Using Drawings to Understand Impacts of Soft Robotics Activity on Elementary Age Students' Perceptions of Robots

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***Abstract*— This Innovative Practice article aims to address the gender disparities that persist across traditional engineering disciplines including mechanical and electrical engineering. Participation in K12 educational robotics is a common foundation to enrollment in engineering majors, however the gender gap in traditional K12 robotics perpetuates the gender disparity. We hypothesize that soft robotics is a field that may promote interest in robotics and appeal to young female students' enthusiasm for bioengineering and healthcare applications of engineering. Our previous work has focused on middle and high school curricula. However, after having the opportunity to bring our soft robotics curriculum to even younger students, we thought critically about project design and ease of implementation for this age group. Perceptions of who can participate in engineering are formed as early as elementary school for some students. We piloted a soft-robotics activity over three one-hour meetings with an elementary-aged Girl Scout troop where participants earned three Daisy Girl Scout Robotics badges. To assess perceptions of robotics, we developed the Draw a Robot Task (DART) from previous Draw a Scientist Tests and Draw an Engineer Tests to better understand children's perception of robots and those who build robots. The survey includes the prompts "Draw a robot." And "Draw someone building a robot". We present results from survey responses from the Girl Scout participants conducted before and after their exposure to soft robotics. Surveys captured the students' drawings and perceptions of robotics and who builds robots. Survey responses and development of a validated measure 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 female students with the goal of reducing the gender disparity in STEM and traditional engineering majors.**

Keywords—robotics, soft robotics, female STEM engagement, engineering education

I. Introduction

Despite outreach efforts by schools and robotics organizations, girls are not participating in robotics prior to college at the same rate as boys [1]. There is an imbalance between male and female students across traditional engineering disciplines such as electrical engineering and mechanical engineering [2]. This may be due to the lack of pre-college robotics activities that girls engage in [3], and confidence in technical activities related to robotics [4]. Engaging girls to participate in robotics activities prior to college may influence them to enter majors and fields with lower female representation [5]. In their own efforts, the Girl Scouts of the USA has prioritized including STEM in their curriculum by creating badges as incentives for girls to learn new skills [6]. Some of the badges Scouts can earn include "What Robots Do", "How Robots Move", and "Design a Robot". Perceptions of engineering and opportunities related in engineering have been shown to develop in girls early in their education [7]. In this work, we created and presented a soft robotics curriculum aiming to engage elementary aged female students in robotics and engineering.

Literature indicates it is especially important to excite young minds towards engineering to see an increase in future female STEM participation [8]. The Draw a Scientist Test (DAST) [9] and Draw an Engineer Test (DAET) [10] use drawings as a research method to assess how students see themselves as engineers before having the ability to articulate their thoughts in writing. There is a long history of education researchers working to understand how young students perceive STEM [11]. First utilized by Chambers, the DAST was used to examine stereotypes in drawings of scientists among elementary aged children. Chambers examined the presence of artifacts that may represent a stereotypical perception of a scientist. Results show that by the second grade,

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the stereotypical image of a scientist begins to form, and by the fifth grade, a majority of the class was likely to draw multiple indicators of a stereotypical scientist [9]. Inspired by the DAST, Carr et al. reports results of a DAET from a study conducted in second through fourth grade classrooms in elementary schools in a single large district in United States. Student's preconceived ideas of what an engineer is include males performing tasks of typical mechanics, laborers, and drivers [12]. Carr reported that students began to think of an engineer as a designer or creator when teachers implemented engineering challenges in their classroom [12]. Similarly, we believe we will be able to understand children's perceptions of robotics by developing a survey based on the principle of using drawings and images as a research method drawn from the DAST and DAET.

Soft robotics is a field anchored in traditional mechanical principles that utilizes soft materials to execute tasks to enhance the human experience [13]. The "Soft Robotics to Broaden the STEM Pipeline" project focuses on implementing soft-robotics in classrooms in to understand high-school students STEM perceptions and how those perceptions can be affected by instructional design [14]. With recent developments of K-12 soft robotics projects and curriculum, we hypothesize the soft robotics field is a solid first step towards closing the gender gap in engineering fields [15]. We have developed the Draw a Robot Task (DART) to evaluate this hypothesis when applied in the elementary age context.

II. Soft Robotics Activity

A. *Badge 1: Building the silicone actuator*

Fig. 1 shows the steps to build a soft robotic silicone actuator. Detailed instructions on the soft robotics activity can be found in a previous article [16][17]. Students were intrigued by the idea of building their own robot. The students' eagerness to learn more about robotics was showcased through comments made by participants such as "This is fun!" and "I can't believe I'm making a robot!"

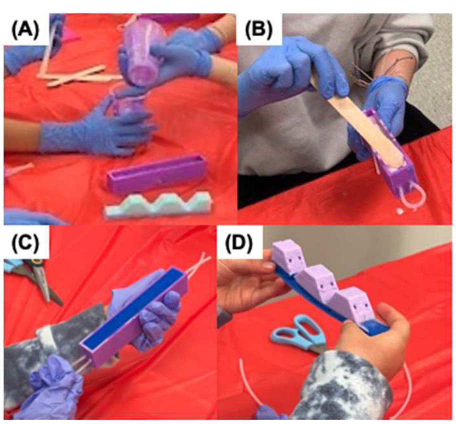

Fig. 1. Children building silicone actuators (A) Children mixing silicone. (B) Child filling mold with silicone mix. (C) Looped tubing for easy molding and removal. (D) Child holding unstrung actuator.

B. *Badge 2: Building and Experimenting with grippers*

During the following meeting, students strung thin cables through the demolded actuators. Participants saw how their actuators moved by pulling on the string. With the help of undergraduate engineering volunteers, students built grippers by combining two actuators. Fig. 2(A) shows the gripper built by students. The team suggested to students that the gripper could be used to assist someone with mobility issues for grasping, and students tested this theory by gripping common household items. Fig. 2(B) shows objects participants used to test grippers, Fig. 2(C,D) shows participants experimenting with grippers.

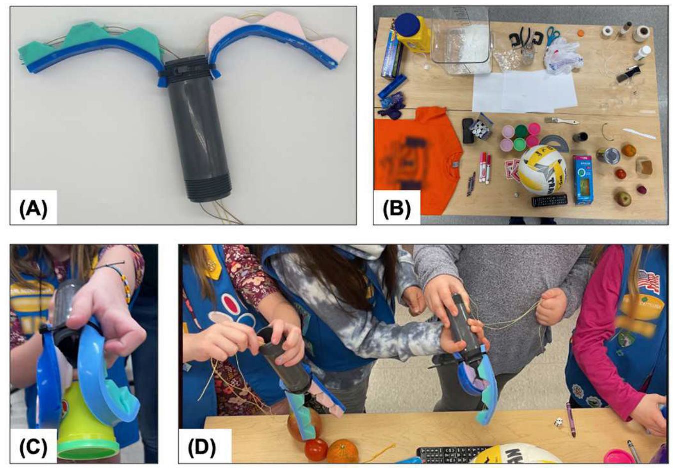

Fig. 2. (A) Grippers built by participants. (B) Objects used to test grippers, (C) child testing gripper, (D) Children experimenting with grippers

C. *Badge 3: Redesigning the grippers*

After experimenting with the gripper, students were asked to formulate a list of objects they could pick up as well as the objects they could not. The team helped the students brainstorm ways their gripper could pick up the items it initially could not. With these ideas in mind, students sketched and prototyped simple changes to the actuators during the Design Activity, which will be expanded upon in the following sections.

III. Evaluation

A. Design Activity

During the final one-hour meeting with the students, we used a design activity where participants were able to redesign the gripper they made. The team encouraged students to draw their inspiration from grippers found in nature, such as animal claws, octopus tentacles, and animal tails, as nature is a justifiable source for creativity and inspiration in engineering designs [13]. Students were given a worksheet with the prompts: (1) Draw a gripper from nature that you are inspired by, (2) What design change will you make to your robot? And (3) Tell us about your changes. Fig. 3 shows an example of a completed design activity.

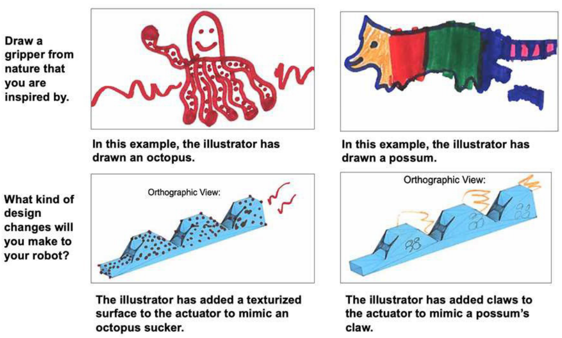

Fig. 3. Design Activity Examples

Participants completing the sketching and brainstorming process can be seen in Fig. 4(A). Volunteers helped students prototype new design changes to the grippers. Changes to the gripper included adding fingernails or claws, shortening, or lengthening the gripper, adding additional actuators, and texturizing the surface of the actuators. Students tested their prototypes on the objects they initially could not pick up with the first gripper. To simulate claws and fingernails, we cut out pieces of plastic sheet and attached them to the grippers with hot glue. Additionally, we used fast-curing silicone rubber to apply in patterns along the top and the sides of the gripper to texturize the surface. Some participants added spoons to the end of their actuator for scooping shown in Fig. 4(B). The team provided students with additional silicone actuators to add to their gripper seen in Fig. 4(C).

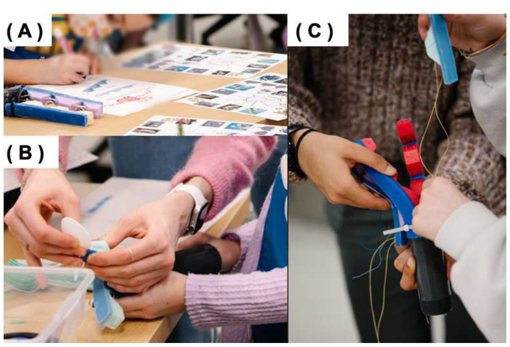

Fig. 4. (A) Child sketching design changes (B) Child attaching spoon to the end of their actuator (C) Child adding an additional silicone actuator to their gripper

Fig. 5 shows the distribution of proposed improvements by students according to their corresponding animal inspirations. Results for the Design Activity were achieved by analyzing student's design changes. If a student suggested adding more actuators, the response was recorded. If the same student suggested making the gripper stickier, that response was also recorded. Responses were then categorized by the animal the student drew inspiration from. Many students indicated they drew inspiration from the octopus, possibly due to their multiple limbs. Most of the design changes suggested by students were bioinspired. This leads us to believe students were influenced by the background information supplied by the research team.

B. Draw a Robot Task (DART)

We modified the DAST and DAET to specifically understand participants' preconceived ideas of what robots do and look like and their perception of who builds robots through drawn responses. We expect that ideas of soft robots will not be present in participants' initial drawings. We call the survey the "Draw A Robot Task" (DART). Participants were given two prompts on the survey: (1) "Draw a picture of a robot." And (2) "Draw a picture of a person building a robot." Along with the prompts, we asked (1) "What is this robot doing?" and (2) "Tell us about the person building the robot." These questions were asked and written by the volunteers for clearer interpretation during the data analysis process. Participants were provided with printed surveys, colored pencils, and a wide variety of washable markers which included the Crayola "Colors of the World" sets. Participants completed the DART before the team discussed soft robotics with them and after their exposure to soft robotics with our team.

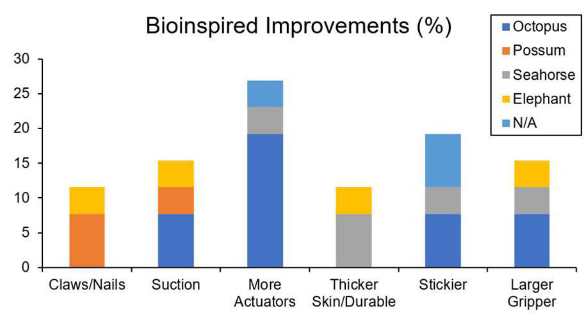

Fig. 5. Distribution of alterations from the Design Activity.

IV. Results

A. Quantifying DART results

These results are the basis of a pilot study investigating elementary-aged students' ideas and perceptions about robotics. The survey only includes female identifying participants from one Girl Scout troop. Out of 11 responses, 73% of participants were in the first grade and 27% of participants were in grades 4-6. Drawings were analyzed for specific tasks robots were portrayed completing, presence of soft or curved surfaces representing soft robotics, and if the robot was bioinspired or not.

The research team determined five artifacts to judge while analyzing the survey results. If a participant drew a robot with animal characteristics, it was marked as bioinspired. If the participant drew a robot performing a task such as picking up toys or cleaning a room, the response was marked as a chore task. Similarly, if a participant drew a robot performing a task such as helping people sleep or "fixing" a heart, the response was marked as a health task. The research team was curious to see how many participants included curved or "soft" surfaces in their robot drawings, as we presume soft or curved surfaces to be indicators of soft robotics. If a participant included soft or curved surfaces in their drawing, the response was recorded. Lastly, we evaluated each response to see whether the participant had drawn themselves as the person building the robot.

When comparing pre- and post-survey results, there was a 19% increase in girls who incorporated bioinspired elements to their robots, and a 37% increase in girl who drew their robot with a soft or curved surface. This leads us to believe students were influenced by our introduction to soft robotics. Fig. 6 shows the quantifiable results between the pre survey and the post-survey results.

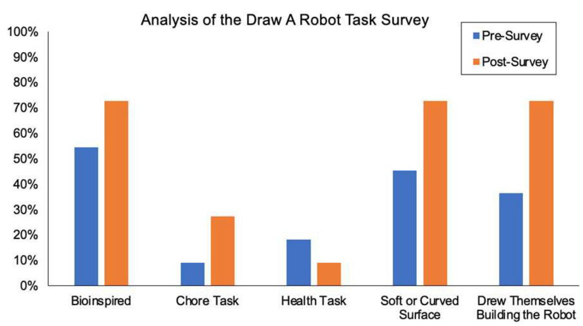

Fig. 6. Quantifiable Results from the Draw a Robot Task Survey

We saw a promising 37% increase in the number of students who drew themselves as the person building robot when comparing pre and post survey results. This leads us to believe our time with the students made an impact on the way they view themselves within engineering and robotics.

B. Observations from the DART analysis

Most drawings analyzed for the pre-survey did not contain representations of soft robotics, instead, we saw many of the drawings containing basic representations of robots. As can be seen in Fig. 7, the pre-survey revealed students' perceptions of robots and engineering was minimal.

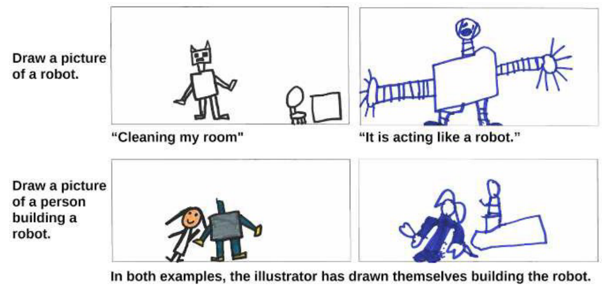

Fig. 6. Examples from the Draw a Robot Task Pre-Survey

It should be noted some of the participants may have shared ideas among each other, influencing their answers and resulting with similar drawings among multiple students. An encouraging number of students drew themselves as the person building the robot, which entails they are already able to see themselves as future engineers.

Post-survey results showed a promising development in participants' perception of robotics. Drawings contained concepts we had discussed with the students, like the gripper built in the Soft Robotics Activity. Example responses to the post-survey can be found in Fig. 8.

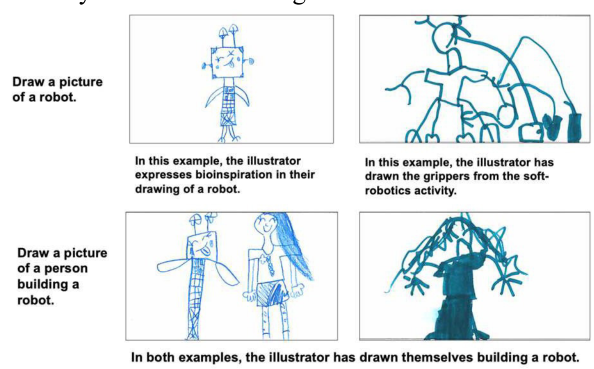

Fig. 7. Examples from the Draw a Robot Task Post-Survey

The team compared pre- and post-survey results side by side of individual participants to observe any changes in the drawings, seeing noticeable differences between the drawings. Fig. 9 shows the comparison of pre- and post-survey results of one student. While the pre-survey drawing represents an abstract robot speaking words, the post survey drawing contains indicators of soft robotics being represented in the drawing, such as rounded legs that seem to mimic tentacles on an octopus.

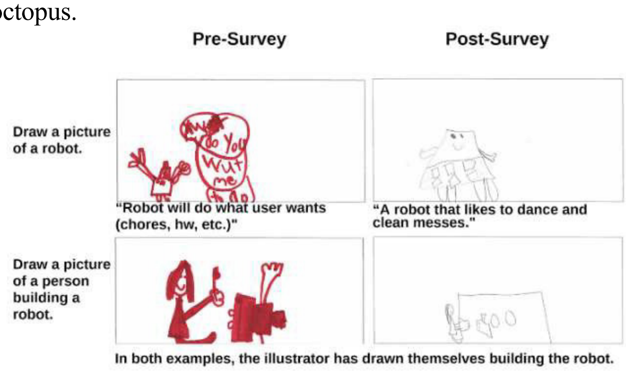

Fig. 8 Pre- vs. Post- Survey Results of one participant

V. Conclusions

Initial analysis of the Draw a Robot Task (DART) shows female participants from a Daisy Girl Scout troop drawing classic examples of humanoid robots performing limited tasks. Students were then exposed to the new field of soft robotics. Post-survey results showed participants were inspired by what they learned. Drawings contained "soft", or curved surfaces, and bioinspired additions, and participants were drawing themselves as the person building the robot. This leads us to believe that our curriculum made a difference and excited the participants towards the idea of pursuing an engineering career in their future. Future work will include testing the DART in other contexts to validate the survey. Based on this pilot implementation, soft robotics may serve as a platform for children as young as the first grade to learn about and build robots and engage in the engineering design process. The DART provided interesting results that may, after validation, serve as a new way to better understand children's perceptions of the robotics field.

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