Pioneering Engineering Pathways: Sustaining High School–University Partnerships Through University Engineering Experiences (Evaluation)

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Kip D. Coonley received the Ph.D. degree in Electrical and Computer Engineering from Duke University, Durham, NC in 2023, the M.S. degree in Electrical Engineering from Dartmouth College, Hanover, NH, in 1999 and the B.S. degree in Physics from Bates College, Lewiston, ME, in 1997. Following graduation from Dartmouth, he developed electronically controlled dimmers for fluorescent and incandescent lamps at Lutron Electronics, Coopersburg, PA. From 2001 to 2005, he was a Research Engineer at RTI International, where he designed high-efficiency thermoelectrics using epitaxially grown superlattice thin-film structures. Since 2005, he has been the Undergraduate Laboratory Manager in the Department of Electrical and Computer Engineering at Duke University, Durham, NC earning the doctoral degree in 2023. His research interests include undergraduate engineering education, energy harvesting, RFID, power electronics, plasma physics, and thin films.

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Adam's dedication to STEM education extends beyond the classroom. He has repeatedly presented at Construct3d conferences, and presented at the STEM in the Park Industry Summit. He's also a contributing author, sharing his expertise in self-regulated learning and performance. His passion for education has led to the establishment of makerspaces in Durham Public Schools and the early adoption of 3D printing technology in DPS classrooms.

Outside of his professional life, Adam is a gaming enthusiast, Lego builder, artist, and an ardent reader and writer. He and his wife shares their home with two disabled cats and a dog, sharing their love for pets and prosthesis.

Looking ahead, Adam is committed to enhancing undergraduate lab spaces and curriculum, facilitating the transition from secondary to post-secondary education in STEM, and improving Undergraduate Teaching Assistant (UTA) training. His mentorship and guidance continue to impact individuals, educators, and STEM enthusiasts, solidifying his role as a leader in the field.

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Abstract

This paper is an evaluation that reports on the continued development of a collaborative outreach model designed to align high school engineering curricula with university-based laboratory activities. It consists of three (3) consecutive interventions over the course of three (3) years. National efforts to broaden participation in engineering emphasize the importance of sustained partnerships between K–12 schools and universities that connect classroom instruction with authentic engineering experiences. Building on our prior work, *Pioneering Pathways for High School Students in STEM Education* [1], this study reports on the continued development of a collaborative outreach model designed to align high school engineering curricula with university-based laboratory activities. As a longitudinal study spanning multiple semesters and iterations, this work captures the evolving impact of repeated high school–university engagements over time.

In the fall of 2023, a local public high school's engineering program brought 15 students to campus for a Sensors and Displays laboratory focused on sensor integration and data visualization. The students engaged in hands-on activities mentored by undergraduate engineering students and connected these experiences to their classroom learning.

The success of this pilot informed a broader implementation in spring 2025, when nearly 80 high school juniors across six sections of a Digital Electronics course participated in a university-hosted Digital Logic laboratory. Students explored binary counting, Karnaugh mapping, and microcontroller-based display design while gaining exposure to college-level laboratory environments. Providing logistical and transportation support enabled the partnering teacher to concentrate on curricular connections, greatly expanding student participation and instructional alignment.

In fall 2025, a second high school partner implemented the Sensors and Displays laboratory with 30 sophomores enrolled in a Principles of Engineering course, embedding the experience earlier in the engineering sequence. This iterative collaboration furthered the breadth of the work, continuing to emphasize integration with the existent high school curriculum while continuing to partner closely with the teacher.

Overall, this work demonstrates how structured, scalable outreach can enhance both teacher capacity and student engagement by bridging formal classroom learning with practical university-level engineering experiences. The results of these ongoing partnerships show a sustainable framework for integrating outreach, instruction, and curricular relevance and offers a replicable approach for universities and schools seeking to strengthen local curricular outreach efforts.

Introduction

As reported in this and prior work, national efforts to broaden participation in engineering have emphasized the importance of early, sustained exposure to authentic engineering experiences, particularly for students from groups historically underrepresented in STEM [1, 2]. Professional organizations such as the American Society for Engineering Education (ASEE), the National Academy of Engineering (NAE), and the National Science Foundation (NSF) have consistently called for coordinated partnerships between K–12 schools and universities that integrate hands-on, interdisciplinary engineering experiences with formal classroom instruction [3]. Research has demonstrated that such collaborations are especially impactful when they align directly with existing curricula and provide students with repeated opportunities to engage with engineering concepts in authentic contexts [4].

Prior work has documented the widespread growth of engineering outreach programs aimed at increasing pre-college students' awareness of engineering careers and improving attitudes toward STEM. These programs vary widely in format, duration, and instructional depth, ranging from short-term demonstrations to immersive summer camps. While many outreach initiatives report positive short-term gains in student interest, knowledge, and self-efficacy, fewer studies examine longitudinal or iterative models that intentionally align outreach activities with high school engineering curricula and sustain engagement over multiple years. Furthermore, evaluation research has underscored the importance of accountability and systematic assessment to understand not only student outcomes, but also the instructional and partnership structures that contribute to program effectiveness. [5]

Informal and university-based engineering experiences have been shown to play a critical role in shaping students' perceptions of engineering, particularly when formal K–12 curricula lack sufficient engineering content. Studies of middle and high school outreach programs, including summer camps and residential experiences, indicate that hands-on laboratory activities, mentorship by undergraduate students, and exposure to university environments can positively influence students' interest in STEM, their understanding of engineering practices, and their aspirations for postsecondary education. Importantly, this body of work also highlights the value of sustained engagement and structured reflection in supporting meaningful changes in student attitudes and identity development. [6]

Building on this literature, our prior work, *Pioneering Pathways for High School Students in STEM Education* [1], introduced a collaborative outreach model that partnered a local public high school engineering program with a university-based electrical and computer engineering laboratory experience. That work demonstrated the feasibility and positive reception of adapting a first-year undergraduate laboratory for high school students, emphasizing close collaboration with the high school teacher, alignment with Project Lead the Way (PLTW) curricula, and the removal of logistical barriers such as cost and transportation. Initial findings suggested that students valued the authenticity of the laboratory experience and that teachers viewed the model as scalable and instructionally meaningful.

The present study extends this prior work through a longitudinal evaluation of a collaborative outreach model implemented across three subsequent interventions over the course of three academic years. As an evaluation study, this work reports on the continued development and refinement of the model as it was scaled across multiple cohorts, courses, and partner schools. In Fall 2023, a pilot Sensors and Displays laboratory engaged 15 high school students in hands-on sensor integration and data visualization activities, mentored by undergraduate engineering students. The success of this initial implementation informed a broader Spring 2025 deployment, in which nearly 80 high school juniors across six sections of a Digital Electronics course participated in a university-hosted Digital Logic laboratory emphasizing binary counting, Karnaugh mapping, and microcontroller-based display design. Providing logistical and transportation support enabled deeper curricular alignment and expanded student participation. In Fall 2025, the collaboration further evolved through the addition of a second high school partner, embedding the Sensors and Displays laboratory earlier in the engineering sequence with 30 sophomores enrolled in a Principles of Engineering course. Across all three interventions, the outreach model emphasized close collaboration with high school educators, intentional alignment with existing curricula, and iterative refinement informed by prior implementations.

Collectively, this work contributes to the engineering education literature by demonstrating how a structured, scalable, and curriculum-aligned outreach model can support sustained high school–university partnerships. By examining multiple iterations over time, this study highlights how repeated engagement with authentic university laboratory experiences can enhance student engagement, strengthen teacher capacity, and provide a sustainable framework for integrating outreach, instruction, and curricular relevance. The findings offer a replicable approach for institutions seeking to move beyond one-off outreach events toward sustained, locally responsive engineering education partnerships.

Methods and Data Collection

Three (3) consecutive field trips are being reported on in this work. All 3 fields trips were attended by high school students enrolled in a PLTW curriculum. Each trip was limited to a 4-hour university visit during the regular academic semester. Students worked in teams of two. A certified university instructor introduced expository and inquiry-based learning through a prepared Arduino robot experiment. Following this introduction, the student teams were guided by a trained and experienced university teaching assistant in the hands-on implementation of the experimental exercises. Activities were not graded. Learning from failure was encouraged.

Significant effort was placed on pre-trip planning with the high school teacher. Prior to the trip, ECE faculty and staff consulted with the high school educator whose course would be impacted. Specific care was taken to integrate what was offered at the university with what was being taught at the high school. In addition, through prior experience and expressed need, provision for logistical and transportation support enabled the partnering teacher to concentrate on curricular connections, greatly expanding student participation and instructional alignment.

Pre- and post-trip surveys were completed by students. Students identified their interests, the exercises attempted, and whether they liked or disliked them. They were asked to provide their overall comments and thoughts on improving the experience. The educator who attended the field trip also completed a post-trip survey and provided further feedback during a follow-up meeting two months later.

Table 1. High School Grade Level of Student Pre-Participants

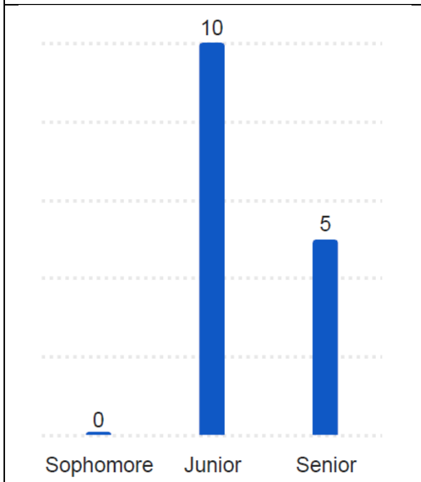
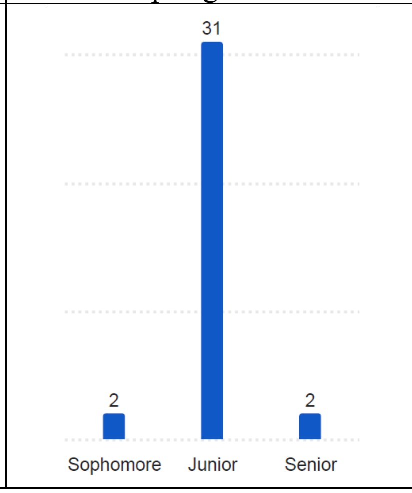
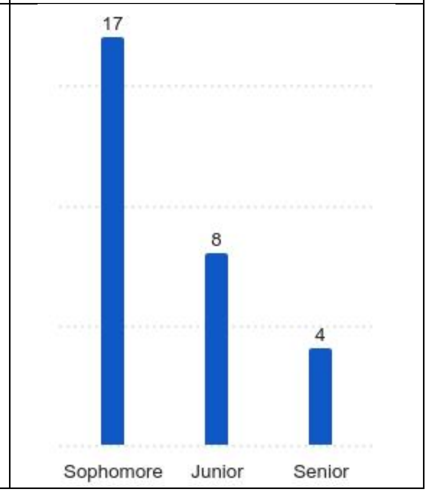
Fall 2023	Spring 2025	Fall 2025
		

Table 2. Table 1 shows comparison pre-data across all 3 field trips. It highlights number of participants, their PLTW course, and high school grade level.

Characteristics common to all 3 field trips
• Free of charge • 1/2-day event (4 hours) • Integrated with Project Lead the Way (PLTW) certified high school engineering program • On campus (at university) • Hands-on laboratory experience (teams of 2-3 students) • On-site lunch with educators (instructors and college teaching assistants) • Campus tour

Specific details for each field trip that differentiate it from the others are as follows:			
	First field trip [1]	**Second field trip**	**Third field trip**
Date	Fall 2023	Spring 2025	Fall 2025
Laboratory	Sensors and Displays laboratory offering four sensory options	Digital Logic laboratory	Sensors and Displays Laboratory offering five sensory options
No. students	15 students	80 students	29 students
PLTW course	Principles of Engineering (POE)	Digital Electronics (DE)	Principles of Engineering (POE)
School	Local district public high school	Local district public high school	Nearby area public high school

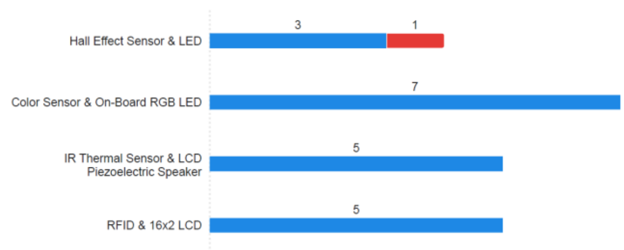
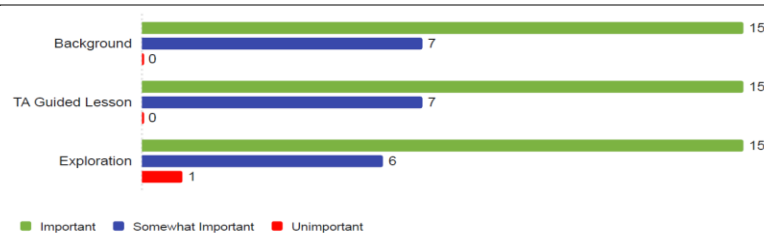
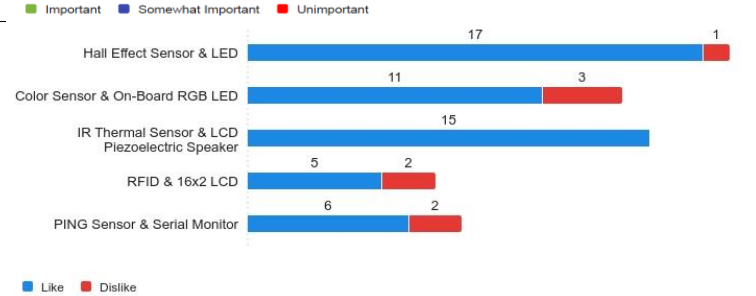
Context: The Field Trip Experiences

Each of the field trips consisted of 1.) the pre-approved laboratory, 2.) a tour of the engineering school, and 3.) a provided lunch. Upon arrival, participants were welcomed and sat around a large table in the middle of the lab where they encountered several pre-built Arduino robots. Hardware in the form of sensors, displays, and digital breadboards were made available in the lab. Following introductions, the students were split into groups. In these groups, they were either engaged in the laboratory experiment first or were taken on the campus engineering tour first. This arrangement was mirrored at the 1 ½ hour mark. The laboratory experiments were led by a university-trained undergraduate teaching assistant. Students were told that they should try to complete at least one of the experimental exercises but were encouraged to attempt as many as possible. Student learning was self-regulated: trying first and discovering the results. The tour was led by a trained undergraduate university student tour guide.

Results and Feedback from the Participants

Of the 15, 80, and 29 student participants, respectively, student feedback was sought pertaining to the laboratory experiences they performed. Results are summarized in Table 3.

Table 3. Laboratory experiment feedback from students. Results refer to portions of the laboratory experiment including the Background, TA Guided Lesson, and Exploration.

<table>
<tr><td>Fall 2023
(Sensors and Displays)</td><td>
</td></tr>
<tr><td>Spring 2025
(Digital Logic)</td><td>
</td></tr>
<tr><td>Fall 2025
(Sensors and Displays)</td><td>
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Results and Feedback from the Educators

The high school educators whose classes participated in the field trips were also asked questions following the trip. These questions focused on 4 aspects of the experience including: 1.) lessening the field trip burden on them, 2.) why the field trip was worth the time and effort expended, 3.) why they would like to offer the field trip in the future, and 4.) whether they would recommend the field trip to other schools and programs. The specific questions and the educators' responses are shown in Table 4.

Table 4. High School Educator responses following field trips.

1.) Are there ways in which we could have lessened the burden on you?	
Fall 2023	Any "troubles faced when coordinating this field trip were due to [the public school]." And to paraphrase, everything that could have been done on the university end was done.
Spring 2025	There were no "additional ways in which the burden could be lessened." And "[f]or this field trip, Duke and the ECE department handled much of the brunt." "As a teacher, I only had to do minimal paperwork which Duke could not assist with."
Fall 2025	There were no "ways [to] lessen the burden of planning/preparing due to paperwork compliance requirements of [the] district." And "It is about as streamlined as [the district] policy allows."

2.) Please tell us why you feel this field trip was worth the time and effort you expended.	
Fall 2023	The educator said that trip was worth the time and effort and strongly agrees that we should offer it again in the future. Furthermore, the impact this field trip had on his students was assessed anecdotally through positive conversations about the field trip for days afterward. What is more, students were making connections between their DE course work and the laboratory work they completed.
Spring 2025	Overall, the lab experience was at a high level and the educator felt that the material was appropriate and that the pacing was good.
Fall 2025	The instructor felt that the value of this field trip was already quite high, but one suggestion to increase the value would be to have someone from admissions talk to students about college applications in general and Duke Engineering specifically.

3.) Please tell why you would like to offer this field trip to students in the future.	
Fall 2023	The educator highly recommends continuing the effort and integrating it with the course in the future.
Spring 2025	Feedback indicates that "the field trip [occurred] during a crucial moment of students' high school careers: They are juniors, with college applications less than a year away, who need to understand what college is, they need to know to tour their prospects, they need to be exposed to this form of 'life readiness.'"

Fall 2025	First, Duke is a first class, top notch school with an awesome engineering program. I want my students to see what they could look forward to at the next level. Second, I want them to see what they could expect in terms of content and rigor. I especially want them to see how it is related to and relevant with what they are doing in their PLTW class.

4.) Would recommend this field trip to other schools and programs?	
Fall 2023	The educator said that "this trip was 'much better.' And during a follow up meeting, he elaborated by saying, "[other universities] have similar opportunities, but what [Duke University] did was more inviting and intimate for [the educator's] students."
Spring 2025	The educator strongly believes that "[e]xposure and preparedness" are keys to high school success and concludes with, "If our goal as teachers is to teach and prepare for the real world, why do we not take students on more field trips?"
Fall 2025	The educator commented that the fall experience was "an awesome experience for my students" and that we should "[keep] the overall plan largely the same for our spring [2026] visit."

Conclusions and Next Steps

This work is an extended evaluation of a comparable intervention offered between a high school PLTW curriculum and an area university. It represents the beginning of a longitudinal study of the impact of engineering outreach efforts on high school curriculum.

As with prior outreach efforts [1], a focus of this work was to address the burden public school educators' face in organizing and implementing a college-level field trip. As such, specific efforts were taken to reduce the overhead involved in organizing and conducting a field trip at the level of one that collaborates with a university. In particular, providing transportation and developing self-regulated laboratory content in line with the students' learning was a focus.

Acknowledgments

This work was supported in part by the generosity of a Maclin grant endowed by Ms. Valecia Maclin '92, U.S. National Science Foundation funding as part of the AI Institute for Edge Computing Leveraging Next Generation Networks (Athena) under Award #2112562, Duke University's Pratt School of Engineering, and the Pierre R. Lamond Department of Electrical and Computer Engineering.

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Appendices

Appendix A: The Laboratory Experiment

The 3 field trip experiments used modified laboratory manuals and supplementary documentation used for the first-year Fundamentals of Electrical and Computer Engineering laboratory [7]. The versions provided to attending students are located at the provided links.

Fall 2023	Spring 2025	Fall 2025
https://bit.ly/42vFxb8	https://duke.is/DigiLogicLab	https://duke.is/SensorsAndDisplaysLab

Appendix B: Field Trip Interest Flyer

Information about the field trips was provided to all students through a joint effort. Duke University staff created a digital flyer and a Qualtrics survey for interested students. The school educators included the flyer in a weekly newsletter sent to all students and families associated with the engineering program. The flyer instructed students to contact their educators if they were interested in attending, to which the educators provided them with a link or QR code to the survey and recorded their names for distribution of district mandated paperwork.

Fall 2023	Spring 2025	Fall 2025
https://bit.ly/DukeInterestFlyer	https://duke.is/InterestFlyer	N/A

Appendix C: Pre-Trip Surveys

The educator provided a pre-trip survey for students interested in attending the field trip, allowing the staff at Duke University to gather information intended to help them tailor the trip for the population. Below are links to the pre-trip surveys.

Fall 2023	Spring 2025	Fall 2025
https://bit.ly/Pre-Trip_Survey	https://duke.is/S25Pre-TripSurvey	https://duke.is/F25Pre-TripSurvey

Appendix D: Post-Trip Surveys

The educator followed up after the field trip with a post-trip survey for students who attended the field trip. Below are links to the post-trip surveys.

Fall 2023	Spring 2025	Fall 2025
https://bit.ly/Post-TripSurvey	https://duke.is/S25Post-TripSurvey	https://duke.is/F25Post-TripSurvey