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First-Year Student Interest in Hands-On Final Project with an Autonomous Robot

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First-Year Student Interest in Hands-On Final Project with an Autonomous Robot

Abstract

All incoming students at the University of Louisville's J.B. Speed School of Engineering, regardless of their engineering major, are required to take a two-course introduction to engineering sequence. The first course of the sequence is ENGR 110: *Engineering Methods, Tools, & Practice I*. ENGR 110 covers fundamental engineering skills: engineering graphics, introduction to programming (Python), spreadsheets, critical thinking, etc. The second course is ENGR 111: *Engineering Methods, Tools, & Practice II*. ENGR 111 applies and expands the skills and knowledge learned in ENGR 110 to a hands-on semester-long Cornerstone project. ENGR 111 uses a 15,000 square feet makerspace and has the students work in teams of 3-4. The ENGR 111 project incorporates many different engineering skills, and the project varies by semester that it is taught. Projects used in the past are a Windmill System introducing power generation, a Water Filtration System based on a partnership with the Metropolitan Sewer District, and the most recent project added to the course was based on a robot.

This paper focuses on the robot project which centers on an autonomous robot controlled by an Arduino microcontroller that could drive around a course and sense various aspects of its surroundings. After students were taught the basics of both circuitry and Arduino programming, they were given instructional modules to interact with and practice using this robot. Student teams gained experience with the basic movements of the robot and using various sensors (line-following, ultrasonic distance, and IR proximity) to detect objects and roadways that could be useful for navigation. Ultimately, the students completed a final Cornerstone Project that involved the robot following a road to a security gate that would only open for a RFID tag with the correct access. Students programmed their robot to drive the RFID tag to a scanner, detect if the gate opened or not, and then drive through the gateway if it opened.

At the end of the semester, students were asked to complete a survey regarding their interest in engineering with respect to this new cornerstone project as well as interest based on different skills (programming, circuitry, etc.) used in ENGR 111. The survey included multiple Likert-scale questions, including one particular question that asked, "How much did the opportunity to work with a robot for this semester's cornerstone experience impact your interest in the ENGR 111 course?" The Likert-scale was: Not at all, Somewhat, Slightly, Very, and Extremely. Previous research shows a relationship between student interest and persistence [1][2][3]. The summer semester allows the authors to pilot possible new cornerstone project to a smaller cohort of students, while being aware of improvements and necessary adjustments before using the cornerstone project in the larger semester. Thus, the purpose of this paper was to assess students' interest in the course due to the new Cornerstone project. Results could inform instructors of student perceptions across engineering disciplines and provide directions for course improvements.

Introduction and Course Description

First-year students, regardless of their major, at the J.B. Speed School of Engineering (SSoE) at the University of Louisville are required to take a two-course sequence of introduction to engineering courses. These courses are titled *Engineering Methods, Tools, & Practice I* (ENGR 110), and *Engineering Methods, Tools, & Practice II* (ENGR 111). ENGR 110 is an introduction to the profession and some fundamentals of engineering. ENGR 110 introduces engineering graphics, ethics, professionalism, Python programming, teamwork, etc. ENGR 111 is taught in a 15,000 ft^2 makerspace, this makerspace is controlled and directed by the SSOE. ENGR 111 incorporates application and integration of fundamental engineering skills learned in ENGR 110. ENGR 111 consists of instruction for skills such as teamwork, circuitry, Arduino microcontrollers, three-dimensional graphics, 3D-printing, and technical writing.

ENGR 111 includes a semester long team-based Cornerstone project that all student teams complete, demonstrate, and present at the end of the semester. The instruction, activities, and deliverables throughout the semester are designed to help students towards completion of their Cornerstone project. The semester instruction scaffolds their knowledge towards the Cornerstone project. The nature of this project is to simulate a long-term industry project [4]. The project also involves team based hands-on learning with the presence of multiple instructors and teaching assistants to assist the teams [5][6].

ENGR 111 is a large enrollment course, averaging 400+ students in the spring semester of the students' first year. The students are broken into six sections with up to twenty 3-4 person teams. Each section for a given semester works on the same Cornerstone Project. There are various Cornerstone Projects that have been used in this course: a Windmill System introducing power generation, a Water Filtration System based on a partnership with the Metropolitan Sewer District, and the most recent project added to the course was based on an autonomous robot. New projects are typically tested as a proof of concept first with undergraduate teaching assistants, then in the summer iteration of ENGR 111. The summer iteration of ENGR 111 is a smaller enrollment (ten to fifteen 3-4 person teams total) to allow for quicker pivoting should a situation arise. The smaller summer enrollment allows the instructors to pilot the new project with the expectation of using the new project the following spring semester. As previously stated, this course is required for all engineering majors regardless of discipline. Therefore, the use of a robot in this course to teach the basics programming, circuitry, control, 3D-modeling was deemed an interesting project for all engineering majors.

Autonomous Robot Project (Robot)

The Robot Cornerstone Project was based on controlling an autonomous robot (Figure 1) with an Arduino microcontroller. The robot was expected to drive around a course and sense aspects of its surroundings.

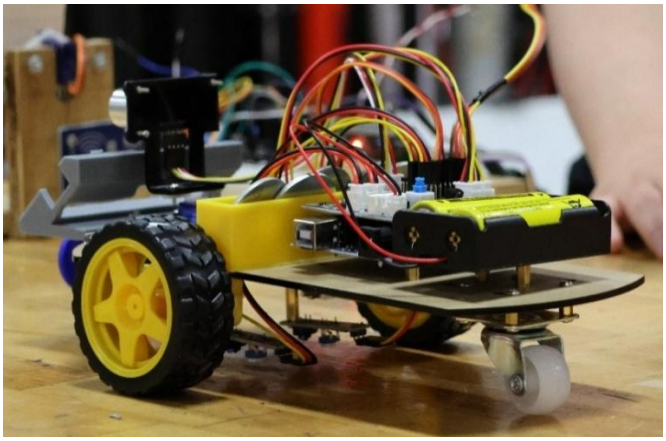

Figure 1: Robot Platform

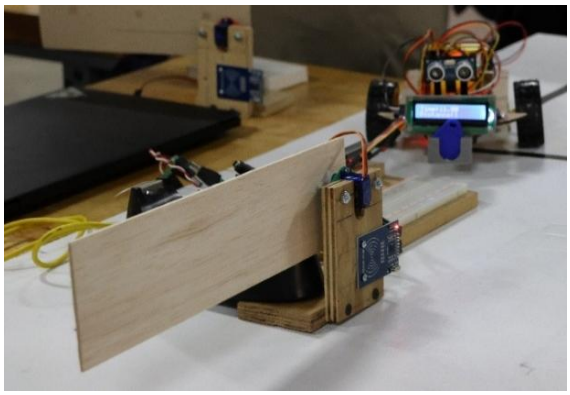

Figure 2: RFID Security Gate

The scaffolded lessons taught the students the basics of circuitry and Arduino programming. The programming lessons helped the students see the similarities to Python they had learned in a previous course. After the lessons on circuitry and programming, the teams were given lessons on how to interact with the robot and to practice using different sensors that exist on the robot.

This first lesson with the robot was how to move the robot in different directions. Next the teams were given lessons on how to use the sensors (line-following, ultrasonic distance, and IR proximity), that would be useful to detect objects and roadways that would be necessary for navigation.

The students had to use 3D modeling to design and print a RFID tag holder for the robot. This RFID tag was used to open a certain gate to allow the robot to pass. The opening of this security gate (Figure 2) was also programmed by the student teams, and it was to only open if the correct RFID tag was put in front of it.

The final Cornerstone Project had the teams complete a robot that would follow a road to their security gate. The robot had to drive its RFID tag to a scanner for the security gate. If the RFID was correct, the gate would open. Then the robot would use a sensor (the teams could choose to use whichever sensor they wanted) to determine if the gate was open or not, and if it was open the robot was to drive through the gate. If the RFID was incorrect, the robot had to determine the gate was not open and continue along the road until finding another security gate to test. The security gates were randomly placed on the course for testing, so there was variance on how many gates would need to be found and tested.

Figure 3: Final Course for Demonstrations

Survey

An end of semester survey was given to all students in the summer 2024 ENGR 111 course. The survey contained various questions over different aspects of the course trying to determine the students' interest in engineering based on different skills (3D modeling, programming, circuitry, etc.) and the Cornerstone project used in their ENGR 111.

The Likert-scale question added for the robot Cornerstone was "How much did the opportunity to work with a robot for this semester's cornerstone experience impact your interest in the ENGR 111 course?" The answers that the students could choose were: Not at All, Somewhat, Slightly, Very, and Extremely.

There was a qualitative question that followed the Likert-scale that asked: "What aspects about working with your ROBOT led you to selecting the level of course interest impact from the previous question?"

Results

Summer 2024 was the pilot summer implementation of the robot Cornerstone. The summer section consisted of 23 students. The Likert-scale answers are in Table 1. Additionally, Table 2 shows student responses by declared major.

Table 1: Likert-scale responses to "How much did the opportunity to work with a robot for this semester's cornerstone experience impact your interest in the ENGR 111 course?"

Category	Count	Percentage
Not at all	2	8.70%
Somewhat	5	21.74%
Slightly	7	30.43%
Very	6	26.09%
Extremely	3	13.04%

Table 2: Likert scale responses to "How much did the opportunity to work with a robot for this semester's cornerstone experience impact your interest in the ENGR 111 course?" by declared Major: Bachelors of Arts in Computer Science (BACS), Civil and Environmental Engineering (CEE), Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE), Mechanical Engineering (ME), and Undecided Engineering Major (U)

Category	BACS	CEE	CSE	ECE	ME	U
Not at all	1	0	0	0	1	0
Somewhat	0	1	0	1	3	0
Slightly	0	1	1	0	4	1
Very	0	2	2	0	2	0
Extremely	0	0	2	0	0	1

Table 3 lists a sampling of the students' answers to the open-response question regarding why they chose the Likert rating they did.

Table 3: Sample responses to "What aspects about working with your ROBOT led you to selecting the level of course interest impact from the previous question?"

Category	Sample Response 1	Sample Response 2
Not at all	It was inferior to any I have prior experience with.	Didn't feel like I engineering the robot or understood the details of how it worked
Somewhat	The robot was a fun project, but there were aspects of it that were frustrating, mostly because my own level of knowledge concerning the programming parts. Sometimes it felt like the parts were introducing a level of frustration that was outside of my control (such as line following not working consistently) but this may also be due to our program not being as good as it could be, so it's hard to say.	Debugging code was the most challenging part but overcoming and having the robot work in the end was a great feeling.
Slightly	The design and being able to immediately see my work.	There was a significant amount of programming I did not enjoy.
Very	The robot is very useful tool and the robot included all aspects of engineering and critical thinking along the way.	It's great to see real life examples of potential projects that I could be doing in the future and applying knowledge learned in school.
Extremely	The robot used my strengths and weakness, increasing my knowledge impacted my interest in engineering.	Coding teamwork and designs and critical thinking

Discussion and Future Considerations

As the results show in Table 1, overall, the students felt the robot project positively impacted their interest in engineering. Approximately 39% selected Very or Extremely from the Likert-scale. The results in Table 2 show most of the class was made up by ME majors and the ME responses were 60% in the Somewhat or Slightly category. CSE majors had higher rankings with 80% choosing the Very or Extremely category. The CEE were split 50% Somewhat or Slightly versus 50% with

the Very category. The BACS which is a non-engineering degree offered by the engineering school had the only student choose the Not at all category. Referring to Table 1 and the percentages, the majority chose a value in the Likert scale from the middle (Slightly) and higher (Very or Extremely). Coupled with the findings that different majors reported interest in the project, this shows promise for the Robot Cornerstone as project in a course for all engineering majors. Upon reviewing the open responses (samples in Table 3), the instructors concluded that the robot project is a valuable addition to the Cornerstone rotation, with some modifications.

The authors understand the small sample size is a limitation to performing meaningful statistical analysis. The summer iteration of this course is always a smaller cohort than the spring semester. New cornerstone projects are piloted during the smaller enrollment for purposes of easier adjustments to the course for one section of approximately 50 students, vs 450 students enrolled in six sections during the spring semesters. Future research will be conducted during the larger enrollment semesters. This was a new survey question added in the 2024 summer semester, which does not allow the authors to compare this new Robot Cornerstone to previously introduced cornerstones. This question will continue for future iterations of this course using previously established cornerstones as well as any new piloted cornerstones to allow for future comparisons.

The current robot platform, although beneficial for first-year students due to its simplicity, caused frustration because of unreliable components. The first recommendation for a future pilot of this course is to find a robot that is still approachable to first-year students built with better components. There are robots that fit this category, but the price is a hindrance for scalability to over 100 teams. The second modification that is recommended is improving the reliability of the RFID communication. The RFID communication was not consistent enough for first-year students of varying engineering backgrounds and majors. The instructional team is investigating the best way to move forward with the robot project while improving the high interest responses. This will necessitate another pilot summer with the updated components.

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