

# Emulating a Career Experience At-Scale so Students Can Make Informed Decisions About Electrical Engineering Early in Their Academic Career\*

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At Colorado State University, we are actively reinvigorating our Electrical and Computer Engineering (ECE) curriculum to increase diversity and retention. In Fall 2019, we implemented a novel, one-credit hour, career emulation course for first-year students considering a degree in ECE. The course was deliberately designed to help students imagine working as a professional engineer so they could make more informed decisions about their academic endeavors. Throughout the course, students were engaged in realistic engineering tasks and interacted with a diverse range of professional engineers. These experiences were created to ensure all students had the opportunity to visualize themselves in a professional engineering environment. Eighteen students were initially enrolled in the Fall 2019 implementation and a new cohort of 16 students enrolled in the Fall 2020 course offering. Course surveys, instructor observations, and discussions with students regarding their future career expectations were used to assess the effectiveness of the course. Based on these metrics, we achieved our primary goal of helping students make an informed decision about pursuing a degree in ECE by emulating informative workplace learning opportunities.

**Keywords:** first-year engineering; introduction to engineering; internship experience; engineering identity; non-technical engineering skills; career emulation

## 1. Introduction

Engineering education is notoriously faced with challenges in both retention and diversity. A 2017 report from the ASEE indicated fewer than 60% of engineering students received an engineering degree within 6 years in 2015. The same report also confirmed under-represented minorities in engineering experienced disproportionately lower graduation rates [1]. Efforts to increase diversity and retention in engineering have been partially successful but more needs to be done. The 2018 Status Report on Engineering Education concluded that, although there was a noticeable increase in the number of engineering degrees conferred to under-represented groups (URGs), this growth did not keep pace with the college-age demographics for each corresponding state [2]. The report authors went further saying, “Strategies and initiatives must be implemented to increase enrollment, retention and graduation of URGs in engineering.”

The mismatch between graduation rates and workforce demand for creative engineering solutions continues to drive research into the qualities, motivations, and experiences of students who persist in engineering. There is no singular solution to increase the number of successful engineering graduates, but common trends have emerged from the

research. Positive experiences like internships and summer camps have been strongly associated with increased success in engineering [3, 4] as has forming connections with relatable role-models [5, 6]. Summarizing these correlations through the expectancy value theory framework, many students who persist in engineering have higher levels of expectancy and better perceive the value of what they are learning [7]. Unfortunately, not all engineering students have the opportunity to experience their chosen discipline prior to entering college and informative experiences like internships are not widely available to beginning students. This gap is especially prevalent in the case of first-generation students or under-represented groups. The lack of tangible experience makes it difficult for first-year engineering students to understand how courses contribute to the development of successful engineers, much less what an engineer actually looks like in industry, and contributes to low expectancy levels. Low confidence levels and uncertainty about potential career options in turn appear to be significant contributing indicators for high attrition rates [8].

At Colorado State University, our goal is to reimagine the Electrical and Computer Engineering (ECE) curriculum. Active discussions with our Industrial Advisory Board have been used to direct the weaving of professionalism threads

throughout our program. We have worked to highlight common technical threads across ECE courses and connect those threads to physical applications to better anchor key concepts [9]. In this paper, we focus on the first step in this restructured program which is a newly developed, career emulation course for first year ECE students.

Inspired by The University of Wisconsin's "virtual internship" model [10], the one-credit hour emulation class is broken into two components. The first portion is an *Engineering Role* phase where students contribute to a socially relevant project while exploring a range of engineering roles. During the second portion, the *Engineering Concentration* phase, students propose and implement a final product to gain kinesthetic experience while exploring concentrations within ECE. The two phases are designed to broaden students' awareness about the wide variety of career opportunities available within ECE and increase the range of skills students identify with engineering by placing them in an emulated workplace. We are also structuring both phases so the course can be implemented at scale thereby helping first-year students at our university make informed decisions about pursuing an ECE degree early in their academic career.

## 2. Motivation and Course Development

### 2.1 Background

In order to better support our students who have expressed an interest in ECE, it is necessary to increase both students' expectancy of their own skills as well as their perceived value in course material so they can make an informed decision about their academic endeavors. Both of these goals also require providing a clearer image for what engineers actually do in practice. Strategic planning meetings with our Industrial Advisory Board identified internships and project-based classes as two of the most significant educational experiences for practicing engineers. These positive, applied experiences provide anchoring points for many theoretical concepts presented in class, increase individual student confidence, and create opportunities for students to connect with relatable role-models to further boost students' levels of expectancy. Research affirms that workplace learning opportunities significantly accelerate students' formation of an engineering identity which is a strong indicator of perseverance in an engineering program [11].

Unfortunately, there are many barriers to providing an internship to all first-year students even though these are the students that can best benefit from such experiences. Inspired by efforts to formalize introductory engineering courses as in [12,

13] and facilitate the development of an engineering identity for students, we focused on designing a one-credit hour career emulation course for first-year engineering students. We restricted the course to a single credit hour so as not to detract from foundational curriculum courses. A similar motivation was described in (15) but, unlike the implementation there where each class period was set aside to focus on a specific ECE topic, our career emulation course was constructed around two critical phases: an *Engineering Role* phase and an *Engineering Concentration* phase. These two distinct segments help students imagine working as a professional engineer by emulating informative workplace learning opportunities and therefore push beyond the traditional problem based learning courses. During the *Engineering Role* phase, a large emphasis is placed on highlighting the variety of professional paths available to engineers beyond the often overly emphasized design route. The *Engineering Concentration* phase allows students to engage kinesthetically by proposing, implementing, and demonstrating an interactive ECE project. Combined, these two phases lead students through an entire engineering cycle from concept to testing and implementation so students can visualize a potential career in ECE and make an informed decision about pursuing an ECE degree. Both phases rely on a wide range of activities and diverse groups of ECE professionals to provide relevant experiences at-scale for first year students.

### 2.2 Engineering Role Phase – Expanding the Perceived Roles of ECE Professionals

Our goal with the *Engineering Role* phase was to emulate a professional engineering experience so students could better visualize themselves in a work environment and thereby raise the level of perceived value for engineering. Like many workplace experiences, we wanted to provide students with an open-ended engineering task where they are gently assisted in forming connections between the engineering curriculum and their personal interests. Though this aspect appears similar to many problem based learning approaches, we emphasize the complete development of a project from a preliminary social need, through a concept development phase that incorporates community feedback, to evaluating the impact of the proposed solution. We also highlight the variety of roles that engineers play in this process beyond traditional design. This phase can be considered an orientation to the profession [12]. From personal interactions with graduates and discussions with practicing engineers, we believe many students misappropriate the term "design" as a synonym for engineering. Some students who do not enjoy design-specific

courses or who do not excel as much as their peers then inappropriately decide to transfer away from engineering not realizing that, in reality, the majority of engineers do not work in design specifically.

To create a cohesive engineering experience while presenting a spectrum of potential career paths for students, we took a multifaceted approach in the *Engineering Role* phase. First and foremost, we wanted to synthesize the inspiring opportunities of an internship into an accessible course for students considering an ECE degree. Students contribute to a relevant project that has no singular correct solution. They gain knowledge on a specific aspect of the project and collaborate with other “experts”, communicating clearly during the collaboration to reach a team agreement with respect to inherent trade-offs between different options. This student experience aligns strongly with the desired student outcomes identified by ABET [14]. Second, pushing beyond a traditional internship experience, students should also have some freedom to explore a spectrum of ECE concentrations to find the domains of greatest interest to them. This better connects students to ECE, helps them develop an engineering identity, and motivates their future studies. We focused on highlighting the six ECE concentrations available at our university – communication and signal processing, computing engineering, control and robotics, electric power and energy systems, electromagnetics and remote sensing, lasers and photonics – which undergraduates can pursue through their choice of electives.

We further extend beyond the internship concept during the *Engineering Role* phase by having students contribute to all stages of a project life cycle – from preliminary company portfolio, through a community forum, to a final project report. Emulating the entire life cycle of a project helps showcase a wide range of professional roles in which engineers can excel and extends beyond traditional problem based learning. Interactions with the community are an especially important component of this phase because the experience emphasizes a number of valuable skills that may not be clear from traditional engineering courses including:

- (1) the importance of communicating technical material at an appropriate level for diverse audiences,
- (2) the value of clear documentation,
- (3) the need to justify key decisions,
- (4) the ability to identify and understand different stakeholder perspectives,
- (5) the benefit of evaluating the impact of a proposed engineering solution on a social, environmental, and cultural level.

Placing students in a setting where they see the

importance of these less traditional skills for an engineering project further aids students in making an informed decision about engineering because they see the value of their own skills in context. These skills are also identified by ABET as important student outcomes and our course structure provides students with a unique, tangible application of each student outcome. Once again, students are also exposed to the flexibility of an engineering degree because they are not limited to just doing technical design.

To implement these many facets in a one-credit hour course, students became employees of Quixote Wind Consultants, a fictitious wind farm consulting company. The wind farm task was selected after considering many other potential ECE projects because we wanted every student participating in the project to have a similar entry-level experience. Unlike many ECE applications that may be abstract or specialized, wind turbines are an increasingly common sight, so the application is generally relatable to students. It also offers an intriguing technical challenge by being far more complex than initially perceived and demonstrates the interplay between common concentrations of ECE. Students are also unlikely to have technical experience with wind turbines during their K-12 education so all team members will have a similar background despite previous educational opportunities. The same cannot be said of many other projects. For example, a robot challenge would be much more accessible to students from affluent schools that had competitive FIRST robotics teams. Selecting a project that is more familiar to a subset of the class would likely reinforce feelings of unpreparedness for under-represented groups who traditionally do not have access to the same resources as other students. We firmly believe that with our approach, the wind farm task is a relatable project that will be equally accessible to all students.

We also wanted students to experience the range of engineering skills needed to successfully implement a technical solution in the real world. While there is always some interplay between engineering and society, wind farms are a very tangible application for first-year engineering students. Implementing the technical wind turbine solution in a community to create an entire wind farm provides an excellent platform for fluid discussions about social responsibility. Students must consider social constraints on the project like environmental concerns, economic impact, and stakeholder values where there is no absolute right or wrong answer. They will also need to decide how these social constraints impact their technical design, thereby strongly addressing ABET student outcomes numbers 2 and 4.

In order to become knowledgeable employees of Quixote Wind Consultants, students focused only on the technical constraints of a wind farm design for the first half of the *Engineering Role* phase. After a high-level introduction to wind turbines, students self-selected into one of five technical subteams: blade control, blade design, farm location, system monitoring, and utility constraints. The technical subteams were chosen to be realistic demonstrations of how complex systems are often segmented but also to still provide opportunities for students to explore different ECE concentrations within each subsystem. Specifically, we highlighted a few examples of how the six concentrations available to undergraduates at our university can be applied to a wind turbine. Table 1 presents the six ECE concentrations and how they connect to one or more of the selected subsystems with a specific example. While more connections could be drawn, the chosen applications provided a concrete example for first-year engineering students.

Students used guided questions and key terms to direct their research in identifying fundamental considerations and common practices for their respective subsystem. Students first performed research individually and then collaborated with other members of their technical subteam. This separation of research time was a deliberate mechanism to support a variety of learning styles and promote balanced and informed team collaborations. The research was all done online and required no computer programming or complex math to again ensure all students had an equitable introductory experience. Together, technical subteams culminated this stage of the project by preparing a summary of their subsystem which was included in the company portfolio. The portfolio extended the company theme and challenged stu-

dents to reach a consensus on important system considerations and then justify those decisions in a concise manner.

Upon submitting their respective subsystem reports for the company portfolio, it was announced that Quixote Wind Consultants had been awarded several different project bids. To fulfill these bids, technical team members were promoted to technical experts and then assigned to a wind farm team. Every wind farm team included technical experts from relevant subsystems to ensure each team could make informed decisions for the wind farm and enforce the need to collaborate with other specialists in order to create a complete engineering solution. Each wind farm team was also assigned a unique project site that had specific power requirements as well as a selection of technical and social considerations. In Fall 2019, all the wind farm projects were actual proposals being considered throughout the United States. Table 2 summarizes the requirements for each location, which were quite diverse, ranging from a large, 800 MW facility off the coast of Massachusetts to a single house turbine in Roswell, New Mexico. These physical locations also included real social concerns like the impact of the farm on local fish habitats or bird migration routes. We modified the wind farm locations in Fall 2020 to be fictional projects but preserved the variety of key technical and social considerations.

Teams had two class periods – just four hours – to combine their technical expertise and prepare a formal presentation summarizing their recommendations for the complete wind farm. These presentations were then delivered during class to a simulated community forum. Practicing engineers from our city were brought into the community forum to give a brief overview of their personal

**Table 1.** Correlation of wind farm subsystem with ECE concentrations

Concentration	Example Applications in Wind Turbine
<b>Communication and Signal Processing</b>	Blade Control – clean control signal for blade motors. Farm Location – minimize signal interference. System Monitoring – determine sensor outputs.
<b>Computer Engineering</b>	Blade Control – embedded systems. Blade Design – simulate blade dynamics for stability. System Monitoring – parallel processing of all sensors.
<b>Controls and Robotics</b>	Blade Control – modify pitch and angle for wind speed. Blade Design – limitations on blade size/rotation speeds. System Monitoring – ensure safe operation.
<b>Electric Power and Energy Systems</b>	Blade Design – shape/length for desired rotation speed. Farm Location – transmission loss. Utility Constraints – satisfying community power demand.
<b>Electromagnetics and Remote Sensing</b>	Blade Control – wind speed prediction. Farm Location – minimize signal interference. Utility Constraints – fault detection.
<b>Lasers and Photonics</b>	Blade Control – wind speed prediction. Blade Design – shaping of blades. System Monitoring – measure blade deflection.

**Table 2.** Summary of the locations and given considerations for each wind farm team

Location	Power Requirement	Technical Considerations	Social Considerations
Roswell, NM	14 kW	<ul style="list-style-type: none"> <li>• Low budget.</li> <li>• Farm is located near a residential area.</li> </ul>	<ul style="list-style-type: none"> <li>• In line with migratory bird path to Bitter Lake National Wildlife Refuge.</li> </ul>
Off the coast of southern MA	800 MW	<ul style="list-style-type: none"> <li>• Extremely large facility.</li> <li>• Difficult maintenance.</li> </ul>	<ul style="list-style-type: none"> <li>• Martha's Vineyard is wealthy tourist destination.</li> <li>• Active fishing location.</li> </ul>
Wascoe County, OR	190 MW	<ul style="list-style-type: none"> <li>• Frequent wildfires in vicinity of site.</li> <li>• Have large hydroelectric facility in place along Columbia River.</li> </ul>	<ul style="list-style-type: none"> <li>• Recreation is large part of county income.</li> </ul>
Carbon County, WY	Not specified	<ul style="list-style-type: none"> <li>• Extremely variable wind speeds, large temperature fluctuation.</li> <li>• Vague power goal.</li> <li>• Remote area so consider access and maintenance.</li> </ul>	<ul style="list-style-type: none"> <li>• Sage grouse (endangered bird) breeding area.</li> </ul>

backgrounds before role-playing as fictitious members of communities impacted by each wind farm proposal. Community representatives were deliberately chosen to showcase diversity and exemplify the flexibility of an engineering degree. For example, one guest was the Mayor of our city and he spoke to the value of his mechanical engineering background in politics. Another guest spoke about her experience advocating for herself while working in a male-dominated research group.

The community forum was an important event that combined many of our strategies to create an informative experience for a diverse group of students. During the presentation, students had to clearly justify their collaborative decisions and think beyond the technical constraints to understand how the proposed solution would impact different stakeholders. This activity motivated a range of professional skills identified as important by members of our Industrial Advisory Board and educational research [12]. Students naturally gravitated toward certain roles within the team, which helped them recognize their own strengths and how those skills benefit real engineering projects. Students also had the opportunity to interact with inspiring engineers from their community to see more examples of what can be achieved with an engineering degree.

During the community forum, every team heard valid social concerns that impacted their proposed wind farm. Teams then had to incorporate the community feedback from their presentation into a modified wind farm and summarize their design in a final report. Here we note that the term '*design*' was deliberately omitted from the wind farm project until the final report. We wanted students to focus on the project experience as a whole and discover the varying roles required to complete the project. We emphasized that in a literal sense, design was only one component of the entire engineering process. The term design was re-intro-

duced for the final wind farm report, however, to be more consistent with many engineering courses where design and project are often used interchangeably. Students in this class now had experience with the many stages of a complete project and so were better equipped to see beyond the nomenclature and recognize the literal distinction between project and design.

The final report was also a critical thinking challenge for students because they were not given an initial rubric. Instead, just as in a real work environment, the project manager asked each team to write a report about their project plan. Students had some class time to identify which elements of the project were most important and consider how to best organize those components into a formal report. The class then worked together to develop a rubric for the final report. Creating a collaborative rubric helped students think critically about how to articulate a project plan and how to logically support a sequence of decisions. Once the final reports were completed, teams transitioned from the *Engineering Role* phase to the *Engineering Concentration* phase.

### 2.3 Engineering Concentration Phase – Delving Deeper into a Technical Aspect of ECE

While the wind farm project focused on emulating a consulting company to highlight the breadth of potential engineering careers, the *Engineering Concentration* phase provided students with a traditional ECE design challenge, so they had the tactile experience of designing, testing, and implementing a functional end product. Students were responsible for all stages of the project – from initially proposing a challenging yet achievable design, acquiring necessary materials and investing the time to build their functional design, to presenting their completed project to invited community members as part of an open demonstration evening. This open-ended project allowed students to further

explore a topic of interest to them at-scale because students could personalize their learning without specific direction from an instructor.

The hands-on project was built around an Arduino Uno microcontroller which students needed to program and integrate with other electronic parts to create a functional, interactive project. The Arduino platform is very robust and has a large community of open-source documentation so students could be inspired by existing projects and find useful resources. To ensure all students had a similar foundation with the Arduino, a two-hour workshop was held during class to introduce students to wiring, basic schematics, and programming. Students were then encouraged to independently research interesting projects before working with their assigned teammate to create an initial project proposal. Here we would like to note that in our Fall 2020 course implementation, students were asked to explicitly identify the ECE concentrations that were related to their proposed project, so the activity further served as a program ‘orientation’ opportunity [12]. The class also worked together to develop rubrics for the project proposal as well as the project notebook which they were required to maintain for the duration of the hands-on project. The collaborative rubrics facilitated an open dialogue about the design task and how the professional skills/roles students observed during the *Engineering Role* phase were still applicable to a stereotypical engineering design problem.

While work during the *Engineering Role* phase primarily occurred during class and was guided by the course instructor, the *Engineering Concentration* phase further challenged students to take full ownership of their chosen project. Students were not required to meet during the scheduled class period but were expected to invest sufficient time to complete their project, collaborate fairly and respectfully with their assigned teammate, and document the development of their design in a formal project notebook. To ensure students remained on track to complete their projects and continue supporting their engineering development, each team was responsible for attending a progress meeting where both team members met with the instructor to provide an informal update on their project, receive guidance on challenges they had encountered, and discuss the remaining steps in their project. Teams were also required to meet at least once with an Engineer in Residence (EiR). The EiR program [16] brings practicing engineers to campus to share their knowledge and experience with students. EiR participants span a range of companies and technical expertise so meeting with these valuable volunteers further exposes students

to the diverse potential within ECE while creating potential mentorship opportunities [17].

The culminating experience for the hands-on project was an open demonstration evening where teams from the career emulation course set up small booths alongside upper-classmen from other open design classes to showcase their completed project. Members of the EiR program, industry leaders from our community, fellow students, and department professors were all invited to attend the demonstration evening and interview students about their projects. Students gained increased confidence in their engineering skills – professional and technical – as a result of the supportive feedback and genuine interest of guests. Overall, this interactive experience helped students further emulate an engineering career by engaging in dialogue with other professional engineers, exchanging ideas, and sharing their enthusiasm. Students concluded the *Engineering Concentration* phase of the course by returning their project hardware and submitting a final report along with their project notebook. The deadline for these assignments was one week before the start of final examinations so students could focus on their core exams without feeling overwhelmed by an elective course.

### 3. Results and Student Evaluations

Fall 2019 was the first implementation of the career emulation course with a second implementation occurring during Fall 2020. The course was offered as a one-credit hour elective primarily for incoming freshmen enrolled in ECE. Here we note that at our university, freshmen are encouraged to enroll directly in a department with only a small number pursuing an engineering “undeclared” option. Students were expected to meet Wednesday evenings from 5:30–7:30 pm to ensure there was no conflict with other courses. Despite the late hour and relatively rigid Freshmen schedule, 18 students initially enrolled in the 2019 course with 16 students remaining actively engaged for the entire semester. Of the 16 active students, five were initially enrolled in Computer Engineering, nine were enrolled in Electrical Engineering, one was undeclared, and we had one guest student from a local high school. Fall 2020 had a similar level of participation with 16 students enrolled – eight initially enrolled in Computer Engineering and eight enrolled in Electrical Engineering. The preliminary impact of the course was qualitatively measured through three student surveys as well as instructor observations throughout the semester.

During the first class period, students were asked to complete a pre-class survey. Three questions from the pre-class survey were designed to measure

students' incoming knowledge of ECE, initial level of expectancy with respect to their own skill, and the overall value they placed in an ECE degree. Specifically, these three questions asked:

- (1) How would you define Electrical and Computer Engineering?
- (2) What skills do you have that will benefit you in an engineering career?
- (3) Why are you choosing to pursue an engineering degree?

These three questions were also presented in the post-class survey so we could assess any change in the students' knowledge, expectancy, or value over the span of one semester.

For the pilot implementation, we focused on promoting the career emulation course as an introductory class for students to experience being an ECE professional so they could better establish their academic interests. It is therefore unsurprising that in the pre-class survey, the majority of students only provided vague definitions for ECE with many references to 'design' and 'circuitry'. The post-class survey responses contained more concrete definitions with references to 'improving society' and terms like 'understanding' or 'applying' occurring as frequently as 'design'. Overall, the refinement of responses observed between the pre-class and post-class surveys indicates that students gained a better understanding of ECE during the semester. We believe this improved understanding helped students make informed decisions about whether they really wanted to pursue an ECE degree.

We also observed a large shift in students' levels of expectancy between the pre- and post-class surveys by comparing student responses to the question, "What skills do you have that will benefit you in an engineering career?" During the pre-class survey for Fall 2019, there were two mentions of "communication" in the student responses but nearly every single post-class survey referenced communication or other non-technical skills like empathy and teamwork. Table 3 shows the pre- and post-class survey responses from two representative students. Both students initially listed a variety of valuable skills, but the skills are indicative of stereotypical engineering views. The two students'

responses to the post-class survey question are more mature. The students both recognize they have a diversified set of skills that extend beyond technical skills and are equally valuable in engineering. Several of the course components were focused on expanding the range of skills students associate with engineering, as well as broadening the perceived impact of engineering, to increase students' levels of expectancy and the survey results indicate these efforts were successful.

Students' perceived value for engineering was evaluated by asking why they were pursuing an engineering degree. As an elective course for beginning ECE students, it was unsurprising that the students all expressed general interest in pursuing an ECE degree; however, there were few concrete answers and most of the pre-class survey responses indicated the students were hesitant or uncertain about ECE. Of the students who actively participated throughout the entire semester, there was a noticeable shift from vague interest in ECE in the pre-class survey to citing specific experiences and use of more positive affirmations in the post-class survey. Table 4 presents the pre- and post-class survey responses for two characteristic students who demonstrate the positive development observed over the course of one semester. Student A initially indicated they were only considering an ECE degree but then concluded that they not only enjoyed the field but also recognized they could make a positive impact on the world, which indicates a significant increased value for ECE. The pre-class survey response by Student B indicates they were already quite familiar with an engineering work environment, but they benefited from the *Engineering Concentration* phase where they were fully responsible for taking an idea to completion. Overall, the inclusion of positive phrasing observed in students' post-class survey responses affirms the course did increase students' level of value for engineering. Students also benefited from the two course components to varying degrees depending on their prior experience, so the combination ensured all students had positive development.

The pre- and post-class survey responses indicate that students increased both their level of expectancy as well as perceived value for engineering over

**Table 3.** Response of two students to the survey question, "What skills do you have that will benefit you in an engineering career?"

	Pre-Class Survey	Post-Class Survey
Student A	I have good time management, I'm a quick learner, and I enjoy learning new things.	Empathy, intelligence, desire to help, logical thinking skills, and team/communication skills.
Student B	I have built two PC's and have been able to keep ahead of the curve in math. This should help lighten my load a bit over the next year. I am also a very logical problem solver and I feel that that can be applied frequently in engineering.	The skill that will benefit me the most is going to be the work ethic that I am constantly improving, other necessary skills include communication and the ability to reach a compromise when team members have different opinions on how to solve a problem.

**Table 4.** Response of two students to the question, “Why are you choosing to pursue an engineering degree?” before and after the class

	Pre-Class Survey	Post-Class Survey
Student A	I am not currently pursuing an engineering degree but I am definitely considering. I am taking this class to see what electrical engineering is about. This is will (sic) really help me decide whether I want to major in it.	I am good at math and physics, and being able to put those two together to create something useful is really interesting to me. Also, since I enjoy the field, I feel I could make a greater positive impact on the world through engineering.
Student B	I've always had an interest in circuitry and technology. I've also toured Micron in Boise Idaho and HP in town and the work environments there seem like something that I'd like to have in the future.	It is incredibly gratifying to see the result of lots of brainstorming come to life when a project is completed.

the course of one semester. These two factors are strong indicators that the students will persist in engineering; however, as we mention throughout this paper, our primary goal with this course was not necessarily increased retention. We wanted to help students make informed decisions about engineering so those students that either persist or transfer do so from a position of knowledge. The solidifying of definitions for ECE observed from the survey indicates students had a better understanding of ECE. We also wanted to create a realistic career emulation experience so students could visualize themselves as practicing engineers and decide if that was a desirable future for them. The true effectiveness of this approach requires a long-term study of student attrition and future employment, but we already have indications that the experience was valuable for students.

One compelling pair of observations that support the effectiveness of our career emulation course occurred following the community forum during Fall 2019 when two students remained after the scheduled class period. Student A stayed after the forum to speak with the community members further about their engineering experiences and even took pictures with all the guests. In contrast, Student B remained after the class to discuss the possibility of transferring because he was now confident that engineering was not the academic path he wanted to pursue.

In both interactions, students directly commented on their appreciation for the career emulation experience because it helped them envision a future in engineering. Student A found the possibilities within engineering to be very exciting while student B's experience reinforced his initial inclinations, which were not in engineering. Student B specifically referenced how the wind farm project provided him concrete experiences that he could use to inform a dialogue with his parents who had been a driving force in his initial pursuit of an engineering degree.

Open responses from the surveys further reinforce that our course helped students envision a potential career in engineering. One student commented, “I learned so much about how a real

engineer might think and how it is applicable to our project . . .”, while another said, “This class really opened my eyes and helped me learn what I needed to know about a career in engineering and I am very grateful for that.”

A follow-up survey was emailed to students, independent of class assignments, to solicit additional feedback on the career emulation course. Of the 32 students contacted, 20 students completed the short survey. Question 1 asked students to indicate how strongly they agreed with the following statements related to the course goals:

- A. This course increased my understanding of the breadth of topics included in an electrical engineering program.
- B. This course increased my understanding of the range of jobs that electrical engineers perform.
- C. This course helped me to decide whether I wanted to become an electrical engineer.
- D. Overall, my experience in the career emulation course was beneficial.

Fig. 1 summarizes the survey results. The students generally agreed with each statement with the majority of responses being either “slightly agree” or “strongly agree” on each question though one student responded “disagree” to parts B and C.

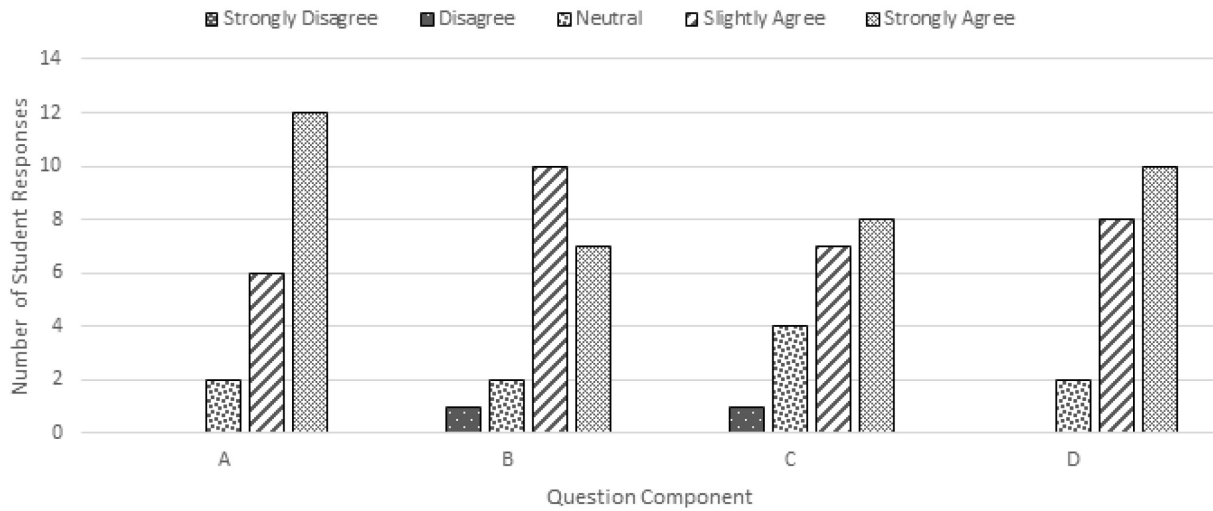
Question 2 on the survey asked students to evaluate the usefulness of different course components, specifically:

- A. Overview of wind turbine components (lecture).
- B. Individual research time for technical subsystem.
- C. Team collaboration on technical subsystem.
- D. Community forum presentation (with guest speakers).
- E. Group collaboration to develop report rubrics.
- F. Research journal.

Survey results are presented in Fig. 2. Once again, the responses were generally positive with the majority of students indicating they found each element “somewhat useful” or “very useful”. It is interesting to note that those course components



### Student Responses to Questions about Course Goals

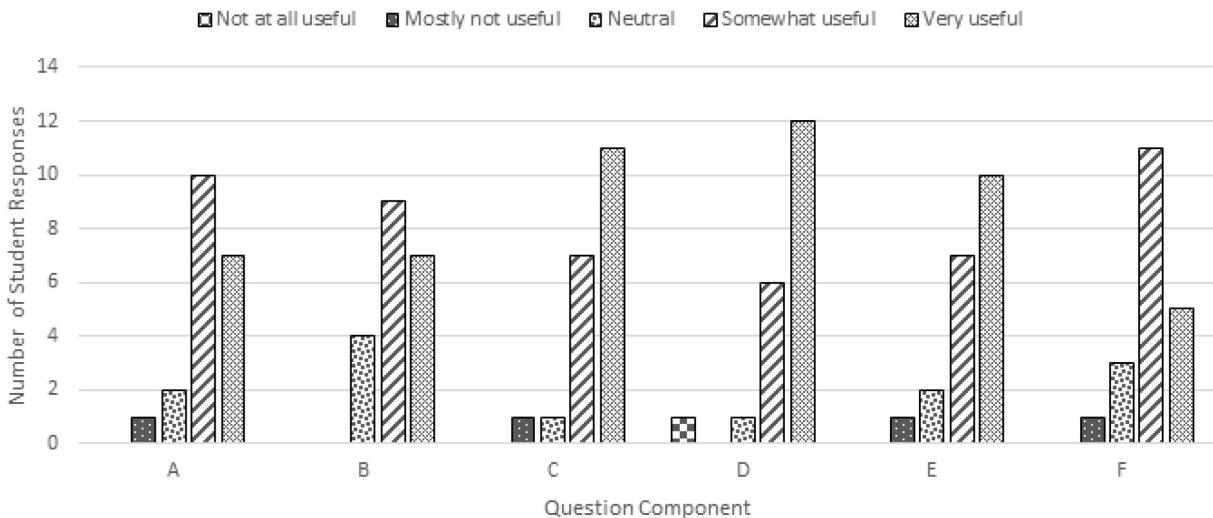


**Fig. 1.** This chart presents all student responses to the four components of Question 1. The four components focused on evaluating student perceptions of ECE and the roles of electrical and computer engineers. The majority of students agreed that the course improved their knowledge of ECE as a potential career path.

indicated to be “mostly not useful” by one student were “very useful” by most of their peers. Likewise, while one student considered the community forum to be “not at all useful”, another student used the open feedback question to say, “the community forum was really helpful because it helped us get a bigger understanding of how it is very important to always do research in depth”. This range of feedback justifies our multifaceted course structure and at-scale approach to support students with a variety of backgrounds.

In addition to the follow-up survey, we looked at upcoming enrollment for those students that participated in the career emulation course. Thirteen of the 18 students who initially enrolled in the career emulation course during Fall 2019 are continuing in ECE one year later. One student said, “I took this durring (sic) my first semester and I didn’t quite know what to expect from this. However, I found that I really enjoyed learning about the engineering process, learing (sic) how to present, and learing (sic) about how keeping a detailed journal on a

### Student Responses to Questions about Course Content



**Fig. 2.** This chart presents all student responses to the six components of Question 2. The six components focused on evaluating student perceptions of each key course element. The majority of students found each course element beneficial to their learning experience.

project is vital. This class was great fun!” Of the remaining students three shifted to related technical degree programs and two withdrew from the course before the end of the semester (one returned to the university as an “undeclared exploring” major and the other is investigating institutions where he can pursue his intellectual passion).

Of the 16 students enrolled in the Fall 2020 semester, 13 are continuing in ECE, two are undecided, and one is transferring to a different school to focus on radiology. The student transferring to radiology was willing to discuss their experience in more detail and indicated they were initially uncertain about ECE but their parents encouraged them to enroll. “The biggest help for me with this class is that it showed me the kind of work that engineers do and the passion that the other kids in the class had for engineering. I felt as if I was not at a high enough level of interest to be in this major.” Thus, the course met its objectives in helping the student make an informed decision even though that decision was to not continue in ECE.

#### 4. Discussion

We are very encouraged by our preliminary results for the career emulation course. Students matured their engineering identity by actively engaging in realistic engineering tasks through two key course phases: an *Engineering Role* phase and an *Engineering Concentration* phase. The *Engineering Role* experience fulfilled desired ABET student outcomes 1, 2, 4, and 5. The community forum satisfied ABET student outcome 3 and further emphasized outcomes 2 and 4. Students were also able to experience the many aspects of engineering that extend beyond the ‘design’ stereotype to better understand the ECE profession as a whole.

The *Engineering Concentration* experience satisfied previously addressed ABET student outcomes but strongly tied in outcomes 6 and 7. Students worked on a classic design task but connected the core design concepts to the diverse engineering roles from the first half of the semester. Students also had multiple opportunities to engage with professional engineers – first through a required EiR meeting and second during the demonstration evening. These interactions provide students with opportunities to develop an engineering identity and again experience engineering roles beyond just the narrow design phase. None of these valuable opportunities were specialized to a particular student so this experience can be implemented at-scale to support first year students.

Although it may be tempting to more rigorously define project constraints and direct students to a “correct answer”, especially when expanding the

class, we want to emphasize the importance of balancing student direction with open-ended project information. Students were not given any specific constraints or project recommendations in the Fall 2019 course to more accurately emulate how practicing engineers must deal with missing and/or ambiguous information. During class, it was observed that some students worked much more confidently in an unrestricted space. These confident students generally assumed a leadership role and directed the work if their teammates were uncertain about how to proceed. This dynamic led some students to feel confined by their teammates. For example, in the post-class survey one student commented, “I think that we all learned a lot but the bar could’ve been set higher. If this were worth more credits, and the expectations for everyone’s (sic) work was set higher, I think it could be a very strong and concentrated learning, engineering class.” More than a “higher bar”, what is needed is to ensure everyone is being equally challenged because, on the other side of the team dynamics, those students who were less confident with open tasks likely felt overwhelmed and at a disadvantage compared to their classmates. The prior experience and associated comfort-level for Freshmen is developed during K-12 and at home where under-represented groups are often at a disadvantage in STEM opportunities.

We do not want prior opportunities (or lack thereof) to negatively impact a student’s experience in this course, so we introduced a company catalogue for the *Engineering Role* phase of the Fall 2020 course. The company catalogue provided a more well-defined starting point and common vocabulary which students could use as a launching point for their own research. With this format, students still had the freedom to extend their research as far as their interest and class time allowed while experiencing a realistic engineering space, but we believe the modification contributed to the more collaborative conversations which were observed during the Fall 2020 course. Further, no single student appeared to be disproportionately directing the project nor lagging behind on team efforts.

In addition to balancing the right amount of support and freedom, it is important to ensure students are exposed to a wide variety of professional engineers, thereby increasing the likelihood of students finding relatable role models [6]. The course instructor is an important element in this as they have regular interactions with the students. Personal report was valued by students according to direct communications and anecdotal feedback from academic advisors. However, the instructor is a single contact. Maintaining the deliberate course

elements which include engineers with diverse backgrounds – specifically the community forum, EiR program, and project demonstration evening – will become increasingly important for larger class sizes to help ensure students do experience meaningful interactions with potential role models.

We believe this course fills an important need in ECE education by ensuring students have a clearer vision about future careers and persist in engineering when appropriate for their interest and skill set. It is our goal to extend this course to a larger scale so all incoming ECE students receive the same benefits. We focus on ECE students because our university has a direct admit program where freshmen are accepted directly into the ECE department. For universities that have a common engineering core, one would need to expand the *Engineering Role* and *Engineering Concentration* phases to accommodate all engineering disciplines.

A key element of this course was bringing in a diverse group of professional engineers with which students could interact. Our university is fortunate to be in a location with access to a large number of companies that employ electrical and computer engineers. This makes it easier to recruit a diverse group of professional engineers to volunteer for our class, but we recognize that recruiting potential guests is another potentially limiting factor.

## 5. Conclusions

Overall, initial results for our career emulation course indicate we achieved our primary goals. Survey responses, instructor observations throughout the semester, and discussions with students regarding their future career expectations indicate students did mature and formulate a clearer direction for their academic studies – be it in engineering or in another program. Through participation in our course, students were able to visualize themselves as working engineers in order to make an informed decision with respect to their academic pursuits. Course assignments were deliberately designed to help students recognize the range of technical and non-technical skills they have which will benefit them in engineering. A diverse group of professional engineers interacted with students at strategic points throughout the course to emulate realistic workplace experiences, provide meaningful advice, and serve as relatable role models. These efforts were aimed at helping students visualize themselves as a successful engineer. Students also gained a better understanding of how an engineering degree can be used and which ECE concentrations could best lead them to their desired career. Combined, these efforts increased students' levels of expectancy and their perceived value for engineering to grow their likelihood of persisting in ECE.

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