts. In the context of electrical engineering education, integrating professional competencies is crucial for preparing graduates for industry demands. Langie and Craps [14] emphasized the importance of selecting professional competencies based on professional roles and the adaptive level of these competencies, which are key elements of the new engineering curriculum. This highlights the need for a curriculum that provides students with solid fundamental knowledge and teaches them how to learn while fostering professional competencies. In addition, [15] investigates problem-based learning (PBL) integration into engineering education. PBL is suggested as a proficient approach to ready upcoming engineers, blending technical competencies with advanced cognitive abilities and professional qualities. Introducing pedagogical advancements such as PBL may disrupt existing practices for instructors and learners. The authors analyze the conflicting factors and motivations linked with PBL in engineering education, providing recommendations for harmonizing the two. We note that the design of the PFE courses and technical tracks were built on the solid foundations of this literature, and by highlighting some of them here, we position our research also from these existing understandings.

Course Description

The PFE series is divided into three 1-credit courses recommended for students to start enrolling in their sophomore year. The objective is to broaden students' skill sets in terms of creating great designs, products, and solutions to solve complex engineering problems and meet social needs.

The first course is an introductory class for students on ethical engineering practices and user-based product design. Departing from the conventional emphasis on technical knowledge in most engineering classes, the activities include finding the answers to campus's problems based on stakeholders' feedback (which are peer students, faculty, or university administrators). Tasks entail researching existing patents and delivering presentations outlining their selected solutions. The culminating projects entail a simulated "senate hearing," wherein students deliberate upon issues pertaining to engineering ethics within the context of hypothetical engineering endeavors.

The subsequent course is built upon the patents selected by the students in the preceding class. The course schedule is structured to include online and in-person classroom sessions alternately. Students must collaborate during the online session to create business models or canvases for the patent's products. Emphasis is placed on creating customer-centric aspects of the product, elucidating how these solutions effectively address consumer needs and challenges from their perspective. Meanwhile in class, in-class sessions provide students with opportunities to cultivate and refine professional skills. Leveraging the instructor's practical expertise and facilitated

company-site visits, students engage in hands-on learning experiences to hone their professional competencies.

The final course is designed as the concluding class of the series aimed at preparing students for successful careers in engineering. Students will finalize the business models for the chosen products with customer-centric mindsets. Additionally, focus is directed towards creating personalized career plans, known as Qualification Plans, tailored to individual aspirations and objectives. Integral to the course is incorporating a dedicated app, facilitating the management and tracking of professional development activities. Drawing from a curated list of exemplified activities categorized by difficulty levels, students are tasked with constructing their Qualification Plans and diligently monitoring their progress. Moreover, student-generated data from these activities serves as a point of reference for peers and contributes to the ongoing enhancement of the app's functionality.

Research Question

Berry et al. [16] discussed the industry's dissatisfaction with contemporary electrical engineering curricula, indicating a need for a shift in the educational approach to better align with professional demands. This suggests that integrating professional competencies into the curriculum is essential to address industry needs and ensure the relevance of graduates in the workforce. Therefore, the PFE courses are created to set students apart from normal technical environments and incorporate activities for developing essential skills valued in professional contexts. Given the curriculum currently crafted to address these gaps at the university and department under study, we ask: *How do the PFE courses and technical tracks support students in preparing for the industry?*

Methodology

We used qualitative research methodology in this study to design the research. The sample population for the study included current EE students at the university who are currently enrolled and/or have taken two or more PFE courses and alumni from the department who had taken the PFE and technical track courses. For the former category, the participants were recruited through email disseminated by the department; for the latter category, selective sampling was applied. Faculty mentors in the EE department provided references, and the alumni were contacted via email. The semi-structured interview questions for each group were drafted, amended to the larger study IRB, and used. The protocol is presented in Appendix A.

Six students and one alumnus who met the criteria for sampling were recruited. Both categories of participants were interviewed after the informed consent process. Semi-structured Interviews (protocols included in Annex A) are the only source of data obtained. Each interview lasted 30-45 minutes and was then transcribed using a third-party AI transcription tool. The transcriptions were then analyzed to extract meaningful patterns and compared to each other between the two

participant groups to realize the differences in the perception and experiences of students in the PFE courses. Following the acquisition of the interviews' transcription, the deductive coding technique was used in the first step of categorizing each response into distinct groups, which are, Experiences linked to PFE courses, Experiences related to technical tracks, Perception of benefits/ perception of skills obtained, Other sources for skills obtained, and PFE activities. These initial categories are obtained based on the theme of the questions combined with the research questions of this paper. During the grouping process, it was also necessary to verify the transcribed data to ensure its accuracy in reflecting the participants' responses and to avoid any errors introduced by the transcription program. Ultimately, the frequency of a specific response within each group is recorded, summarized, and analyzed to obtain the prevailing trend in the participants' answers.

Preliminary Results

The analysis of student interviews so far reveals a consensus among most participants regarding the efficacy of Professional Formation in Engineering (PFE) classes in facilitating the acquisition of professional skills that may be challenging to develop in other educational contexts. Participants uniformly attest to the beneficial nature of their experiences within PFE courses, noting that the unique pedagogy applied in these courses offers knowledge distinct from conventional technical classes. However, while some students acknowledged that projects within PFE courses provide insights into aligning their chosen career trajectory, there appears to be a weak association between PFE and technical classes concerning project content and motivational factors. Specifically, all participants indicated that they had decided on their technical track before enrolling in PFE courses, and the projects undertaken within these courses did not influence their decisions or prompt reconsideration of their chosen paths.

The skills mentioned by students encompass communication, teamwork, presentation, and interpersonal qualities such as customer interviewing and networking. As indicated in Table 1, these skills are predominantly acquired during collaborative group projects wherein students coordinate tasks to maintain progress throughout the course. Participants who secured internships felt prepared for the industry due to their internship experiences. Conversely, those who did not secure internships highlighted the role of PFE courses in augmenting their preparedness for the industry by equipping them with valuable skills.

	Communication	Collaboration/ Teamwork	Presentation skills	Sense of Confidence/ Feelings of preparedness for industry

Number of students who noted as skills obtained during interviews	5	5	3	4

Table 1. Students' perception of skills obtained.

Beyond professional proficiency, most participants perceive PFE courses as catalysts for self-improvement, aiding in their pursuit of ultimate career goals. The Qualification Plan, a tool provided within PFE courses, requires students to organize and plan activities essential for goal attainment. Participants unanimously emphasize the importance of setting and working towards goals, citing the Qualification Plan as instrumental in shaping their career aspirations. Notably, three students directly attribute their internship success in the summer of 2024 to implementing the Qualification Plan. Additionally, two other students acknowledge the resources provided by PFE courses, which serve to cultivate a mindset conducive to career development beyond traditional classroom settings, emphasizing the importance of profile building, resume enhancement, and internship pursuit.

Discussion and Conclusion

The findings from this Work-In-Progress analysis of student interviews regarding Professional Formation in Engineering (PFE) courses provide valuable insights into the role of such courses in facilitating the development of essential professional skills and preparing students for careers in electrical engineering. These insights prompt reflection and discussion among students, faculty, and program administrators regarding the design and implementation of PFE courses and their integration within the broader curriculum.

Integration of Professional and Technical Education

The unanimous agreement among participants regarding the benefits of PFE courses in acquiring professional skills underscores the importance of integrating professional development with technical education. While traditional technical classes focus primarily on theoretical and technical knowledge, PFE courses offer a distinct pedagogical environment conducive to cultivating communication, teamwork, and networking skills. However, the observed weak relationship between PFE and technical classes regarding project alignment and motivation suggests room for seamless improvement in integrating these domains.

Role of Experiential Learning

The significance of experiential learning, mainly through internships, emerges as a critical factor in preparing students for the industry. Participants who secured internships reported feeling adequately prepared for the demands of professional practice, highlighting the practical relevance of hands-on experiences. Conversely, students who did not secure internships still recognized the value of PFE courses in enhancing their preparedness by acquiring transferable skills.

Recommendations for Curriculum Enhancement

In light of these findings, we are considering recommendations to offer for the larger RED program in the department, which has the potential for transfer to other institutions as well.

Enhanced Alignment between PFE and Technical Courses: Faculty should strive to align project objectives and motivational factors between PFE and technical classes to reinforce the interconnectedness of professional and technical skills.

Expanded Experiential Learning Opportunities: Program administrators should prioritize expanding internship opportunities and other forms of experiential learning to provide students with practical exposure to industry practices and enhance their career readiness.

Integration of Reflective Practices: Incorporating reflective practices within PFE courses can deepen students' understanding of the relevance of professional skills and encourage self-assessment and goal refinement.

Investment in Professional Development Resources: Program administrators should allocate resources towards developing and disseminating professional development materials, workshops, and career counseling services to support students in their career exploration and preparation.

In conclusion, the preliminary findings from the analysis of student interviews underscore the transformative potential of Professional Formation in Engineering courses in equipping electrical engineering students with the skills and mindset necessary for success in the industry. Students' interview data is recorded and analyzed, highlighting the influence of the courses on the student's readiness for the industry. Suggestions for improving the PFE series are also provided, contributing to the ongoing effort to enhance the courses to achieve the students' readiness objectives. By heeding the insights gleaned from these findings and implementing targeted recommendations, stakeholders can collaboratively improve the effectiveness of professional development initiatives and empower students to thrive in the dynamic landscape of engineering practice.

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Appendix A – Semi-Structured Interview Protocol

For alumni who have secured a job and took two or three PFEs:

- Tell me about your experience in the PFE course.
- What skills do you find helpful to your jobs acquired from the PFE course?
- What other sources do you think that you also acquired those skills from in the context of USF?
- What activities in the PFE courses do you find resemble the activities found in industry? What skills do you learn from those activities?
- What professional competencies do you find that you lacked when working in an industry that is not covered by the PFE course or endorsed by the PFE course?
- Do you think that the PFE course will help you to prepare for the industry other than giving you professional competency in any way?
- Please list at least three technical skills that you obtained while you were taking your technical track the most helpful to your current job.
- How the professional and technical skills combined help you in finding a job?

For Juniors or Seniors that took two or three PFEs:

- Tell me about your experience on the PFE course.
- What skills do you find helpful to your jobs acquired from the PFE course?
- What other sources do you think that you also acquired those skills from in the context of USF?
- How do you find prepared for the industry? List the reason why you feel so?
- Does the PFE course motivate you to choose a particular technical track? List the reason.
- Does PFE encourage you to learn more about technical competencies? List
- Does PFE help you define your goal or develop the habit to work toward your goals?
- Do you think that the PFE courses serve the purposes which it intends to?
- What aspects of the PFE course that you would like them to improve?