Promoting Student Confidence in a First-Year Electrical and Computer Engineering Course

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Abstract – **First-year electrical and computer engineering (ECE) students who have not yet encountered applications in their discipline often struggle to draw connections between the theoretical concepts from their introductory courses and those specific contexts in which they might apply those concepts in their future careers. As such, these students frequently struggle with relating to their courses and may become discouraged or doubt their ability to become an engineer. To address these challenges, the first ECE-specific course at Valparaiso University has been designed to increase the exposure of students to the various ECE sub-disciplines. The specific applications explored by students in this course range from programming microcontrollers to building amplifier circuits to designing and testing complex digital logic circuits, which are subjects not usually covered until the last two years of study. Results are presented that demonstrate several benefits of the wide range of topics covered in this course. These include helping students choose with greater confidence future elective courses and their major, improving the self-confidence of those students who may struggle with relating to more abstract engineering concepts, and maintaining student interest while providing them with the necessary theoretical background for their future studies.**

Index Terms – First-Year, Electrical and Computer Engineering, Laboratory, Student Confidence.

INTRODUCTION

A common engineering curriculum structure adopted by many programs utilizes the first year to introduce students to general problem-solving skills and provide them with the theoretical technical background required in any engineering field. Students are typically required to take a physics and/or other science course(s), a math course, and an introduction to engineering course. This introduction to engineering course may focus on teamwork, interdisciplinary collaboration, design principles, and a conceptual overview of the various engineering disciplines. In the semesters that follow these introductory courses, engineering students are expected to select a particular sub-discipline of engineering and undertake a first course in that chosen major. In the case of electrical and computer engineering (ECE), this first discipline-specific experience often covers a selection of topics such as number systems, digital logic, computer programming fundamentals, and the analysis of electrical circuits.

This natural progression first prepares students with necessary skills that are applicable to any engineering discipline and then with more specific tools that are relevant in any ECE area of focus. Students may then later specialize within their field by strategically choosing technical elective courses in the last two years of their studies. However, students are typically asked to choose their discipline without having any in-depth or hands-on experiences in that field. Without these experiences, they may struggle to draw connections between their introductory courses and specific engineering applications. Because their coursework and future career seem disconnected, they may become frustrated in their first discipline-specific course, or even worse lose confidence in their ability to succeed as an engineer. Moreover, depending on the curriculum of a particular institution, changing one's major after this initial experience may have other consequences, including delayed time to graduation.

The first ECE course thus has a crucial role in preparing students for future success and providing students with sufficient background to make an informed decision of their engineering sub-discipline. We propose accomplishing this by increasing the breadth of advanced ECE applications experienced by students in their first year. Topics covered in this class include number systems, digital logic, circuit analysis, and computer programming, as would be in a more traditional structure. However, the specific applications explored by students in this course range from programming microcontrollers to building amplifier circuits to designing and testing complex digital logic circuits. The course culminates in a final design project that requires students to construct and program a robot that is capable of playing "soccer." It should be noted that direct contact with such advanced applications is frequently not encountered until the last two years of study.

BACKGROUND

There is a recognized, increasing need for universities to produce successful graduates in engineering and other STEM fields. As such, recent research has focused on understanding and improving student retention in these disciplines. Several studies have been conducted to identify the main reasons that may motivate a student who begins their undergraduate career in engineering to leave that field. One study identified three main sources of students' departures from engineering. First, students may become disengaged with engineering courses due to a lack of hands-on activities. Second, they might struggle with relating the theoretical concepts from their foundational math and science courses to the concrete engineering applications they might encounter in their future careers. Third, they are unsuccessful in building meaningful connections with their engineering faculty and peers, and as such do not develop a strong identity as an engineer [1]. Another study found that the three most common reasons for students leaving engineering were poor advising and teaching, the difficulty of engineering curriculum, and lacking a sense of belonging in the field. It was also identified that the sense of belonging issue was most influential in causing students to leave [2]. Another component to improving student retention is to understand the struggles faced by current engineering students. These include learning to maintain work/life balance, develop time management and organization skills, and operate independently for the first time [3].

Also important is determining how engineering students who persist in the field select their major. Common first-year engineering experiences that provide students with at least one semester to decide upon a major before officially declaring it have been shown to improve student retention both in engineering and at a particular institution [4]. Moreover, providing students with an increased variety of resources, including a longer-term course project, presentations describing the various engineering sub-disciplines, videos documenting successful alumni experiences, and independent research at an early level can help students make an informed decision about their major [5]. Incorporating more active-learning strategies and helping students connect their identity with the course material also allows students to select their major with more confidence, reducing potentially difficult transitions later in their academic careers and delayed times to graduation [6]. Related to this, it was shown in [7] that activities focused on encouraging students to perform their own research about their selected major and continue their studies outside of class were most useful to them in choosing a major.

With an increased understanding of factors that may motivate a student to leave or choose engineering and the challenges they are facing, efforts can be made to mitigate these to improve student retention. For example, to improve students' ability to draw connections between their abstract foundational math and science courses, engineering programs have found success with incorporating more hands-on team experiences [8], open-ended design projects [9], and robotics projects [10] into their curriculum. To help students develop a stronger sense of identity as an engineer and build connections with their engineering peers and faculty, other programs have implemented cohort-style programs and experiences [1, 11]. Such experiences are directly related to the critical sources of self-efficacy in an introductory engineering course identified by students, which include mastery experiences, working in a collaborative team environment, and receiving feedback from their peers [12].

The introduction to electrical and computer engineering course that is the focus of this work incorporates many of these practices. As described in the following sections, it provides students with significant mastery experiences, the opportunity to collaborate on a design project with their peers and apply their theoretical background to concrete engineering activities. Moreover, our results demonstrate that the increased breadth of material covered in this course and integration of advanced electrical components and programming strategies not typically included in first-year engineering courses help develop and improve the self-confidence of first-year engineering students. As such, it addresses several of the crucial factors for improving student retention.

IMPLEMENTATION

The ECE department at Valparaiso University offers two degrees, electrical engineering and computer engineering. Students in both degrees take the same courses in their first three semesters. Moreover, there is a common curriculum for all engineering students in their first semester, typically consisting of Fundamentals of Engineering, Calculus I, and a first physics course in Newtonian Mechanics. In the Fundamentals of Engineering course, students attend lectures that cover topics from the mechanical, computer, electrical, and civil engineering disciplines. They then apply those lecture topics in a 50-minute laboratory experiment on the following day. At the end of their first semester, students select a major to pursue. Second-semester ECE students typically take Fundamentals of ECE (ECE 100), Calculus II, and a second physics course in Electricity, Magnetism, and Waves. These prepare them for their first formal engineering programming and linear circuit theory courses that are taken in their third semester. Students have increased freedom in each subsequent semester to choose from a variety of technical and ECE elective courses covering a range of topics including digital signal processing, fiber-optic communication, control systems, power systems, and computer vision.

ECE 100, the first ECE course electrical engineering and computer engineering majors take in their second semester, is the focus of this work. Taught in a flipped orientation, each class period in this course either presents students with an in-class exercise or a hands-on experiment. Before arriving to each class period, students are required to watch approximately 20-30 minutes of online videos. The preparation materials for a class in which students will complete an in-class exercise consist of a 10-15-minute video that provides a theoretical overview of the daily topic and several 3-5-minute videos of relevant solved problems.

Students work these solved problems in their personal notebooks. In-class exercises then provide more in-depth practice on the same topic. Students complete 19 lessons throughout the course that cover number systems, engineering notation, analog circuit analysis and design, and analysis and design of both combinational and sequential digital circuits.

The preparation materials for a class in which students will complete a laboratory experiment are similar. Students watch a debriefing video, in which they are shown the circuit they will be constructing or a demonstration of the final goal of that experiment. Certain experiments may also require students to complete pre-lab exercises such as designing or deriving the theoretical results of the circuit that will be constructed and tested in the following class. With this structure, students complete 24 experiments that include Ohm's Law, Kirchhoff's Voltage and Current Laws, operational amplifiers, capacitors, combinational and sequential digital logic, and Arduino microcontroller programming. Through these experiments, first-year students have successful initial experiences with advanced devices that include DC motors, piezo speakers, servomotors, flip-flops, keypads, joysticks, infrared transmitters and receivers, capacitors, and microphones.

Students must then integrate all of these devices into their final project, in which they work in pairs to design and build a soccer-playing robot. An example of this robot is shown in Figure 1. This robot is controlled via a wireless PS3 controller and must be able to control a ball launcher with an infrared transmission, as shown in Figure 2. Together, these figures highlight the number of components and advanced nature of the devices involved in this project. Moreover, the project combines designing and constructing both analog and digital circuits with programming an Arduino microcontroller in order for the robot to communicate with a PS3 controller. As such, it requires students to apply the skills learned in all previous laboratory experiments in an authentic engineering context.

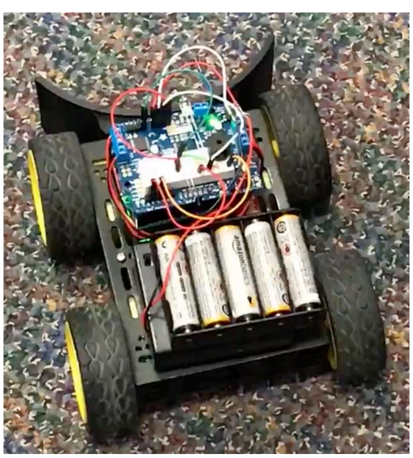

FIGURE 1
FINAL PROJECT SOCCER-PLAYING ROBOT

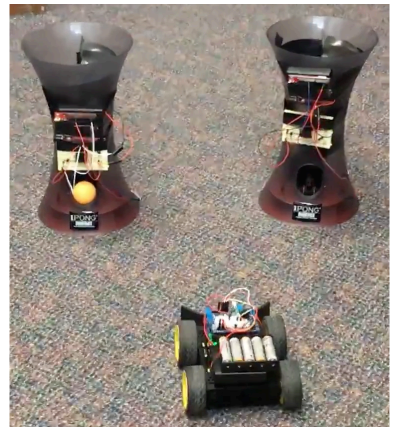

FIGURE 2
SOCCER-PLAYING ROBOT REQUESTING A BALL FROM THE BALL LAUNCHER USING AN INFRARED SIGNAL

Completing this project requires successfully meeting many technical requirements, including the following:

- Design and build an infrared transmitter circuit
- Design and build a piezoelectric buzzer circuit
- Design and build an infrared beam detector circuit
- Pair a wireless PS3 controller with an Arduino microcontroller
- Control the four motors driving each wheel of the robot with a motor driver circuit
- Design a program to use the infrared transmitter circuit to request a ball from the launcher
- Design a program to have the robot "sing a song" and "perform a dance" upon scoring

RESULTS

To evaluate the effectiveness of this course at achieving its objectives, the authors surveyed 33 first-year engineering students who are currently enrolled in their two sections of the course. The survey was designed to determine the degree to which students (1) enjoy learning about the topics in the class, (2) benefited from exposure to a wide variety of ECE topics in the class, (3) benefited from exposure to more advanced topics than typically seen in a first-year class, and (4) are more confident about their academic and professional success as a result of the class.

Figure 3 shows the degree to which students reported that they enjoyed learning about each of the three main topics in the course—analog circuits, digital circuits, and programming Arduino microcontrollers. It appears from these results that the students enjoyed all three topics, although programming seems to be the least popular of the three.

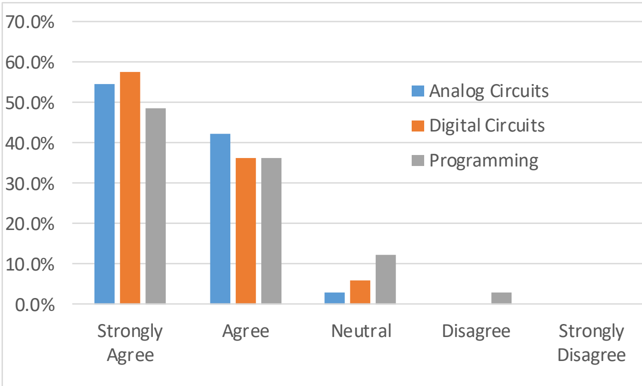

FIGURE 3
PERCENT OF STUDENTS WHO REPORT THEY ENJOYED LEARNING ABOUT EACH OF THE THREE MAIN TOPICS IN THE COURSE.

Figure 4 probes how well the students enjoyed learning about such a wide variety of topics in the course. The first question asks the students to respond to the statement, "I enjoy learning about a wide variety of topics in this class." The second is "I believe that the wide variety of ECE topics in this class will help me to choose between electrical and computer engineering." The third question in this figure asks the students to respond to the statement, "I believe that the wide variety of ECE topics in this class will help me to select elective courses that I will find interesting."

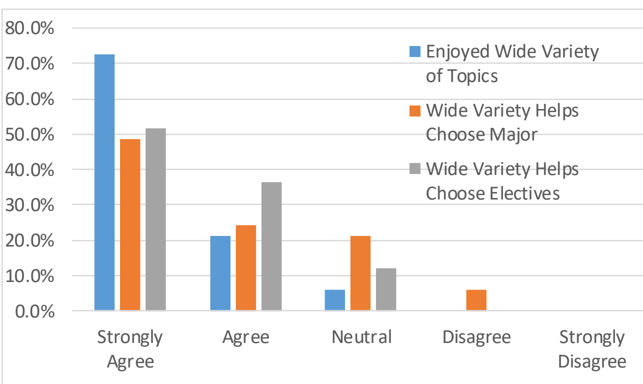

FIGURE 4
PERCENT OF STUDENTS WHO REPORT THEY BENEFITED FROM EXPOSURE TO A WIDE VARIETY OF ECE TOPICS IN THE CLASS.

Again, all three questions received favorable responses. It seems that the students definitely enjoy the exposure to the wide variety of topics, but they are not as convinced that this exposure will help them select their major. Some of the students made comments that they marked this question lower because they had already firmly chosen between electrical and computer engineering.

In Figure 5, students report the degree to which they agree with the statements, "I enjoy learning about advanced devices such as LCDs, servomotors, and piezo speakers in my first ECE course" and "I have encountered an ECE topic in this course that I find interesting and had not yet experienced."

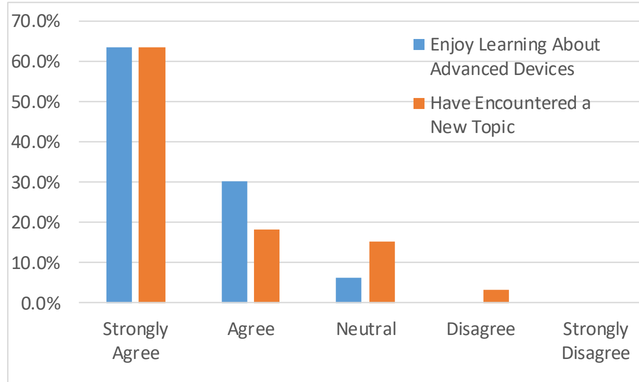

FIGURE 5
PERCENT OF STUDENTS WHO REPORT THEY ENJOY LEARNING ABOUT ADVANCED DEVICES AND HAVE ENCOUNTERED NEW TOPICS.

The students seem to agree strongly with each of these statements, although some students with strong previous ECE experiences have yet to encounter new topics. These results provide evidence that students are encountering new devices and are enjoying that experience.

Figure 6 focuses on the hands-on aspects of the course, asking students to respond to the statement, "I believe that the hands-on experiences from this course help me to effectively explain and apply the abstract concepts I am learning."

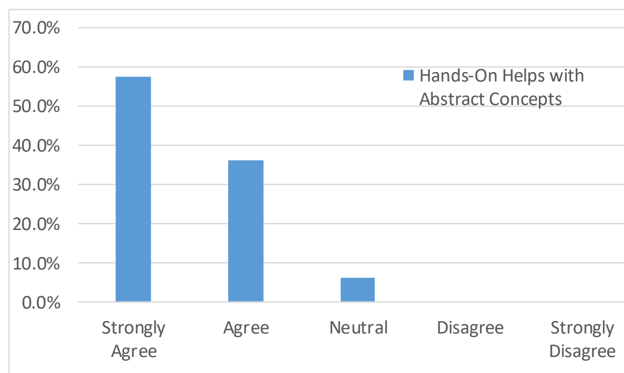

FIGURE 6
PERCENT OF STUDENTS WHO REPORT THAT HANDS-ON EXPERIENCES HELP THEM TO EXPLAIN AND APPLY ABSTRACT CONCEPTS

As most students agree or strongly agree with this statement, these results suggest that the active-learning lessons in this course help them draw parallels between engineering applications and a theoretical foundation.

Finally, Figure 7 investigates the effect this course has had on the students' confidence as an ECE student as well as their confidence in having selected ECE as a major. The three questions asked them to respond to the statements, "I believe that I will be more confident in my future ECE courses because I have worked with advanced devices in this course," "My experiences in this class have increased my confidence that I can succeed as an Electrical and Computer Engineering major," and "I feel more confident in my choice to become an Electrical and Computer Engineering major as a result of my experiences in this course."

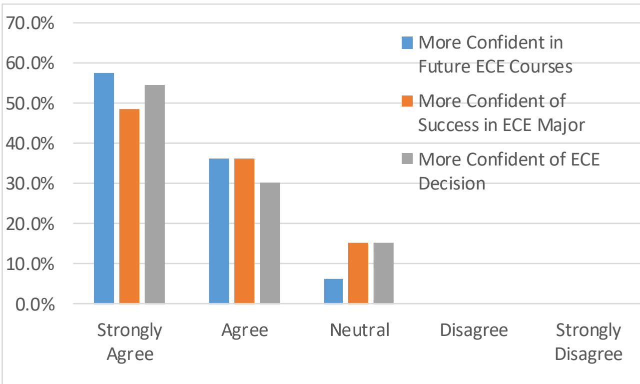

FIGURE 7
PERCENT OF STUDENTS WHO REPORT THAT THE COURSE INCREASED THEIR CONFIDENCE AS AN ECE MAJOR

A significant majority (at least 85%) of students agreed or strongly agreed with all three of these statements. It seems that the strongest agreement was with the first question, which related to their confidence of success in future ECE courses.

DISCUSSION

First-year engineering courses can have many objectives, including teaching technical skills, interpersonal skills, study skills, and many others. Among these objectives is helping students to see the full scope of the discipline they have chosen and helping them to develop self-confidence in their ability to succeed within that discipline. The results of the assessment described in the previous section provide evidence that the course described helps to achieve these two learning objectives, and it does so within the context of conveying technical knowledge.

The course described is quite technically rigorous for a first-year course, yet the breadth of the content covered means that the material moves relatively quickly. Nonetheless, students report (as shown in Figure 3) that they enjoy all three aspects of the course: analog circuits, digital circuits, and programming. In fact, the wide variety of topics covered may be one of the reasons why they enjoy the course, as illustrated in Figure 4. The course was designed to cover such a wide variety of topics primarily to help the students "get the lay of the land," as they explore different topics within the fields of Electrical and Computer Engineering. Many topics are covered with only one or two 50-minute lessons and/or labs, allowing students to get a quick exposure to the topic and determine whether or not it aligns with their interests. This furthermore helps them to determine whether to focus on Electrical Engineering or Computer Engineering, and it also helps them to determine which elective courses to pursue in later semesters.

Another characteristic of this course is that it introduces the students to relatively advanced devices that they would not otherwise see until their sophomore or possibly even their junior year. By the time the survey was given at mid-term, these devices included LCDs, DC motors, piezoelectric speakers, and servomotors, but the second half of the class goes even further, introducing a wide variety of microcontroller sensors and actuators that help the students to get a glimpse of the material they will be studying in the remainder of their academic career. Figure 5 demonstrates that most students recognize that they are seeing more advanced devices and appreciate that fact.

Ultimately, the goal of this course is to help prepare students for the remainder of their academic career, providing them with the technical knowledge and intellectual skills necessary to succeed in their sophomore year and beyond. Not only do we want students to be prepared to succeed, but we also want them to recognize that they are prepared, thereby increasing their confidence. Today's students often gain self-confidence by working with hands-on experiments, and Figure 6 shows that students appreciate the heavily hands-on aspects of this course.

Ultimately, Figure 7 presents the most important result of this paper. It shows that a large majority of students in the course report that they are more confident of their ability to succeed in future ECE courses, in their ECE major overall, and in their decision to study ECE. While self-confidence alone is not sufficient, this self-confidence when coupled with the technical knowledge the students gain in this course is likely to translate to better retention and improved academic outcomes for these students.

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