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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 2

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I. Introduction and Background

Lower-division EE pathways continue to face challenges related to student interest, belonging, and retention especially among first-generation and underrepresented students. Attrition in technical programs remains high, with estimates ranging from 40–50% in the first year [1], and disparities in access, retention, and degree completion have been well documented [2]. A key body of research relates attrition to exposure to academic topic in major and psychosocial factors, including the nature of the classroom environment, relevance of STEM coursework, prior preparation, self-efficacy, interest, and demographic influences [2].

The Year-One of this study, presented in ASEE 2025 Annual Conference in Montreal, framed these issues through two complementary lenses. First, the importance of learning environment: active learning and laboratory centered pedagogies consistently outperform lecture only approaches for conceptual understanding and retention [3]. Second, advising, teaching practices, and departmental culture can differentially affect women and underrepresented students [4], [5], [6]. Interest is also a critical driver; in some studies it surpasses grades as a predictor of persistence [7], while others show students often exit engineering because alternative majors or careers feel more compelling [2], [8]. Early exposure to engineering particularly in secondary settings has been shown to shape students' postsecondary choices [9], [10], [11].

Guided by these findings, the CTE & HE initiative designed a three-course, project-based sequence that connects secondary CTE pathways to community-college certificates/AS degrees and onward to university BS in the Electrical Engineering (EE) programs. The Year-One course architecture intentionally integrated tools and practices common to contemporary EE workplaces (e.g., PLCs, LabVIEW, MATLAB, microcontroller prototyping), aligning course artifacts with technician and engineer roles while cultivating a sense of "active participation" and belonging through authentic projects and collaborative problem-solving [12], [13]. Preliminary institutional data in Year One indicated an increase in EE students' sense of belonging following the introduction of the first course [14].

II. Program Architecture and Year-Two Positioning

The program follows a "top-down-top" logic that begins with systems-level applications to support relevance, then moves into laboratory skills and component-level methods that develop precision and detail knowledge, before returning to integrative design challenges that ask students to

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synthesize theory and practice. The sequence comprises an introduction to EE with core quantities, measurement, and basic analog and digital circuits; the first clinic emphasizing laboratory safety, instrumentation, test plan design and use of Programable Logic Controllers (PLCs), and LabVIEW; and a second clinic that extends programming, modeling, and simulation for EE problems and potentially introduces basics of machine learning tools and generative AI as they relate to EE workflows. Each course is designed for dual enrollment or articulation so that secondary students can complete CTE pathway requirements with authentic skills, community-college students can progress toward technician roles, and university students can follow the path into designing systems or test engineering tracks. By mapping course outputs to recognizable workplace competencies at each level, the sequence aligns education with the current demands of an increasingly automated EE industry while maintaining knowledge required in the EE programs.

The Year-Two evaluation included forty students enrolled across the three courses, reflecting the program's cross-sector design with participants from community colleges and the lower division of the university major. Students completed a five-point Likert survey addressing four core dimensions: overall learning experience, sense of belonging within the EE community, engagement with EE clubs and events, and early career and internship readiness. The evaluation was informed by an assessment framework consistent with Year One and with the broader literature. It incorporated validated psychometric instruments such as the Engaged Learning Index, the General Self-Efficacy and Academic Self-Efficacy scales with early indicators of internships and faculty reflections on curricular alignment with workforce expectations [2], [3], [12], [14]. Analyses included descriptive statistics on the four dimensions and subgroup comparisons by gender, first-generation status, and URM status. Two-tailed tests with an alpha of .05 were used to examine whether observed differences were statistically significant.

III. Results

Students reported a strong overall learning experience with a mean of 4.16 on a five-point scale. Narrative comments and faculty notes indicate that the combination of structured labs, authentic instrumentation, and project-centered assignments contributed to engagement and perceived relevance, consistent with previous evidence that active learning and hands-on work outperform traditional lecture for understanding and persistence [3]. The average sense of belonging was 3.86, which is encouraging for early-stage learners who are still constructing an engineering identity, but also suggests that there is room to move more students into the strongly positive range through expanded mentoring, recognition, and peer networks. Engagement with the EE community, measured as participation in clubs and events, averaged 3.31 and was the lowest of the four dimensions, likely reflecting time constraints, commuting patterns, and competing obligations typical of cross-institutional cohorts. Career and internship readiness averaged 3.61, which is appropriate for lower-division learners and indicates growing confidence that can be further enhanced through structured exposure to industry contexts.

Subgroup analyses revealed that female students' ratings were slightly lower than male students' ratings on average, but none of the differences were statistically significant. Similarly, comparisons between first-generation and non-first-generation students, and between URM and non-URM students, showed no statistically significant differences. These patterns suggest that the instructional design and attention to climate are providing comparable experiences across subgroups, echoing evidence that inclusive pedagogy and early projects can help the confidence and persistence by making the work of engineering more visible and attainable.

IV. Conclusion

Year Two confirms that a hands-on, articulated electrical engineering curriculum can deliver strong learning experiences and equitable outcomes across student subgroups while advancing the broader goal of aligning early coursework with authentic engineering practice. Students reported high engagement and satisfaction with labs and instruction, a solid and improvable sense of belonging, and positive early indicators of participation and readiness. These findings extend the Year-One evidence and support the program's theory of action: when students encounter real tools, meaningful problems, and inclusive communities early in their studies, they are more likely to persist and to see engineering as a field where they can contribute and succeed. The project's next steps will concentrate on deepening internship pipelines and co-curricular participation, strengthening the connective tissue between classroom practice and professional identity in ways that sustain momentum from CTE through community college to the university and beyond.

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