WIP: Engineering, Art, and Education - Designing Practical Robots in an Engineering Course

Eric Bredder
University of Virginia
Charlottesville, USA
eb8ga@virginia.edu

Kim Wilkens
University of Virginia
Charlottesville, USA
ksw8y@virginia.edu

Cody Gonzalez
University of Texas San Antonio
San Antonio,USA
cody.gonzalez@utsa.edu

Justin Boyd
University of Texas San Antonio
San Antonio,USA
justin.boyd@utsa.edu

Camilo Vieira
Universidad del Norte
Barranquilla, Colombia
cvieira@uninorte.edu.co

***Abstract*—In this innovative practice works-in-progress paper we designed an undergraduate/graduate engineering course that fosters learning experiences for students to develop and customize robotics for art and educational contexts. Engineering projects that offer real-world solutions provide students with a sense that they are engaging in something meaningful and see their time in school as a benefit to society. Engineering students in a robotics fundamentals course were paired with a senior art or engineering student mentor with prior experience to help develop a robotics platform for social good. Students were given basic robotics kits to create unique solutions that meet the needs of potential students in art or computer science education. We seek to capture this multidisciplinary approach that provides students with an experiential learning opportunity in engineering to design robotic systems. We report findings from the course and the students' projects. Seven groups created robots for art and three created robots for computer science education.**

Keywords—engineering, robotics, education, art, design, project-based learning

I. Introduction

In this innovative practice, works-in-progress paper, we report on the redesign of an undergraduate/graduate engineering course that fosters learning experiences for students to develop and customize robotics for art and educational contexts. Engineering projects that offer real-world solutions provide students with a sense that they are engaging in something meaningful and see their time in school as a benefit to society [1, 2, 3]. Arts students joined the engineering students in the course to create collaborative and multidisciplinary experiences. We seek to capture this multidisciplinary and experiential approach for students to design robotic systems that have impact outside of their classroom. Student groups participated in the design process and used robotics to solve artistic and educational problems (i.e. art galleries, K-12 classrooms). Instructors in this course collaborated across disciplines, including one engineering faculty, one art faculty, and two instructors from education.

Students in the course were introduced not only to technical concepts to help them understand how robotics work, but were introduced to frameworks for design. Initially students were given the Educational Robotics Applications framework (ERA) [4] to help them identify ways that they can design a robot for educational experiences and offer a lens to design towards a specific audience. The ERA framework was used to help design the educational robot in this course, Roversa. Students were given areas of the framework to focus their design on and think about how they can use the principles to guide their design decisions. Later in the course students were provided another framework for developing technology called Substitution, Augmentation, Modification, and Redefinition (SAMR) [5] to help them adjust their designs for their intended audience. Students were building robots that served unique purposes and this particular framework helped them see how they were using the technology and how it could impact their users. While the SAMR framework is mostly used in educational contexts for selecting technology and its impact [6], instructors felt that it applied well to this undergraduate course and allowed students to have a tangible model for seeing how their innovations would impact users.

II. Course Structure

The original course was designed as an introduction to robotics for engineering students and emphasized learning through extensive numerical simulations and animations. MATLAB was used to demonstrate how to program physics, develop controllers, and animate the system. Student projects were predetermined including creating a pong game, maze navigation and pick and place robot.

In the course redesign, students were introduced to a variety of robotics concepts through traditional lectures, six guest speakers and hands-on activities. Lecture in Robotics and Fundamentals of Robotics was taught jointly with both undergraduate and graduate students. For guest lectures and for project sessions, the Arts students joined for interdisciplinary collaboration through the Arts in Robotics project. Hands-on projects included an introduction to programming robotics using LEGO® block code and a LEGO® Education SPIKE™. Students used the LEGO® block code and Python to program the LEGO® SPIKE™. Student learning was assessed through problem sets and programming homework that used Matlab, an introductory LEGO® lab that focused on basics such as differential drive car movement and displaying numbers on an LCD screen; a take-home midterm examination on forward and inverse manipulator and differential drive car kinematics; an interim report on their arts or education in robotics project, a final presentation, a final project report in the form of a conference paper, and finally a tech symposium to share projects with the wider community.

The Arts in Robotics project and associated robot design elements were a major focus of the redesigned course, accounting for almost half of the final grade. These projects were done in groups that included four mechanical engineering undergraduate students working with peer mentors, one mechanical engineering graduate student and one arts student. Instructors applied for a grant that provided supplemental funds, up to $100, for each of the teams.

During the fifth week of the course, ten groups of students were presented with two Arts in Robotics challenges:

Challenge 1: Seven groups worked on creating a robot that interacts and engages in a new way, one of the five senses.

Challenge 2: Three groups worked on creating an educational robot that engages elementary students in robotics and art.

A. Engaging the Senses Challenge

Students were asked to create a robot that interacts and engages, in a new or novel way, one of the five human senses. The first step was to research if there were any current models or systems that engage touch, taste, smell, sight, or sound in creative and interesting ways and to design a robotics project that engages the senses in an interactive way for a particular audience. These groups were given a LEGO® Education SPIKE™ as their base robot.

B. Educational Robot Challenge

These groups were challenged to create a project for an educational robot that engages elementary students in robotics and art. First they investigated the principles of ERA framework [4] for understanding what it takes to develop an educational robot and associated activities. Groups selected at least one principle from each of the overarching themes from the framework to address in their robot design:

- Technology: Intelligence, Interaction, Embodiment
- Student: Engagement, Sustainable Learning, Personalisation
- Teacher: Pedagogy, Curriculum and Assessment, Equity, Practical

Groups in this challenge were encouraged to research existing educational robots and how robots could engage elementary students in art. This research was used to determine what challenges students and/or educators face when trying to incorporate robotics into the classroom.

The educational robot used in this challenge was a low-cost, multilingual robot, Roversa. This robot was designed by a group of researchers who sought to develop a low-cost solution that also had a low-floor, high-ceiling approach to learning integrated computer science in elementary schools. The robot is currently undergoing beta testing. Roversa can be programmed manually using directional arrows and can move on a mat or grid based on the directions programmed by a student. Roversa has the ability to be calibrated and reprogrammed using block-based and text-based languages. The Roversa utilizes a popular microcontroller, the micro:bit, and can leverage all of those educational materials. The robot itself is open source, and can be locally manufactured using a laser cutter and cheap electronic components. Students in the course were given a kit of materials and design files to assemble the robot.

During the course students were provided feedback from experts in education and robot design. During the design cycle students were able to make adjustments and ask questions as they were developing their robot.

III. Methods

The participants (N=60) in this study were students in graduate mechanical engineering (n=11), graduate arts (n=1), undergraduate engineering (n=40), and undergraduate arts (n=8). Overall data sources included self-evaluations on the engineering project and its impact on student learning, the overall project submissions, short one minute pitch videos on their robot, and a short video summary of their robot and design decisions. Final projects were analyzed to look at how students decided to solve art and education-based problems and see how they presented their solutions to the class and intended audience.

A. Preliminary Results

This works-in-progress draft is focused on the three groups of students who chose to work on the educational robot, Challenge 2. Eventually all the data will be analyzed to help provide an understanding of the students' progression of learning and their engagement during this learning experience.

B. Educational Robot Challenge

Group 1: This group's idea initially focused on technology interaction, student sustainable learning, and student engagement within the ERA framework by creating a relay-race style competition between multiple classes that would be based on questions from the school curriculum. The educational instructors provided feedback towards the initial proposal for this robot, reflecting that the group did not focus its primary usage on engaging K-12 students in robotics or computer science, rather using a robot to replace traditional educational assessments.

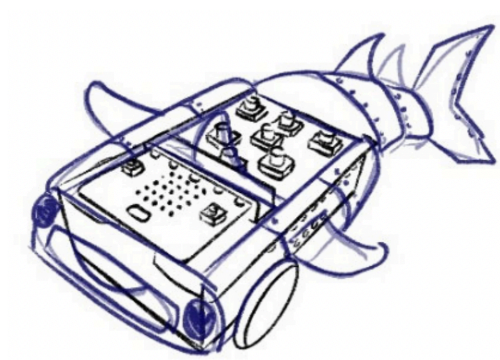

Fig. 1

Group 1 proposal design of the shark costume

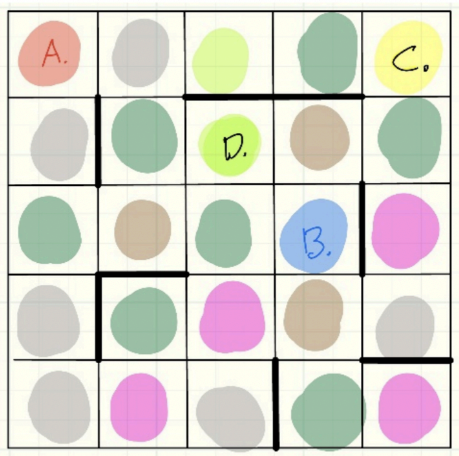

Fig. 2

Group 1 proposal floor mat design for the robot activity

Throughout the course their designs evolved as they created a robot maze game with a customizable maze and robot costume. This group continued to focus on the areas of the ERA framework from their proposal (interaction, sustainable learning, and engagement). They created a 3D-printed shark costume that was painted with whiteboard paint. Students could then draw on the robot using whiteboard markers. They also created a custom mat with colors, each color representing an answer to a question provided by a teacher. This enables K-12 students to program the robot manually in order to send the robot to the color that matches their answer. This is similar to a multiple choice response, but students are interacting with robotics to help them think about solving questions in any content area.

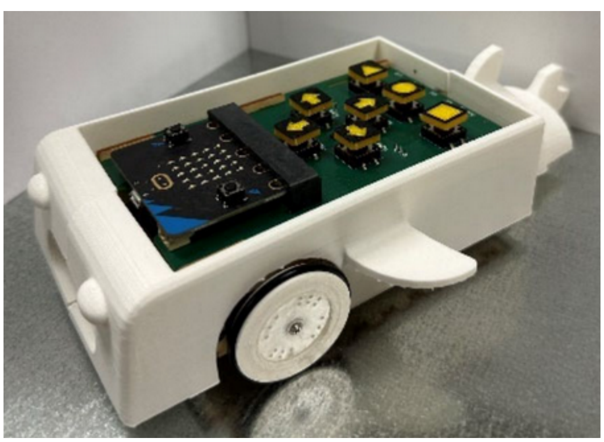

Fig. 3

Group 1 final robot, 3D printed shark costume

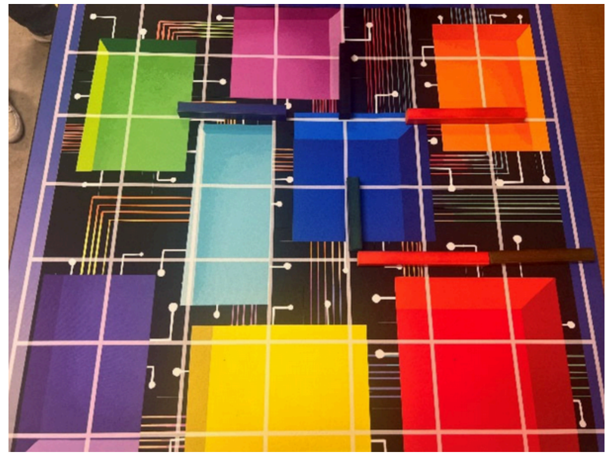

Fig 4.

Group 1 final mat designs with colored areas for students

Group 2: This group proposed a robotics kit that could improve the attention span of students by replacing scantrons with interactive racing robots. They sought to design customizable costumes for students to help with engagement. Initially their ideas focused on personalisation, pedagogy, and interaction within the ERA framework. The educational instructors provided guidance about the group's proposal (i.e. not engaging K-12 students in robotics or computer science).

In their final project, this group wanted to look at engagement and flexibility in both the students and the teachers, so they decided to have two variations of their code. In one version, they re-coded the arrow buttons of Roversa to A, B, C, and D so K-12 students could answer multiple-choice test questions given by the teacher. In the second variation, K-12 students use a computer to answer questions based on a simple MicroPython script created by the teacher. This allows both the students and teachers an opportunity to interface with the code.

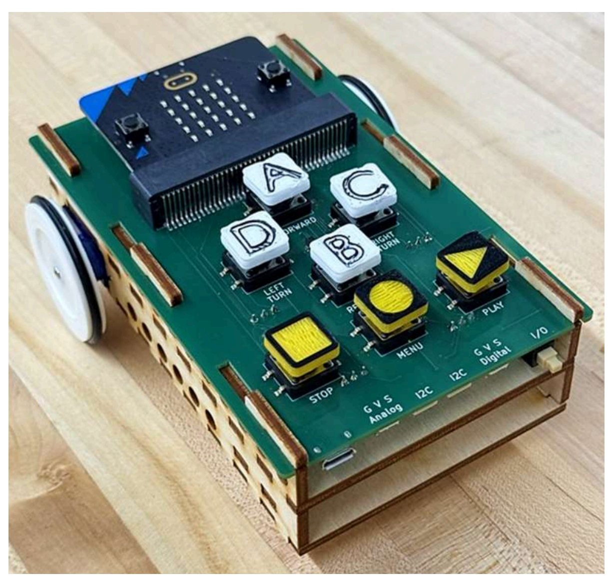

Fig 5.

Group 2 buttons for choosing answers using the robot, ABCD

Fig 6.

Group 2 various costume designs on Roversa robot

Group 3: This group initially focused on the ERA concepts of intelligence, engagement, and pedagogy to develop a robotic vehicle designed to execute simple geometric drawings using a color sensor. During the proposal, the educational instructors provided feedback on the uniqueness of this group's idea: embedding robotics in their learning objectives with colors and shapes, using sensors and a mechanical interface.

This group experienced a variety of small "setbacks" related to their original design. Through resilient iteration, they designed a robot that was able to draw basic 2D geometric shapes. The robot could also draw geometric nets to help K-12 students cut out shapes to form their own 3D shapes. The robot even identified vertices through a loud beep as the robot drew the nets. They also created a lesson plan for integrating robotics into art.

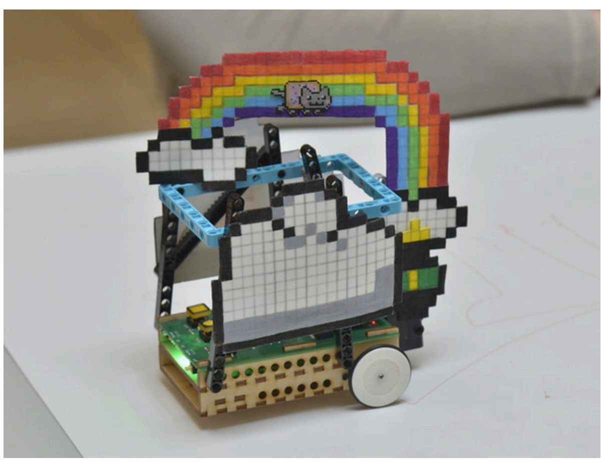

Fig. 7

Group 3 final costume and adapted LEGO chassis

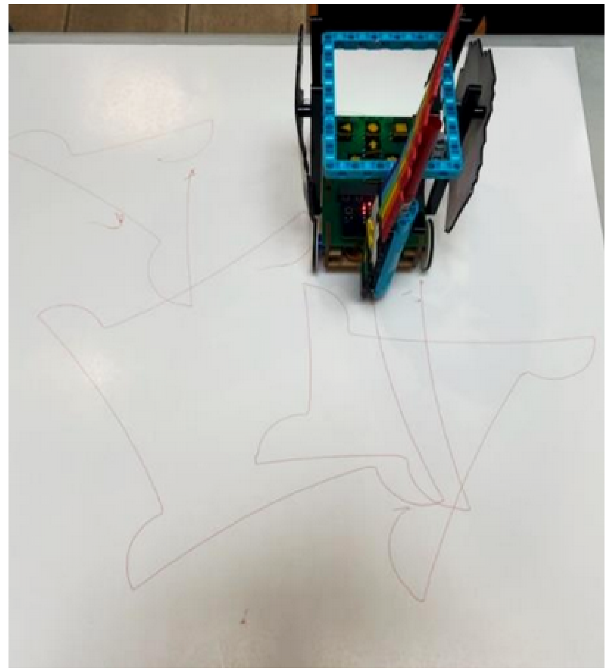

Fig. 8

Group 3 using Roversa to draw geometric shapes on a flat surface

C. *Student Engagement*

At the time of submitting this works-in-progress paper, the course had just concluded, so we did not have time to analyze student self-evaluations. We did see some evidence of engagement in the final papers. For instance, Group 1 acknowledged the opportunity to display their work at the tech symposium. Group 2 wrote that the project was a great learning experience and taught them how to work well with limited resources. Group 3 noted that they were eager to help with improvements to the platform as a way to "make Roversa robot a great tool for education".

Within the written evaluations and through verbal discussion with students, there were many requests and suggestions for additional laboratory portions for the course that focuses on robotics. While students found the Arts in Robotics project interesting and engaging, many wanted more hands-on robotics work leading up to the project.

IV. Significance and Future Work

This works-in-progress paper outlines an interdisciplinary approach to teaching robotics by providing undergraduate engineering and art students with an experience of working across disciplines and building robotics for a specific audience and purpose. Future work will include updates to the course and the Roversa robotics platform based student feedback and experiences from this version of the course. In particular, for the Roversa robotics platform, we will use this experience as a case study for employing educational robotics platforms in undergraduate engineering coursework.

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