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Board 180: Understanding Children's Perceptions of Robotics Through Drawings: Early Development of the Draw a Robot Task (Work in Progress)

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Dr. Henderson has dedicated his career to increasing the number of students who are on pathways to pursue STEM careers. He believes that exposing students to STEM early will have a lasting impact on their lives and academic pursuits. He is the co-founder of the St. Elmo Brady STEM Academy (SEBA). SEBA is an educational intervention aimed at exposing underrepresented fourth and fifth-grade students and their families to hands-on STEM experiences.

Henderson's research interests are in engineering identity development among Black men. He was most recently recognized by INSIGHT Into Diversity Magazine as an Inspiring STEM Leader, the University of Illinois at Urbana-Champaign with the College of Liberal Arts & Sciences (LAS) Outstanding Young Alumni Award, and Career Communications Group with a Black Engineer of the Year Award for college-level promotion of engineering education.

Understanding Children's Perceptions of Robotics Through Drawings: Early Development of the Draw a Robot Task (Work in Progress)

Abstract

As the field of robotics evolves to include bioinspired designs, healthcare applications, and even soft materials, opportunities exist to broaden children's understanding of what robots do and who can be involved in their development. Therefore, understanding the perceptions of robotics and engineering that young children hold is important for broadening participation in STEM fields. One method proposed to understand the perceptions and stereotypes children have about the engineering world around them is the Draw an Engineer Task (DAET). As an extension of DAET, we recently proposed the Draw a Robot Task to understand specifically how children perceive the embodiments and applications of robots and roboticists. Our early work to develop the Draw a Robot Task relied on subjective analysis of the materials, bioinspiration, and applications in children's drawings. In this work-in-progress paper, we explore image analysis software and the development of machine learning tools to quantify features of the drawings to define traditional, rigid, and soft, bioinspired robots. With the goal of validating the Draw a Robot Task as a means to both understand children's perceptions of robots and to study the impacts of the new soft robotics curriculum for K12 classrooms, this paper presents pilot analysis toward a machine learning algorithm to analyze children's drawings. When combined with other measurements, including interviews or observations, the Draw a Robot Task, enhanced with objective analysis tools presented here, can aid researchers in understanding the earliest perceptions and stereotypes of robots held by young children.

Introduction

Recruitment of new students to engineering majors relies on developing their interest and identities in engineering from an early age [1], [2]. With countless activities developed for young, elementary-aged children to experiment with STEM concepts, it is essential that we have a tool to understand changes in their perceptions of engineering and to evaluate these programs and activities [3]. The Draw a Scientist Test (DAST) [4] and Draw an Engineer Test (DAET) [5] are two tools that use drawings to assess how students see themselves as engineers before they are able to articulate their thoughts in writing. Robotics is an engineering discipline that suffers from a distinct lack of diversity both in who participates in K12 programs and later who enters traditional engineering majors associated with robotics [6]. Recently, soft robotics, the sub-discipline focused on soft material designs for wearable robots, has been used as a platform to attract more students to robotics with new materials [7], bioinspired designs [8], and human-centered applications [9]–[11]. To understand young children's perceptions of the variety of embodiments of robots, we proposed the Draw a Robot Task to understand the physical form of robots, applications, and identities of roboticists [12]. In our pilot work, we used a code book to analyze drawings, yet judgement of drawings in inherently subjective. To validate the survey tool and scale its use and application, we aim to develop a machine learning algorithm to recognize children's drawings and curved surfaces to define a soft robot in drawn images. If this quantitative tool can be developed, we can expand the application of the Draw a Robot Task and create a more robust and less subjective analysis tool for understanding children's perceptions of bioinspired robots. This work in progress paper details the effort toward developing a quantitative analysis method for the Draw a Robot Task.

History of Drawing Tasks

The DAST was previously used to examine stereotypes in pictures of scientists drawn by elementary-aged children. Results show that indicators of a stereotypical scientist appear in drawings as early as 2nd grade and are significantly represented by students in 5th grade [4]. Based on the DAST, a version of this tool was developed for examining the perceptions of engineers (DAET). Students' preconceived ideas of what an engineer is include men performing tasks associated with mechanics and truck drivers [13]. However, students perceptions changed in response to curricular interventions. Students began to think of an engineer as a designer or creator when teachers implemented engineering challenges in their classrooms [13]. Similarly, we aim 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.

Development of the Draw a Robot Task (DART)

We recently piloted the DART measure to understand children's very early perceptions of robotics and the engineers who build them [12]. This pre- and post-instrument prompts participants to answer two prompts with drawings. The first prompt asks participants to "Draw a picture of a robot". There is also space for an adult volunteer and research team member to write in "What is the robot doing?" in consultation with the child. The second prompt asks participants to "Draw a picture of someone building a robot". There is write in space below the drawing space for an adult volunteer and research team member to write in "Tell us about this person and what they are building" in consultation with the child. Figure 1 shows the instrument (V1)

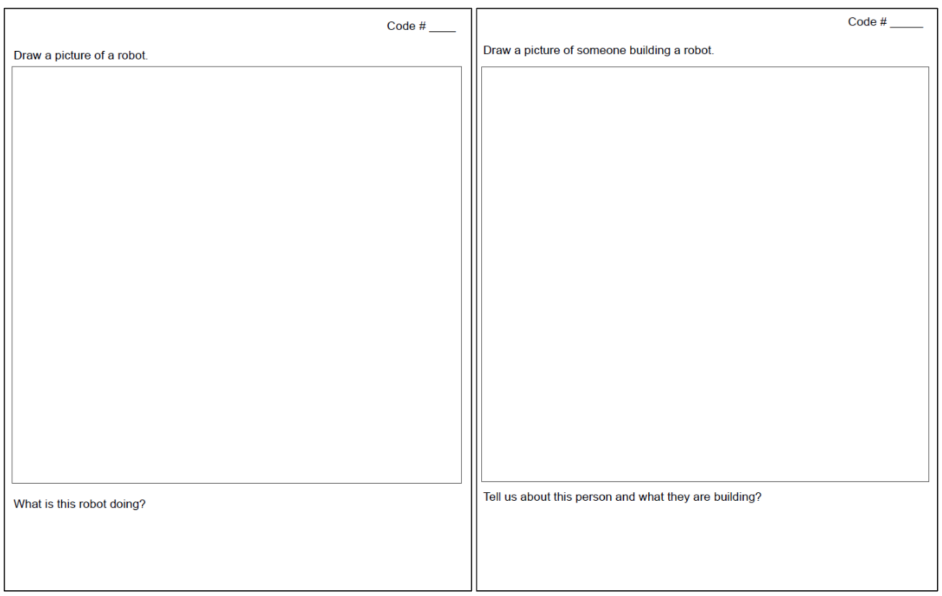

Figure 1. Draw a Robot Task instrument (V1).

This IRB-approved study was piloted with a group of girl scouts who were completing a soft robotics building activity to earn robotics badges (Figure 2). Because the instrument was used in a soft robotics outreach context, we were interested to understand participants' perceptions of what robots look like and their applications. For this reason, we aimed to understand if participants were drawing traditional rigid robots or soft or bioinspired robots. To analyze the results from a pilot study using this instrument, we created a code book of the features of drawings we were interested to understand: (a) task robot is performing (chore task, health task, etc.), (b) colors used in the drawing, (c) is the robot "bioinspired" (animal type, features), (d) who is building robot (themselves, other person, characteristics of that person), (e) presence of curved surfaces vs. "blocky" robots. The analysis was conducted on deidentified drawings by three members of the research team for triangulation of the findings. Despite efforts to create an objective analysis method, subjectivity does come into play when viewing images. Due to the subjectivity in judging rigid and soft robots, we now aim to develop computational image analysis to provide quantitative analysis of drawings.

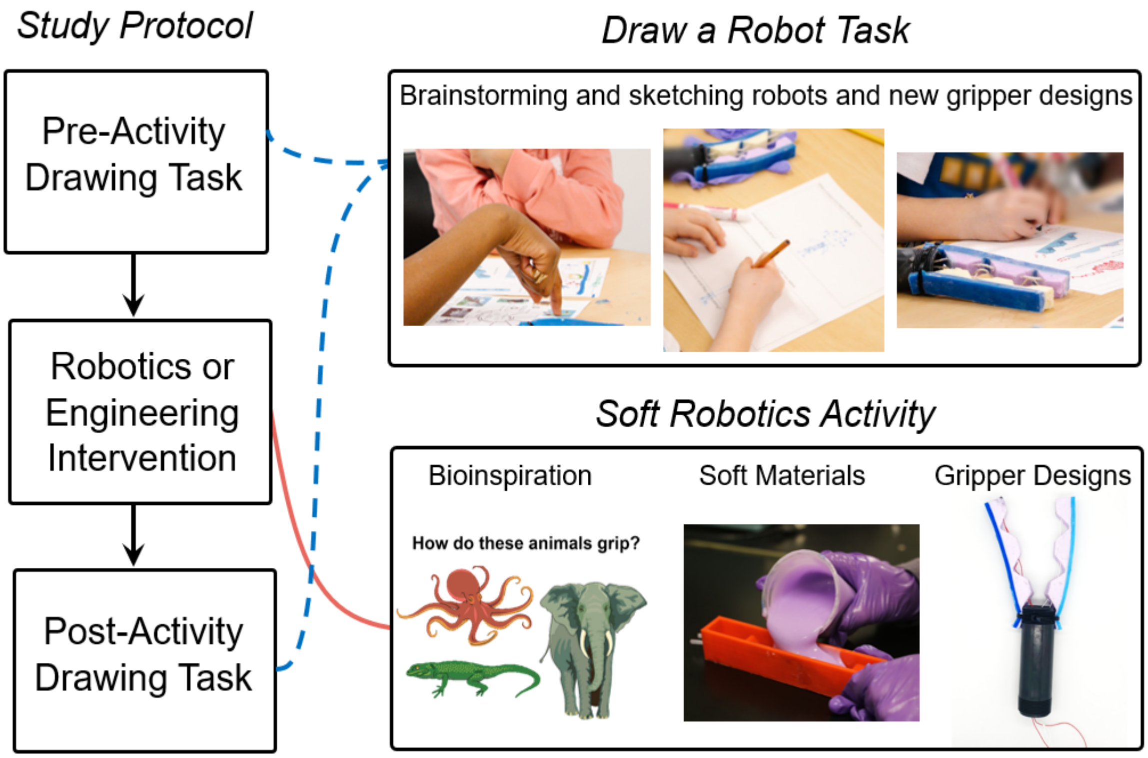

Figure 2. Outline of implementation and evaluation schedule.

Image Analysis to Understand Drawings of Robots

To begin the development of this tool, we first manually quantified features in the drawings. Before analysis, we cleaned the images to contain only the "robot". While in the future, it will be beneficial to understand the context in which the robot is drawn, for simplification purposes, we start with only the robot itself. Figure 3 shows an example of an originally drawn entry and the processed image in which we manually isolate the robot in a bounding box. In this way, the machine will not have to find objects prior to interpreting them.

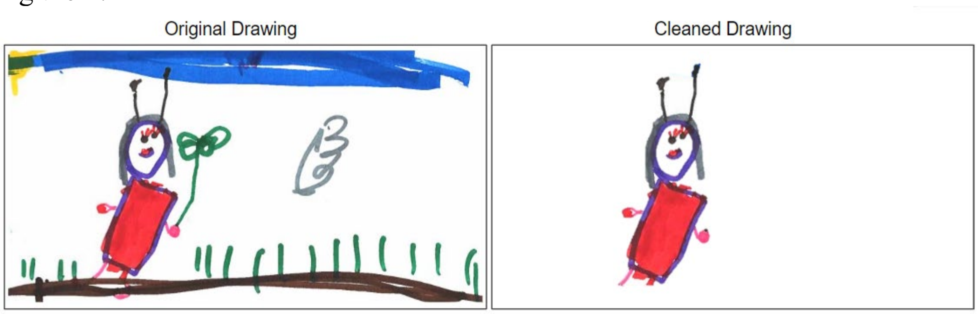

Figure 3. Example of original and cleaned drawings for analysis.

Next, we manually inspected each drawn entity and counted features in the drawings: (a) number of heads, (b) number of eyes, (c) number of arms, (d) number of tools, and (e) number of times a feature is round. This exercise is used to determine how well an algorithm should do in determining differences in the images. Our hypothesis is that if we can detect differences, it is reasonable to assume that we can develop an algorithm to detect these changes as well. Analysis was performed in ImageJ (NIH) to count items in the image manually. Preliminary results are shown in Table 1.

Table 1. Features manually counted in drawn robots (Mean ±Standard Deviation)

	Heads	Eyes	Arms	Legs	Tools	Round Features
PreSurvey	1±0	1.8±0.57	1.8±0.57	1.5±0.9	0.09±0.3	3±1.8
PostSurvey	0.9±0.3	1.6±0.8	1.9±0.5	2±1.25	0.2±0.6	6.7±3.5

Counting arms, legs, eyes, and heads are relatively straightforward. When it comes to counting "round features," it becomes more difficult. While there were, on average n=3 round features in Pre-survey images, those features were typically decorations or designs on the body of the robot, or circles on the ends of antennae or wheels rather than round features on the robot body. While the number of round features found in the Post-survey was double that of the Pre-survey, it was highly variable across images and so not statistically different from the Pre-survey data. To address this in development of a computer-based image analysis program, image cleaning may need to involve removal of decorations and non-body features. To test this, we re-evaluated the "Round features" on images but excluded decorations on the robot, wheels, and circles on the end of antennae. Table 2 compares the analysis when images are binned to original drawings. While the Post-survey is still highly variable, the difference is larger and more representative of a subjective view of the images.

Table 2. "Round features" manually counted in drawn robots (Mean ±Standard Deviation).

	Original Drawings	Cleaned Drawings
PreSurvey	3±1.8	1±1.6
PostSurvey	6.7±3.5	5±3.4

Application of Hough Transform for Image Analysis

We next turned to image analysis tools embedded in the ImageJ software. Figure 4 shows an attempt to apply a watershed threshold to automatically detect circles. However, as shown in the image, many complex curved shapes are grouped together and cannot be individually recognized by this threshold.

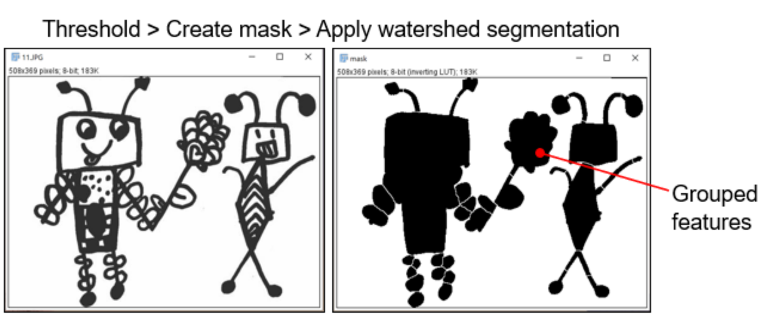

Figure 4. Attempt to perform curved surface thresholding using ImageJ software.

Next, we used an ImageJ Hough Circle Transform (UCD Vision Sciences) plugin to detect circles in the drawings. Using a thresholding function, we found edges in the drawings and applied the Hough Circle

Transform to images for circle detection. The plugin allows us to define the approximate size of circles of interest in the drawings. We experimented with multiple ranges to determine their applicability in our case. Figure 5 shows multiple attempts at applying the Hough Circle Transform to one image of drawn robots.

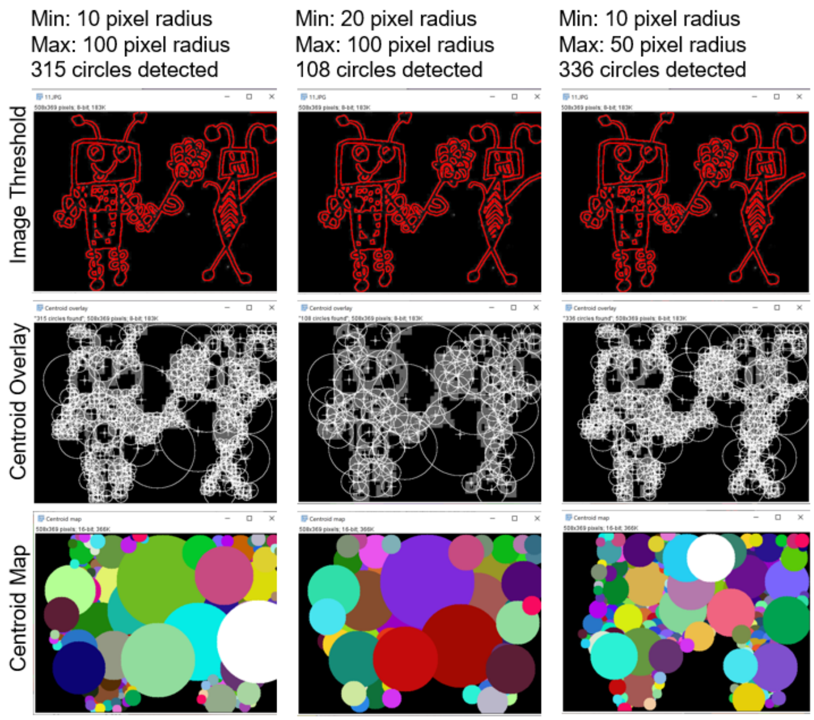

Figure 5. Analysis of robot drawings using a Hough Circle Transform.

Limitations and Next Steps for Development

Initial exploration of tools to automate analysis of drawings tasks in engineering education research lead us to understand the limitations of our current approach and some ideas for development in the future. Early on, we realized that differences in the drawing medium (pencils, pens, crayons) may be confounding. The thickness of markers likely leads to a different definition of what an edge is than in the "softer" crayon or pencil drawings. In future implementations, we will provide participants with a singular type of drawing tool to simplify analysis. Simply looking for curved lines can cause issues when participants choose to decorate their drawings with designs or buttons. These features do not necessarily define a soft robot but nonetheless are a factor we will need to deal with in analysis. We also see a wide variability in “soft” features present in final drawings. Our next steps are to explore other image analysis techniques, as well as refine our survey tool to elicit responses that represent the participants' understanding of robotics. Simultaneously while previous studies have attended to gender in DAET, we will also intentionally code for race and ethnicity [14].

Acknowledgements

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References

[1] M.-T. Wang and J. L. Degol, “Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions,” *Educ Psychol Rev*, vol. 29, no. 1, pp. 119–140, Mar. 2017, doi: 10.1007/s10648-015-9355-x.

[2] J. Henderson, V. Snodgrass Rangel, J. Holly, R. Greer, and M. Manuel, “Enhancing Engineering Identity Among Boys of Color,” *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 11, no. 2, Sep. 2021, doi: 10.7771/2157-9288.1311.

[3] Y. Li, K. Wang, Y. Xiao, and J. E. Froyd, “Research and trends in STEM education: a systematic review of journal publications,” *IJ STEM Ed*, vol. 7, no. 1, pp. 11, s40594-020-00207–6, Dec. 2020, doi: 10.1186/s40594-020-00207-6.

[4] D. W. Chambers, “Stereotypic images of the scientist: The draw-a-scientist test,” *Sci. Ed.*, vol. 67, no. 2, pp. 255–265, Apr. 1983, doi: 10.1002/sce.3730670213.

[5] M. Knight and C. Cunningham, “Draw An Engineer: Development Of A Tool To Investigate Students' Ideas About Engineers And Engineering,” in *2004 Annual Conference Proceedings*, Salt Lake City, Utah: ASEE Conferences, Jun. 2004, p. 9.482.1-9.482.11. doi: 10.18260/1-2--12831.

[6] A. Sullivan and M. Umashi Bers, “Girls, Boys, and Bots: Gender Differences in Young Children's Performance on Robotics and Programming Tasks,” *JITE:IIP*, vol. 15, pp. 145–165, 2016, doi: 10.28945/3547.

[7] S. Edward and H. M. Golecki, “Gelatin Soft Actuators: Benefits and Opportunities,” *Actuators*, vol. 12, no. 2, p. 63, Jan. 2023, doi: 10.3390/act12020063.

[8] L. Garcia *et al.*, “The Role of Soft Robotic Micromachines in the Future of Medical Devices and Personalized Medicine,” *Micromachines*, vol. 13, no. 1, p. 28, Dec. 2021, doi: 10.3390/mi13010028.

[9] A. H. Greer *et al.*, “Soluble Polymer Pneumatic Networks and a Single-Pour System for Improved Accessibility and Durability of Soft Robotic Actuators,” *Soft Robotics*, p. soro.2019.0133, Jun. 2020, doi: 10.1089/soro.2019.0133.

[10] E. McNeela, T. Tran, A. Adnan, and H. Golecki, “Understanding Impacts of Soft Robotics Project on Female Students' Perceptions of Engineering (Work in Progress),” in *Proceedings of the American Society of Engineering Education*, Jun. 2022.

[11] D. P. Holland *et al.*, “The Soft Robotics Toolkit: Strategies for Overcoming Obstacles to the Wide Dissemination of Soft-Robotic Hardware,” *IEEE Robot. Automat. Mag.*, vol. 24, no. 1, pp. 57–64, Mar. 2017, doi: 10.1109/MRA.2016.2639067.

[12] S. Lamer, A. Adnan, E. McNeela, T. Tran, and H. Golecki, “Using Drawings to Understand Impacts of Soft Robotics Activity on Elementary Age Students' Perceptions of Robots,” presented at the IEEE Frontiers in Education, Upsala, Sweden, Oct. 2022.

[13] R. Carr and H. Diefes-Dux, “Change in Elementary Student Conceptions of Engineering Following an Intervention as Seen from the Draw-an-Engineer Test,” in *2012 ASEE Annual Conference & Exposition Proceedings*, San Antonio, Texas: ASEE Conferences, Jun. 2012, p. 25.299.1-25.299.12. doi: 10.18260/1-2--21057.

[14] T. Lightner, M. E. Cardella, N. Huggins, C. Hampton, W. C. Lee, and D. B. Knight, “Draw an Engineer: A Critical Examination of Efforts to Shift How Elementary-Aged Students Perceive Engineers,” *2021 CoNECD*, 2021.