Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #46093

BOARD # 376: Improving Electrical Engineering Education Structure by Bridging CTE, Community College, and University Programs through Hands-on Skills Integration

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NSF ATE: Improving Electrical Engineering Education Structure by Bridging CTE, Community College, and University Programs through Hands-on Skills Integration: Year 1[1]

1. Introduction

Student engagement and retention in lower-division electrical engineering courses, particularly among first-generation college students, represent significant ongoing challenges. Minority engineering students often have less exposure to engineering-related careers and applications. Studies indicate a substantial attrition rate in technical programs, with 40-50% of students dropping out during their first year [1]. This issue is further compounded among underrepresented students, who are less likely to both enroll and persist in technology and engineering majors [2].

A review of existing literature by Geisinger and Raman identified several systemic failures contributing to student attrition in engineering and technology programs. These failures include a lack of emphasis on the human element of technical education, insufficient relevance of core STEM principles, doubts about the attainability of rapid technical training, failure to inspire student interest, and a non-welcoming learning environment. Their research concluded that six key factors influence students' decisions to leave technical education: classroom and academic climate, grades and conceptual understanding, self-efficacy and self-confidence, high school preparation, interest and career goals, and race and gender. Importantly, they also suggested that addressing one or more of these factors can improve retention rates [2].

The proposed CTE & HE courses hold particular relevance as they fulfill requirements for both CTE pathway completion at the secondary level and technology degrees at local community colleges. As the electrical engineering industry increasingly adopts automation, a new generation of interns, technicians, and engineers is needed. They are supplied by community college and university institutions respectively. This program aims to address this need by providing students at all levels with pathways to enter the workforce upon completion of each respective program at each partner institution. Furthermore, engaging and retaining qualified teachers at the secondary and community college levels is equally crucial. This challenge stems from the complexity of the subject matter, limited resources for training and equipping project-based learning labs, and misconceptions about the actual work performed in the Electrical/Electronics Technology industry. This project addresses these challenges by recognizing the importance of classroom and academic climate in student retention [2], and the established benefits of active learning over traditional lecture-based instruction [3]. Research also suggests that certain aspects of teaching and advising in STEM fields can disproportionately affect women and minorities [4] [5] [6]. Grandy's work highlights the stronger predictive power of student interest over grades in determining retention [7]. Other studies have shown that students who leave technical education often cite greater interest in other majors or more appealing career options outside of STEM [2] [8]. Early exposure to engineering courses in secondary education also plays a significant role in influencing students' pursuit of engineering in higher education [9] [10] [11].

CTE & HE will address these issues through two primary approaches: 1) providing secondary school students with the skills to explore compelling topics in electrical engineering (EE), and 2) educating students about higher-level job opportunities and diverse career paths available after completing a CTE pathway at the secondary level, a certificate or associate's degree at the

[1] This work was supported by the National Science Foundation Advanced Technological Education (NSF-ATE) program under Award No. 2400983. The authors express their gratitude for this essential funding, which has significantly contributed to the research and findings presented in this paper.

community college level, or a bachelor's degree at the university level. This will be achieved by creating project-based learning environments and courses that meet dual-enrollment requirements between secondary schools and community colleges, and facilitate articulation between community colleges and universities. CTE & HE will bridge the gap between existing lower-division major courses and EE technician jobs and industry requirements, effectively connecting coursework with future careers. It will also improve access to technology that supports student engagement with standards-based curricula and develops 21st-century skills. Moreover, CTE & HE will foster a sense of belonging to the field, encompassing attention, importance, dependence, appreciation, and ego extension (shared success). By prioritizing the student perspective, CTE & HE will connect learning to all these aspects of belonging. Project-based learning within CTE pathway sequences will be the primary tool for enhancing attention, dependence, and appreciation. Importance and ego extension will be fostered through hands-on team projects and the provision of current knowledge about electrical engineering [12] [13].

2. Activities

The CTE & HE program offers a flexible roadmap for student advancement through a proposed three-course series, designed for dual enrollment and/or articulation across three educational levels: secondary schools (high schools), institutes of higher education (IHE) – community colleges, and IHE – universities. This structure provides multiple pathways for students to gain workforce-ready skills at various stages of their education.

Secondary school students can complete the three-course series to fulfill requirements for the Career Technical Education (CTE) Engineering Technology pathway within the Engineering and Architecture sector. This pathway equips them with skills suitable for internships and entry-level technical apprenticeships. Students can also dual-enroll in one or more of these courses while in secondary school and apply them towards a certificate or Associate of Science (AS) program at a community college (IHE-CC). This pathway prepares students for electrical engineering technician positions. Furthermore, students can articulate one or more completed courses from either secondary school or community college towards a Bachelor of Science in Electrical Engineering (BSEE) degree program at a university (IHE-University). This pathway develops the skills needed for roles such as EE design, systems, or test engineers.

The three proposed courses are:

Course 1: Introduction to Electrical Engineering: This course introduces students to the fundamental principles of electrical engineering such as quantities and their units, providing exposure to electronics and the laboratory environment. Modules cover various aspects of electrical engineering in both analog and digital domains such as basic circuits with applications, including historical context, measurement units, and laboratory techniques. The course incorporates project-based learning with basic component-level design, simulation, and circuit-level practices.

Course 2: Electrical Engineering Clinic I: This course focuses on developing a comprehensive understanding of the laboratory environment, covering topics such as laboratory safety protocols, basic equipment operation, requirements interpretation, and test plan creation and implementation. Students gain practical experience using Programmable Logic Control (PLC) programming and LabVIEW. Each module combines theoretical knowledge with hands-on exercises to ensure the development of essential electrical engineering skills.

Course 3: Electrical Engineering Clinic II: This course builds a strong foundation in programming, simulation, modeling, machine learning, and generative AI tools, enabling students

to apply these skills to electrical engineering problems and projects. Like Course 2, each module combines theoretical knowledge with practical exercises to reinforce essential skills.
These courses will be aligned with the career pathways for the three programs involved in the project. Figure No.1 shows the career pathways plan for the project.

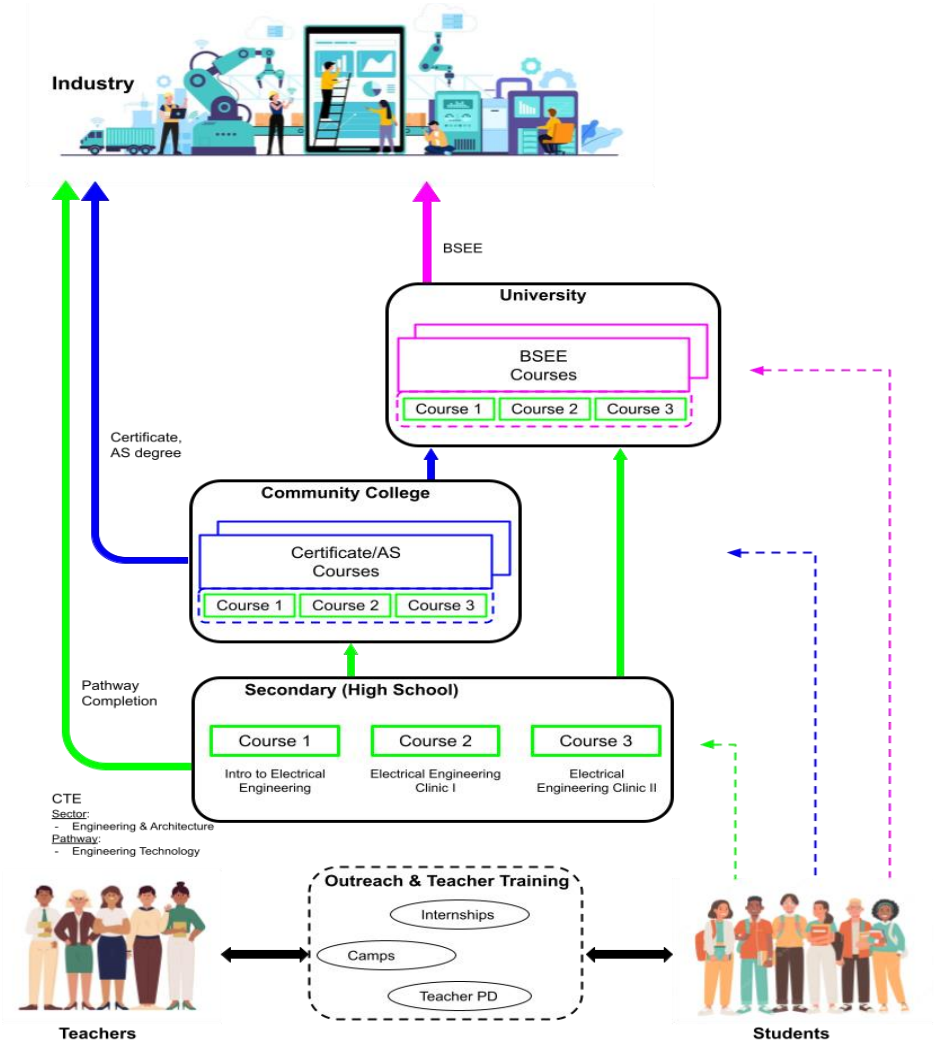

Figure 1: Career Pathways with stackable credentials utilizing the proposed courses.

3. Research Plan

The research goals of the project will investigate the CTE & HE program's impact on student learning outcomes, teaching curriculum, and teacher training/pool expansion. The research will address the following aspects of the project:
a) Impact on Student Learning Outcomes:
A research team (PI, Co-PIs, and participating students) will compare two student groups:
Intervention group: Students participating in at least one CTE & HE course.
Control group: Students in conventional courses (or, if unavailable, other students from the institution). Key research questions:
Retention Rates: Comparing first-to-second and second-to-third-year retention rates between intervention and control groups, specifically examining improvements for first-generation and

minority students. Engagement and Belonging: Using learning index measures (Engaged Learning Index) and a custom "sense of belonging" questionnaire, along with psychometric tools (General Self-Efficacy Scale, Academic Self-Efficacy Scale, Psychological Sense of Belonging, Growth Mindset Scale), to compare mean scores between groups using t-tests.
Internship/Job Offers: Comparing the rate of internship offers between the two groups.
b) Impact on Teaching Curriculum:
This will involve investigating the differences between CTE & HE courses and conventional courses.
Figure No.2 shows an improvement in sense of belonging to their major in the students of Electrical Engineering before and after implementation of changes in this study. The first column in Figure No.2 shows a 6.07 out of 10 for the mean value in the sense of belonging for the students in academic year of 2019-2020. In 2019-2020 28 students participated in the program and 2020-2021 32 students.

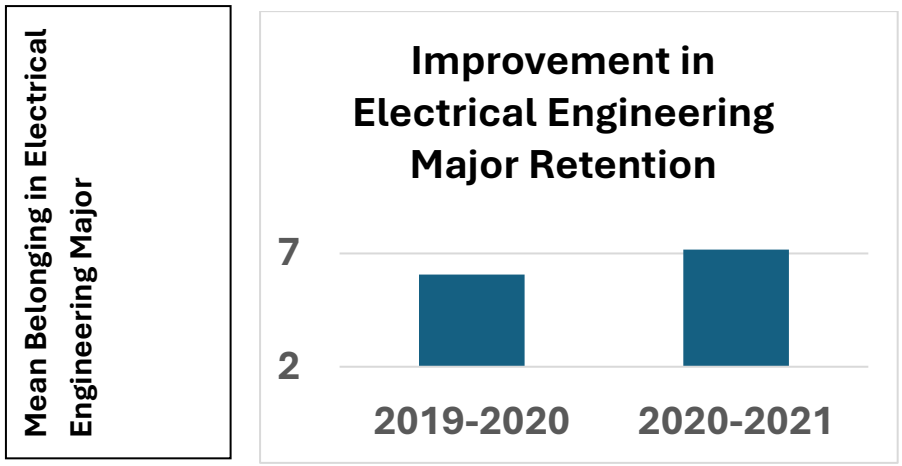

Figure No.2, A comparison for the sense of belonging among the students of Electrical Engineering in academic year of 2019-2020 and 2020-2021. It shows an improvement in sense of belonging during this study [14].

The second column in Figure No.2 shows the sense of belonging to their major between the students of Electrical Engineering after EE students take the first course developed in this study. This figure shows 7.17 points out of maximum 10 for the mean values of belonging among the students of Electrical Engineering major. It means an improvement after offering the first course in this study.

Conclusion

This first-year report details the development of a three-course series designed to bridge the gap between CTE programs, community colleges, and university-level electrical engineering education. The project emphasizes hands-on skills integration using industry-standard tools like LabView, MATLAB, PLC programming, and microcontroller boards. This approach aims to provide students with practical experience in analog and digital systems, preparing them for both further academic pursuits and the demands of a rapidly automating workforce. The focus on design and project-based learning fosters critical thinking and problem-solving skills, while early exposure to these tools aims to increase student engagement and retention in STEM fields. This

aligns with research advocating for early hands-on technical skills development to better prepare students for future careers. The project's structure creates seamless transitions between educational levels, ensuring students acquire both theoretical knowledge and practical skills. Preliminary pilot data from CSUSM (Figure No.2) indicates a positive impact on students' sense of belonging within the Electrical Engineering major after the implementation of the first course, with an increase in the mean value from 6.07/10 to 7.17/10 between academic years 2019-2020 and 2020-2021. Future research will rigorously investigate the program's impact on student learning outcomes (retention, engagement, internship/job offers), curriculum development, and teacher training.

5. Acknowledgment

This work was supported by the National Science Foundation Advanced Technological Education (NSF-ATE) program under Award No. 2400983. The authors express their gratitude for this essential funding, which has significantly contributed to the research and findings presented in this paper.

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