7-26-2021

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Published Citation

Balaji, U. (2021, July), Service Learning Through Robotics Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://peer.asee.org/37710

2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33260

Service Learning Through Robotics

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Service Learning Through a Course on Robotics

Introduction

Getting young people especially from the under-represented and minority communities interested in science and technology has always been a challenge that educators have faced and responded through various measures. The need for STEM education initiatives particularly in low-income and underperforming school districts has been well documented. In 2018-2019, only 52.6% of Bridgeport public schools students met or exceeded the standards set by the State of Connecticut's Smarter Balanced Assessment [1] in Mathematics, which means that 47.4% of students are performing below grade level expectations. Middle school students participating in appropriate mentoring activities are more likely to be interested in STEM areas and have a greater chance of choosing an engineering or technology related discipline while pursuing higher education. Middle school curriculum-based classroom activities do not provide essential STEM related learning experiences and hands-on practice. Non-traditional settings such as through after school activities in community centers can provide the necessary impetus. Providing mentorship at such after-school centers by university students pursuing engineering courses can provide a useful resource that can build mutual confidence of both the university students and that of the middle schools children.

Robotics is an exciting way to introduce school students to different STEM fields, since the students will be exposed to engineering, sciences as well as computer programming. Increasingly, engineering schools embed mentoring opportunities for undergraduate students through robotics club activities [2,3]. Some schools provide service learning credit for courses in robotics [4] in their curriculum. When mentoring middle/high school children, it is essential to communicate the fundamental concepts in simple, easy to understand and for-fun ways. Studies indicate that a practice of journal writing about the mentoring activity [5] and using reflection leads to improved mentoring. This can improve among mentors the ability to communicate complex engineering topics to lay and non-technical audience. For engagement of youth in robotics commercial kits from LEGO Mindstorms or VEX Robotics are often used to deliver desired learning outcomes. Students in K-12 participate in competitions organized by them and participants are mentored to prepare for these competitions. In the current work, participants were not prepared for any competition and robotics was promoted as an activity in a community center setting. The purpose was to serve youth populations and motivate them to pursue a creative activity for learning and fun without focusing on a competition. Arduino, an easy to use, affordable open source platform was chosen to engage school and university students in the development of mobile robot. It has been shown to be successful as a learning activity among middle and high school students [6]. The focus was to provide service-learning opportunities for undergraduate engineering students using a hardware in the laboratory, utilizing open source platform and support STEM activities among school children in the community.

A service-learning course titled Robots at the Fairfield University's School of Engineering was offered in 2017-2018 with an objective of providing mentoring opportunity for enrolled students in preparing high school students for First Robotics competition [7]. A course with this title was offered in spring 2020 to provide community engaged mentoring opportunities for enrolled students at the after-school program of the local community center. This course incorporates knowledge and skills in STEM areas, enquiry and teamwork that are important qualities to motivate school children for STEM education in future. The course, in addition enables mentors to contribute to the identity formation among younger mentees.

Methods and Materials

The course ‘Robots’ was offered as an elective to students in mechanical and electrical engineering majors. It develops understanding of how robotic systems integrate sensors, actuators, and control systems to achieve specific goals. The course integrates STEM outreach through service learning at the community center. All students in the course had to participate in weekly mentoring of a child from middle school to put into practice the principles learned in class, and to develop communication skills required for the delivery of lesson plan.

The goal of the STEM initiative was 1) to give undergraduate students in the Robots course a service-learning opportunity by participating as mentors to middle school students; and 2) to introduce middle school students to the basics of robotics.

The specific course learning outcomes are i) understand how robotic systems integrate sensors, actuators, and control systems to achieve specific goals; ii) program Arduino microcontrollers and apply skills to develop an integrated robotic systems; iii) understand how different type of motors such as stepper motors, dc motors work and measure and control their speed to build a robot that can navigate; iv) understand specifications of commercially available parts and use them to create a system – “obstacle avoiding robot” and v) create a robot or a subsystem. In addition, the course envisaged that students develop lesson plans in order to engage in mentoring of middle school students based on the understanding of their educational background, write a weekly reflection report and make improvements on the delivery of lesson plan and help mentees build a finished product – an obstacle avoiding robot, from the commercially available parts.

Topics covered in the course included – Microcontrollers, Programing, Digital I/O, Encoders, Infrared sensor, Ultrasonic sensor, LIDAR, Gyroscope, Accelerometer, Magnetometer, Wireless interface to microcontroller, RC Servo Motor, Stepper Motors, DC motors with encoders, Drivers for motors, Relays and solenoids, PWM based control of motors, Feedback methods such as PID to control motors and design of a robotic system.

Student assessment in the course had the following components: homework/quizzes, development of a project and its presentation, service-learning activity, mid-term, and final examination. The Project assessment criteria are given in Table 1.

Students constructed an “obstacle avoiding robot” on Arduino platform using ultrasonic sensor, DC motors, motor driver board and a chassis. The robot was powered by batteries mounted on a small chassis with wheels driven by motors and other commercially available electronic parts. The Arduino accepted inputs from an ultrasonic sensor in order to stop the motors on finding an obstacle. The hands-on project enabled the undergraduate students to mentor school children as a service learning experience.

In order to engage in mentoring, students had to understand the educational background of mentees and develop lesson plans to cover the activities outlined in Table 3. The journal entries had a brief section on the plan for the next service-learning activity. A sample lesson plan by a student team for week 4 had the following: “i) review of material from the previous meeting; ii) demonstrate multimeter using a simple LED setup and allow students to measure voltages; iii) demonstrate and practice the running of DC motor connected to a battery; iv) help understand how the wheel stop using ultrasonic sensor demonstrated in the previous week; and v) start assembly of robot starting with wheels.”

Table 1: Project assessment criteria

Areas of assessment	Exceptional	Acceptable	Unacceptable
Project Details			
Title, Objective and Concept of project	Very clear	Requires more details	Not enough information
Electrical and Mechanical specs	Dimensions of product included, Electrical and mechanical Inputs and outputs specified	Partial details	Unclear
Parts and battery supplies required	All required parts identified meet specs	Missed a few parts	Not identified parts
Drawing of the product in Solidworks	Detailed diagram	Not specific	Unclear
Electrical wiring of motors/sensors to Arduino	Shows the connection of motors and sensors	Partially Done	Incorrect
Programming Arduino	Identified programs to sensor/motors	Not specific	None
Presentation			
Slides (Describes the project)	Very Clear	Acceptable clarity	Unclear
Oral Presentation	Clear and responses to questions were correct	Incorrect or missed answering questions	Unclear

Table 2: Template to chronicle weekly journal

Plan prior to Mentoring:
What were the learning objectives of your meeting today?
Record the activities (steps) towards meeting the objective:
Reflection on Mentoring:
What went well?
What did not go well?
Did you collect any response on his or her learning from the mentee?
Did you use any of the mentees response to adjust your teaching method?
Any corrective measure that you plan to include during future meeting:
What was your main accomplishments during this meeting?
What was your main concern during this meeting?
Plan for next service-learning meeting:

The delivery of the lessons to mentees was through weekly meetings of an hour and fifteen minutes each at the community center. A weekly journal (see template in Table 2 above) of activity and reflection was due after every meeting. Students used the previous reflection reports and instructor feedback to make improvements on the delivery of the subsequent lesson plans for mentees.

Table 3 covers the topics for the weekly meetings with middle school students. While mentoring, the objective was to keep the information as simple as possible without overwhelming the middle school students. The primary objective was to expose them to hands-on activity with basic parts and keep it fun.

The mentoring of the middle school students in the after-school program at local community center by the undergraduate students from the course helped build communication skills, to convey technical knowledge to K-12 students in the community center. The ability to communicate to a range of audience is a critical skill required for engineers. The service-learning opportunity such as this helps learn that skill and it also instills a sense of social responsibility.

Table 3: Schedule of Mentoring activity

Wakeman's Robotics – After-school Schedule of Activities	
Week 1	Orientation for enrolled students with the STEM teacher at the community center regarding engaging in activities with school children
Week 2	Program begins – Intro to Binary numbers, Introduction to programming with Arduino and blinking LED from Arduino
Week 3	Review of Binary Concept and intro to basics of ultrasonic sensor and how to measure distance to an obstacle
Week 4	Review of distance measurement, measuring voltage output from a battery, Concept of DC motor, Running a motor with battery
Week 5	Assembling Chassis of motor, and running the motor from Arduino board with motor driver shield
Week 6	Integrating motor and sensor with Arduino microcontroller (the brain of the robot) to form the obstacle avoiding robot
Week 7	Testing, adjusting parameters of the motor and sensor and complete successfully the Obstacle Avoiding Robot
Week 8	Trip to School of Engineering at the University to showcase the developed obstacle avoiding robot as well as familiarize with Commercial robot (Fanuc Robot) in the laboratory

The University students pursuing the course met twice a week for 75 minutes each. For the first seven weeks of the 15 weeks' course, they would spend time in class understanding the development of the mobile robot in the first session of the week and during the second session of the week, they would visit the community center and engage in mentoring the middle school students. The class schedule was set up to facilitate the required mentoring opportunity for all. There were 8 students majoring in Mechanical Engineering and 4 on Electrical Engineering. All the students did not have the same background knowledge of Arduino. Also, all students did not have previous mentoring experience. The design project for the course required the use of Solid Works; and while some were well versed with its use, others had only limited experience.

A pre-course survey was conducted at the beginning of the course to enable the faculty to adjust course delivery based on students' knowledge. Table 4 below summarizes students' own assessment of their understanding and prior knowledge in the materials relevant to the course topics.

Table 4: Students self-assessment of prior knowledge in course topics

Response categories (out of n = 12) → **Experience in Knowledge/Skill area ↓**	**None**	**Limited**	**Sufficient**
Programming	7	2	3
Solidworks	0	6	6
Arduino & similar	5	3	4
3-D Printing	7	3	2
Electric circuits, test and measurement	4	5	3
Motors	6	4	2
Sensors	5	5	2

From the pre-course survey, it was clear that students' knowledge and skills in programming, Arduino or similar tools, 3-D printing, electric circuits and use of equipment to measure and test, motors and sensors was at best only 33% (in Arduino and similar toolkits), 25% for programming and electric circuits and use of equipment to measure and test and 16.7% for 3-D printing, Motors and Sensors. The course content and the plan for the 'Robotics' course was accordingly adjusted to address the areas where majority of students responded as 'No or Not at all' and as being 'Limited or Somewhat knowledge and skills in the area'.

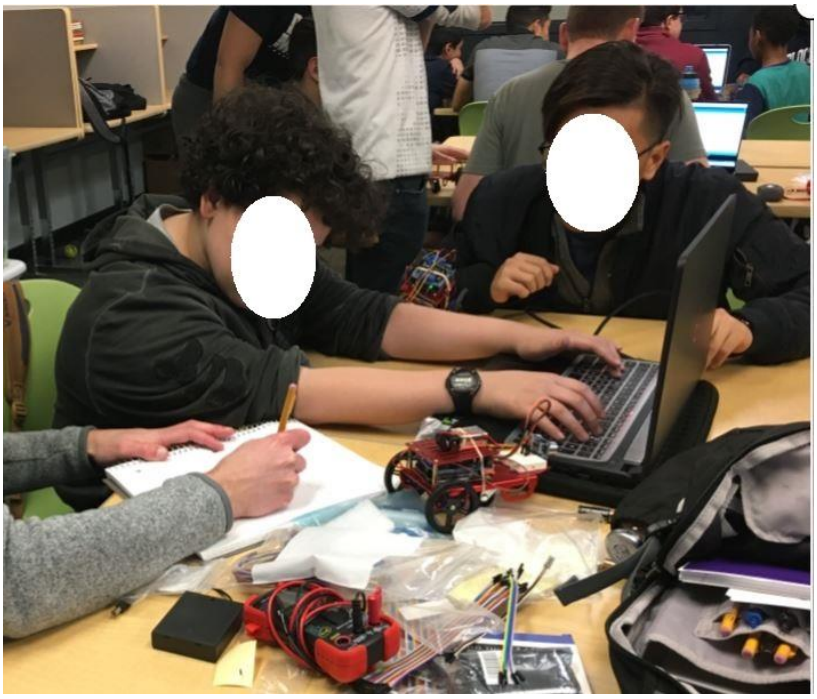

Fig. 1: Mentor-Mentee interaction on Robotics

Several learning materials and reading assignments were posted in the university learning management portal for students providing supplemental material to help engage in hands-on activities with Arduino in preparation of the mentoring. They were encouraged to do mock presentations to their peers to teach themselves on how to present information to young middle school children. They were also encouraged to watch videos on the web to learn making math and science topics fun for middles school children. All students were provided with the parts for the obstacle avoiding robot development at the first class meeting. Parts included Arduino, ultrasonic sensor, Motors, Motor drivers, chassis, wheels, and battery pack. Datasheet and manuals of all parts were posted in the portal for students to browse prior to class and be ready for hands-on learning during class meeting. Reading assignments based on the posted material were essential to get started on the hands-on work in the lab. A graduate student was engaged to support students with hands-on activity. A team of two students worked to develop one robot during these class meetings in the laboratory. This team then mentored two middle-school students each as a team at the community center. The students were given a set of questions to respond to for their journal homework (Table 3).

The exercise of getting the obstacle avoiding robot in seven weeks with middle school children was fast paced. The mentees were advised by their mentors to speak about the fun hands-on experience with their family. The team of two mentors for a team of two mentees ensured continuity if for some reason one of the mentor or mentee was absent at any time.

A post-course survey (Table 5) was conducted at the conclusion to assess the outcomes of the service learning course in building creative mindset among students and determine their interest or motivation for mentoring in future. The middle school children who were mentees or their parents were not assessed to understand the impact of the mentoring on them. Information on their experience was limited to those obtained in the journal entries chronicled by the student mentors. The COVID-19 outbreak limited the ability to conduct such an assessment.

Table 5: Mentors post-course perception survey

Increased ability to communicate engineering topics increase	Yes Maybe	10 1
Knowledge and Skills level (CAD, Microcontroller basics) to create an integrated system from commercially available parts – following the course	Very good Good Satisfactory Poor	6 3 1 1
Instill a sense of volunteerism to mentor	Yes Maybe	10 1
Able to explain topics relevant to the building of an obstacle avoiding robot	Successful Highly successful	4 7
Can develop lesson plans for engaging mentees based on their background	Successful Highly successful	5 6
Effectiveness of weekly reflection report in the delivery of lesson plan	Successful Highly successful	4 7
Mentees engagement	Yes Mostly	2 9
Mentees understand the basic concepts of building the obstacle avoiding robot	Yes Mostly Somewhat	4 6 1
Mentees able to construct the obstacle avoiding robot	Successful Highly successful	3 8
Likely to pursue robotics as at least a hobby	Yes Maybe	4 6

Discussion

The Journal entries by the engineering student mentors suggested that they were able to identify the need for prior preparation ahead of each session, address their initial anxiety on how to overcome boredom that may creep in among the mentees and the need to develop content and methods that will help learning to be more fun. As part of their strategies, they were able to identify suitable analogies (such as water through a pipe) to explain essentials of electricity – current, voltage and resistance and value of visualization. Mentors reported that after the initial exposure, they had to focus on simpler language, devoid of technical terms and jargon for explaining key concepts and principles underlying the building of Robot. Based on the mentee responses, they also had to adjust the pace of teaching-demonstrating-learning to make sure that the mentees can grasp – sometimes slowing down and at other times pacing faster.

The mentors also identified the following key reactions from mentees: although initially some mentees were slow to grasp and understand, once the mentors adjusted their language and pace, the mentees exhibited excitement, were motivated, and developed sparkling enthusiasm about mathematics. The mentees reported discussing the activity with their siblings and family members and demonstrated interest and enthusiasm of learning new and novel stuff.

Both mentors and mentees learnt through some 'mishaps' or 'accidents' when they damaged an LED lamp due to excessive current that was passed. Feedback from the university students through their journal entries gave an indication of the middle school students' ability to comprehend issues of programming. For example, a journal record indicated that the mentees were able to see how physical components interact with the Arduino board through the codes in IDE, to perform 'Blink' with LEDs. Also as mentioned in the journal by a team, the mentees with some coaching were comfortable in modifying the script in the Arduino IDE.

All the mentees teams successfully tested a working mobile robot on the seventh week. The final meeting that had been planned to give the mentees a tour of the engineering laboratory at the University to show-case and demonstrate the working of a commercial robot could not be undertaken by the mentors due to disruptions related to the ongoing COVID-19 pandemic.

The following eight weeks of instruction of the course to undergraduate students was completed using online modality. Prior to that students had practiced PWM control of DC motors, motor control circuits, and uses of stepper motor and servos in the laboratory. The remaining topics in the course were covered online synchronously. Short recorded videos of demonstrations as performed by the instructor were shared with students. Sample demonstrations include relays and solenoids to control motors using Arduino. Feedback control mechanism such as PID control was taught with simulations. Torque calculations problems was worked for specific load applications. Choice of commercially available DC motor based on their specifications was learned by solving problems for the torque requirements.

Students engaged in class project in teams of two. For example, for a project on building a robotic arm with limited degrees of freedom they completed the design plan and prepared the drawing for 3D printing. They identified the parts and designed the system. They also wrote an Arduino code to control the arm. While these were reviewed and assessed, practical construction by 3D printing of the robotic arm was not possible as there were restrictions in students' ability to access laboratories following their departure from the university campus due to ongoing pandemic.

Analysis of post-course survey by university students suggests that 91% of the students self-assessed themselves as having the requisite knowledge and skills in terms of CAD and microcontrollers to create an integrated robotic sub-system. Their gradation of the response for the same was satisfactory (9%) and good or very good (82%). Only one student (9%) self-assessed as being poor. All students also assessed that they were able to get the mentees create obstacle avoiding robots. This was verified by the instructor.

In the post-course assessment, 91% of the students responded that participation in the course has resulted in a greater sense of volunteerism to mentor school children through this exercise. All students in the post-course assessment reported that they were successful in developing lesson plans for engaging in mentoring school children and that they were able to engage with their mentees on basic concepts and were able to explain topics relevant to the working and construction of obstacle avoiding robots. Further, 9 out of 12 (75%) had rated their learning interest as a hobbyist through use of professional websites, YouTube videos and articles in magazines and journals as little (50%) or only moderate (25%). Participation in the course had not only kindled their interest in learning further, as many as 10 (91%) felt that either they may or most likely would pursue building robots as a serious hobby. Further they reported effectiveness in the weekly reflection reports in their delivery of lesson plans promoting improvement of their mentoring activity.

Ability to communicate on engineering topics to various audiences is a key outcome of undergraduate engineering education programs. Since the course had a major component on mentoring and communicating the work with younger audiences, almost all (91%) of the students who participated in the course confirmed that the course has made them confident in this key competency area when only 7 out of 12 (58.3%) were only somewhat comfortable in the pre-course survey.

Conclusion

Twelve middle school students were exposed to robotics educational activities through 12 undergraduate students pursuing engineering majors. The goal to stimulate an interest in STEM fields particularly in low-income and underperforming school districts through a service-learning component in Robots course was successfully executed. All student teams prepared a functional obstacle avoiding robot within seven weeks of meeting. Arduino based robotics activities were found suitable by the successful mentoring of middle-school children in the after-school program. Self-assessment by the undergraduate students in the class indicated that they are more confident about their ability to communicate engineering topics to various audiences. The course also instilled a greater sense of volunteerism. Due to the ongoing pandemic eight weeks of instruction was conducted online through synchronous class meetings and asynchronous video recordings made available by the instructor. Students worked on design projects such as the robotic arm, automatic mobile camera and mobile robots. They were successful in preparing design plan, drawings and programming Arduino and presented it to the instructor and rest of the class online. A future run of the course is expected to study in-depth, the learning outcomes of the course.

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