Board 81: Electrical Engineering Faculty and Student Perceptions of a Professional Formation Course Sequence

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At Magnolia Consulting, Dr. Banse leads a portfolio of studies in STEM, early childhood, and prek-20 education products and tools. She is a methodological expert in multiple regression, logistic regression, multilevel modeling, and structural equation modeling, as well as in mixed-method study designs. She also oversees Magnolia's internship program for BIPOC researchers and evaluators.

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WIP: Student and Faculty Perceptions of a Professional Formation Course Sequence for an Undergraduate Electrical Engineering Program

Introduction

With funding from a NSF Revolutionizing Engineering Departments (RED) grant, an undergraduate electrical engineering (EE) program located in the Southeastern United States seeks to its department from a mostly unidirectional Research-Teaching-Service approach to a connected Research-Students-Practice model with outreach to industry and community at every step. The transition to a Research-Students-Practice model has led to the creation of a Professional Formation of Engineers (PFE) course sequence, comprised of three-courses and an associated Qualification Plan. The PFE courses serve as a means to inform and involve students in departmental and program activities. Having a sequence of courses that all EE students take provides an effective mechanism for getting the word out about innovations to change departmental culture to be more student oriented.

The PFE course sequence aims to support the development of students' identities as professional engineers and to motivate them to persist in their degrees. Originally taken as optional electives, the PFE I–III courses became a required part of the core curriculum for EE majors. Broadly, the PFE course sequence teaches ethical engineering principles, identifies areas of career opportunities for students, and hones students' skills in soliciting community stakeholder feedback in order to generate innovative solutions. In PFE I, students are introduced to engineering and ethical best practices, as well as various career opportunities. In PFE II, students are further introduced to careers in technology development, research, and academia. Students tour engineering labs, experience faculty guest lectures, and consider how to solicit and integrate community stakeholder perspectives as they generate solutions to engineering-related problems. Finally, in PFE III, students learn how to use ethical engineering principles to create designs that meet societal needs. In each PFE I–III course, about 50 out-of-class hours are allocated for working on students' capstone projects; 10 out-of-class hours to attending two seminars in a departmental lecture series and completing assignments; and 35 in-class hours to addressing knowledge and skills that build the student's capacity for completing their capstone projects.

The PFE course sequence is available to students beginning in their second semester of the program, and students can take the PFE course sequence through their junior year. Students are not required to take each PFE course consecutively. The same instructor teaches all three courses, ensuring that the courses follow a logical progression of skill development. Course enrollment is increasing each semester, as students now entering as freshmen have the courses as requirements for graduation. Objectives for each course in the PFE sequence are shown in Figure 1.

Figure 1. *Professional Formation of Engineers Course Objectives*

In addition to supporting professional growth, the PFE courses are the mechanism through which EE undergraduates develop a Qualification Plan. In their Qualification Plans, students commit to required and elective PFE activities during their sophomore year in order to be fully prepared for the eventual job market. Students choose four focus skills from among the following: career management, communication, teamwork, professionalism, leadership, critical thinking, technology, and global citizenship, amongst others. Students develop these skills through required and elective PFE activities. These required and elective activities range from student forums to capstone projects. Students also have the option of pursuing certifications through their Qualification Plan, such as Python, Fundamental of Engineering, or Advanced Design Systems. The PFE course instructor oversees the Qualification Plan process through an online learning management system.

The present submission uses formative external evaluation data to describe faculty and student perceptions of the PFE course sequence. The submission concludes with recommendations for other EE programs looking to adopt a similar course sequence.

Methods

Evaluators are using a program effects case study to evaluate this EE department. This type of case study can determine impacts and provide strong inferences about reasons for effects (U.S. General Accounting Office, 1990; Zucker, 2009). The unit of analysis for this case study is the EE Department. A case study will allow evaluators to describe and explain the contextual factors and conditions within the department that hinder and support how innovations are integrated and manifested at the student, faculty, and department levels within the case.

Evaluators are using quantitative and qualitative methods to address the evaluation questions. Measures relevant to the present submission include interviews and surveys. Mixed methods strengthen the evaluation design by allowing for triangulation of findings across data sources (Patton, 2015; Creswell & Plano Clark, 2010).

Data Analyses

Evaluators cleaned survey data and conducted descriptive statistics, including frequencies and means. To facilitate interview analyses, evaluators imported data into Atlas.ti, a qualitative data analysis software program. Evaluators analyzed qualitative data using the techniques of analytic induction (Erickson, 1986). Following a thorough review of the data record from all qualitative data sources, evaluators generated a set of preliminary assertions (i.e., statements believed to be true based on the whole dataset) regarding the evaluation questions. Next, evaluators refined these assertions and established whether each was warranted. Evaluators linked the assertions, themes, and findings in a manner to support analytic generalization (Glaser, 1978).

Student Perceptions of the PFE Sequence

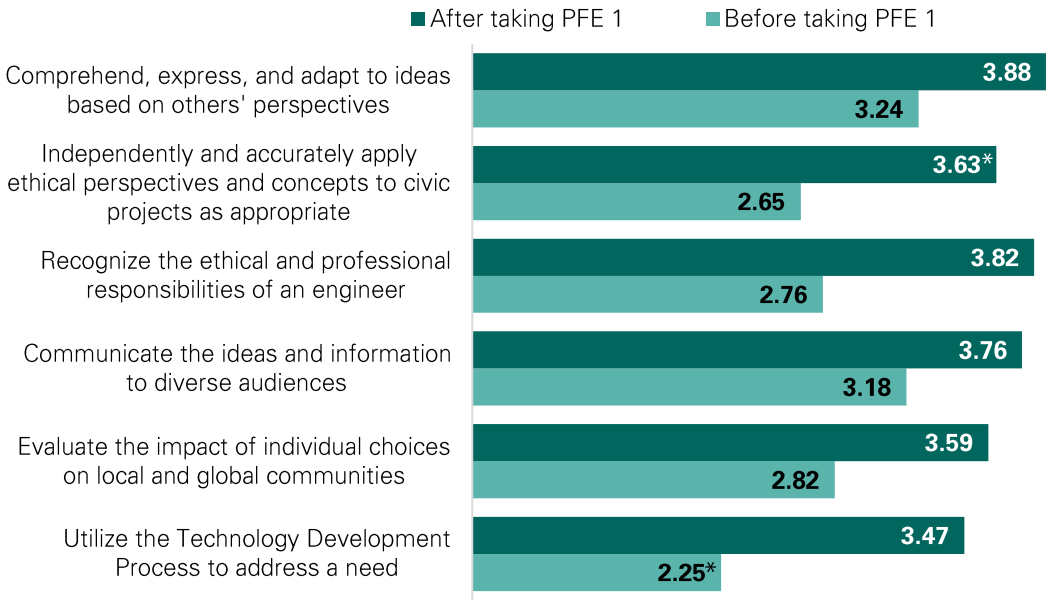
Professional Formation of Engineers 1

PFE 1 is typically taken during students' sophomore year. PFE 1 introduces students to engineering and ethical best practices and provides insight into future career opportunities. In December 2021, 17 of 35 students completed end-of-course surveys, for a 49% response rate.

Student Self-Ratings Increased From Start to Finish of PFE 1

To understand students' perceived growth in the key objectives of PFE 1, students rated their abilities in course objectives prior to starting the PFE course and at the end of the course on a 5-point scale, from 1 (*novice*) to 5 (*expert*; Figure 2). Students were not expected to be an expert at the end of the course. The ratings were meant for students to assess where they felt their skills were at that point in their degree program. Students indicated that their abilities, on average, increased from before starting the PFE I course to the end of the course for all course objectives.

Novice (1): Minimal or textbook knowledge of this skill; little to no experience applying this skill to my own practice.
Advanced Beginner (2): Working knowledge of key aspects of this skill; beginning to apply this skill to my own practice.
Competent (3): Good working and background knowledge of this skill; apply this skill to my own practice and reflect on my performance.
Proficient (4): Deep understanding of this skill; regularly apply this skill to my own practice; able to reflect and make judgments related to achieving a goal in this area.
Expert (5): Authoritative knowledge of this skill; vast knowledge of how this skill applies to real-world practice; regularly apply this skill to my own practice.



(n = 16)

Figure 2. *Students' Mean Ratings of Their Abilities Related to Course Objectives Prior to Starting PFE 1 and at the End of the Course* (*n* = 17)

The Majority of Students Felt the Course Contributed to Their Professional Competencies

Students then rated the extent to which the course contributed to their learning and abilities on a 5-point scale (Figure 3). At least half of the students indicated that the course supported them in each way to a good or great extent.

Figure 3. *Students' Ratings of the Extent to Which PFE 1 Supported Them in Professional Skills* (*n* = 16)

The Majority of PFE 1 Students Agreed or Strongly Agreed That the Course Met Its Objectives

Using a 5-point scale, students than rated their level of agreement with aspects of PFE 1 overall (Figure 4). The majority of students agreed or strongly agreed with all statements about the course overall. Most notably, the majority of students agreed or strongly agreed that the course was taught in an engaging way, helped them feel like part of a learning community, helped them reflect on their work, and increased their interest in an engineering career.

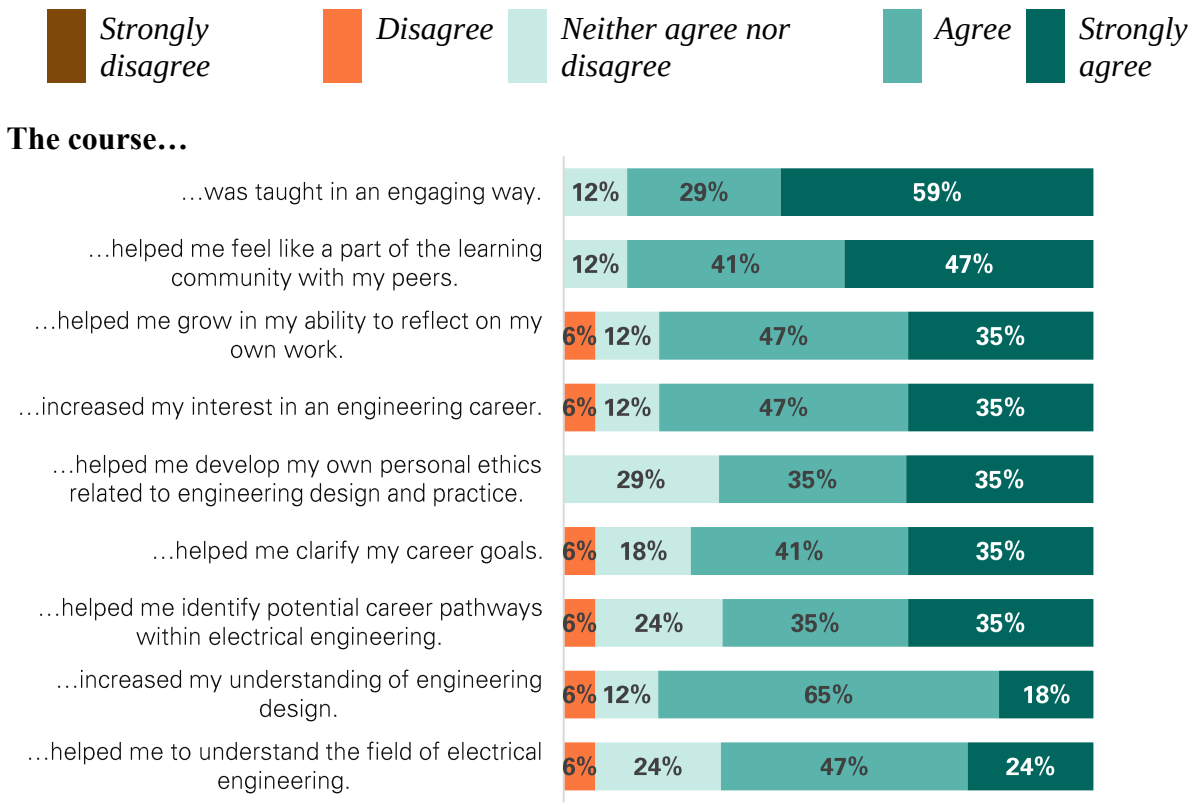


Figure 4. *Students' Level of Agreement With Statements About PFE 1 Objectives* (*n* = 17)

Students Gained Professional Skills From PFE 1

Students responded to a question about their greatest learning or area of growth as a result of PFE 1. Several themes emerged, including the ability to communicate professionally (*n* = 5), teamwork and collaboration skills (*n* = 2), understanding ethics in engineering (*n* = 2), creating a road map for a professional career (*n* = 1), and how to research patents (*n* = 1).

> *"PFE 1 helped me in creating a proper road map of my professional career. I have always had a mental picture of what I wanted to do, but never wrote it down."*
> – PFE 1 student survey response

> *"I learned how to be more professional and how to speak to different types of audiences. PFE 1 also taught me how to speak about a subject in a confident and knowledgeable way."*
> – PFE 1 student survey response

Students Offered Suggestions for Improving PFE 1

Students responded to a question about how PFE 1 could be improved for future students. Suggestions included providing guidance on how to provide peer feedback, combining all three PFE courses into one class, more focus on career networking, and more background for the ethics hearing assignment.

Professional Formation of Engineers 2

In December 2021, evaluators conducted a survey with 25 students who took the CRN 94436 Professional Formation of Engineers 2 course (PFE 2). Thirteen students completed[1] the survey, for a 56% response rate, and provided feedback on the course. Slightly over half (54%) of the students who completed the survey had taken PFE 1 prior to this course.

Students Felt Competent or Proficient on Most Skills Addressed in PFE 2

Students rated their abilities in course objectives at the end of the course on a 5-point scale, from 1 (*novice*) to 5 (*expert*; Figure 5). Students were not expected to be an expert at the end of the course. The ratings were meant for students to assess where they felt their skills were at that point in their degree program. Most students rated their abilities as either competent or proficient for most course objectives.

Novice (1): Minimal or textbook knowledge of this skill; little to no experience applying this skill to my own practice.
Advanced Beginner (2): Working knowledge of key aspects of this skill; beginning to apply this skill to my own practice.
Competent (3): Good working and background knowledge of this skill; apply this skill to my own practice and reflect on my performance.
Proficient (4): Deep understanding of this skill; regularly apply this skill to my own practice; able to reflect and make judgments related to achieving a goal in this area.
Expert (5): Authoritative knowledge of this skill; vast knowledge of how this skill applies to real-world practice;

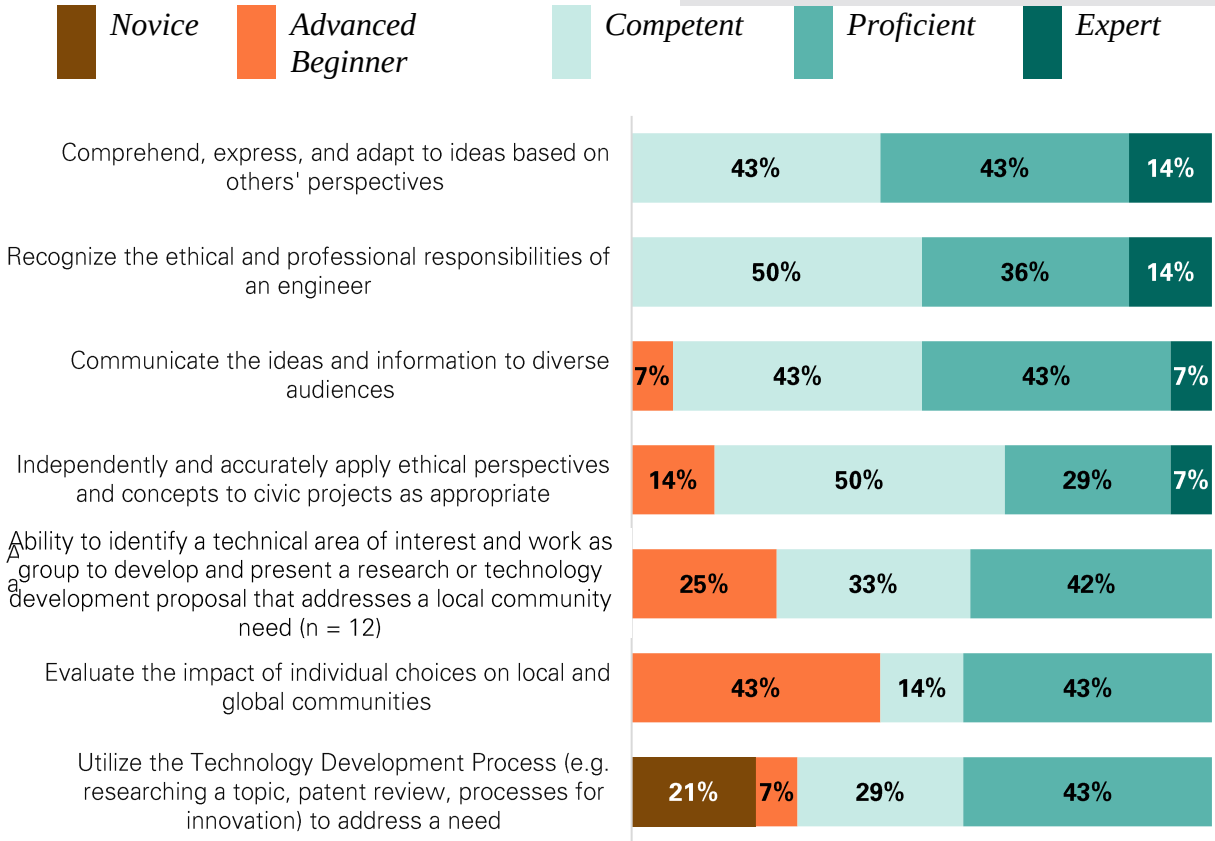


Figure 5. *Students' Ratings of Their Abilities Related to PFE 2 Course Objectives at the End of the Course* (*n* = 14)

The Majority of Students Felt That PFE 2 Supported Them in Professional Skills

[1] Evaluators included one partial survey because the student completed the first question bank.

Students then rated the extent to which the course contributed to their learning and abilities on a 5-point scale (Figure 6). At least half of the students indicated that the course supported them in all ways to a good or great extent. Most notably, most students indicated that the course supported their ability to function effectively as part of a team to a good extent (62%) or great extent (23%).

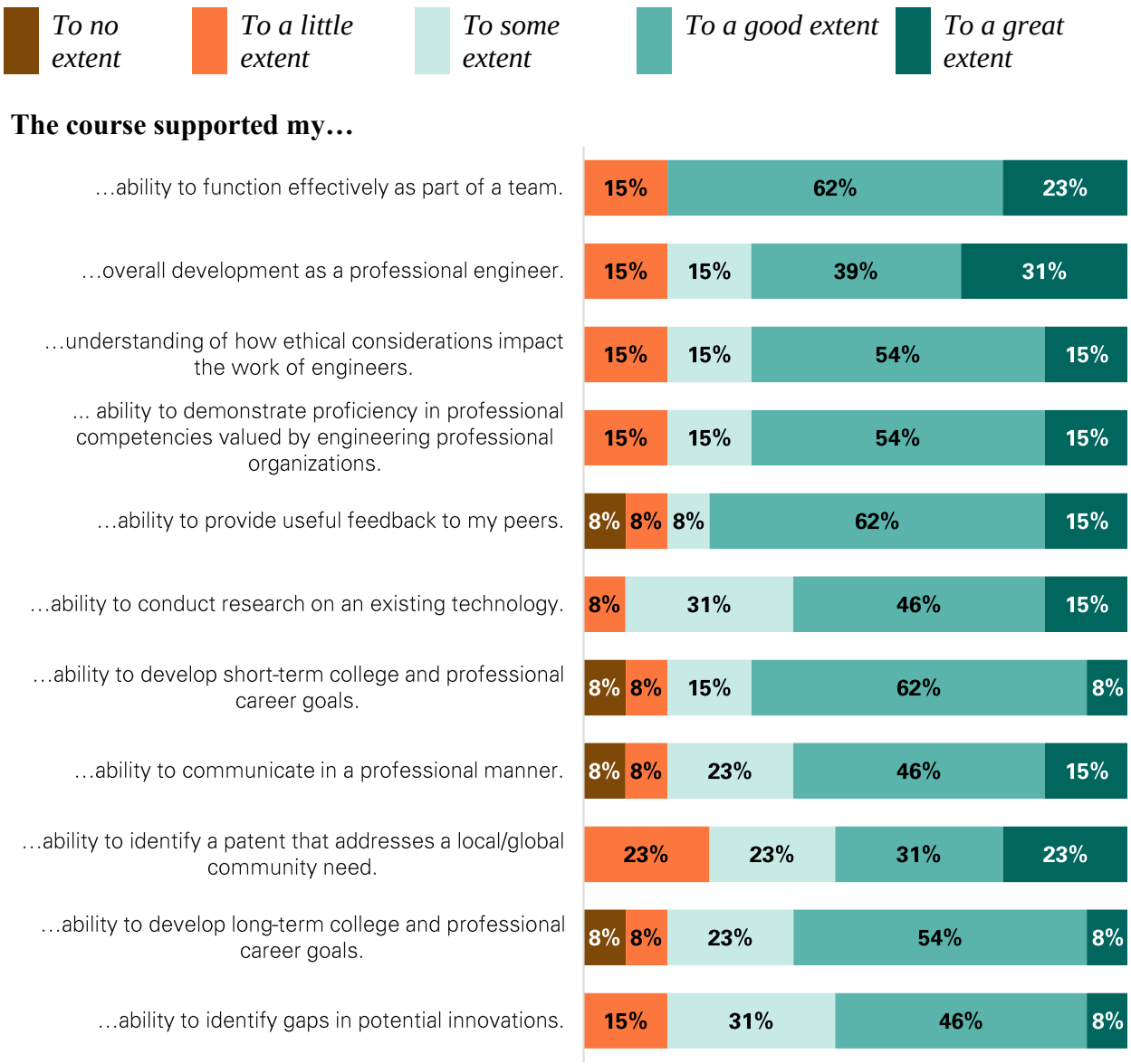


Figure 6. *Students' Ratings of the Extent to Which PFE 2 Supported Them in Professional Competencies* (*n* = 13)

The Majority of PFE 2 Students Felt That the Course Met Its Objectives

Using a 5-point scale, students than rated their level of agreement with aspects of the course overall (Figure 7). The majority of students agreed or strongly agreed with all statements about the course overall. Most notably, all students either agreed (46%) or strongly agreed (54%) that the course helped them feel like a part of the learning community with their peers.

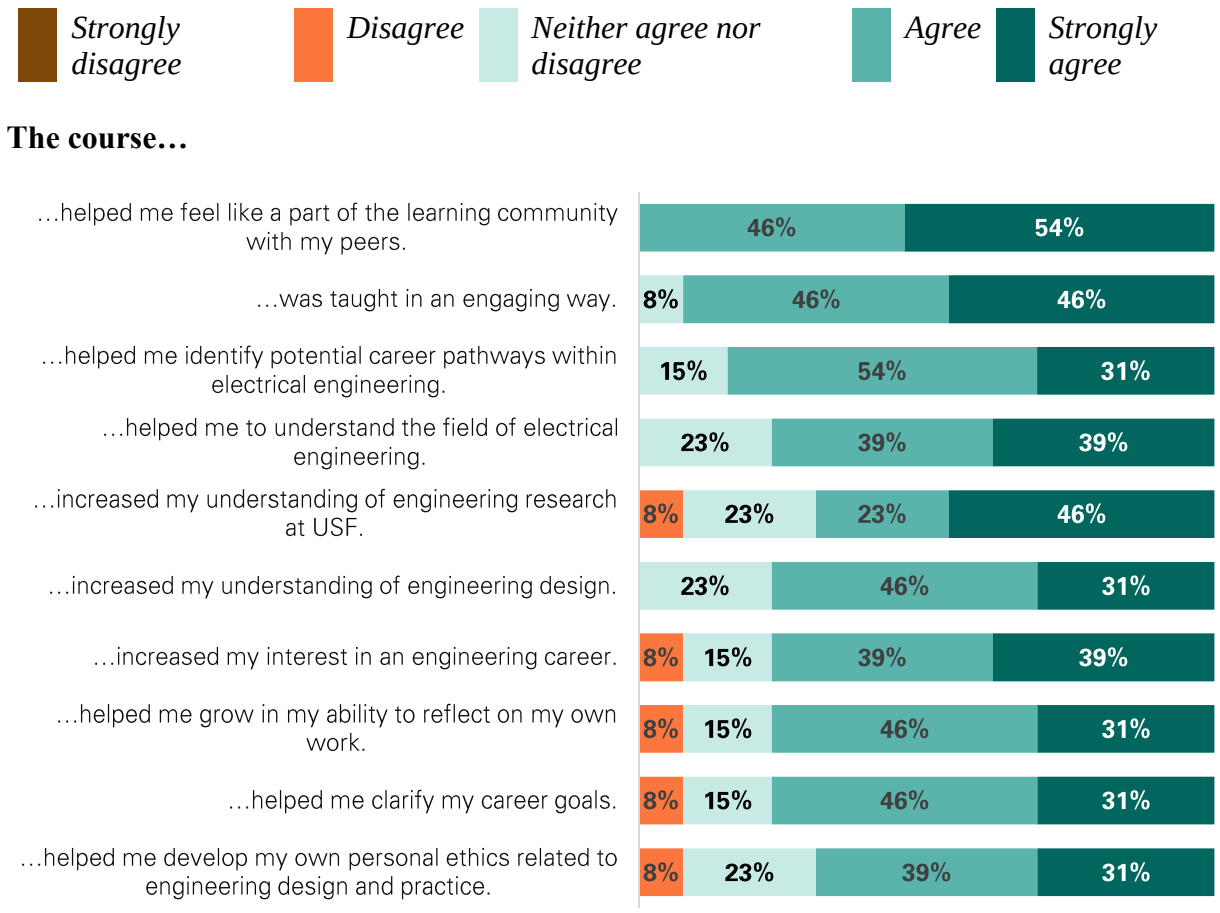


Figure 7. *Students' Level of Agreement With Statements About PFE 2 Course Outcomes* (*n* = 13)

Students Gained Professional Skills From PFE 2

Students responded to a question about their greatest learning or area of growth as a result of PFE 2. Several themes emerged, including teamwork (*n* = 2), learning the patent process (*n* = 2), and conducting research (*n* = 2).

> *"Teamwork has been my greatest area of growth taking PFE 2, especially when trying to work out how to get things done and who does what, as well as what ideas are good and what ideas are not sufficient."*
>
> – PFE 2 student survey response

Students Offered Suggestions for Improving PFE 2

Students responded to a question about how PFE 2 could be improved for future students. Suggestions included expanding the project to span across PFE 3, having keynote speakers, having hands-on projects, and focusing on communication skills.

Professional Formation of Engineers 3

In December 2021, evaluators conducted a survey with 27 students who took the CRN 94451 Professional Formation of Engineers 3 course (PFE 3). Eleven students completed[2] the survey, for a 41% response rate. Almost all students who completed the survey had taken PFE 1 (91%), and all students had taken PFE 2 (100%) prior to this course.

Students Felt Competent or Proficient on Most Skills Addressed in PFE 3

Students rated their abilities in the course objectives at the end of the course on a 5-point scale, from 1 (*novice*) to 5 (*expert*; Figure 8). Students were not expected to be an expert at the end of the course. The ratings were meant for students to assess where they felt their skills were at that point in their degree program. Students tended to rate their abilities as either competent or proficient for most course objectives. All students rated their ability to identify attributes of competencies of successful inventors as advanced beginner (64%) or competent (36%).

Novice (1): Minimal or textbook knowledge of this skill; little to no experience applying this skill to my own practice.
Advanced Beginner (2): Working knowledge of key aspects of this skill; beginning to apply this skill to my own practice.
Competent (3): Good working and background knowledge of this skill; apply this skill to my own practice and reflect on my performance.
Proficient (4): Deep understanding of this skill; regularly apply this skill to my own practice; able to reflect and make judgments related to achieving a goal in this area.
Expert (5): Authoritative knowledge of this skill; vast knowledge of how this skill applies to real-world practice; regularly apply this skill to my own practice.

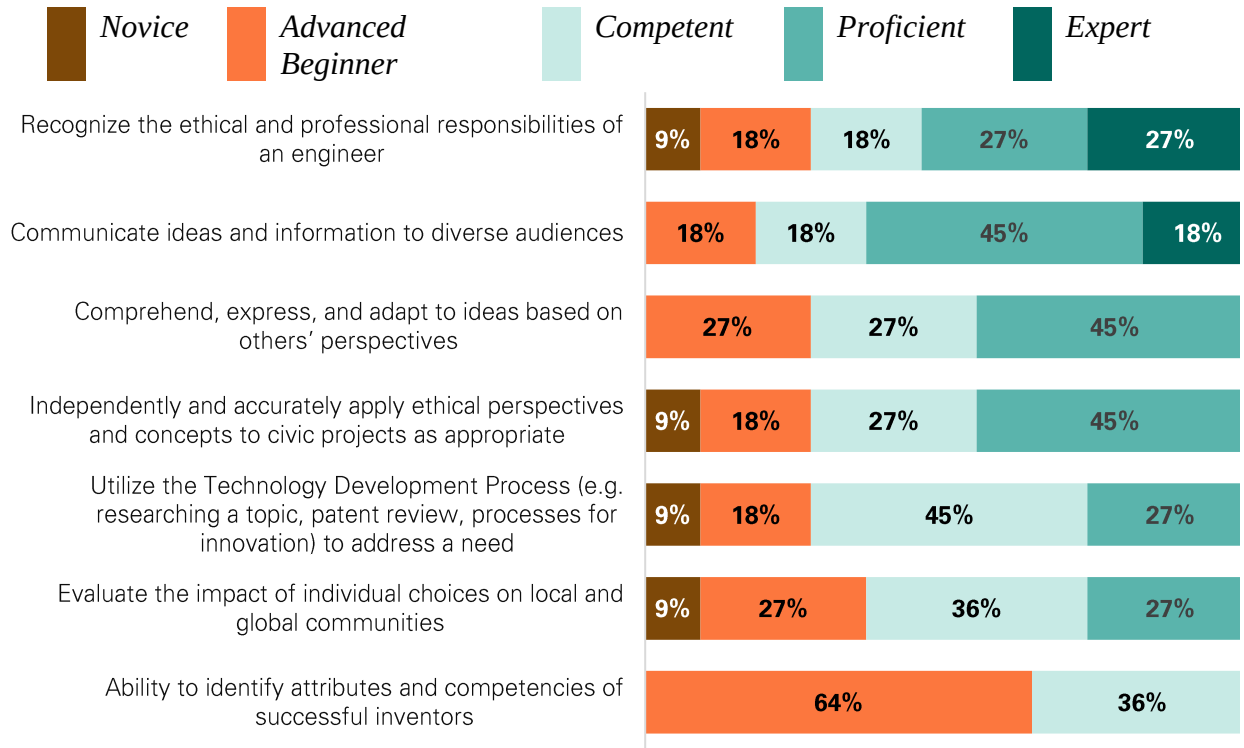


Figure 8. *Students' Ratings of Their Abilities Related to PFE 3 Course Objectives at the End of the Course* (*n* = 11)

[2] Evaluators included two partial surveys because the students completed at least the first question bank.

The Majority of Students Felt That PFE 3 Supported Them in Professional Skills

Students then rated the extent to which the course contributed to their learning and abilities on a 5-point scale (Figure 9). Mean ratings suggest that the course supported students in most ways from some extent to a good extent. Most notably, the majority of students indicated that the course supported their ability to function effectively as part of the team (90%) and to develop short-term college and professional goals (80%) to a good or great extent.

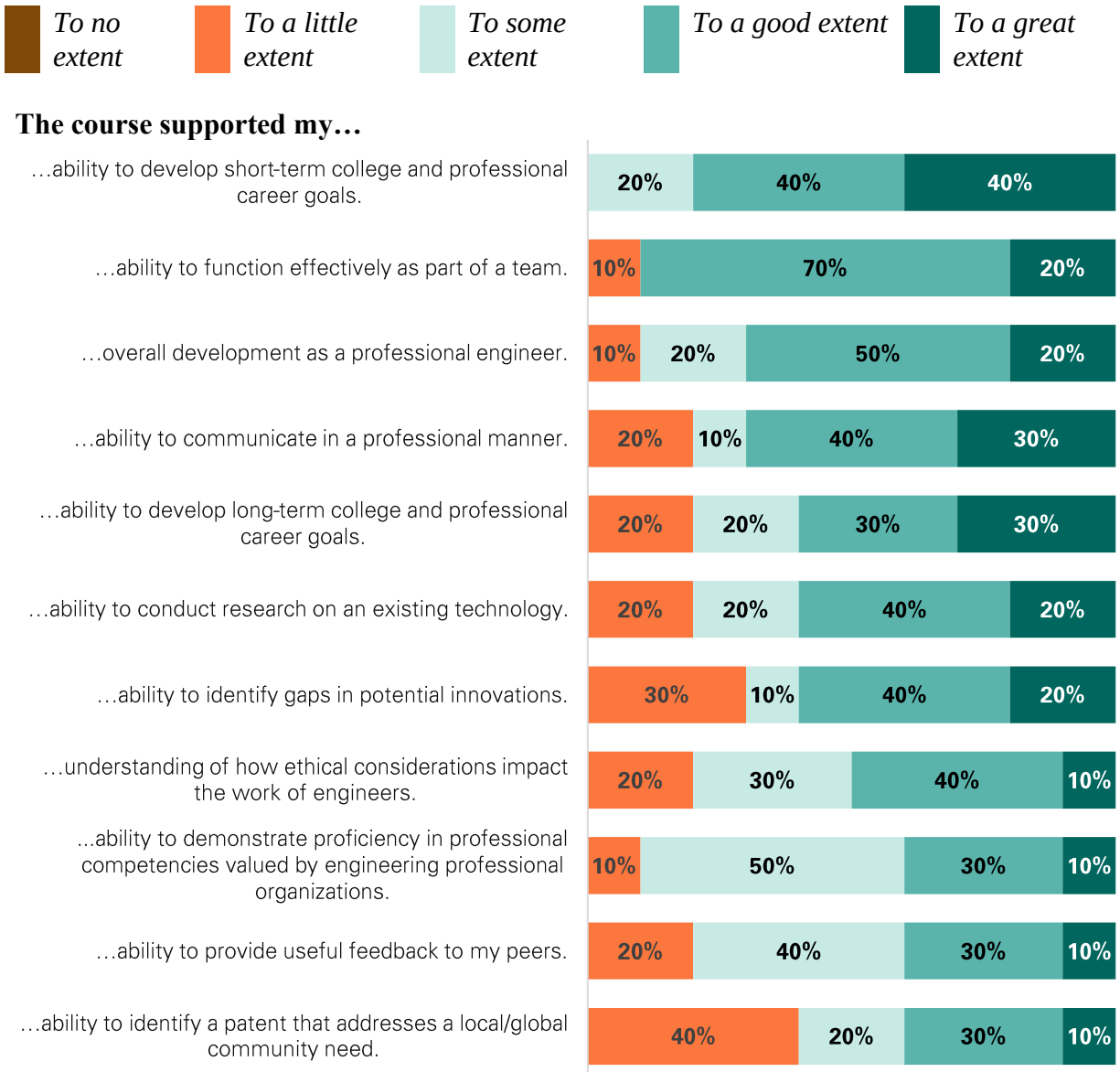


Figure 9. *Students' Ratings of the Extent to Which PFE 3 Supported Them in Professional Competencies* (*n* = 10)

The Majority of PFE 3 Students Felt That the Course Met Its Objectives

Using a 5-point scale, students than rated their level of agreement with aspects of the course overall (Figure 10). Half or more of students agreed or strongly agreed with each statement about

the course overall. Most notably, almost all students agreed (40%) or strongly agreed (50%) that the course was taught in an engaging way.

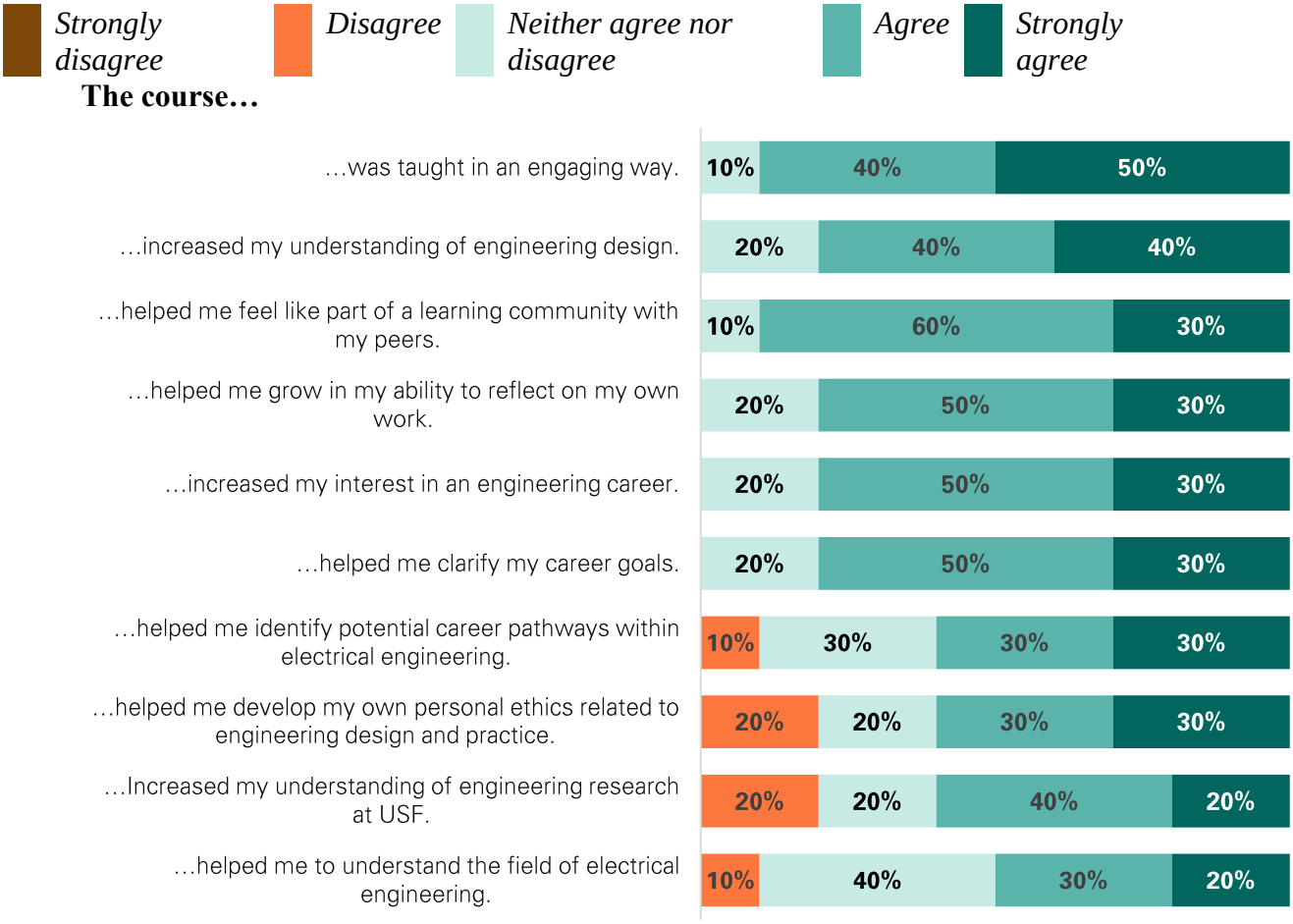


Figure 10. *Students' Level of Agreement With Statements About PFE 3* (*n* = 10)

Students Gained Professional Skills From PFE 3

Students responded to a question about their greatest learning or area of growth as a result of PFE 3. Students felt they learned about teamwork (*n* = 3), communication, and other skills.

> *"Learning how to effectively work in a team and set long-term and short-term goals for myself. I learned how important soft skills are and the competencies needed to begin my career."*
> – PFE 3 student survey response

Students Offered Suggestions for Improving PFE 3

Students responded to a question about how PFE 3 could be improved for future students. Suggestions included life skills and learning about different career paths. Several students indicated that they had no suggestions for improvement, and that they enjoyed the course and the instructor.

Student Progress and Feedback on Qualification Plans

On the course surveys, students provided information about the four key skills they were focusing on in their Qualification Plan. They also provided feedback on the extent to which their Qualification Plan was supporting their professional growth.

Students Are Using the Qualification Plan to Work on Varied Professional Skills

The majority of students selected career management, followed by communication and teamwork. Other responses included a focus on "career building" (Figure 11).

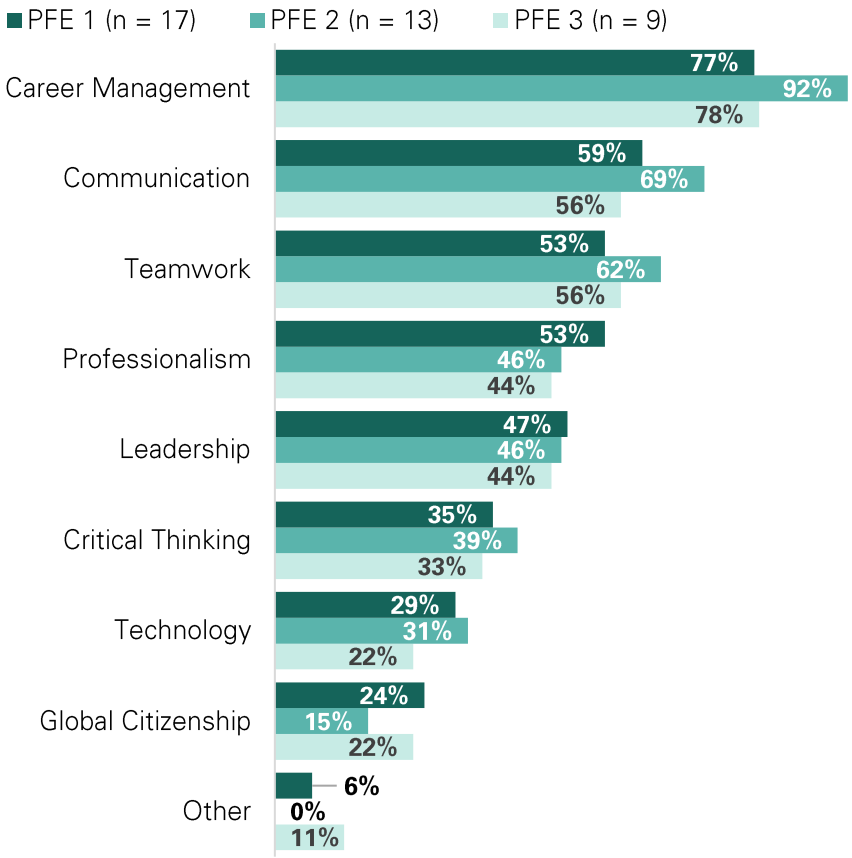


Figure 11. *Skills That PFE 1, PFE 2, and PFE 3 Students Were Focusing on in Their Qualification Plan*

Students in each course listed any activities they had completed at the time of the survey for the four focus skills in their Qualification Plan. PFE 1 students indicated that they worked on securing internships; attended and participated in professional development societies, including the Institute of Electrical and Electronics Engineers, Tau Beta Pi engineering honor society, and the Society of Hispanic Professional Engineers; conducted career research; expanded their presence on professional networking sites; and took on leadership roles. PFE 2 students shared that they applied for jobs and internships, learned to provide peer feedback, developed LinkedIn profiles, and worked toward graduation. PFE 3 students noted that they worked to obtain internships, developed professional communication skills, expanded their presence on professional networking sites, improved their interview skills, participated in LinkedIn Learning, and began taking graduate courses to fast-track a master's program.

> *"One activity I'm actively working towards is career management. I am looking into companies that have electrical engineering internships available for next summer."*
> – PFE 1 student survey response

> *"I'm [working on] not criticizing peers or teammates; always finding something good to give praise; not speaking out of turn or giving advice that is not warranted, and staying positive."*
> – PFE 2 student survey response

> *"I participated in mock interview sessions and had interviews with three companies during the Society of Women in Engineering conference. I also learned how to write effective emails and messages."*
> – PFE 3 student survey response

Some Students Are Pursuing Certifications Through Their Qualification Plan

PFE 1 students then shared whether they intended to pursue any certifications through their Qualification Plan (Figure 12). Nearly half of students (47%) were not sure, and 35% did not intend to pursue any certifications. Only 18% of students indicated that they planned to pursue certifications through their Qualification Plan. These students shared the following certifications that they would like to pursue:

- Advanced Design Systems
- Fundamentals of Engineering (FE)
- Professional Engineer (PE)

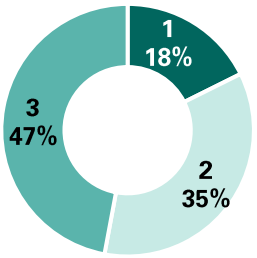


Figure 12. *PFE 1 Students' Intent to Pursue Any Certifications Through the Qualification Plan* (*n* = 17)

PFE 2 students shared whether they had completed or were in the process of completing any certifications as part of their Qualification Plan. Thirty-eight percent indicated no. Nearly half of students (46%) indicated yes, and 15% indicated they were in progress (Figure 13). These students then shared the following certifications they have completed or were in the process of completing:

- Entrepreneurship – completed
- Fundamentals of Engineering (FE)
- Multiple certifications

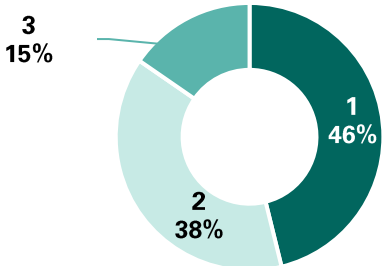


Figure 13. *PFE 2 Students Pursuing Certifications as Part of the Qualification Plan* (*n* = 13)

PFE 3 students then shared whether they had completed or were in the process of completing any certifications as part of their Qualification Plan (Figure 14). Over half of students (56%) indicated no. Twenty-two percent of students indicated yes, and 22% indicated they were in progress. These students then shared the following certifications they had completed or were in the process of completing:

- Fundamentals of Engineering (FE) – completed
- Python
- Fundamentals of Engineering (FE) – in progress

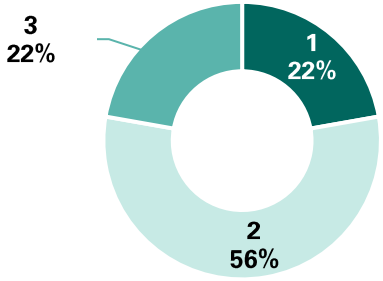


Figure 14. *PFE 3 Students Pursuing Certifications as Part of the Qualification Plan* (*n* = 9)

The Majority of Students Agreed That the Qualification Plan Was Supporting Their Career and Academic Goals

On all three surveys, students rated their level of agreement with statements regarding the Qualification Plan on a 5-point scale (Figure 15). Across surveys, students agreed or strongly agreed that the Qualification Plan was supporting their career and academic goals, has increased their interest in an engineering career, and has supported their academic and career growth.

> *"I hadn't ever really looked into the details behind a patent, but they are pretty vague. Each part is broken down to its most basic form and patented, and the sum of multiple patents makes up something useable."*
>
> – PFE 2 student survey response

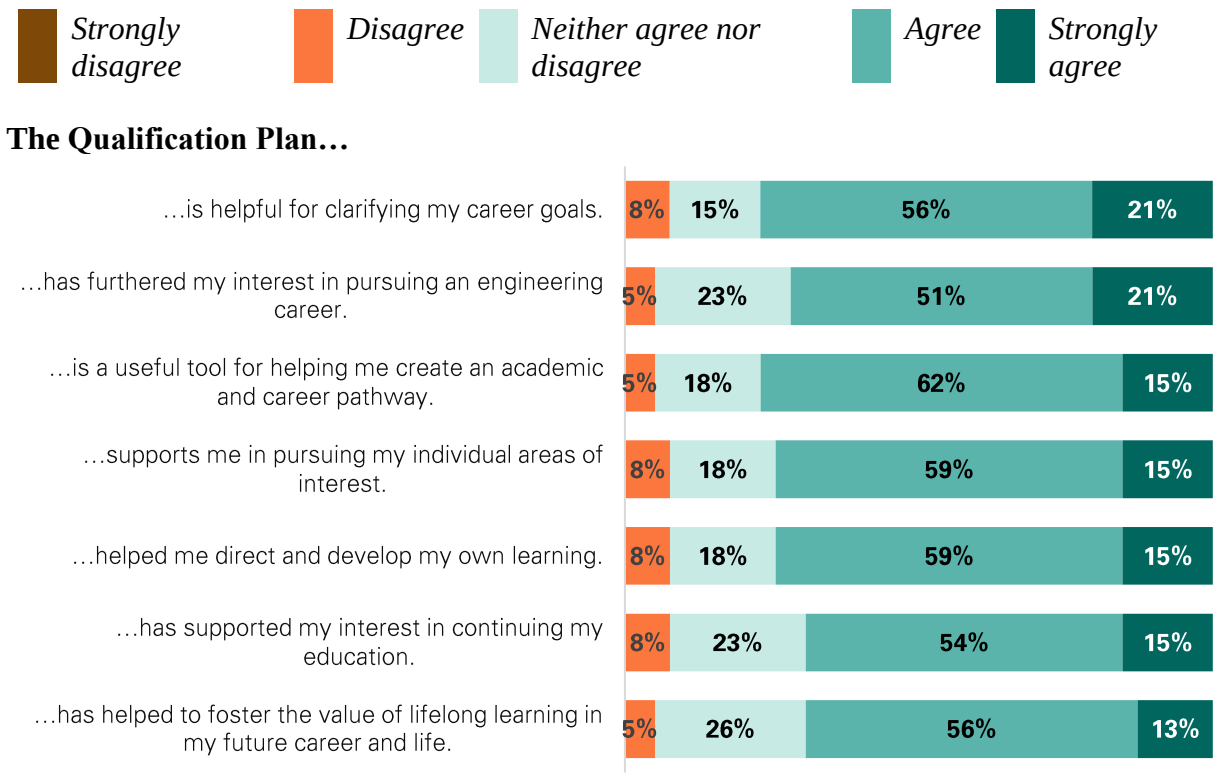


Figure 15. *PFE 1, PFE 2, and PFE 3 Students' Perceptions of the Usefulness of the Qualification Plan* (*n* = 39)

Faculty Perceptions of the PFE Sequence

Evaluators also collected data on EE faculty's perceptions of the PFE sequence. In interviews, three team members discussed the interest and eagerness of students to be more engaged in their professional growth. Faculty noted that PFE courses serve as a means to leverage students' desire to engage, because PFE courses provided an outlet through which students could learn about and choose to take part in other departmental activities. Moreover, faculty in this EE department are working to shift their departmental culture to be more student-focused. During interviews, faculty shared that having a sequence of courses that all EE students take provides an effective mechanism for getting the word out about innovations to change departmental culture to be more student oriented. As one faculty member stated:

PFE is working in a way to help students learn skills that are supposed to help them in the professional arena. So, not only is PFE showing that it is a good place to work on those competencies, but it's also a good place to test some of the other departmental ideas with the students.

Survey data indicate that faculty awareness of the PFE sequence has changed over time (Figure 16). For example, in 2021, 30% of EE faculty indicated they had no awareness of the PFE course sequence. In 2022, only 17% indicated they had no awareness of the PFE course sequence. All other faculty in 2022 were at least aware of the sequence, or involved in some way in implementing or improving the course sequence.

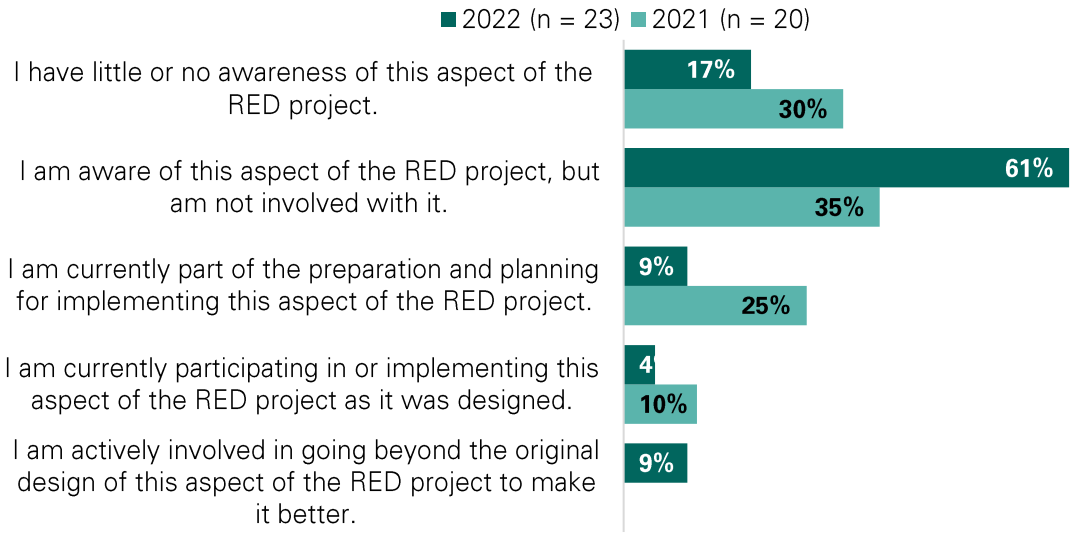


Figure 16. *EE Faculty Members' Awareness of the PFE Three-Course Sequence in 2021*

Recommendations

Overall, findings indicate that the EE department is leveraging the PFE 1, PFE 2, and PFE 3 courses as a means to support students in their professional growth, through course content and the development of Qualification Plans. Students perceive the PFE courses positively and feel that the courses are supporting them academically as well as helping them to develop a professional identity. Similarly, faculty are gaining awareness of the PFE courses and indicating that the PFE courses serve as a mechanism for getting EE undergraduates involved in other professional formation activities offered by the department. Given the success of the course sequence, including the Qualification Plan, we provide the following recommendations to departments seeking to adopt a similar course sequence:

- Begin by developing buy-in from departmental faculty, so that faculty at least are aware of the importance of intentional professional formation activities, including through coursework.
- With input from departmental faculty, consider specific professional skills around which to structure the course or course sequence. To do so,
    - Solicit feedback from recent EE graduates regarding professional skills they needed support developing when they entered their post-graduate jobs.
    - Solicit feedback from industry partners regarding professional skills they perceive recent graduates are lacking as they enter the job market.
- Similarly, the PFE course sequence covers a breadth of professional skills, including teamwork and collaboration, project designs which center on community needs, understanding of ethical responsibilities, and communication, amongst others. Consider incorporating similar breadth in PFE courses and activities.
- If a qualification plan already exists for students within their departments, consider how the plan can intersect with and inform the course or course sequence.

- The PFE instructor for this course sequence has personal and extensive industry experience, which then informs course content. Consider asking someone with similar experiences to both develop and implement the initial courses.

Conclusion

Faculty and student perceptions of the PFE course sequence were positive overall. Students reported that they gained skills from the course, increased their understanding of professional opportunities, developed professional ethics, and pursued professional development opportunities through their qualification plans. Faculty reported increased awareness of the PFE course sequence, and noted in semi-structured interviews that the PFE course sequence was serving as a mechanism for shifting departmental culture in a positive way. Taken together, these findings suggest that EE programs not already incorporating a PFE course sequence should weigh the merits of adopting a similar requirement.