A Pre-College Summer Program to Inspire and Educate Future Electrical and Computer Engineers

Dr. Tahmid Latif, Wentworth Institute of Technology

Tahmid Latif is an assistant professor of electrical and computer engineering at the School of Engineering of Wentworth Institute of Technology. He received his doctorate in electrical engineering from North Carolina State University, Raleigh, NC. His research interests lie at the intersection of electronics and biology, with a focus on bioelectronics and instrumentation, biohybrid insect robots, insect-machine interfaces, and educational robots. He is a member of IEEE and Sigma Xi.

Dr. Federica Aveta, Wentworth Institute of Technology

Federica Aveta received the B.S. and M.S. degrees in Electronic Engineering from La Sapienza University, Rome, Italy, in 2012 and 2016, respectively, and the Ph.D. degree in Electrical and Computer Engineering from the University of Oklahoma (OU), Tulsa, Oklahoma, in 2020. Before joining Wentworth Institute of Technology, Federica has worked as an Optical Engineer where she designed, built, and tested optical fiber lasers for medical applications. She is currently an Assistant Professor in the School of Electrical and Computer Engineering at Wentworth Institute of Technology. Her research interests include Optical Communications and Signal Processing.

Dr. Jiahui Song, Wentworth Institute of Technology

Jiahui Song received her B.S. in Automation and M.S. in Pattern Recognition & Intelligent Systems from Southeast University. She received her Ph.D. in Electrical and Computer Engineering from Old Dominion University. She is currently an Associate Professo

Pilin Junsangsri, Wentworth Institute of Technology
Jayshri Kulkarni, Wentworth Institute of Technology
Meysam Ahangaran, Wentworth Institute of Technology
Saurav Basnet, WentWorth Institute of Technol
Dr. Afsaneh Ghanavati, Wentworth Institute of Technology

Afsaneh Ghanavati received her B.S. in Electrical Engineering from Shiraz University, Iran, in 1998, and her M.S. and Ph.D. degrees in Electrical Engineering from Northeastern University, Boston, MA, in 2012 and 2018, respectively. She is currently an Associate Professor and serves as the Director of the Electrical and Computer Engineering Programs (ECE) in the School of Engineering at Wentworth Institute of Technology, Boston, MA. She is the recipient of the Douglas D. Schumann Professorship, one of the highest honors bestowed upon Wentworth faculty. Dr. Ghanavati has conducted collaborative research projects with Eversource in Massachusetts and has made significant contributions to ABET-related requirements, focusing on continuous program improvement and accreditation.

Dr. Ghanavati's research interests include power systems, signal processing, dynamic phasors, dynamic power decomposition, power quality, microgrids, and the entrepreneurial mindset in engineering education. She is a member of the Eta Kappa Nu (HKN) Engineering Honor Society, the IEEE Power & Energy Society (PES), the IEEE Industrial Electronics Society (IES).

Dr. Marisha Rawlins, Wentworth Institute of Technology

Dr. Marisha Rawlins is an Associate Professor in the Electrical and Computer Engineering Program at Wentworth Institute of Technology (WIT). Her research interests include computer architecture optimizations, embedded systems and devices used in teaching and healthcare, and methods and systems for improving teaching and learning. Dr. Rawlins received her PhD in Electrical and Computer Engineering from The University of Florida. Prior to working at WIT, she was an Assistant Professor in Computer Engineering, and the Discipline Coordinator for the BASc in Computer Engineering and the MSc in Information and Communication Technology Programmes, at The University of Trinidad and Tobago.

Dr. Anuja Kamat, Wentworth Institute of Technology

A Pre-College Summer Program to Inspire and Educate Future Electrical and Computer Engineers

Abstract

Early exposure to experiences and practices in engineering can attract and sustain student interest in several STEM disciplines in colleges and universities. While high school covers physics, mathematics, and programming, for example, conceptual and hands-on engineering knowledge are typically underrepresented in the curriculum. Immersive pre-college summer programs or camps can play an essential role in connecting students to practical and experiential learning in engineering, while shaping their awareness of diverse engineering career pathways, including those in the fields of electrical and computer engineering (ECE).

The paper describes the development and implementation of a two-week ECE summer camp for rising high school seniors and juniors that was offered for the first time in Summer 2025. The aim of the program was to educate and inspire the attendees to pursue electrical engineering, computer engineering, or related majors. The curriculum was developed to include interactive hands-on sessions on electric circuits, simulation and measurements, digital logic, programming and microcontrollers, sensors, renewable energy and solar power, antennas and wireless communication, artificial intelligence, robotics, neural interfaces, and soldering and prototyping.

Introduction

Electrical and computer engineering, or ECE in short, is the foundational backbone to many modern technological marvels, ranging from embedded systems, communication protocols and networks, energy and power infrastructures, cyber-physical systems, and robotics and automations. Despite its relevance, ECE may often remain poorly defined or largely invisible to many high school students. In many middle and high school settings, students are exposed to the mathematics and science prerequisites for engineering without explicit discussion on how the subjects translate into real-world engineering practices. Consequently, students may enter college overlooking the discipline altogether when selecting a major, or choose a loosely related major with an incomplete or inaccurate perception of ECE. Often, it is conflated with computer science or deprioritized.

Pre-college summer programs can offer a mechanism for addressing this information and knowledge gap. By placing students in immersive, college-like environments, such summer programs or summer camps can provide exposure to engineering tools, practices, and ways of thinking that are typically unavailable in typical high school classrooms or settings. Previous work has shown that pre-college engineering experiences can shape students' perceptions of engineering and help them make informed academic decisions, even when the effects are subtle or difficult to quantify [1]–[4]. Additionally, such experience may potentially improve representation by underrepresented groups [5]-[6] and improve the academic performance or retention rates of students in general in ECE and related majors [7]-[8]. Within the ASEE ECE and pre-college community, there has been growing interest in these types of outreach efforts that emphasize experiential, hands-on, and systems-oriented learning rather than isolated coursework or skill development.

The paper describes the development and implementation of a two-week residential ECE summer camp for rising high school seniors and juniors. While we previously offered summer programs on Robotics [9] and sessions on a focused area on ECE [10], this was the first time an ECE program was offered in Summer 2025 at Wentworth Institute of Technology in Boston, MA. The aim of the program was to educate and inspire the attendees to pursue electrical engineering, computer engineering, or related majors. The developed curriculum was intentionally kept modest to introduce students to the breadth of several ECE topics aligned to their interests. Topics included interactive hands-on sessions on electric circuits, simulation and measurements, digital logic, programming and microcontrollers, sensors, renewable energy and solar power, antennas and wireless communication, artificial intelligence, robotics, electrophysiological signals, and soldering and prototyping. The paper outlines program overview, activities, and insights drawn from a qualitative analysis of survey responses and discussions.

Program Overview

The two-week program followed a residential format designed to resemble key aspects of the undergraduate experience. Thirteen students applied to the program through the university website. These students lived on campus, and attended scheduled morning (9 am-12 pm) and afternoon (1 pm-4 pm) laboratory sessions, Monday to Thursday, modeled after college-level courses under the supervision of ECE faculty and undergraduate assistants. This structure allowed students to spend sustained time with technical material while also experiencing the routine of a college-level schedule.

To gain a clear understanding of the participating students' backgrounds and expectations, a pre-camp questionnaire was administered before the start of the program (n = 13). The survey included both closed-ended and open-ended questions addressing prior exposure to ECE-related topics, hands-on experience, areas of interest, learning expectations, and goals. The responses were analyzed using a qualitative thematic analysis. Responses were first read in full to gain familiarity with the data. An inductive coding process was then used to identify recurring ideas and phrases across responses. Initial codes were refined through multiple passes, during which related codes were merged and less salient ones were discarded. The result was a smaller set of themes that captured common patterns in how students described their interests and expectations.

A common motivation for attending the camp was the desire to better understand whether ECE would be an appropriate college major. Students viewed attending the summer camp as a low-risk opportunity to explore engineering before making formal academic commitments later in college. Some themes emerged consistently from the pre-camp responses, including limited or no familiarity with ECE concepts, exploration to clarify academic direction, and interest in creative and hands-on work. They viewed ECE primarily as a hands-on, practical field rather than a theory-driven one. Numerous responses suggested uncertainty about knowing the differences between electrical or computer engineering and computer science, indicating a gap between their interest and conceptual understanding. About 70% of the students had some idea or knowledge about ECE, while the other 30% had merely heard of it. Thematic analysis of their responses revealed a strong interest in robotics, programming, and hands-on experimentation, with about

77% reporting some hands-on experience, most commonly through robotics or coding-related experiences at school or club activities. The participants expressed limited familiarity only with fundamental circuits, measurements, and core ECE concepts. Although many reported experiences with robotics or programming, few expressed confidence in foundational topics such as circuits, measurements, or instrumentation.

The program curriculum was designed to reflect the breadth of contemporary areas in ECE rather than focusing on a single subdiscipline, informed in part by the pre-camp survey responses indicating student interest in exploring multiple areas of the field. The goal was not comprehensive coverage, but sufficient exposure for students to develop practical skills and gain a sense of ECE across different contexts. Table I shows the program schedule.

The sessions were designed with incremental complexity, allowing students to build on foundational ideas over time. Instructors intentionally allowed room for trial-and-error rather than prescribing a single correct approach. Core concepts were revisited across multiple applications, helping students see connections between topics that are often viewed as separate. This approach allowed participation from students with varying levels of experience to participate without separating them by ability. Each session typically began with a short lecture to introduce key ideas and provide context, followed by guided demonstrations and hands-on activities in which students built, tested, analyzed, or programmed systems. Depending on the task, students worked individually or in small groups of two to three.

Table I. Program Schedule

<table>
<tr><th colspan="6">Week 1</th></tr>
<tr><th></th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><th>9 am-12 pm</th><td>Intro to electrical engineering</td><td>Intro to computer engineering and logic gates</td><td>Sensors and indoor sensing system using Arduino</td><td>Renewable Energy</td><td rowspan="2">No classes - local industry visit</td></tr>
<tr><th>1 pm - 4 pm</th><td>Simulation and measurements</td><td>Intro to programming and Arduino</td><td>Actuators and indoor sensing system using Arduino</td><td>Solar panel/Wind energy</td></tr>
<tr><th colspan="6">Week 2</th></tr>
<tr><th></th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><th>9 am-12 pm</th><td>Antenna simulations and network analyzer</td><td>Activity with wheeled robot</td><td>Soldering</td><td>Neural signals</td><td rowspan="2">Program closing</td></tr>
<tr><th>1 pm – 4 pm</th><td>AI/ML and examples on gaming</td><td>ML algorithms and activity with wheeled robot</td><td>Soldering</td><td>Electrophysiological signals; Elevator pitch</td></tr>
</table>

Introduction to Electrical Engineering, Circuits, and Bioamplifiers

Students started with a module on electrical engineering (EE) where they learned to construct a circuit, use a function generator, and record and observe signals using an oscilloscope. Additionally, students received detailed instruction on safety in the lab, especially when working with electrical equipment and power supplies. Students received instructions on essential circuit-building techniques, then constructed an electrocardiogram (EKG) circuit (Figures 1 and 2), evaluated it with a test signal, and used it to collect EKG waveforms using skin-surface electrodes. In the testing mode, the students used the function generator to apply an input signal to the circuit and an oscilloscope to observe the output signals of the circuit to evaluate the gain of the circuit—the amplitude of the output voltage divided by the amplitude of the input voltage. In the data collection mode, students formed an Einthoven's triangle by replacing the connection to the function generator with electrodes attached to their right and left forearms, and by connecting a third electrode attached to their left ankle to the ground terminal [10]. Students learned to take advantage of the built-in capabilities of the oscilloscopes to apply a low-pass filter to the EKG signal and reduce the noise to obtain a reasonable result [10].

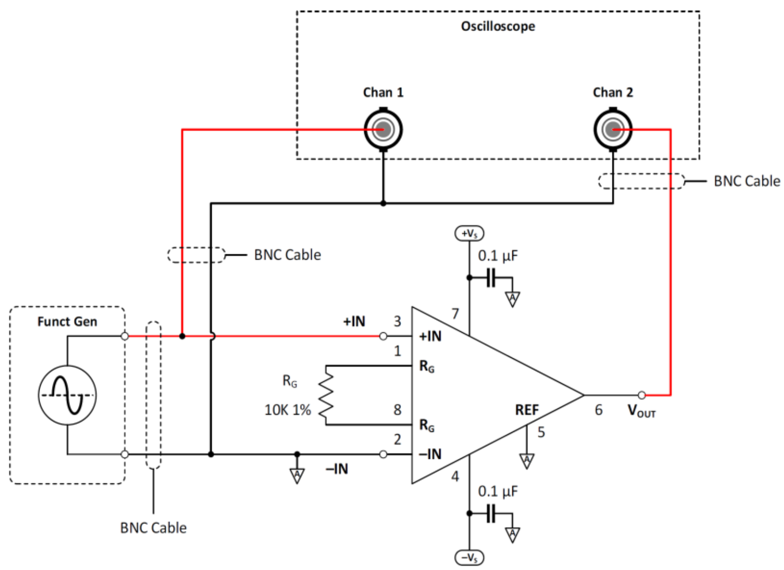


Figure 1. Circuit Diagram of the EKG Circuit

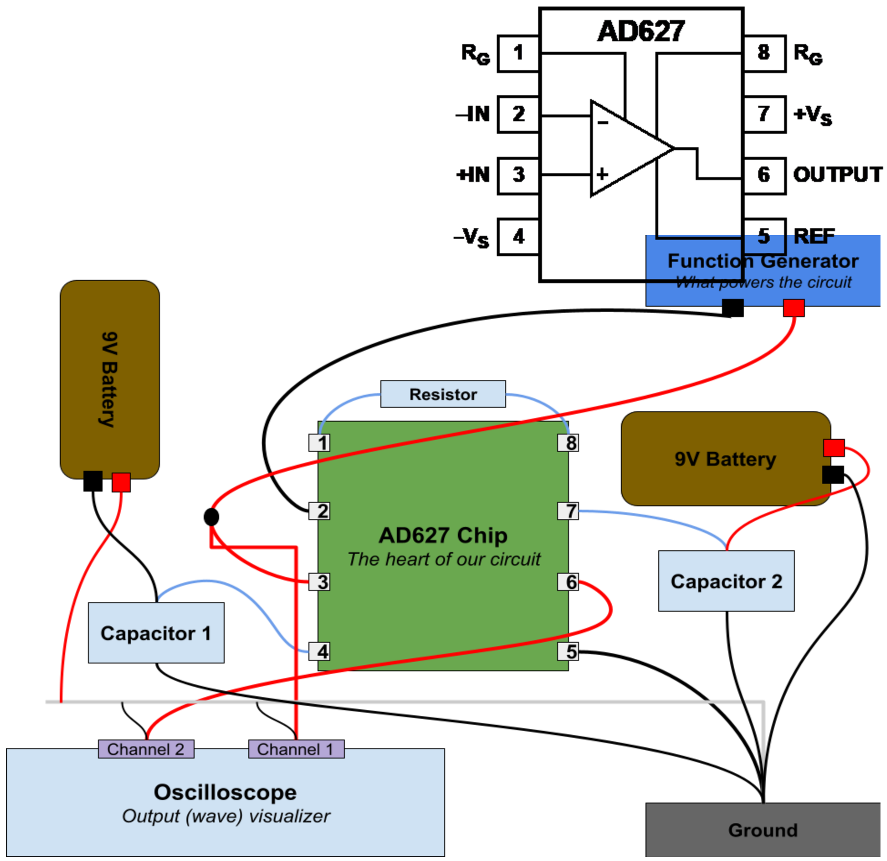


Figure 2. Block and Connections Diagram of an EKG Circuit

Students received brief instructions on how all electrophysiological signals are "tiny" electrical signals generated by living tissues such as nerves, muscles, and the heart. The session underscored how simple circuits may measure an electrophysiological signal like an EKG as voltages using electrodes attached on skin or electrodes implanted in tissue. They also used needle electrodes to observe neural signals from cockroach legs using a bioamplifier (Neuron SpikerBox, Backyard Brain, US) and study the signal properties using recording software on their PCs.

They also studied EMG signals and muscle contraction. The lab equipment helped them understand how a "thought" is transformed into electrical impulses, which travel down motor neurons (in the spine and peripheral nerves) to the neuromuscular junctions that form a motor unit. They attached three electrodes to their forearm to record EMG muscle signals using a PC-based sensor interface (LabQuest Mini, Vernier Software & Technology, US). They used a hand dynamometer to observe, analyze, and correlate the strength of their grasp to the collected EMG signals. Additional tasks included guided demonstrations of passive EMG signals and muscular control. These tasks, spanning over three sessions, provided them with insights into the use of ECE theories and techniques in medicine, disease diagnosis, and evaluating human performance.

Soldering

A lecture and live demonstration were delivered by faculty members in collaboration with a laboratory technician to introduce fundamental soldering and desoldering techniques, safety practices, and component identification. Introducing soldering to high school students served as an effective educational activity that promotes early engagement with engineering and technology disciplines while maintaining a high level of student interest and enjoyment. Soldering provided a hands-on learning experience that bridges the gap between abstract scientific principles and real-world electronic systems. Such experiential learning has been shown to increase technological self-efficacy and positively influence students' interest in pursuing ECE or other related STEM fields.

The activity was implemented over two laboratory sessions. Each soldering station had a soldering iron, fume extractor, magnifier, solder, hand tools, and a desoldering pump. Students were divided into six groups, with each group assigned to one station. Each team received a sound-to-light unit soldering kit (Figure 3). The kit included a printed circuit board (PCB) and a variety of electronic components, including resistors, transistors, light-emitting diodes (LEDs), capacitors, a potentiometer, and a microphone.

Students assembled and soldered the components onto the PCB. The primary objectives of the laboratory exercise were to develop basic soldering proficiency and to introduce troubleshooting skills. In several instances, improper soldering resulted in non-functional circuits. These teams were instructed to troubleshoot their assemblies, identify defective solder joints, and rework the connections until correct circuit operation was achieved.

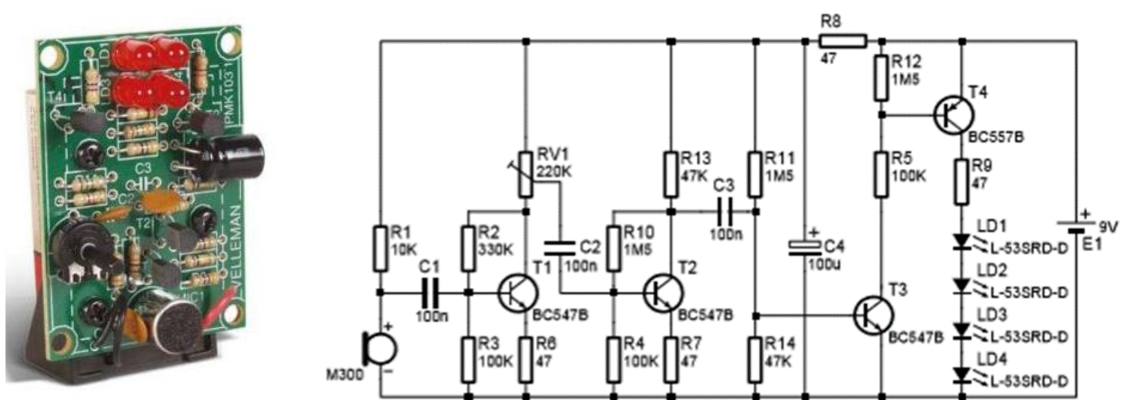


Figure 3. Sound Activated LED Kit WSL104 Velleman | Jameco Electronics. (Available: https://www.jameco.com/z/WSL104-Velleman-Sound-Activated-LEDs-Kit_147571.html)

Introduction to Computer Engineering, Digital Logic, and Embedded Systems

Students were introduced to the field of computer engineering through a structured combination of conceptual instruction and hands-on activities on digital logic and embedded systems. Digital logic instruction began with an explanation of how engineers represent and process information using binary systems, including number representation and basic binary arithmetic. Students were subsequently introduced to fundamental logic gates—AND, OR, and NOT—through truth tables, logic symbols, and Boolean equations. Instruction emphasized how individual logic gates can be interconnected to form logic diagrams.

The primary exercise required students to design and construct a circuit that illuminated an LED under specific conditions. The task modeled a simplified air-conditioning control system, where the LED represented the operation of an air conditioner. The system was designed to activate when humans were detected, and the room temperature exceeded a predefined threshold, or when a manual override button was pressed. To simplify implementation, push buttons were used in place of actual motion and temperature sensors. By the end of the session, students completed the task and demonstrated a clear understanding of binary logic, Boolean reasoning, and basic circuit construction.

Introductory programming and embedded systems used a microcontroller platform. Students were first introduced to fundamental programming concepts using the Python language, including data types and conditional (if/else) statements. After completing several guided exercises, instruction transitioned to Arduino programming, selected for its accessibility as an entry point into embedded systems. Students learned about Arduino code structure, program execution flow, and the interaction between software and hardware components. Students then completed a series of progressively challenging exercises, including programming LEDs to blink at varying speeds and modifying LED behavior based on push-button input. The session culminated with the introduction of an ultrasonic distance sensor. Students were tasked with developing both a circuit and a program to control LED behavior based on object distance, according to the following specifications:

- When the distance exceeded 50 cm, all LEDs were off.
- When the distance was between 50 cm and 30 cm, the green LED was on.
- When the distance was between 30 cm and 20 cm, the green and white LEDs were on.
- When the distance was below 20 cm, all LEDs (green, white, and red) were on.

As a final integrative challenge, students incorporated a push button representing a braking mechanism. When pressed, the button forced all LEDs off regardless of distance; otherwise, the LED behavior followed the distance-based logic described above. This task required students to synthesize digital logic, programming, sensor integration, and circuit design concepts learned throughout the day. By the end of this session, most student groups completed the distance-based LED control task. A smaller number of groups completed all tasks, including the brake override functionality, and elected to remain beyond the scheduled session time to finish the challenges. Some groups completed earlier intermediate tasks involving button-controlled LED blinking patterns.

Indoor Smart Monitoring System

The activity on an indoor smart monitoring system was designed to introduce fundamental concepts in hands-on prototyping. The activity was centered on the Arduino Uno platform. Students progressed through four distinct technical modules, each focused on a specific sensor–actuator interaction, before culminating in a final system integration exercise. The modular design allowed students to complete each module at their own pace, thereby increasing confidence in STEM-related skills while minimizing frustration and discouragement.

Smart Fan Control: Students prototyped a temperature-regulated cooling system by interfacing an LM35 temperature sensor with a cooling fan and the microcontroller. The system logic was designed to activate the fan only when the ambient temperature exceeded a user-defined threshold.

Light-Sensing LED System: Students utilized a photoresistor (light-dependent resistor, LDR) to measure ambient light intensity and interfaced it with an LED. The resulting prototype automatically illuminated the LED when light levels fell below a predefined threshold.

Motion-Activated Alarm: Students implemented a motion-detection system using a passive infrared (PIR) sensor. Upon detecting movement, the microcontroller triggered an auditory alert through a speaker, simulating the operation of a commercial burglar alarm.

Air Quality Warning System: Students connected an MQ135 air quality sensor to monitor the presence of pollutants or vapors. A safety baseline was established, and the system was programmed to activate a visual warning in the form of a flashing LED sequence when air quality degraded beyond acceptable levels. Isopropyl alcohol (IPA) was used to temporarily alter the sensor system's ambient air quality for demonstration and testing purposes.

System Integration: The session concluded with a capstone challenge in which students integrated the hardware and software components from all four modules into a unified monitoring system.

Smart Waste Segregation Activity

The second project-based learning activity focused on embedded systems and automation through the design and implementation of an Arduino-based smart garbage segregation system. The societal impact of engineering through sustainability-focused applications was underscored through the project in this session. Students constructed a system that classified waste as wet or dry using a moisture sensor and ultrasonic sensor, with a servo motor directing waste into appropriate bins and a 16×2 LCD providing real-time feedback. A system-level block diagram was used to explain the interaction between sensors, processing, and output components, helping students develop intuition for input–processing–output relationships in embedded systems (Figure 4).

Through guided hands-on assembly and testing, students observed how sensor data is processed by the Arduino and translated into physical motion and visual display outputs. The completed prototype demonstrated real-time automation and reinforced concepts such as control logic, system integration, and debugging (Figure 5). This activity was particularly effective in engaging students due to its hands-on nature and direct connection to environmental sustainability.

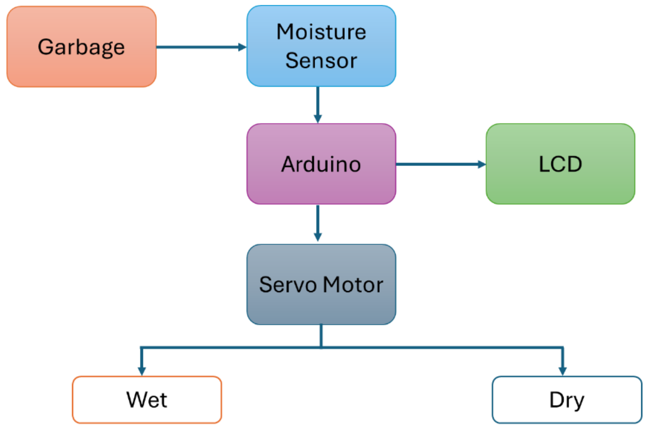


Figure 4. *Block diagram of the Arduino-based smart garbage segregation system.*
The diagram shows the system-level interaction between sensors, microcontroller, actuator, and display, helping students understand input–processing–output relationships in embedded systems.

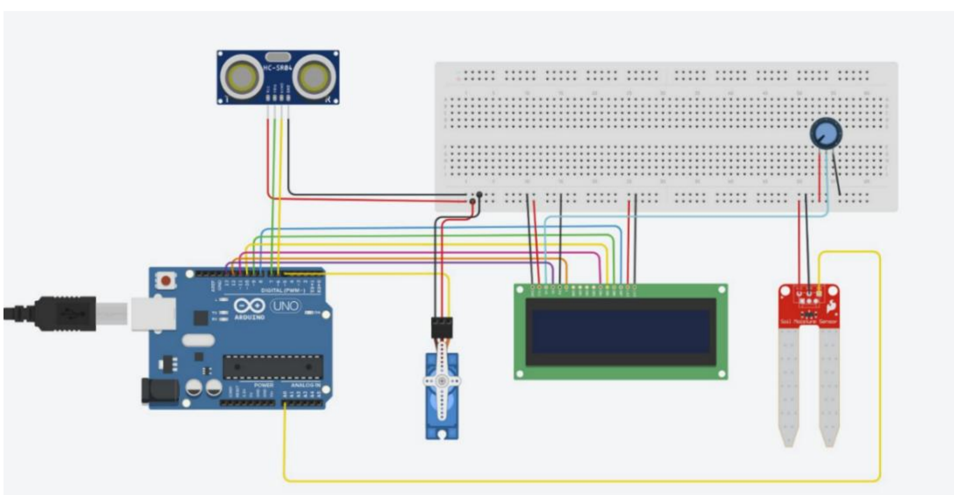


Figure 5. Assembled smart garbage segregation prototype developed by students during the program. The prototype integrates an Arduino UNO, moisture sensor, ultrasonic sensor, servo motor, and LCD display, demonstrating real-time automation and the societal application of embedded systems in sustainable waste management.

Artificial Intelligence and Robotics

Students received instruction on the developing field of artificial intelligence (AI). With an emphasis on AI as a crucial and unifying element in modern ECE applications, the session introduced the idea of search space complexity through a comparison of games like Tic-Tac-Toe and Chess in order to highlight the necessity of AI-driven problem solving. The use of heuristics and informed search techniques was encouraged by this comparison, and the notion of estimation was introduced, which gave an intuitive understanding of AI-based problem solving and why brute-force or uninformed search strategies are workable for simple problems, but may become impractical for complex, real-world engineering challenges. This foundational discussion served as an entry point for introducing core AI concepts and their relevance to engineering decision-making.

The session on AI also presented machine learning (ML) as a crucial AI paradigm for resolving problems in engineering. Using examples from signal processing, pattern recognition, and control systems, students learned the fundamentals of supervised, unsupervised, and reinforcement learning. The session went on to introduce artificial neural networks (ANNs) and deep learning (DL), with an emphasis on how well they work for large-scale problems like computer vision. These instructions placed added emphasis on conceptual understanding, architectural intuition, and real-world engineering use cases rather than on mathematical formalism. Students were able to understand how AI models learn from data and how these techniques are integrated into contemporary ECE systems.

Following the sessions on AI and ML, students applied AI concepts in a real-world engineering setting through an experiential, hands-on robotics learning session. Students investigated motion planning and perception tasks using LiDAR and vision sensors following an introduction to fundamental robotic system architecture, including sensing, actuation, and control. Through a mobile application interface, student groups experimented with line following, object tracking, obstacle avoidance, and hand recognition using a wheeled robot platform. As students engaged with the robots and observed how the systems behaved, theoretical AI and robotics concepts were reinforced in real-time. Their comprehension of AI in ECE was strengthened by this interactive and cooperative experience, which also generated excitement through playful but significant experimentation.

Additionally, students attended a guided demonstration of a highly advanced four-legged robot with a 6-DOF arm (Spot, Boston Dynamics, US), to understand the role and functioning of robotic platforms in industrial applications. Students remotely controlled the robot—equipped with an array of sensors for obstacle detection and avoidance—with a hand-held controller and observed several aspects of kinematics, sensors, and robot control.

Renewable Energy

The sessions on renewable energy included guided hands-on activities with solar panels, simulation with solar energy production, and wind energy conversion and turbine operation principles (Figure 6).

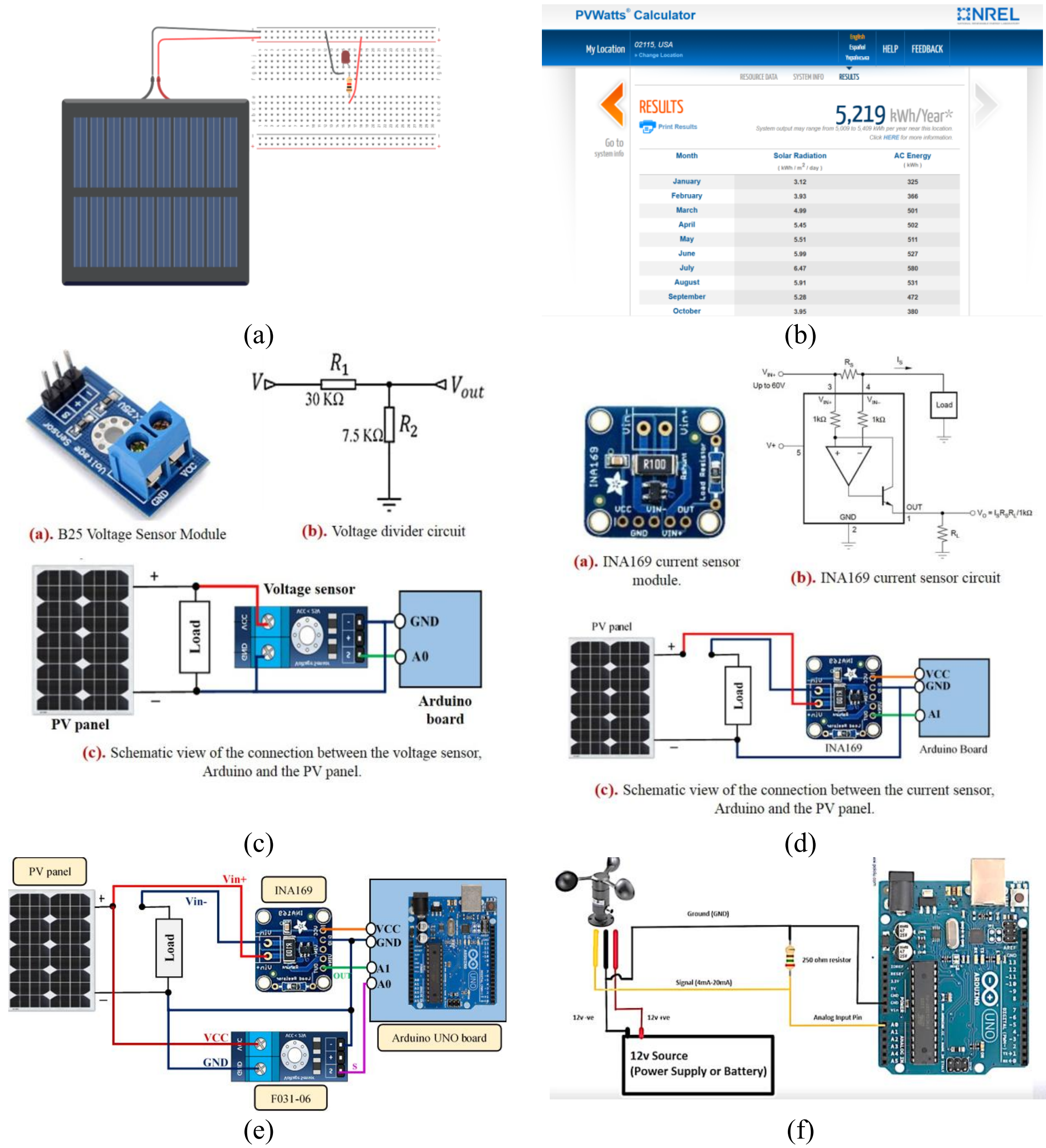


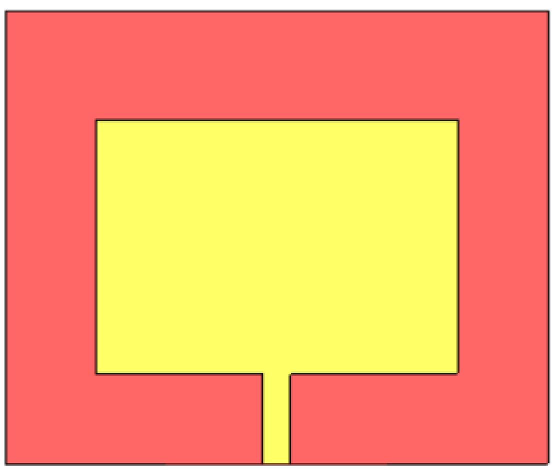
Figure 6. (a) Solar LED activity where students analyzed basic photovoltaic (PV) power generation and load behavior. (b) PVWatts Simulation where students estimated solar energy yield using geographic and system-level inputs (https://pvwatts.nrel.gov/pvwatts.php). (c) Voltage sensor measurement introducing voltage as an electrical parameter through real-time data acquisition. (d) Current sensor measurement focusing on quantifying electrical flow and load demand. (e) Combined voltage/current measurements reinforcing system-level analysis through power and energy calculations. (f) Wind speed measurement connecting environmental data to wind energy conversion and turbine operation principles.

Wireless Communication and Antenna Design

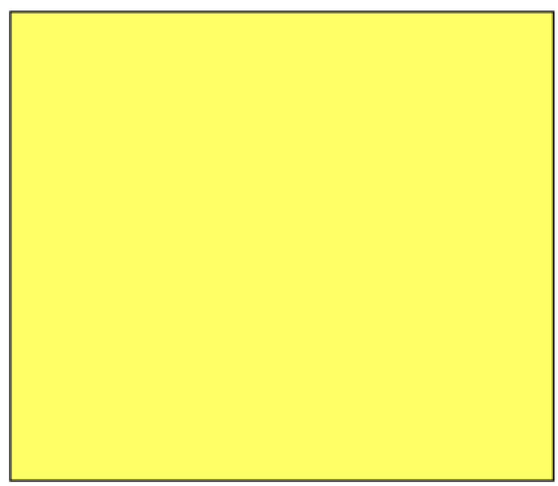
Students were introduced to fundamental concepts of wireless communication and electromagnetics through the design and simulation of a rectangular microstrip patch antenna operating at the 2.4 GHz ISM band. The activity was adapted from a guided antenna design laboratory manual and was structured to emphasize conceptual understanding, visualization, and experimentation rather than mathematical derivations.

Students began by exploring the basic components of a microstrip antenna, including the radiating patch, dielectric substrate, feedline, and ground plane. Using CST Studio Suite, participants followed a step-by-step workflow to model the antenna on an FR-4 substrate and observed how physical parameters influence antenna performance (Figure 7).

Simulation results such as return loss (S11) and VSWR were analyzed to help students identify antenna resonance, impedance matching, and bandwidth behavior (Figure 8). To reinforce real-world relevance, experimental validation using a Vector Network Analyzer (VNA) was demonstrated, allowing students to compare simulated and measured antenna responses. This comparison helped students recognize practical non-idealities such as fabrication tolerances and material losses, while strengthening their understanding of the design–simulation–test cycle commonly used in RF engineering and other related areas in ECE.

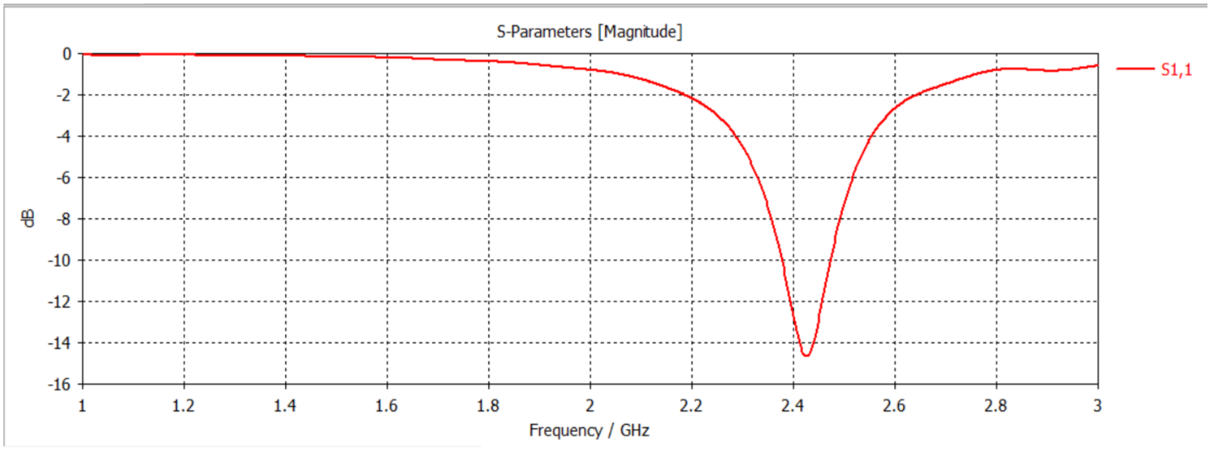


(a) Front View

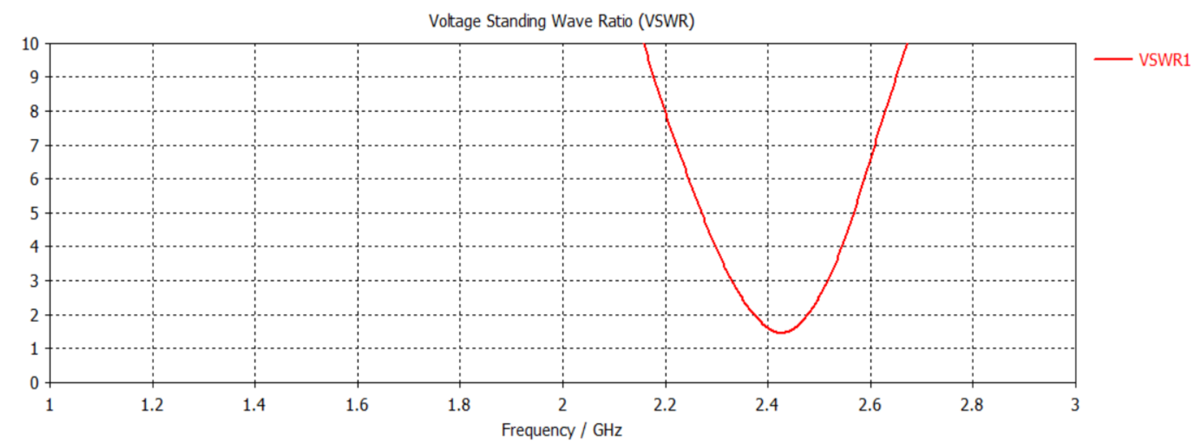


(b) Back View

Figure 7. Geometry of the microstrip patch antenna used in the summer engineering program. This figure shows the rectangular microstrip patch antenna structure, including the radiating patch, dielectric substrate, feedline, and ground plane, as introduced to students using the antenna design lab manual.



(a) Return Loss (S11) dB



(b) Voltage Standing Wave Equation

Figure 8. *Simulated return loss (S11) and VSWR response of the 2.4 GHz microstrip patch antenna.* Students use this plot to visually identify antenna resonance, −10 dB bandwidth, and impedance matching behavior, reinforcing key wireless communication concepts without requiring advanced mathematical analysis.

Discussion

The pre-camp survey responses pointed to a familiar challenge in pre-college ECE education. Many students arrive with enthusiasm for applied STEM activities, but limited exposure to the foundational concepts that define ECE as a major. Core concepts were introduced through practical contexts rather than as abstract prerequisites, which appeared to help students engage with unfamiliar material within a single, cohesive educational framework. The program concluded with a team-based elevator pitch for conceptual projects that encouraged students to integrate ideas from multiple sessions. Students presented their ideas and visions for conceptual projects on, for example, a robot-controlled kitchen platform, home-based assistive platform, etc.

Given the limited sample size, the thematic analysis of the pre-camp survey responses prioritized interpretive insight over statistical analysis of the data. Several limitations should be acknowledged. For example, participation in the program was voluntary, and the sample reflects a self-selected group of students with at least some prior interest in STEM or specifically engineering. The analysis captured students' perspectives before the program and does not address longer-term changes in interest or academic outcomes. These constraints limit the scope of the findings, but they do not necessarily diminish the value of the insights for informing pre-college program design.

The range of student backgrounds highlights the importance of balancing structure with flexibility; too much instruction risks limiting creativity, while too little guidance can leave less experienced students frustrated. Finding an appropriate middle ground remains an ongoing design challenge. The use of structured instructional manuals, visual aids, and instructor-guided discussion ensured accessibility for students from diverse academic backgrounds. The offered sessions allowed the students to explore how ECE incorporates hardware, software, and/or artificial intelligence through sessions, for example, on sensor integration in an indoor sensing system, detecting neural activity with bioamplifiers, and implementing motion planning with robots. While overall engagement was high, student focus during the afternoon sessions was observed to be relatively lower compared to the morning sessions, likely due to fatigue from the extended duration of the activities. Nevertheless, student reflections, qualitative feedback, and instructor observations indicated increased confidence and greater awareness of ECE as an interdisciplinary field, underscoring the role of pre-college programs like this in supporting student interest, learning, and skill development in ECE. Students gained confidence, developed engineering intuition, and recognized the relevance of ECE concepts to modern technologies and real-world challenges.

Qualitative feedback highlighted the value of exposure to multiple distinct activities, particularly the integration of simulation tools, real time sensor measurements, and physical energy systems. These outcomes indicate that the Impact Lab successfully supported applied engineering learning by enabling students to transition from conceptual understanding to measurement, analysis, and system-level interpretation within a single, cohesive educational framework.

Conclusion

The paper presented an overview of a hands-on pre-college summer camp on topics in the field of ECE. Offered for the first time at Wentworth Institute of Technology, the program's focus was breadth of topics, and student interest and skills in those. A qualitative analysis of pre-camp survey responses showed strong interest of the students in hands-on, application-driven learning alongside limited familiarity with foundational ECE concepts. These insights informed the structure and pacing of the sessions offered and underscored the potential value of interactive summer programs in helping students develop a more accurate understanding of ECE.

Future iterations of the program would continue to refine the balance between foundational instruction and open-ended explorations. Additionally, large sample sizes, alternative assessment methods, and longitudinal follow-up with the attendees may provide further insight into enhancing the curriculum and evaluating how early exposure to ECE influences students' academic choices over time.

Acknowledgments

The authors thank Lucas Boehnke, Dylan Cadigan, Evan Jalbert, Shubaan Meyyappan, Sophia Puga, Sophia Sistachs Losada, Konstantinos Theodoropoulos, Christian Vallerand, Rudolph Vincent, Nick Whitcomb, Doreen Cialdea, Joe Diecidue, and Herb Connors for assistance with running the program. They also thank Andreas Armenis, Xiu Zhai, and Anuja Kamat, as well as the Douglas D. Schumann School of Engineering at Wentworth and the Pre-College Programs at Wentworth, for their logistical support and assistance.

References

[1] R. Hammack, T. A. Ivey, J. Utley, and K. A. High, "Effect of an engineering camp on students' perceptions of engineering and technology," *Journal of Pre-College Engineering Education Research*, vol. 5, no. 2, pp. 1–12, 2015.

[2] B. Zhou, "Effectiveness of a precollege STEM outreach program," *Journal of Higher Education Outreach and Engagement*, vol. 24, no. 3, pp. 61–72, 2020.

[3] P. Kotlikoff, A. S. Rahman, and K. A. Smith, "Minding the gap: Academic outcomes from pre-college programs," *Education Economics*, vol. 30, no. 1, pp. 3–28, 2021.

[4] J. Rodriguez, S. Butt, and T. Fredericks, "Pre-college activities to promote positive perceptions of engineering careers," in *Proceedings of the International Conference on Interactive Collaborative Learning*, 2014, pp. 715–719.

[5] C. Knobloch, "The Pennsylvania State University 'MTM Engineering Camp for Girls:' Generating Under-Represented Pathway Prospects Through A Diversity-Rich Pre-College Outreach Project," *Women in Engineering ProActive Network*, Jan. 2005.

[6] M. Shirley, A. Long, S. Nguyen, K. Wallace, and L. Locke, "Ensuring a Successful Transition: Understanding the Role of Pre-College Programs in Supporting Racially Underrepresented Students Early in the Access Process", *Journal of The First-Year Experience & Students in Transition*, vol. 36, no. 2, pp. 53-73(21), 2024.

[7] J. M. Raines, "FirstSTEP: A preliminary review of the effects of a summer bridge program on pre-college STEM majors", *Journal of STEM Education: Innovations and Research*, vol. 13, no. 1, 2012.

[8] B. C. Bradford, M. E. Beier, and F. L. Oswald, "A Meta-analysis of University STEM Summer Bridge Program Effectiveness," *CBE Life Sci Educ*, June 1, 2021.

[9] T. Latif, D. E. Dow, G. G. Ma, and M. F. Halim, “Introduction to robotics: An impactful summer program for high school students,” in *Proceedings of the 2025 ASEE Annual Conference & Exposition*, June 2025.

[10] F. Aveta, A. Ghanavati, M. Rawlins, and P. Junsangsri, “Designing effective STEM outreach activities to inspire students to ultimately pursue careers in the electrical and computer engineering fields,” in *Proceedings of the 2025 ASEE Annual Conference & Exposition*, June 2025.