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Introducing Project-based Engineering Laboratory to Non-engineering Undergraduate Students

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Introducing Project-Based Engineering Laboratory to Non-Engineering Undergraduate Students

Abstract

Project-based engineering laboratories were introduced in a general elective (GE) course enrolled by non-engineering major students. These laboratories aimed to provide the students a hands-on experience opportunity with engineering tool and to encourage students to pursue careers in engineering fields. The lab activities consisted of four two-hour-and-fifty-minute sessions on sensors, actuators, microcontroller, and 3D printing. The first activity constituted of a set of experiments with various sensors and actuators. The second activity was based on an Arduino robotic car kit. Students assembled, programmed, and tested the car in two lab sessions. The third activity was conducted at the Sonoma State University Makerspace. Students worked with 3D printers, CNC Mill, laser cuter, heat press, and other equipment. Feedback surveys were conducted at the end of each lab activity. The survey responses for all four labs were highly positive. In addition, the survey indicated that these laboratories helped the students acquire a better understanding of engineering field, and to raise their interests in engineering programs. The developed laboratories, implementation methods, and assessment results, including student feedback and responses, are presented and discussed.

Introduction

Project-based engineering laboratories have been widely accepted as more effective tools in improving student engagement, learning experience, and understanding of the course materials [1-3] compared to laboratories with predefined experiments that do not motivate all students and often result in missed learning opportunity [4]. Open-ended design experience has also been shown to significantly improve student engagement, participation, and perception of competence [5]. However, design-based activities require more resources and planning compared to project-based activities, and, thus, may not be feasible for resource limited institutions. Nedic et al. presented project-based laboratories for first year students studying non-major courses [4]. These laboratories included power supply, racing car, and moisture probe and required limited prior technical knowledge to complete the projects. The project-based laboratories were reported to increase student satisfaction, reduce attrition rate, and improve student success rate [4]. Similarly, electrical engineering laboratory projects developed for non-majors were shown to induce student interest to apply the technical knowledge gained in the course to their engineering practice [6]. Krupczack et al. reported hands-on laboratory projects developed for non-science majors [7-9]. These projects were aimed to provide practical knowledge to the students, and to foster positive attitude toward learning about science and technology. The developed project used common materials and tools such that the students can take home the finished products.

Students with non-engineering majors at our institution take general elective (GE) engineering laboratory courses to fulfill their GE requirements. Students often take these courses either due to their interest in learning basic engineering concepts or experience engineering field and explore possibilities of pursuing an engineering degree. Some students simply take these courses because they fit in their schedule. Traditionally, these laboratory courses have been taught as simplified versions of electrical engineering circuit laboratories, which revolve around basic electrical engineering principles and fails to provide a broader engineering perspective. Thus, to provide the students with a better understanding of engineering discipline and an experience that is rich with skill development and fun activities, project-based laboratories that utilize cutting-edge technologies, including sensors, robotics, and 3D printing, were developed and implemented. These laboratories were designed to provide the knowledge of engineering practices, basic engineering skills, and hands-on experience with engineering tools. For small engineering programs, GE courses can be a great feeder. Thus, the presented laboratories were also aimed to encouraging students to consider pursuing a degree in science technology engineering and mathematics (STEM). The laboratories were implemented in the Fall 2017 semester. The developed laboratories, utilized implementation methods, and assessment results, including student feedback and responses, are presented and discussed.

Developed Laboratories

Activities for four two-hour-and-fifty-minute lab sessions were developed. The lab sessions included sensors and actuators, assembly and programming of an Arduino-based robotic car (CurieBot: Arduino 101 Mini Robot Rover [10]), and 3D printing and other activities at a makerspace. The lab activities and implementation methods are described below.

Day-1

Sensors and Actuators Lab: In this lab students experimented with various sensors and actuators and observed translation of physical changes into electrical signals, and vice versa.

Materials and Equipment: Breadboard, DC power supply, oscilloscope, function generator, light emitting diode (LED), resistor, potentiometer, photocell (light sensor), temperature sensor, tilt switch, piezo buzzer, servo motor, Arduino Uno microcontroller [11], computer, multimeter, and wires (some components are shown in Figure 1)

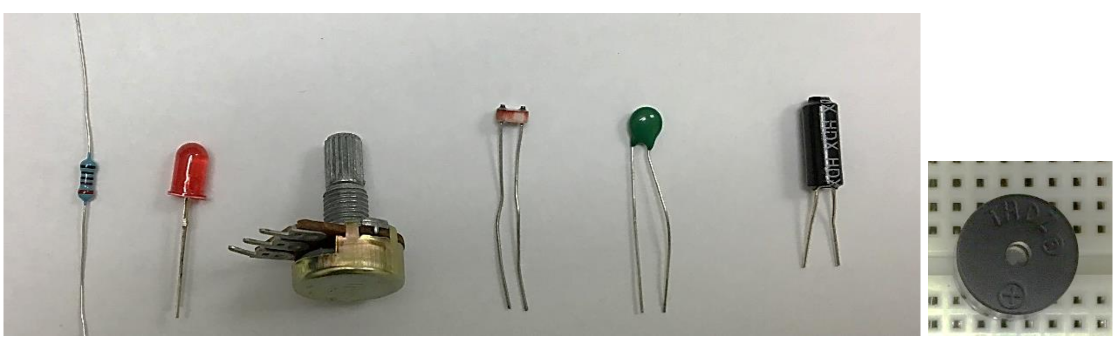


Figure 1: From left to right - Resistor, LED, Potentiometer, Photocell (Light Sensor), Temperature Sensor, Tilt Switch, and Piezo Buzzer

Implementation Method: Students were assigned to a group of two. Each group performed the experiments below, recorded their measurements, and described their observation. After each experiment, students demonstrated the results to the instructor and explained their observation. After all groups completed the experiments, students shared their experiences and observations.

Experiments: (i) Measure the resistance of the photocell, temperature sensor, and tilt switch with and without the presence of the quantity being sensed. (ii) Build a circuit on the bread with DC supply, resistor, potentiometer, LED, and a sensor. Change the quantity being sensed and observe the change in intensity of the LED. Repeat the experiments with other sensors. (iii) Build a circuit on a bread board with potentiometer and buzzer and with connection to a signal generator. Observe the signal on the oscilloscope. Generate an audible signal on the buzzer and change the volume using the potentiometer. With the potentiometer fixed, change the frequency of the signal until the sound becomes inaudible, both for lower and higher frequency. (iv) Connect the microcontroller (per-programmed), servo motor, and a potentiometer (as shown in Figure 2 [12]) and control position of the motor using the potentiometer.

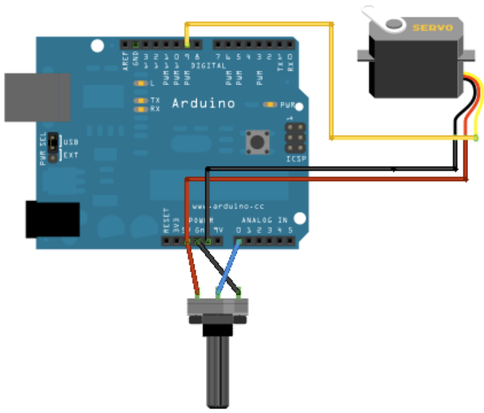


Figure 2: Schematic showing the connections between microcontroller, servo motor, and potentiometer [12].

Assessment: After completion of the lab, student completed an anonymous survey. Total of 22 students were present in the lab, however, only 13 students completed the online survey. The survey questions and results are shown below (Figure 3).

Overall, how would you rate this lab in the scale of 1 to 5? (5: Liked it a lot, 1: Not so much)

5		84.62 %
4		7.69 %
3		7.69 %
2		0 %
1		0 %

How would you rate the difficulty level of the lab in the scale of 1 to 5? (5: Very high, 1: Not so much)

5		0 %
4		0 %
3		23.08%
2		53.85 %
1		23.08 %

Would you recommend these experiments be used in similar future labs? (3: Absolutely, 2: Maybe, 1: No)

3		100 %
2		0 %
1		0 %

Figure 3: Survey results, Day-1 (Sensors and Actuators).

Day-2 and Day-3

Arduino-Based Robotic Car Project: This was conducted as a project over two laboratory periods. Students assembled a kit-based robotic car on Day-2 (Assembly) and programmed and tested it on Day-3 (Programming and Testing).

Materials and Equipment: CurieBot: Arduino 101 Mini Robot Rover kit, screw drivers, solder, mutlimeter, computer, smartphone. The CuiriBot kit includes Arduino 101 microcontroller board, two servo motors, motor shield, car chassis assembly parts, and other necessary components and wires. An app to connect to the microcontroller via Bluetooth is available to download from the App Store and Google Play.

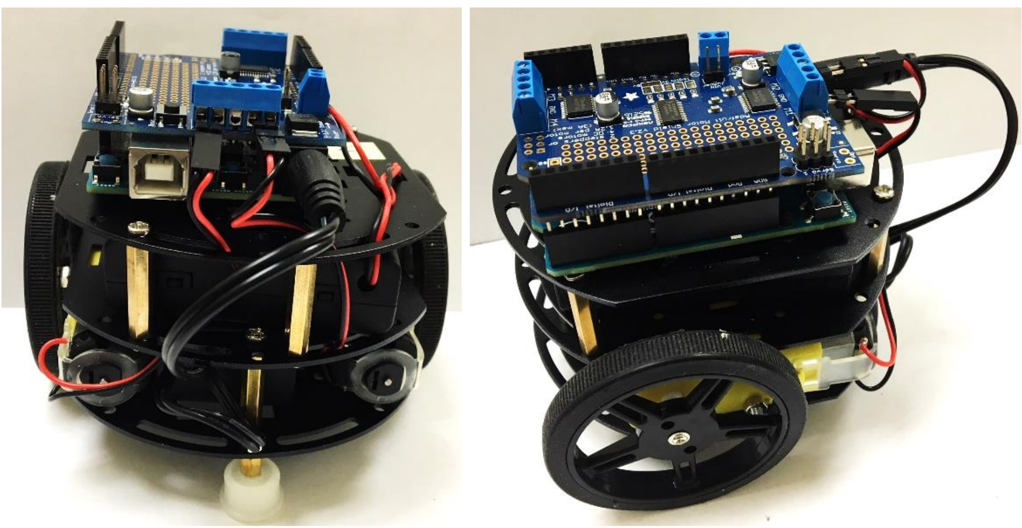


Figure 4: Images of assembled robotic cars [13].

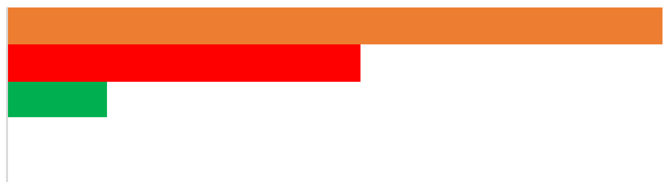
Implementation Method: Students were assigned to a group of four to five, and each group was provided with a CurieBot: Arduino 101 Mini Robot Rover [10] kit and necessary instructions. Working as a group, students assembled the robot, programmed and conducted motor tests using the code available from the vendor's website. After each experiment, students demonstrated the results to the instructor and explained their observation. Next, the students programmed the robot to control through their smart phone. After all groups completed the experiments, students shared their experiences and observations.

Project Tasks: (i) Assemble the robotic car following the provided instructions. (ii) Program Arduino 101 microcontroller using Arduino Integrated Development Environment (IDE) [14].

(iii) Test servo motors. (iv) Program the microcontroller for Bluetooth control. (v) Control the robotic car using a smart phone.

Assessment: After completion of the lab, student completed an anonymous survey. Total of 22 students were present in the lab, and all participated in the survey. The survey questions and results are shown below (Figure 5: Day-2, Assembly and Figure 6: Day-3, Programming and Testing).

Overall, how would you rate this lab in the scale of 1 to 5? (5: Liked it a lot, 1: Not so much)

5		59.09%
4		31.82%
3		9.09%
2		0 %
1		0 %

How would you rate the difficulty level of the lab in the scale of 1 to 5? (5: Very high, 1: Not so much)

5		23.81%
4		33.33%
3		28.57%
2		4.76%
1		9.53%

Would you recommend these experiments be used in similar future labs? (3: Absolutely, 2: Maybe, 1: No)

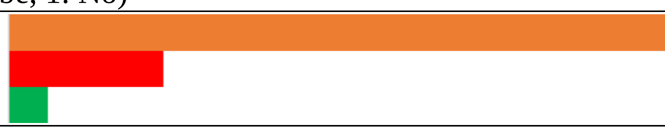
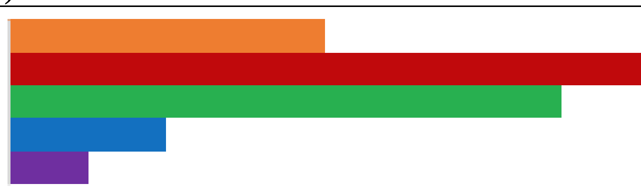
3		77.27%
2		18.18 %
1		4.55 %

Figure 5: Survey results, Day-2 (Robot Assembly).

Overall, how would you rate this lab in the scale of 1 to 5? (5: Liked it a lot, 1: Not so much)

5		72.73 %
4		13.64 %
3		13.64 %
2		0 %
1		0 %

How would you rate the difficulty level of the lab in the scale of 1 to 5? (5: Very high, 1: Not so much)

5		18.18%
4		36.36%
3		31.82%
2		9.09%
1		4.55%

Would you recommend these experiments be used in similar future labs? (3: Absolutely, 2: Maybe, 1: No)

3		86.36 %
2		13.64 %
1		0 %

Figure 6: Survey results, Day-3 (Robot Programming and Testing).

Day-4

Makerspace and 3D Printing: This lab was conducted as hands-on activities at makerspace facility. Students used software tools to design and create printed models.

Materials and Equipment: 3D Printer, Heat Press, Vinyl Cutter, and Laser Cutter.

Implementation Method: Students were assigned to a group of two. Each group worked with an equipment and created a model of their choice. Each group had a chance to work with two to three equipment of their choices. After each experiment, students demonstrated the results to the instructor and explained their observation. After all groups completed the experiments, students shared their experiences and observations.

Tasks: (i) Based on the equipment, use appropriate software tool and design or choose a model (ii) Create a model. (iii) Evaluate the produced model and repeat if necessary. (v) Move to a different equipment.

Assessment: After completion of the lab, student completed an anonymous survey. A total of 22 students participated in the lab activities and 21 surveys were collected. The survey questions and results are shown below (Figure 7).

Overall, how would you rate this lab in the scale of 1 to 5? (5: Liked it a lot, 1: Not so much)

5		80.95 %
4		9.05 %
3		0 %
2		0 %
1		0 %

How would you rate the difficulty level of the lab in the scale of 1 to 5? (5: Very high, 1: Not so much)

5		0%
4		33.33%
3		42.86%
2		14.29%
1		9.52%

Would you recommend these experiments be used in similar future labs? (3: Absolutely, 2: Maybe, 1: No)

3		90.48 %
2		4.76 %
1		4.76 %

Figure 7: Survey results, Day-3 (3D Printing and Makerspace).

Results and Discussions

Survey results presented in Figures 5, 6, and 7 show that the lab, project, and makerspace activities received highly positive feedback from the students. To assess if these activities affected the students attitude towards engineering, a separate survey was conducted. A set of surveys were given at the beginning of the first day of the project (Day-2), end of each of Day-2, Day-3, and Day-4. The results showed that the labs had positive effect in improving the students understanding of engineering field and career opportunities as well as in encouraging them to consider engineering as a major. For example, students were asked if they knew about the field of Engineering. The results analyzed between beginning of Day-2, indicated as Pre-Survey, and at the end of Day-4, indicated as Post-Survey, are shown in Figure 8. It was observed that the number of students who said they understood it very well went up from 9% to 24% and the number of students responding they understood very little went down from 45% to 29%. Their perception of engagement in solving engineering problems was also observed to improve. The number of students responding that they were very much engaged went up from 27% to 53% (Figure 9). We also analyzed the results by separating students based on their current standings. For example, on a question about how likely they would be to choose Engineering as a major if they were able to do so, in the Pre Survey 14% of sophomore standing students indicated they were very like to choose Engineering as a major. This improved to 29% in the Post Survey. The results are shown in Figure 10.

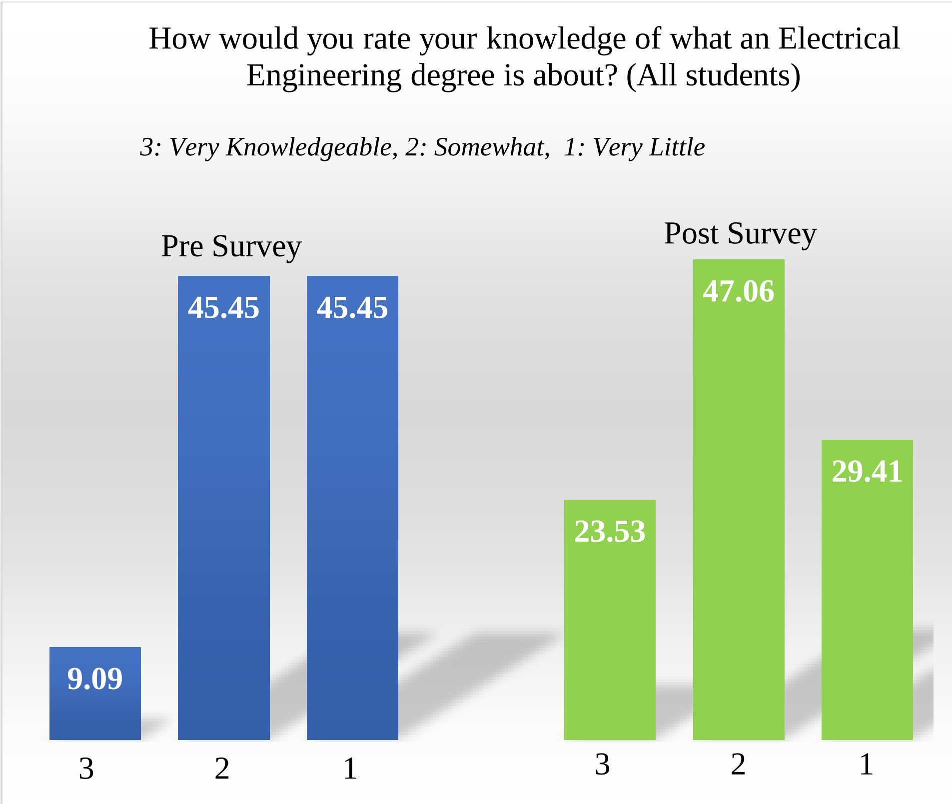


Figure 8: Pre and Post Survey results, all students.

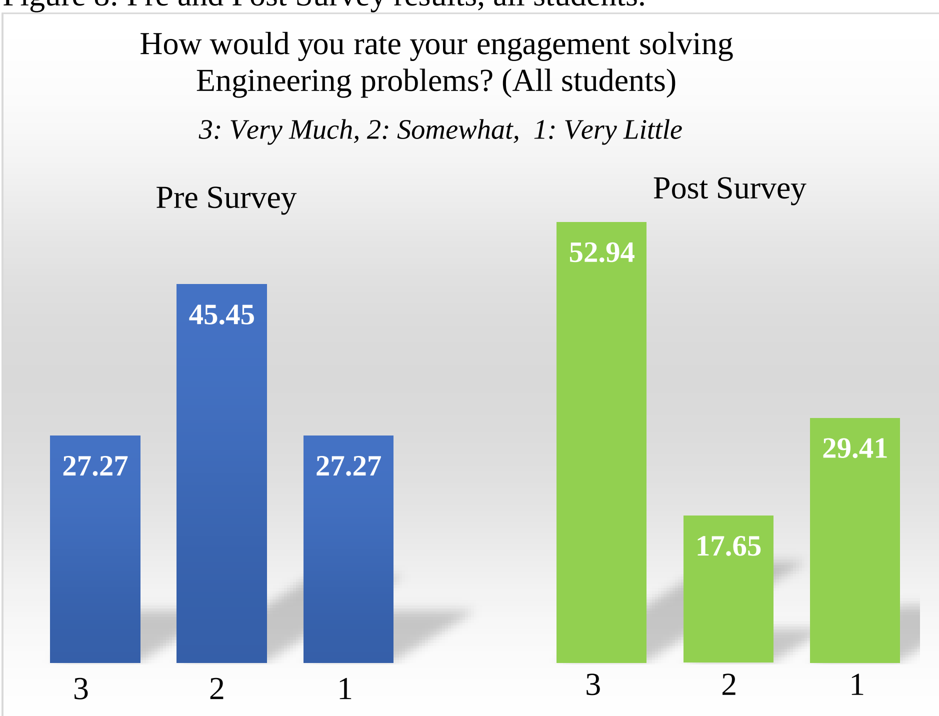


Figure 8: Pre and Post Survey results, all students.

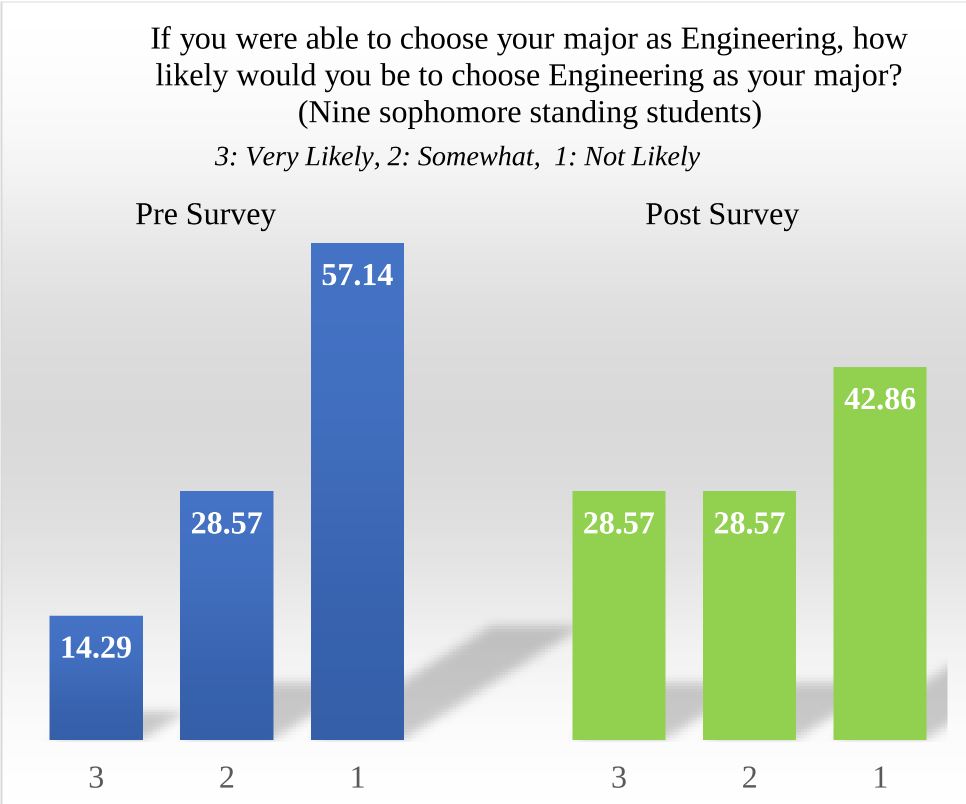


Figure 8: Pre and Post Survey results, nine sophomore standing students.

Conclusion

Project-based engineering laboratories developed around sensors, actuators, microcontroller, robotic car, and 3D printing were developed and implemented in an Engineering GE course. The goals of these laboratories were to provide the students with a better understanding of engineering field and to test if these laboratories could be utilized to encourage non-engineering major students to consider engineering as a major. The developed activities included one lab session experiments with sensors and actuators, two lab session project on robotic car where students assembled the car from a kit, and programmed and tested. The third activity was one lab session hands-on experiments with 3D printing and other equipment at the Sonoma State University (SSU) Makerspace.

Analysis of feedback survey shows that the student experiences were highly positive. In addition, the activities helped improve their understanding of engineering field as well as encouraged them to consider engineering as a career path. The survey conducted at the beginning of the first project day and the end of each project days showed that the labs improved student understanding of engineering field and career opportunities, and had a positive effect in encouraging them to consider engineering as a major. In particular when the students were asked if they knew about engineering, the respondents who said they understood it very well went up from 9% to 24% and those responding they understood very little went down from 45% to 29%. The perception of student engagement was also observed to improve. The number of respondents who indicated interest in pursuing engineering as a major increased in the post survey. However, the number of responses in this category was limited. In addition, no further study tracking the students after the conclusion of the semester whether they enrolled in engineering programs, was conducted. Future iteration of the study is recommended to conduct such surveys to assess effectiveness of the developed laboratories in that regard. While the activities were found to be effective and a significant improvement to the experiment-based laboratories, for many students changing major was not practical as they were well into their majors. Enrolling students in this course in their freshmen year would make the major switch more practical. In the presented study, only four lab sessions were used for project-based learning. Introduction of these and similar activities earlier in the course would further benefit the students.

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