Experiential Learning for AI-Driven Robotics in Northeast Pennsylvania

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WIP: Experiential Learning for AI-Driven Robotics

Abstract

The rapid growth of artificial intelligence (AI), robotics, and automation is reshaping workforce demands and highlighting persistent gaps between pre-college engineering preparation and industry expectations. In particular, many students lack sustained access to advanced, hands-on learning experiences that connect early STEM interest to postsecondary pathways and emerging technology careers. This Work-in-Progress paper presents an NSF-funded experiential learning initiative designed to address these challenges through a longitudinal, cohort-based pipeline focused on AI-driven robotics.

Grounded in experiential learning theory and guided by the National Society for Experiential Education (NSEE) principles, the initiative integrates three interconnected phases: (1) high school robotics clubs that provide early, sustained exposure to AI and robotics concepts; (2) dual-enrollment coursework combined with structured industry mentorship to deepen technical rigor and workforce awareness; and (3) immersive summer and postsecondary transition experiences that reinforce professional identity, persistence, and career readiness. The program is implemented through a regional partnership involving a private comprehensive university, public high schools, and an industrial automation company, ensuring alignment with evolving workforce needs.

The paper describes the program design, theoretical framework, industry alignment strategies, and mixed-methods evaluation approach. Preliminary results from the first year of implementation indicate strong student participation and engagement, positive shifts in confidence and problem-solving readiness, and early evidence of increased awareness of AI- and robotics-related pathways. While long-term academic and workforce outcomes are still under evaluation, these early findings suggest that sustained, authentic experiential learning can strengthen STEM pathways at critical transition points. By documenting design principles, early outcomes, and implementation lessons, this Work-in-Progress contributes to the CEED and ASEE communities by offering a replicable model for integrating experiential learning, workforce engagement, and evaluation across high school-to-postsecondary pathways in emerging technology domains.

1. Introduction

AI, robotics, and automation continue to transform advanced manufacturing, logistics, healthcare technologies, and intelligent systems. Workforce projections indicate sustained demand for professionals with computational fluency, systems integration skills, and the ability to solve open-ended technical problems [1], [2]. Despite this growth, many high school students encounter engineering primarily through short-term camps, competitions, or isolated enrichment events. While valuable, such experiences often lack continuity, mentorship depth, and clear connections to workforce pathways.

Research in engineering education suggests that experiential learning, particularly when sustained over time and supported by structured reflection and mentorship, can enhance student motivation, technical confidence, and persistence [3], [4]. However, the challenge lies in moving beyond episodic interventions toward coherent, multi-year learning pathways.

To address this gap, we developed an NSF-supported, cohort-based experiential learning pipeline in AI-driven robotics for high school students. The initiative integrates robotics clubs, advanced project work, industry mentorship, and immersive summer experiences within a longitudinal structure. This Work-in-Progress (WIP) paper presents the program design, evaluation approach, and preliminary Year 1 findings.

2. Experiential and Pipeline Framework

The program is grounded in experiential learning theory, particularly Kolb's model of learning through cycles of concrete experience, reflective observation, conceptual abstraction, and active experimentation [3]. In engineering contexts, experiential learning enables students to construct knowledge through authentic engagement with physical systems and computational tools rather than through passive instruction alone. Prior work in engineering education demonstrates that project-based and inductive learning approaches are associated with increased engagement, deeper conceptual understanding, and the development of engineering expertise over time [4], [8]. The pipeline design also draws on research emphasizing sustained STEM exposure across educational transitions [5], [6], indicating that multi-stage programs connecting early engagement to progressively advanced experiences are more likely to support identity development and persistence than isolated enrichment opportunities [7]. Guided by these findings, the initiative intentionally sequences learning experiences across high school years, increasing technical complexity while maintaining mentorship continuity and industry alignment.

3. Program Design: Three-Phase AI Robotics Pipeline

This initiative is implemented through a regional partnership involving a private comprehensive university in the northeastern United States, multiple public high schools serving urban and rural communities, and an industrial automation company specializing in AI-enabled manufacturing and robotics integration. The university serves as the academic anchor, providing faculty mentorship, laboratory access, curriculum design, and coordination across educational stages. The industry partner contributes technical expertise, mentorship, and workforce-aligned project feedback to ensure authenticity and relevance. Supported through the National Science Foundation's Experiential Learning for Emerging Technologies (ExLENT) Explorations Track, the program is intentionally structured as a cross-sector model that integrates secondary education, postsecondary preparation, and regional workforce development. Students participate as part of a cohort and engage in progressively advanced experiential components throughout high school. As illustrated in Figure 1, the pipeline is designed to increase technical rigor, industry engagement, and student autonomy across phases while maintaining mentorship continuity and cohort identity.

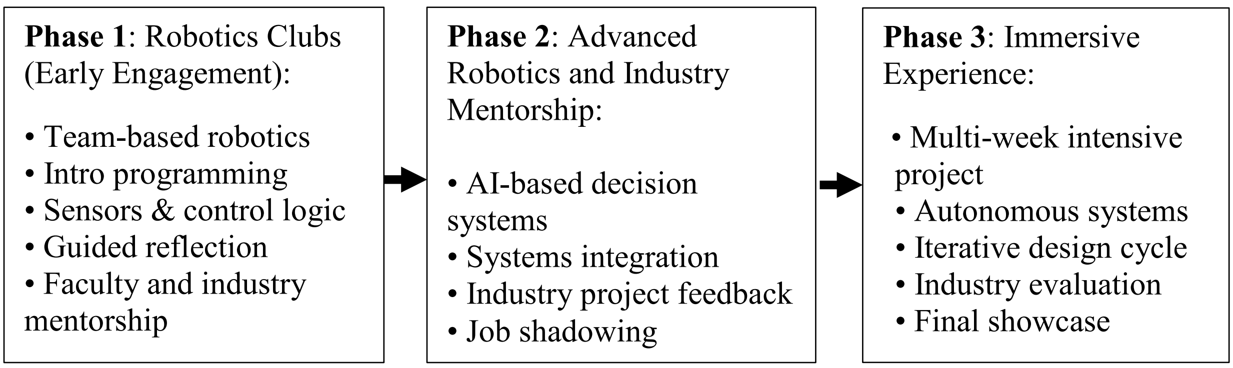

Figure 1. Longitudinal Three-Phase Experiential Learning Pipeline in AI-Driven Robotics.

Phase 1: Robotics Clubs

The entry point to the pipeline is a school-year robotics club implemented at participating high schools. Clubs meet weekly and engage students in team-based design challenges using modular robotics kits and AI-enabled programming platforms. Activities emphasize foundational programming, sensor integration, control logic, and iterative troubleshooting.

Instruction is scaffolded to accommodate varied preparation levels. Students begin with guided exercises and progress toward open-ended design challenges requiring collaborative problem solving. Faculty advisors and industry mentors provide technical guidance and model professional engineering practices. Structured reflection activities and periodic project showcases encourage students to articulate design decisions and connect technical work to real-world applications.

Phase 2: Advanced Robotics and Industry Mentorship

Students who demonstrate sustained engagement progress to more advanced robotics projects incorporating AI-based decision-making and systems integration. This phase emphasizes greater autonomy and increased technical rigor. Students work on projects aligned with industry-relevant technologies, such as autonomous navigation, data-driven control strategies, and integrated hardware-software systems.

Industry mentors play a more prominent role in this phase by offering technical feedback, discussing workforce expectations, and hosting job shadowing opportunities [9]. Students assume increasing responsibility within teams, often mentoring newer participants, thereby reinforcing leadership development and cohort identity.

Phase 3: Summer Robotics Lab

The pipeline culminates in a multi-week summer Robotics Lab that provides immersive, hands-on engagement. Students work in teams to design, build, and test AI-powered robotic systems addressing authentic engineering challenges. Faculty and industry mentors guide students through structured design processes emphasizing experimentation, iteration, and performance evaluation.

The summer experience concludes with formal project presentations to academic and industry audiences. These presentations reinforce communication skills, professional identity formation, and confidence in articulating technical work. Across all phases, the program emphasizes sustained engagement, mentorship continuity, and alignment with workforce-relevant competencies.

4. Evaluation Approach

As a Work-in-Progress, evaluation focuses on early indicators of learning, engagement, and workforce alignment rather than long-term employment outcomes. An external evaluator collaborates with program leadership to implement a mixed-methods design aligned with program objectives.

Quantitative measures include pre- and post-surveys assessing student confidence in programming, problem solving, and working with AI-enabled systems. Surveys also measure interest in engineering careers and perceived preparedness for advanced technical learning. Participation and retention data are tracked across program phases to examine sustained engagement.

Qualitative data are collected through student reflections, focus groups, and mentor observations. Students document design processes, challenges encountered, and lessons learned. Industry mentors provide structured feedback on students' ability to apply technical concepts, troubleshoot systems, collaborate effectively, and communicate ideas. These data sources allow triangulation of early outcomes and inform iterative program refinement. Survey instruments were designed to measure constructs such as technical self-efficacy, problem-solving confidence, career awareness in AI and robotics, and perceived preparedness for advanced technical coursework. Mentor feedback rubrics assess students' ability to apply programming concepts, troubleshoot integrated systems, collaborate effectively, and communicate technical ideas. This structured measurement framework supports triangulation across self-reported, observational, and participation-based data sources.

5. Preliminary Year 1 Findings

During Year 1 implementation, the initiative engaged over 100 high school students across participating schools, with the majority entering through the robotics club phase and a subset progressing into advanced experiential components. Weekly attendance remained consistently high throughout the academic year, and retention across the robotics club phase exceeded typical expectations for voluntary STEM programming. A measurable proportion of participants elected to continue into advanced project work or dual-enrollment pathways, indicating sustained engagement beyond initial exposure.

Pre- and post-participation surveys revealed positive shifts in students' self-reported confidence in programming, debugging, and integrating hardware and software systems. Students reported increased willingness to experiment with unfamiliar technologies and greater comfort engaging in iterative design processes. Mentor evaluations corroborated these findings, noting improvements in students' troubleshooting approaches, systems-level thinking, and ability to articulate technical reasoning. Participation in industry site visits and job shadowing experiences further strengthened students' awareness of AI- and robotics-related career pathways.

Qualitative findings further reinforce these trends. Student reflections frequently referenced improved teamwork, communication, and systems-level thinking. Industry mentors observed increased technical fluency and more structured approaches to troubleshooting over the course of the year. Although findings are preliminary and largely perception-based, they suggest that sustained experiential engagement may enhance technical confidence and workforce awareness. Multi-year tracking is ongoing to examine student progression into advanced phases and continued participation in robotics-related coursework.

In addition to learning indicators, early workforce-alignment measures were examined. These include mentor assessments of technical readiness during project reviews, structured feedback from job shadowing experiences, and student enrollment in dual-enrollment or advanced STEM coursework following initial participation. While long-term employment outcomes are not yet available, these leading indicators provide early evidence of alignment between experiential learning activities and workforce-relevant skill development.

6. Lessons Learned and Ongoing Refinement

Year 1 implementation revealed several considerations relevant to experiential learning practitioners.

First, coordination across schools and industry partners requires clearly defined communication structures and aligned scheduling. Regular planning meetings and clearly articulated expectations proved essential to maintaining consistency.

Second, careful scaffolding is necessary to accommodate varied student preparation levels. Early-phase technical support and structured reflection activities were particularly important in supporting student persistence.

Third, modular design enhances sustainability. Team-based robotics activities allow equipment sharing, making expansion feasible without proportional cost increases. Defined industry mentor engagement intervals also supported manageable and mutually beneficial participation.

Planned refinements include enhanced alignment between school-year robotics content and summer projects, expanded structured reflection to deepen learning integration, and strengthened peer mentoring structures.

7. Scalability and Required Resources

The experiential learning pipeline was intentionally designed to be modular and scalable across diverse high school settings. Implementation requires coordinated personnel, accessible infrastructure, and structured partnerships but does not depend on specialized laboratories or extensive capital investment.

At the personnel level, a program coordinator and high school teacher facilitators sustain robotics club activities, while industry mentors provide structured engagement through project feedback, guest instruction, and job shadowing. Mentor participation is organized in defined intervals, supporting manageable and sustainable involvement. As cohorts mature, experienced students may serve as peer mentors, expanding program capacity without proportional increases in staffing.

Infrastructure needs are modest and include modular robotics kits, laptops capable of supporting AI programming, and access to shared classroom or maker spaces. Because robotics platforms are team-based and commercially available, enrollment can grow without linear increases in equipment costs. Initial investments primarily involve robotics kits and curriculum development, while ongoing costs center on coordination and facilitation. The phased, modular structure allows schools to begin with robotics clubs and expand to advanced projects or summer experiences as capacity increases, supporting scalability while maintaining experiential quality.

8. Discussion and Next Steps

This Work-in-Progress contributes to the CEED community by presenting a longitudinal experiential pipeline that integrates sustained mentorship, authentic AI-driven robotics projects, and structured evaluation for high school students. Early findings suggest that multi-year experiential engagement may strengthen student' confidence, technical readiness, and awareness of workforce pathways more effectively than isolated enrichment experiences.

Future work will focus on longitudinal tracking of cohort progression, analysis of technical skill development, and examination of transitions into advanced STEM coursework. Continued evaluation will inform iterative refinement and support dissemination of transferable lessons for institutions seeking scalable experiential models in emerging technology domains.

Acknowledgment

This material is based upon work supported by NSF grant #2526169 under the NSF Experiential Learning for Emerging and Novel Technologies (ExLENT) program, which is jointly sponsored by the National Science Foundation (NSF) and the Micron Foundation.

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