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Introduction to Robotics: An Impactful Summer Program for High School Students

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Abstract

Many colleges and universities across the globe offer pre-college programs to high school students. Such programs aim to provide opportunities for students to gain exposure to college by attending a program related to a college major or area of interest, exploring research inquiry, enhancing their skills, and becoming more informed to make better decisions about their intended college major in the not-too-distant future. This paper details the development, implementation, and outcome of a pre-college summer program held at our university. The two-week-long program, modeled after college-level courses, had a mix of rising juniors and seniors. The students resided on campus and attended laboratory sessions four days a week, in two three-hour periods each day. The topics covered included the basics of robotics and key components such as sensors, actuators, kinematics, obstacle avoidance, and trajectory planning. Each session started with a short lecture providing an overview of the activities and relevant theory. Students then worked on several platforms over the two-week camp, including robotic arm manipulators, mobile robots, and a four-legged robot. Simultaneously, students worked in groups on a research project that focused on proposing a robotic design to address a real-world problem. The students entered the camp with varying levels of prior experience. Out of 11 participants, 36% had no prior experience participating in robotics camps and competitions. Between 45% and 63% of the participants reported no or beginner-level knowledge in programming, circuits, or mechanical designs. A combined 81% reported being very and somewhat satisfied with the program with 55% agreeing that the learning outcomes met their expectations. In the future, we could modify the breadth and depth of topics based on student recommendations, needs, and the background of the students. This type of program can offer relevant knowledge and hands-on learning experience to high school students in an immersive environment and thus better equip them for pathways toward higher education and career.

Introduction

Pre-college programs can play an immense role in introducing and encouraging high-school students to science, technology, engineering, and mathematics (STEM) fields and majors in colleges or universities [1-4]. Current research suggest involvement in pre-college programs may encourage student attendees to study STEM-related majors [5-6], potentially improve their academic performance or retention rates [7-8], and improve representation by underrepresented groups [3, 9]. These programs or summer camps can potentially enhance the student participants' learning experience by covering topics not typically offered in schools. The programs aim to make them better prepared for college-level education through appropriate knowledge dissemination together with active and experiential learning. Additionally, the students get a college-like experience by attending the scheduled lectures and labs, living on-campus, and using the university facilities.

The students may gain a deeper understanding of the engineering discipline as a whole or specific engineering majors, for example, robotics or robotics engineering. Robotics is an interdisciplinary field for the use, study, operation, and design of robots. Many robots can perform tasks often considered mundane or unsafe for humans [10-14], potentially leading to improved quality of life and economy. The field is in high demand with automation and the rise in the number of tools and equipment across the globe. As such, the discipline needs more qualified robotics engineers or roboticists with appropriate knowledge and training. Through a pre-college robotics experience, high-school students can learn about the area of robotics and relevant topics, including electronic circuits, robotic sensors, data analysis, kinematics, and embedded systems. This will help them examine the area and their affinity towards it to potentially develop a level of comfort in the area. Then they can make a more informed decision when choosing their college major, and use their learned skills and knowledge when they go to college. Alternatively, such skills and knowledge may be transferred to other robotics-relevant majors, including electrical, computer, and mechanical engineering.

Program Overview

This paper describes the development, implementation, and outcome of the pre-college summer program on robotics held at our university in the Summer of 2024. The two-week-long program, modeled after college-level courses, had 11 participants: a mix of two rising juniors and nine rising seniors. The students applied to a two-week residential program of their choice through the university website. All programs, including the "Introduction to Robotics Engineering," ran in two daily sessions —9 am-12 pm morning session and 1pm-4pm afternoon session— four days a week from Monday to Thursday. Each session typically included a short lecture module and a hands-on or laboratory module where students worked in a group of two to three students. Table I shows the program schedule with a short description of the sessions.

Table I Program schedule

Week 1					
	Monday	Tuesday	Wednesday	Thursday	Friday
9 am-12 pm	Lecture session: Introduction to Robotics, components, robotic areas, sensors and actuators, kinematics, emerging areas.	Haptics	Robotic arm manipulator kinematics and assembly	Haptics in surgical robotics	No classes - local industry visit
1 pm - 4 pm	Sensors: data collection, analysis, and presentation.	Block coding and hardware interfacing. Project assignment	Robotic arm manipulator with an end-effector	Robotic arm manipulator with an end-effector. Project work	
Week 2					
	Monday	Tuesday	Wednesday	Thursday	Friday
9 am-12 pm	Four-legged robot: understanding robotic sensing and kinematics	Python coding fundamentals	Mobile robot obstacle avoidance and navigation	Project work	Program closing
1 pm – 4 pm	Introduction to mobile robots and Python	Mobile robot navigation	Mobile robot dance recital. Project work	Project presentation	

The “Introduction to Robotics Engineering” program began with an introduction and overview of robots, several types of robots, and safety with robots. An instructor discussed the principal components of a robot which included (1) a physical body that occupied a physical space, (2) sensors to sense its surroundings, (3) tools or end-effectors for locomotion or manipulation of objects, (4) a microcontroller or brain to give the robot “autonomy” and to control it, and (5) a power source [15]. Following this, an instructor gave demonstrations of robotic components like sensors and actuators, and went over their data collection methods. Students used the discussed methods to collect data from color sensors and potentiometers as a measure of position, analyzed the data, and presented them in a tabular and graphical manner.

The sessions related to each robot type were planned with incremental complexity. For each session, students were guided by a laboratory manual consisting of a set of instructions, tasks, and deliverables. Students were asked to plan their steps and develop coding algorithms for completing each assigned task by analyzing the problem and required hardware. They demonstrated the function and robotic behavior to an instructor, and improved their deliverables as required based on instructor feedback.

The first robotic platform the students used was a robotic arm manipulator (VEX V5 Workcell, VEX Robotics, US). The VEX V5 Workcell (Figure 1) is a 4-DOF educational robot which is equipped with DC motorized joints and an array of pre-packaged sensors—optical, infrared, bumper, and potentiometers. The arm used an ARM Cortex A9-based (Arm Holdings, UK) processor that students programmed using block coding on a proprietary integrated development environment (IDE). Students used step-by-step instructions to assemble the robotic arms and attach end-effectors. The students learned how to calibrate and program their setups to complete tasks, including drawing different shapes and texts, and pick-and-place tasks. They were

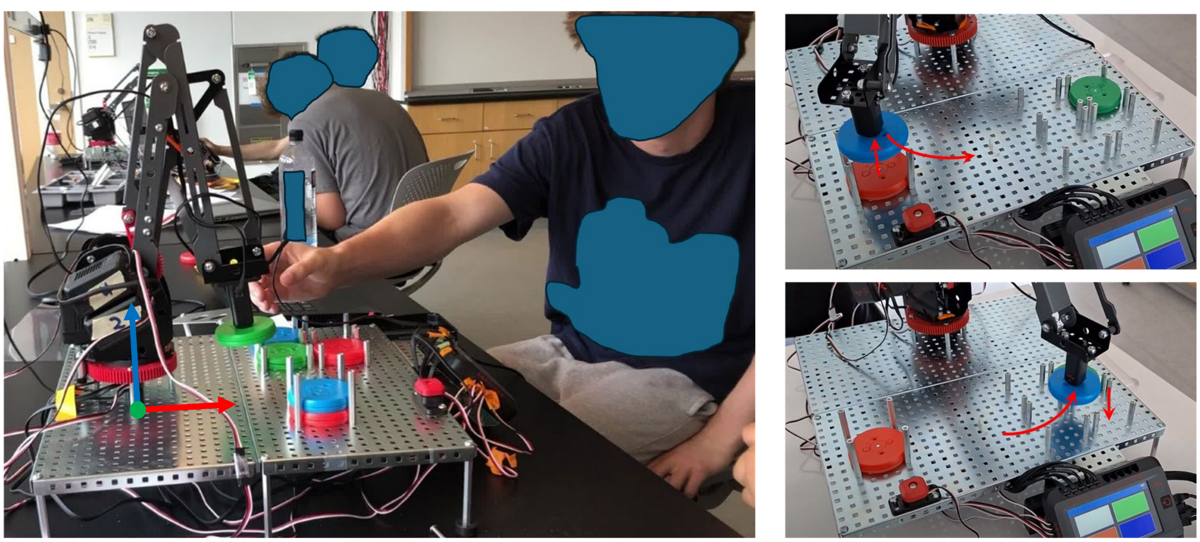

Figure 1. (left) Students worked, in groups, on the VEX V5 4-DOF robotic arms for pick-and-place tasks using discs or pallets with a metal center. Sensors like potentiometers help sense the joint positions while a magnetic end-effector helps pick and place the discs. (right) Sample images from a pick-and-place experiment: (right-top) a blue disc picked up from a stack of discs and (right-bottom) placed at a designated location.

instructed on the basics of kinematics, including frame assignments, for sessions with the robotic arm.

Students started their research project towards the middle of the first week. The goal of the project was to devise a robotic or an automated solution to some existing problem using agriculture robots, household or assistive robots, industrial robots, search-and-rescue robots, etc. The students worked on a preliminary design for their solution, selected required components for their design, and addressed the applications and challenges or limitations of their design. They mostly worked on the project during the second week and presented their work during their last session of the program. Examples of presented projects include a robot for marking lines on athletic fields, hydroponics bay with environmental quality monitoring, and an automated step stool lifting platform. The idea behind the project assignment was to encourage teamwork among the students to collaboratively work on the project objective and tasks. This idea was motivated by the ABET student outcome of "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objective." Through the project, they had an opportunity to develop some of these soft skills.

Additionally, they had two hands-on sessions on haptics sensors and their use in surgical robotics. The second week started with the introduction of a four-legged robot (Spot, Boston Dynamics, US). Spot (Figure 2) is a highly advanced 1.1m-long robot with an array of sensors for obstacle detection and avoidance. Students remotely controlled the robot with a hand-held device and observed several aspects of kinematics, sensors, and control using Spot. For the rest of the second week, students worked on their project assignment and a mobile robot (Create 3, iRobot Corporation, USA). The Create 3 (Figure 3) is an educational robot platform whose functioning is similar to the iRobot Roomba robot vacuum (iRobot Corporation, US).

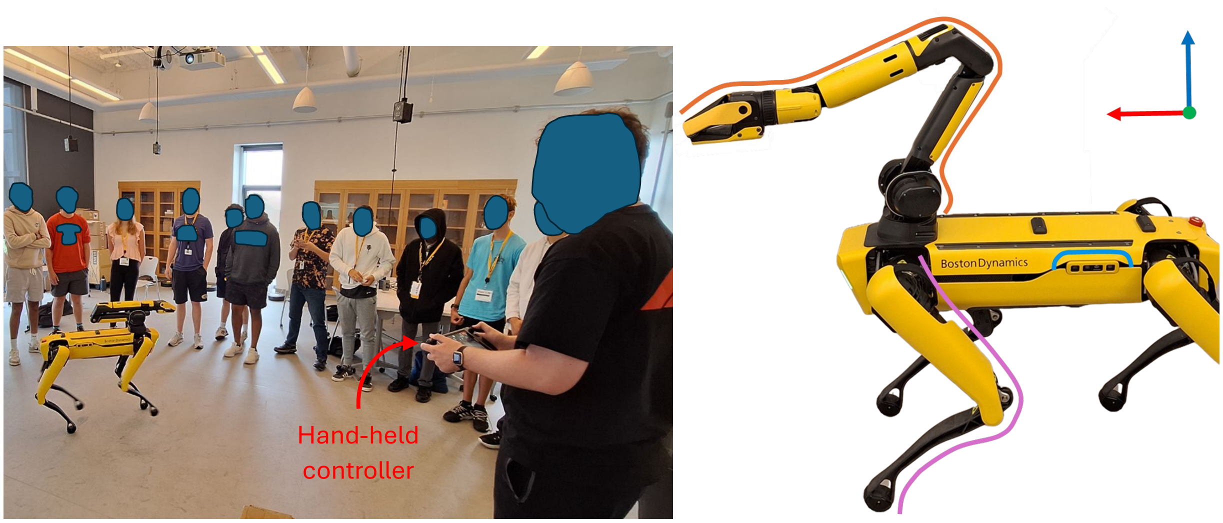

Figure 2. (left) Students remotely controlled the four-legged Spot robot with a hand-held controller. They worked on mini-tasks to learn how the robots detect several types of objects and perform tasks using its array of sensors and actuators. (right) The robot has five camera arrays located on the left (marked in cyan), right, rear, front-left, and front-right; four 3-DOF legs (one marked in purple); and a top-mounted 6-DOF arm (marked in orange) with a gripper as the end-effector.

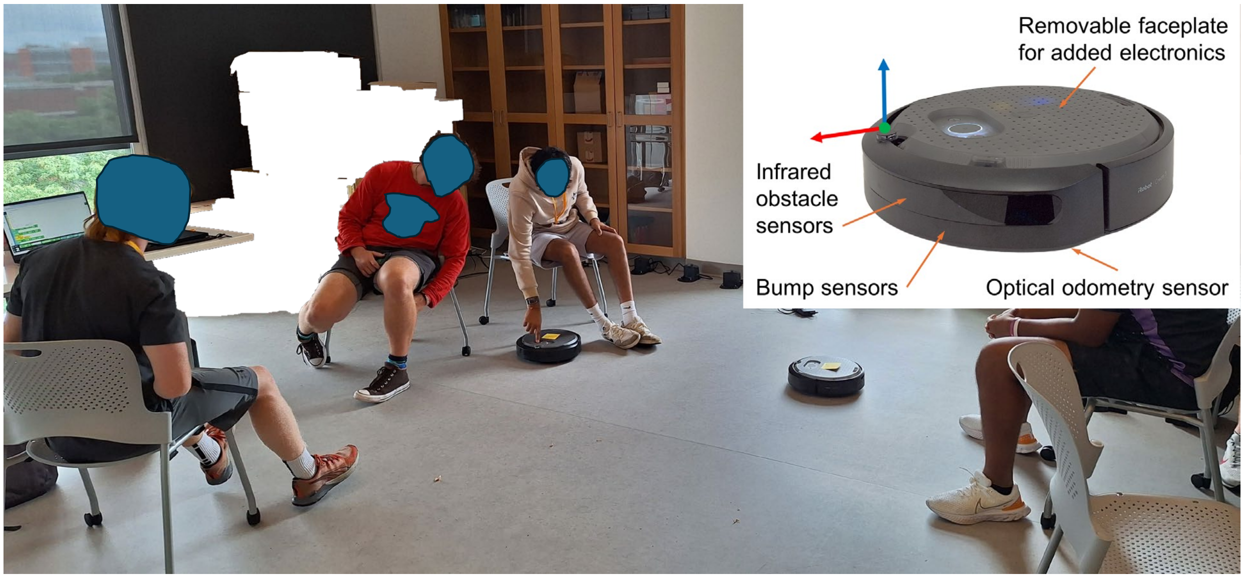

Figure 3. Students worked in small groups to program the robots for basic navigation and obstacle avoidance through an area defined by the instructors. (inset) Create 3 mobile robot with some of its sensors labeled.

Students took part in an instructor-led discussion on mobile robots where they talked about mobile robots, obstacle avoidance in such robots, and self-drive cars. During their lab sessions with the mobile robot, they worked on basic navigation and obstacle avoidance using on-board sensors and bug algorithms for automated exploration in unknown territories [16]. The mobile robot could be programmed with two separate IDEs: one for basic functions using block coding and the other for all available functions using Python. Students familiarized themselves with the robot using block coding after which they received instructions and tutorial session on Python. Once able to program with Python, students attempted to complete their lab tasks.

To summarize, students received instructions and participated in discussions on robots and their applications, several topics related to robotics, and their experience and background with robots. They worked on robotic sensors, a robotic arm manipulator, a mobile robot, haptic sensors, a four-legged robot, and a research project. Some with prior experience tried to relate them to their "new" knowledge when working on their lab work.

Program Findings

A total of 11 students participated in the camp. These students were asked to complete an exit survey on their last day. The anonymous survey collected data on their prior skills/knowledge on robotics, their expectations, and reflections. The low sample size of 11 was not sufficient for a statistical data analysis. Nevertheless, we performed a thematic analysis of the collected survey data to understand the perspectives and experiences of the attendees.

The students entered the camp with different levels of prior experience. Out of 11 participants, 36% had no prior experience participating in robotics camps and competitions. Between 45% and 63% of the participants reported no or beginner-level knowledge in programming, circuits, or mechanical designs. A combined 81% reported being very and somewhat satisfied with the program with 55% agreeing that the learning outcomes met their expectations.

To describe their most engaging or beneficial experience with the robotic arm manipulator, mobile robot, and research projects, participants used “prowess of the system”, “versatile”, “python programming”, “topics”, “skills and team.” At the same time, they used lack of “consistent results”, “coding”, “learning python”, and “time constraints” to describe some of the challenges associated with the modules. Finally, the respondents used “classes”, “programming”, “reward or prize”, and “designing assignments” to describe ways to improve these modules. A total of 91% of participants reported that the camp facilities were adequate for completing the activities. We asked the participants to rate their knowledge as 'none', 'beginner', 'intermediate', and 'advanced' in the areas of mechanical design, build, programming, and electronics and circuitry.

Comparing the before and after responses of their knowledge, we see that the 'none' and 'beginner' levels decreased from 45%-64% before the program to 27%-36% after the program. The biggest change was in the 'intermediate' level, which increased from 27-36% before the program to 36-55% after the program. Given that this was a pre-college program, it is natural to see the biggest change in the intermediate level of knowledge, before the participants can enter their undergraduate programs for a more in-depth learning experience. Survey also reported that 64% of the participants would recommend this camp to others who provided the following suggestions for improvement with “CAD”, “robotics and fundamentals”, “quick intro” among others. Finally, we received “robot design”, “a lot more projects”, “design process” as additional topics and activities that could be added in future robotics camps. In the future, the breadth and depth of topics could be modified based on student recommendations, needs, and the background of the students.

Conclusion

The paper gives an overview of a hands-on pre-college program or summer camp on robotics. Still in its earlier stages, the program aimed at developing further with inputs and feedback from the student participants. We plan on conducting similar surveys as we continue to conduct this camp, so that we can keep collecting feedback and suggestions for improvements. Given that the sample size is fairly small, in future we hope to conduct more qualitative assessments among the participants to gauge the various aspects of the robotics camp. Such feedback could help us modify the stages, complexity, and time allotment for each session so that the students have great learning experience with the subject area. These experiences could potentially help them in their decision to consider robotics or a related STEM field for their higher education major.

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References

[1] E. Jablonski and M. Vigeant, "Engineering Camp: A Residential Experience Designed to Build Academic Capital in Pre-college Students," *Papers on Engineering Education Repository (American Society for Engineering Education)*, Sep. 2020.
[2] 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 (J-PEER)*, vol. 5, no. 2, Nov. 2015.
[3] 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.
[4] J. Rodriguez, S. Butt, and T. Fredericks, "Pre-college activities to promote positive perception of engineering and engineering technology careers," In *2014 International Conference on Interactive Collaborative Learning (ICL)* (pp. 715-719). Dec. 2014. IEEE.
[5] 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.
[6] B. Zhou, "Effectiveness of a Precollege STEM Outreach Program." *Journal of Higher Education Outreach and Engagement*, vol. 24, no. 3, pp. 61–72, 2020.
[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] 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.
[10] R. A. Beasley, "Medical Robots: Current Systems and Research Directions," *Journal of Robotics*, vol. 2012, pp. 1–14, 2012.
[11] A. Bechar and C. Vigneault, "Agricultural robots for field operations: Concepts and components," *Biosystems Engineering*, vol. 149, pp. 94–111, Sep. 2016.
[12] T. Wang, B. Chen, Z. Zhang, H. Li, and M. Zhang, "Applications of machine vision in agricultural robot navigation: A review," *Computers and Electronics in Agriculture*, vol. 198, p. 107085, Jul. 2022.
[13] J. P. Queralta et al., "Collaborative Multi-Robot Search and Rescue: Planning, Coordination, Perception, and Active Vision," *IEEE Access*, vol. 8, pp. 191617–191643, 2020
[14] J. Zhao, J. Gao, F. Zhao, and Y. Liu, "A Search-and-Rescue Robot System for Remotely Sensing the Underground Coal Mine Environment," *Sensors*, vol. 17, no. 10, p. 2426, Oct. 2017.

[15] M. J. Mataric, The Robotics Primer. MIT Press, Cambridge, MA, 2007.
[16] V. J. Lumelsky and A. A. Stepanov, "Path-planning strategies for a point mobile automaton moving amidst unknown obstacles of arbitrary shape," *Algorithmica*, vol. 2, no. 1–4, pp. 403–430, Nov. 1987.