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Understanding Impacts of Soft Robotics Project on Female Students' Perceptions of Engineering (Work in Progress)

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Abstract

Gender disparities persist across traditional engineering disciplines such as mechanical engineering and electrical engineering in colleges. Participation in K12 educational robotics is a common precursor to enrollment in traditional engineering majors, however the gender gap in K12 competitive robotics perpetuates this gender disparity. We hypothesize that soft robotics, consisting of robots made from complaint materials that safely interface with the body, is a field that may appeal to female students' enthusiasm for bioengineering and healthcare applications of engineering. While much of soft robotics work exists in research laboratories, there are efforts to develop soft robotics curricula for K12 students. Our previous work has focused on middle and high school curricula. When we had the opportunity to bring our soft robotics curriculum to even younger students, we had the chance to think critically about project design and ease of implementation as well as preconceptions children hold of robots and roboticists at this age. Perceptions of who can participate in engineering are formed as early as elementary school for some students. In this work, we present three one-hour soft robotics lessons that were piloted with a first-grade girl scout troop in order to earn their Daisy Girl Scout robotics badges. The lessons include instruction on robotics and programming as well as hands on activities for students to design and build their own soft gripper. This paper details the soft robotics curriculum adapted for 6-8 year old children. These materials will allow other girl scout troop leaders to instruct similar lessons to earn these badges. We also present initial survey responses from the girl scout participants. Surveys captured the students' drawings and perceptions of robotics and who builds robots. Survey responses will inform the use of soft robotics in grades as early as elementary school. We aim to evaluate an alternative robotics curriculum that is specifically designed to create inclusive robotics spaces for girls with the goal of reducing the gender disparity in STEM and traditional engineering majors.

Introduction

Despite outreach efforts by schools and robotics organizations, girls do not participate in pre-college robotics at the same rate as boys [1]. Sullivan et al. reported low confidence in technical activities related to robotics as a reason for the participation disparity [2]. An analysis of pre-college extracurricular activities and their mapping to engineering majors showed the disciplines with high percentages of male students, such as mechanical engineering and electrical engineering, had more students tinkering with electrical and mechanical components outside of school prior to starting college [3]. When girls are not part of extracurricular robotics programs, they miss vital opportunities to develop tinkering self-efficacy. Attracting more girls to participate in pre-college robotics may open a pathway for these students to enter majors and fields with lower female representation [4].

Girls are shown to develop perceptions of engineering and opportunities in related careers very early in their education [5]. The Girl Scouts of America (GSA) is an organization that has prioritized inclusion of STEM in their badge curricula [6]. GSA partners with Google for a program called "Made with Code" which encourages girls to get a head start on computer science. Along with partnering with Google, the Girl Scouts have also introduced various STEM badges for the Scouts to earn. Some of these badges include "What Robots Do", "How Robots

Move", and "Design a Robot." These efforts are intended to promote gender diversity in STEM fields by introducing girls as young as five years old to STEM focused careers and industries. In this paper we will describe adaptation of soft robotics outreach activities for utility in completing the Daisy Girl Scouts Robotics badge series. We will rationalize why soft robotics may be an ideal platform for engaging young girls in STEM. Lastly, we will discuss initial development of a drawing task to understand children's perceptions of robots and roboticists.

Soft Robotics Context

Soft robotics is an emerging subfield of robotics inherently linked to human-centered design and healthcare applications. Soft robots interface with humans by replacing hard components with mechanically programmed polymers and flexible electronics. The field of soft robotics emerged as a result of robotic devices being deployed as bioinspired machines [7], grippers of delicate objects in manufacturing [8] or the ocean [9], as exoskeletons [10], or implantable devices [11]. Soft robotics represents a new field, combining traditional principles with soft materials for human-centered applications.

The simple fabrication techniques of some soft robotic devices have led to the development of activities geared toward inspiring young students to experiment in this field [12]. Holland et al. developed the Soft Robotics Toolkit, an online repository of soft robotics projects [13]. After an SRT design competition drew innovative entries from high school students, Holland and colleagues saw an opportunity to engage K12 students [14]. Additional efforts to engage K12 students in soft robotics have followed including accessible methods to test mechanics of silicone materials [15], development of gelatin-based candy actuators [16], and a soluble insert actuator [17].

While there are countless kit-based robotics projects for use in K12 schools, they typically consist of traditional line-following or object-placing robots [18],[19]. These systems are effective at attracting students who are inherently interested in robot function and do not alter the gender disparity [1]. There is a gap in available educational robotics products using human-centered applications. Soft robotics is a field, anchored in traditional mechanical principles, that utilizes soft materials to execute tasks to enhance the human experience. With the recent development of K12 soft robotics projects and curricula, we hypothesize that this field may provide a foundation to close the gender gap in engineering majors.

To support local girl scouts in outreach and to test our hypothesis, we developed a curriculum to facilitate a troop of 1st grade Daisy Girl Scouts in earning three robotics badges. The activities outlined in this paper were adapted from previously executed middle and high school programs. Given the age of the participants and the total contact time (3 hours), the activities were adapted for ease of facilitation, age appropriateness, and to align with the badge outcomes. Table 1 details the recommended tasks for each GSA Daisy robotics badge. In the right column, the soft robotics activities we developed for this event are mapped to the badge outcomes. In this implementation, the scouts visited a university laboratory, on three days for one hour each day during normal scout meeting times. Girls were accompanied by scout leaders and parents. Undergraduate, graduate, and faculty volunteers from served as mentors and the mentor-to-scout ratio was 1:2.

Table 1. Soft Robotics activities to complete the robotics badge.

Robotics Badge 1: What robots do	
Learn about robots	Learn what soft robots are and what they do, discuss videos showing soft robots in exosuits and manufacturing applications
Find out what robots can do	
Team up and build your own robot	Teams of two will build silicone cable actuated grippers (See Soft Robot Activity below)
Robotics Badge 2: How robots move	
Learn the parts of a robot	Learn terminology: actuator, silicone, motors, code
Find out how robots move	Experiment with manual operation of soft grippers and observe motor-controlled bending
Make a robot move	
Robotics Badge 3: Design a robot	
Plan your robot	After testing soft grippers in picking a number of items, work with engineer volunteer to develop new ideas and designs for improved grippers
Create a prototype	Build soft gripper. After testing, use supplies provided to prototype improved designs
Get feedback on your robot	Present designs to the group, get feedback from engineer volunteers and peers

Soft Robotics Activity

Daisy Girl Scout participants built cable-actuated silicone SDM fingers inspired by the activity previously published and available on the Soft Robotics Toolkit website [20]. Based on previous outreach events, the instructions and molds for this activity have been modified for ease of facilitation and to increase the success rate of molded actuators. New designs are presented in Figure 1.

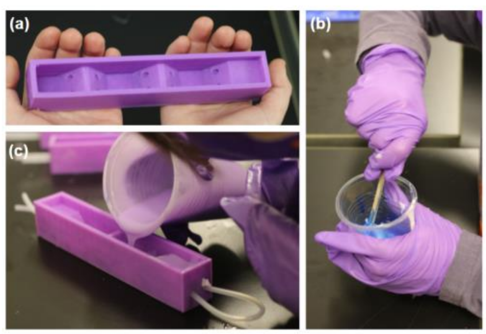

Figure 1. (a) 3D printed molds, (b) child mixing silicone, and (c) child pouring silicone into their mold.

Figure 1 shows the 3D printed molds used in the activity as well as a child mixing Ecoflex 30 silicone (Smooth-On Inc.) to pour into molds. For this outreach event, molds were sprayed with mold release and silicone parts A and B were pre-measured into plastic cups. The scouts combined parts A and B, mixed for 5 minutes, and poured the uncured material into the mold. Molds were half filled with silicone by the scouts. Ecoflex 30 takes approximately 4 hours to cure. The following day after the silicone was cured, our team completed the molding process by filling the molds with Mold Star silicone (Smooth-On, Inc), a stiffer material that provides a structural backbone to the actuator. An additional feature, new to this activity, is the addition of looped tubing, as seen in Figure 1c. This tubing molds holes through the actuator for string or cables. The loop makes the tubing easy to remove after molding.

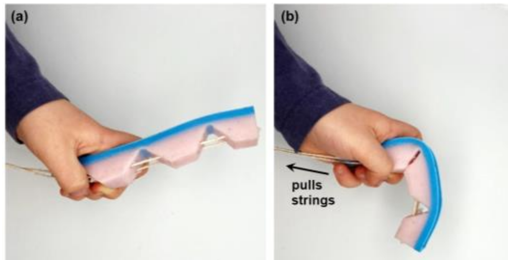

Figure 2. Child participant demonstrating curling of the cable-based silicone actuator.

Once the tubing was removed, strings were added, and the scouts experimented with their actuators. Two actuators were combined as shown in the reference above [20] to create a gripper. Our team proposed to the scouts that this gripper could be used to help someone at home without mobility for grasping. Scouts experimented with gripping common household items. Scouts made a list of which items could be picked up and which could not. An observation made by the research team is that if an item could not be picked up, it was not likely to be added to the list. Instead scouts would search for items they could successfully pick up. It appears participants valued successful gripping and would search for items they could successfully add to the board. In the next meeting scouts sketched out and prototyped some simple changes to the actuators such as adding fingernails, shortening the gripper, or adding a textured surface that would allow them to pick items from the "can not pick" list.

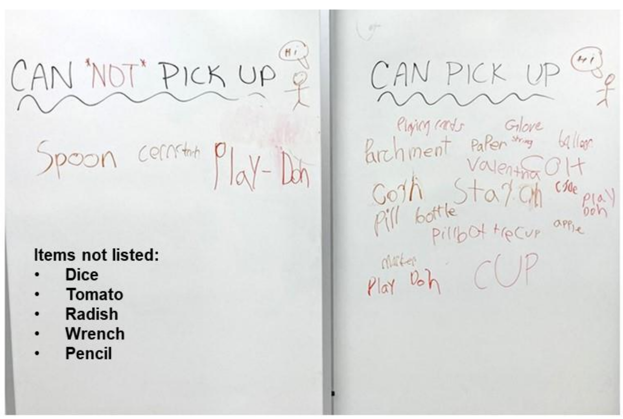

Figure 3. Results of the picking activity. Participants were asked to write down which items their gripper could pick and which it could not. Research team annotated the image with items that were not picked and not reported in the bottom left.

Evaluation

As 'soft robotics' is a new concept to these scouts, the research team was interested to understand the children's preconceptions of robotics and who builds and participates in robotics. The Draw an Engineer Test (DAET) [21] is a method used to understand how students see themselves as engineers before they are able to articulate their thoughts in writing. As part of this study, we adapted the DAET to understand specifically participants perceptions of who builds robots and preconceived ideas of what robots look like and do. We anticipate that ideas of soft robots will not be represented in children's initial drawings. We call the survey the "Draw A Robot Task" (DART). On the survey we give two prompts: (1) "Draw a picture of a robot." And (2) "Draw a picture of a person building a robot."

To supplement the drawings, we asked (1) “What is the robot doing?” and (2) Tell us about the person building the robot”. Volunteers asked the children these questions and helped write the answers out on their paper for better understanding. Children were provided with printed surveys, colored pencils, and washable markers. Markers and pencils included a wide variety of colors as well as the Crayola “Colors of the World” sets. This set includes a wide range of skin tones. Figure 4 shows example responses to the presurvey that was administered when the scouts first entered the lab. At the time of presurvey data collection, students had not discussed soft robotics with the participants.

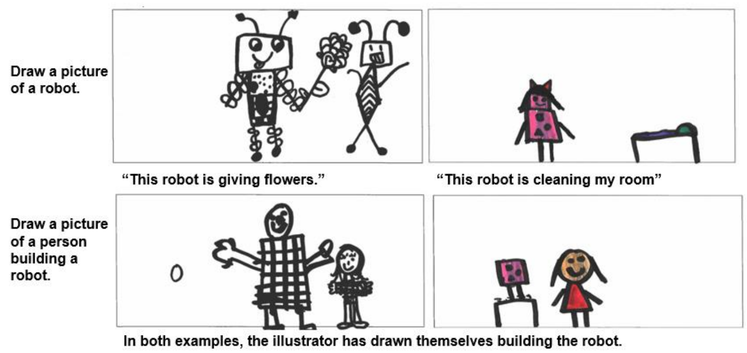

Figure 4. Example results from the Draw-A-Robot-Task presurvey.

Evaluation and Future Work

Initial analysis of the in-development Draw-A-Robot-Task (DART) shows that participants from a Daisy Girl Scout troop, drew classic examples of cartoon robots performing limited tasks and many participants drew themselves as the person building a robot. The girls were then exposed to a conceptually new field of soft robotics. Initial observations by the research team include the children’s willingness to share their responses, leading to similar responses on the DART for participants near one another. While the number of siblings attending was limited, the research team did observe some indication of gendered differences in answers, something that will be explored in a co-ed environment in the future. Contrary to results seen in previous Draw a Scientist Tests and DAET surveys [21], almost half of participants (46%) drew themselves as the person building the robot in question 2 on the DART survey. This data is important for understanding age-related perceptions of science and engineering and will be explored further. Similar to the DAET [21], many responses included drawings of people of indistinguishable genders. Future work will include development of an analysis method of DART responses based on this work and future pilots.

As we work to develop the DART survey, analysis will include metrics from previous DAST and DAET surveys including: demographics, analysis of tasks completed by robots (Q1) and by people building robots (Q2), discerning gender of people in drawings building robots (Q2), and common images across drawings. More immediately (1) analysis of the DART results after exposure to human-centered soft robotics and (2) testing the DART in other contexts (boy scouts, co-ed school settings, etc) to validate the tool will be conducted. Based on this pilot implementation, soft robotics may serve as a platform for children as young as 1^{st} grade to compete scout badges and learn about and build robots, as well as engage in the engineering design process. The DART presurvey provided some initial interesting results that may, after validation, serve as a new tool for understanding children’s perceptions of the field of robotics.

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