ASEE'S VIRTUAL CONFERENCE
At Home with Engineering Education JUNE 22 - 26, 2020 #ASEEVC
Paper ID #29597

Assessing the Effects of a Robotics Workshop with Draw-a-Robot Test (Fundamental)

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1. Introduction

Pervasive adoption of technology is transforming all manner of human endeavors, including but not limited to commerce, communication, defense, education, entertainment, healthcare, industry, and transportation. This has given rise to an increasing demand for a well-prepared STEM workforce. Thus, various decision makers in education, government, and business are focused on creating, reformulating, and offering innovative learning opportunities for students at all levels. In this vein, our team has designed and conducted a summer robotics workshop to increase the robotics knowledge as well as technical and entrepreneurial skills of high school teachers and students.

For more than five decades, robots have been automating manufacturing and assembly operations in factories. Moreover, in recent years, people have started to incorporate robots to serve varied roles in different aspects of their personal and professional lives. Thus, it is plausible to assume that everyone has some views about what robots are and what they do. However, such everyday perceptions of robots may be stereotypical with misconceptions arising from movies, science fiction, and other media. For this exploratory study, we were interested to know the initial views about robots and their use held by high school teachers in our summer robotics workshop. Next, we sought to determine and understand whether teacher perceptions of robots would change as a result of their participation in our robotics workshop. We also wanted to examine if there was any relation between changes in teacher perceptions of robots and their race and/or gender. To answer these questions, we conducted a "draw a robot test" at the beginning and at the end of the robotics workshop. In the next section, we begin by describing the literature that motivated this study.

2. Motivation

Young students' perceptions of scientists are often informed by stereotypes that lead to their misconceptions about science professions and impede their interest in pursuing higher studies and careers in sciences [1-3]. The "Draw-a-Scientist Test" (DAST) is one of the tools that has been frequently used for understanding student views of scientists [4]. Studies that used DAST have shown that, for example, young children often do not perceive women as scientists [5,6]. Ref. [7] reported on a modified version of DAST that was administered in an introductory computer science course to understand student perceptions of a particular kind of scientist, *viz.*, computer scientist. Findings of [7] show that the majority of the students, regardless of their race or gender, perceive computer scientist as a white male. In [8], an extended version of the test, called DAST-C, was developed that used a checklist to differentiate student drawings with respect to the appearance of scientists, presence of instruments and signage, and work environments that students associated with the work of scientists. Analysis of student drawings in [8] showed that wearing lab coat and eye glasses, having facial hair, and presence of items signaling knowledge, technology, etc., are some of the stereotypical images of a scientist.

Similar to science, the field of engineering also suffers from misconceptions among young students. Even the general population has *only* a partial understanding of engineers and their work [9,10]. Although students use engineering products regularly, their views of engineering as a profession are very limited. Except for those who have direct experiences in engineering field, most students' perceptions of engineering are formed from sources such as the media. Inspired by the draw a scientist test, several researchers have developed drawing tests, and detailed coding protocols [11], to investigate students' dominant perceptions about engineering [12]. In [13], a combined test, draw an engineer and a scientist was utilized to understand similarities and differences in student perceptions of scientists and engineers. According to the results of [13], students mostly perceive scientists as individuals who conduct experiments indoors and engineers as workers who perform physical work outdoors. Having understood the prevalence of student misconceptions of engineers, in recent years, engineering education researchers have begun to explore approaches for helping students to gain appropriate conceptions of engineers and their work [14,15].

We posit that, similar to students' perceptions of scientists and engineering that are often dominated by stereotypes, there are misconceptions about what a robot is and what it can do. As robots are becoming increasingly common in workplaces (e.g., factories, warehouses, hospitals, etc.) and homes (e.g., Roombas), all people, including young students, acquire some discreet bits and pieces of knowledge and start to build their own perceptions about what robots are and what they can do. Perceptions of robots held by people are rife with many misconceptions arising from movies, science fiction, and other media. Studies have shown that student perceptions of scientists are influenced by their parents [16], school and teachers [17], and popular culture [5]. Just as science misconceptions can cause students to be disinterested in science, it is possible that some of the misconceptions of robotics may prevent students from seeking higher education or careers in robotics.

Even though the prevailing science standards emphasize and promote engineering and technology practices in K-12 classrooms [18-20], there are concerns regarding U.S. students' lack of fundamental knowledge in technical fields [19]. These concerns highlight the need for preparing, training, and graduating more science and engineering professionals to enable the U.S. to remain competitive in the global innovation race. Moreover, recent years have witnessed accelerating advances in technologies that have reinforced the need for preparing citizens for the expanding technological workforce. In fact, according to recent workforce forecasts [21], on-going technological advancements are expected to result in the emergence and growth of entirely new job roles, e.g., "Robotics Specialists and Engineers". Thus, it is of paramount importance to identify, address, and correct learners' misconceptions about robotics for promoting their preparation to participate in higher education and the future technological workforce.

In support of the above goal, we used a "draw a robot" test in our robotics workshop. Previously, a similar test was conducted to find the relation between the drawings of healthcare robots and blood pressure readings and negative emotions among middle-aged participants [22]. During interaction with the actual healthcare robot, participants who had drawn a human-like robot had increase in their blood pressure readings and negative emotions compared to those who had drawn a box-like robot. Moreover, the larger the size of drawings of healthcare robots the higher was the ratings of negative emotions during the robot interaction. In our exploratory study, we conducted the test with high school students and teachers to understand their perceptions about robots at the beginning of the workshop and how those perceptions changed by the end of the workshop. In the next section, we briefly describe the structure of the professional development and education enrichment (PDE^2) workshop.

3. Structure of the Professional Development Workshop

Ten teachers and 22 students from 8 urban inner-city high schools attended the summer PDE^2 workshop. Participants were divided into five teams consisting of two teachers and four to five students. While some teams consisted of students and teachers from the same schools, others were formed by participants as they met each other on the first day of the workshop. The workshop was divided into two weeks of guided training and two weeks of collaborative robotic-product development. Engineering and education faculty, post-doctoral researchers, and graduate and undergraduate engineering students worked together on the development, implementation, and assessment of the PDE^2 program.

In the two-week guided training, workshop participants were introduced to fundamental concepts in the following five areas.

Physics: forces, momentum, equilibrium, stability, center of mass, center of gravity, and laws of motions

Electrical components, circuits, and miscellany: conductors, insulators, resistors, capacitors, inductors, batteries, Ohm's law, voltage-current relations, series and parallel networks, breadbroad principles, switches, speakers, and relays

Electronic components, circuits, and miscellany: semiconductors, diodes, LEDs, transistors, microcontrollers, Boolean algebra, logic gates, analog and digital signals, noise, accuracy, and precision [23]

Robotics: motivation [24], mobile robot kinematics [25], different coordinate systems, reference frames, drive mechanisms for mobile robotics, different types of wheels, and 3D printing [26]

Entrepreneurship: business planning, business model canvas [27], product development process, market analysis, product market matrix [28], Porter's 5 forces [29], technology S-curve [30], venture capital, crowd funding, grants, social entrepreneurship, and managing intellectual property

Corresponding to each lesson on fundamental concepts, participants worked on hands-on learning tasks in teams. VEX Robotics Clawbot kit [31] and Arduino UNO microcontroller [32] were used for building the chassis of the robot and the microcontroller circuitry of the robot, respectively. The research team introduced participants to operating principles, electrical schematic, coding, and microcontroller interfacing of components (e.g., DC motor, servomotor motors, infrared (IR) sensor, light dependent resistor (LDR), ultrasonic sensor, etc.). All robot programming was done using the Arduino IDE that was introduced during the workshop.

The last two weeks of the workshop focused on collaboratively developing a robotic-product. The teacher-student teams developed their robotics creations to compete on a mock-up game field inspired by a real-world scenario of garbage collection and recycling for the Department of Sanitation New York City (DSNYC). Teams were asked to design and program their robots to pick up trash bins from each house on the streets, sort the trash, and deliver it to the sorting facility based on the type of recyclables contained in the garbage bin.

Figure 1 shows the mock street view resembling the real street layout of NYC where the workshop took place. Given the limited amount of time in the workshop for completing the project, the mock street view was simplified to the project schematic depicted in Figure 2. The game field had four streets numbered 1 to 4 with houses on both sides. The bins containing recyclable garbage were placed randomly at the end of each branch in front of each house. In other words, not every house had a trash bin present in front of it. Moreover, to demo a realistic scenario, the recyclables might vary in different trash bins. The primary task of the robot was to determine the presence of a trash bin in front of a house. If a trash bin was present, the robot needed to pick it up and deliver it to the sorting facility corresponding to the recyclable contained in it. Classifying the trash bins was done based on the color of bins or their material (e.g., metal versus non-metal). The method for identifying the type of garbage was open-ended and the teams had to decide what method to use. However, it was required that the robot should be able to identify at least three different types of recyclable garbage. The robot could traverse the arena by employing different sensor combinations to decide where and when to make a turn, move forward, or stop.

Figure 1: Mock street view

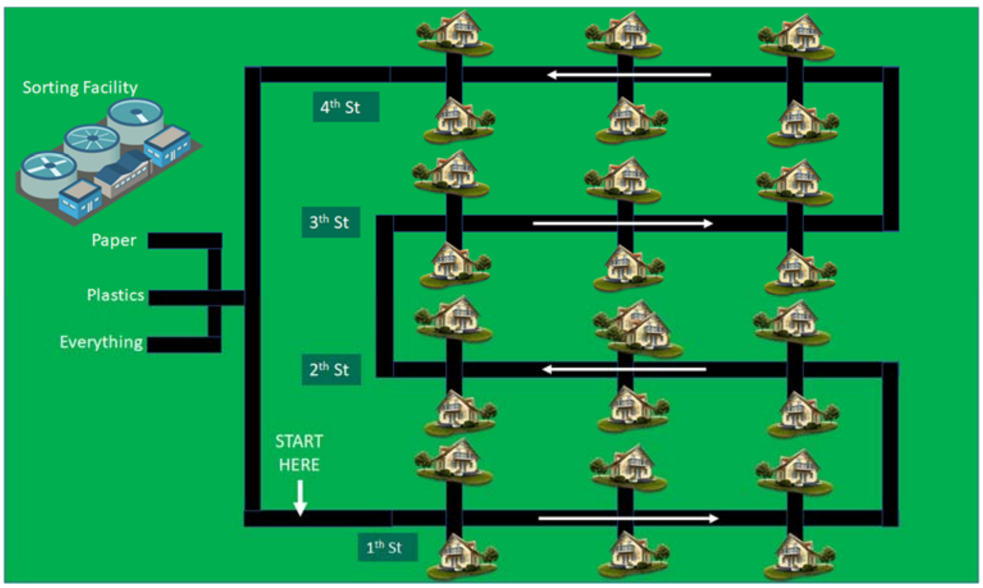

Figure 2: Block arena in project

4. Research Procedure

In this paper, we aim to explore the following questions. (1) What were the participants' initial views about robots and their use? (2) If and how did their initial perceptions change as they learned about robotics and engaged in the project? (3) Is there any relation between gender and race in terms of robot perception and changes in perception after attending the workshop?

To address the first question we conducted the draw a robot test during the first session of the workshop (pretest) and analyzed the drawings. To answer the second question, a similar test was conducted at the end of the workshop (posttest) and we compared each participants' pre and post workshop drawing sheets. To answer the third question, we examined the results with respect to gender and race. Since a key objective of our workshop was teacher professional development, in this study we focus on teacher perceptions about robots.

In this draw a robot test the participants were asked to draw any robot in its environment and label different parts of the robot. All responses were anonymous, however, to match pre and posttests, the participants labeled their drawings with unique self-assigned numeric codes.

5. Analysis and Findings

We coded participant drawings based on (1) type of the robot, (2) function of the robot, and (3) the parts of the robot identified by the participants. Table 1 shows the gender and race of the participant teachers. In the pretest, four teachers drew wheeled robots and used few technical terms to label parts of their robots. Table 2 shows the relation between the teacher demographics and the functions of their drawn robots in the pretest. Three female teachers drew household assistant robots (e.g., cleaning and cooking robots). Possibly these teachers have used or seen these types of robots in television shows or in product advertisements, for example floor cleaning Roomba robot. The two African American male teachers drew biomimetic and telemedicine robots. The movie Minority Report had an insect like robot that could have been the inspiration behind the teacher drawings of biomimetic robots. Three teachers (a female and two male) drew robots that resembled human form. We posit that the inspiration for such humanoid robots may have come from science fiction [33] and movies like Terminator. To summarize, in the pretest, teacher drawings of the robots appeared to be inspired from fiction and fantasy with less real-world grounding.

Table 3 shows the pre *vs.* posttest comparison of the type (appearance) of the robots with respect to the gender and Table 4 shows the same comparison with respect to the race. In the posttest, seven teachers drew wheeled robots as compared to pretest where only four teachers drew wheeled robots. Given that we introduced the wheeled robots in the workshop, these results are anticipated.

Comparing the pre and posttests shows that at the end of the workshop teachers used more technical terms such as microcontroller, servos, gears, color sensor, and ultrasonic sensor in their robot drawings. Specifically, in the pretest few teachers specified the name of the sensors like IR, and ultrasonic, the exact type of motors (servo and dc), and the type of wheels (omnidirectional), whereas in the posttest all of the teachers used technical terms to identify components of their robots. To expand the analysis, we examined the frequency at which these parts were labeled and if there were any differences based on the teachers' race. Table 5 shows the results of this analysis—the labels that teachers used in their robot drawings in the posttest included microcontroller indicated by four teachers; battery or power indicated by two teachers; sensors indicated by four teachers; motors indicated by three teachers; arms or claws indicated by five teachers; and wheels indicated by three teachers. These results indicate that teachers' familiarity with robotic components increased considerably as they participated in the workshop. There was no significant difference in labeling based on teacher gender, however three Asian American teachers labeled more parts compared to the other teachers.

Table 1: Demographic information of the teachers

	Gender		Race			
Total 10	Male	Female	White	African American	Hispanic	Asian
	5	5	3	2	2	3

Table 2: Teacher demographics and the type (function) of robot drawn in the pretest

Type of robot	Gender		Race			
Household assistant	Male	Female	White	African American	Hispanic	Asian
	0	3	0	0	1	2
School assistant	Male	Female	White	African American	Hispanic	Asian
	2	0	1	0	1	0
Biomimetic	Male	Female	White	African American	Hispanic	Asian
	1	0	0	1	0	0
Nuclear power plant robot	Male	Female	White	African American	Hispanic	Asian
	1	0	1	0	0	0
Playing robot	Male	Female	White	African American	Hispanic	Asian
	0	2	1	0	0	1
Telemedicine robot	Male	Female	White	African American	Hispanic	Asian
	1	0	0	1	0	0

Table 3: Teacher gender and the type (appearance) of robot drawn in the pre and posttest

Type of robot	Pretest		Posttest	
Wheeled	Male	Female	Male	Female
	1	3	3	4
Fixed base	Male	Female	Male	Female
	1	1	0	1
Others	Male	Female	Male	Female
	3	1	2	0

Table 4: Teachers' race and the type (appearance) of robot drawn in the pre and posttest

Type of robot	Pretest				Posttest			
Wheeled	White	African American	Hispanic	Asian	White	African American	Hispanic	Asian
	1	0	1	2	2	0	2	3
Fixed base	White	African American	Hispanic	Asian	White	African American	Hispanic	Asian
	1	0	0	1	1	0	0	0
Others	White	African American	Hispanic	Asian	White	African American	Hispanic	Asian
	1	2	1	0	0	2	0	0

Table 5: Demographics of the teachers with respect to the labelling in the posttest

Labels	Gender		Race			
Microcontroller	Male	Female	White	African American	Hispanic	Asian
	2	2	2	1	0	1
Power	Male	Female	White	African American	Hispanic	Asian
	1	1	1	0	0	1
Sensors	Male	Female	White	African American	Hispanic	Asian
	2	2	0	2	1	1
Motors	Male	Female	White	African American	Hispanic	Asian
	1	2	1	0	1	1
Arm/claw	Male	Female	White	African American	Hispanic	Asian
	3	2	2	1	2	0
Wheels	Male	Female	White	African American	Hispanic	Asian
	2	1	1	0	1	1
Total	11	10	7	4	5	5

Figures 3—5 depict three sets of drawing by three teachers. In the pretest (see Figure 3(a)), teacher A drew a fixed base robot whereas in the posttest (see Figure 3(a)), the same teacher drew a wheeled robot. The pre and posttest drawings of Figures 4(a) and 4(b), by teacher B, show that not only the type of the robot drawn changed but the teacher also used more technical terms to label the robot. The robots that teacher C drew in pre and posttests were similar in their function as service robots, where one does cleaning (see Figure 5(a)) and the other serves food (see Figure 5(b)). However, in the posttest drawing, teacher C used technical terms for describing how the robot works (e.g., degrees of freedom) and labeling its part (e.g. gears and IR sensors).

Many teachers in this workshop were formally learning about robots for the first time. In their pretest, most teachers drew imaginative robots with very advanced features (e.g., humanoid robots and biomimetic robots). The major misconception that is noticeable from the pretest drawings is that the teachers were primarily driven to depict the external capabilities of the robot. Moreover they paid little attention to the robot parts or components to achieve its *imagined* functionality as suggested by the limited labeling in their drawings. None of the teachers marked controller or power supply, which are essential robot parts, for the robot that they drew.

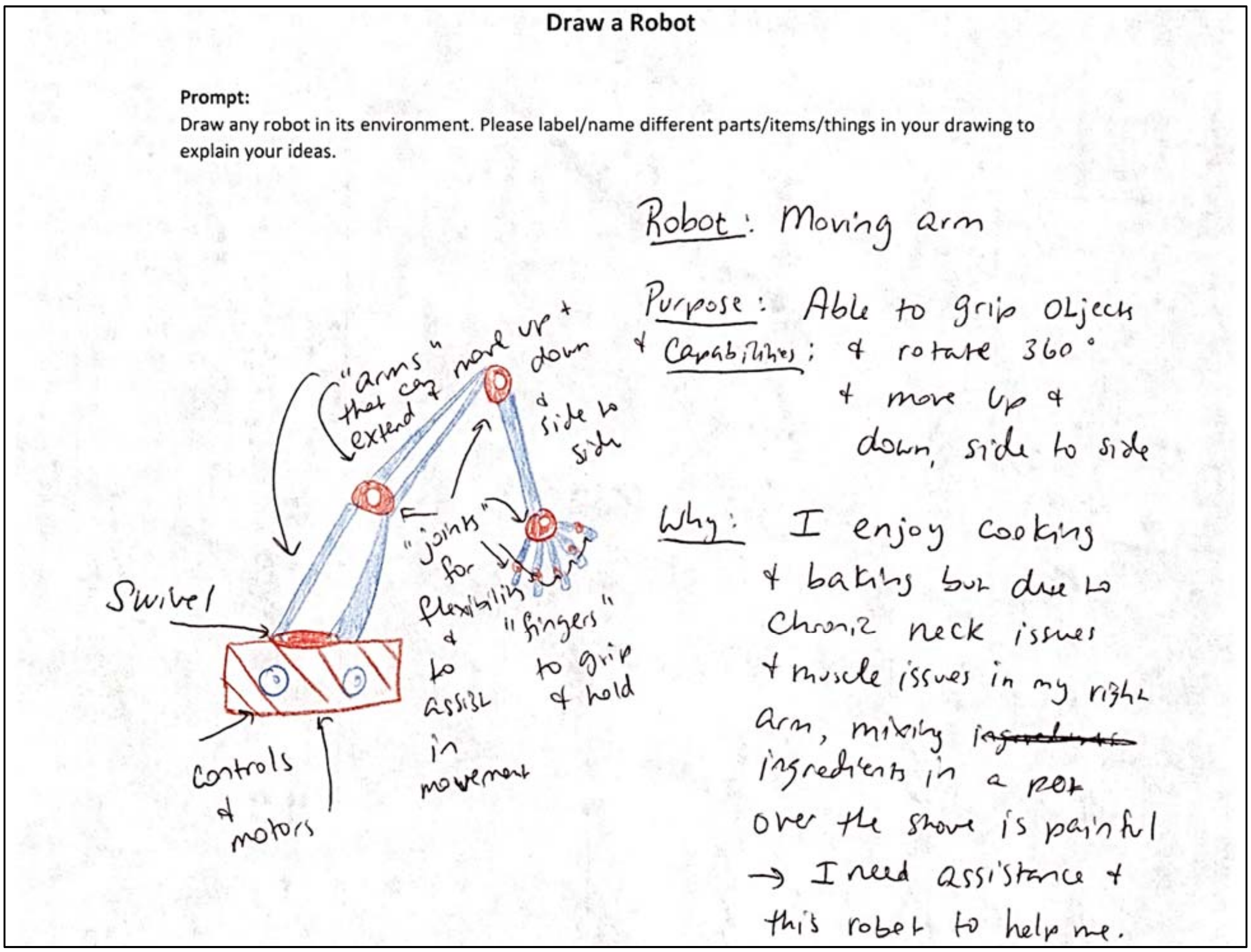

Figure 3: (a) Pretest robot drawings of teacher A

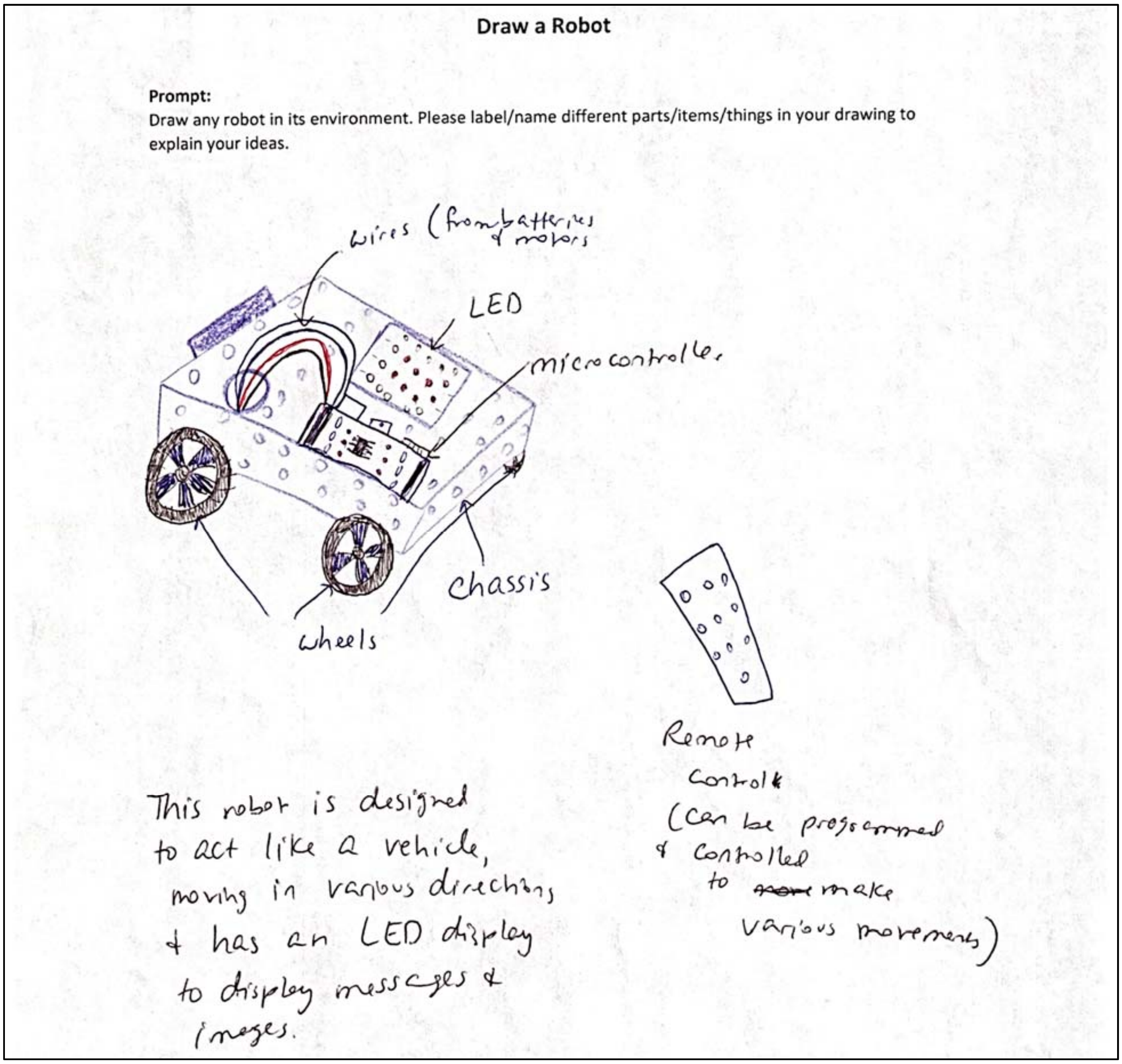

Figure 3: (b) Posttest robot drawings of teacher A

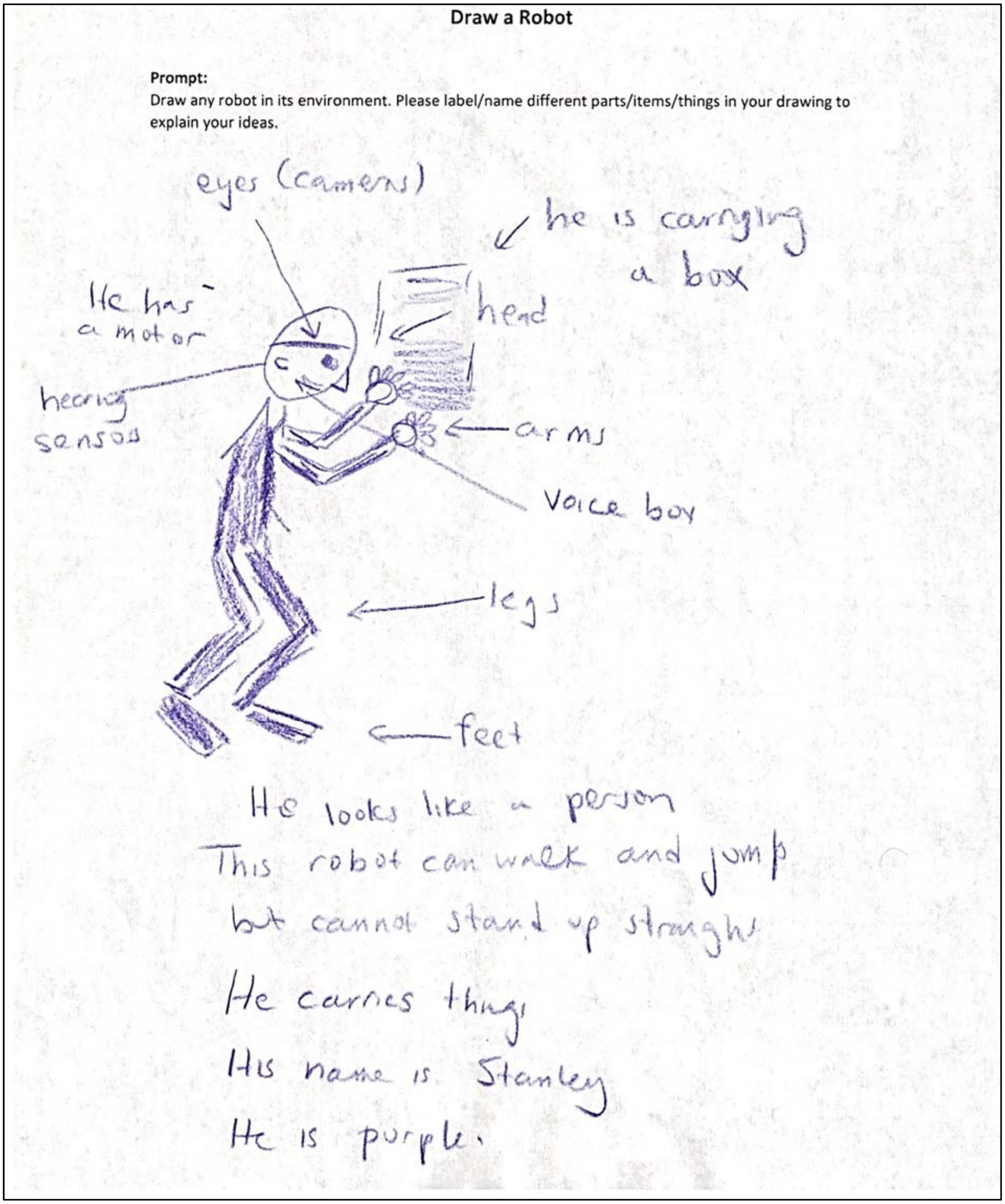

Figure 4: (a) Pretest robot drawings of teacher B

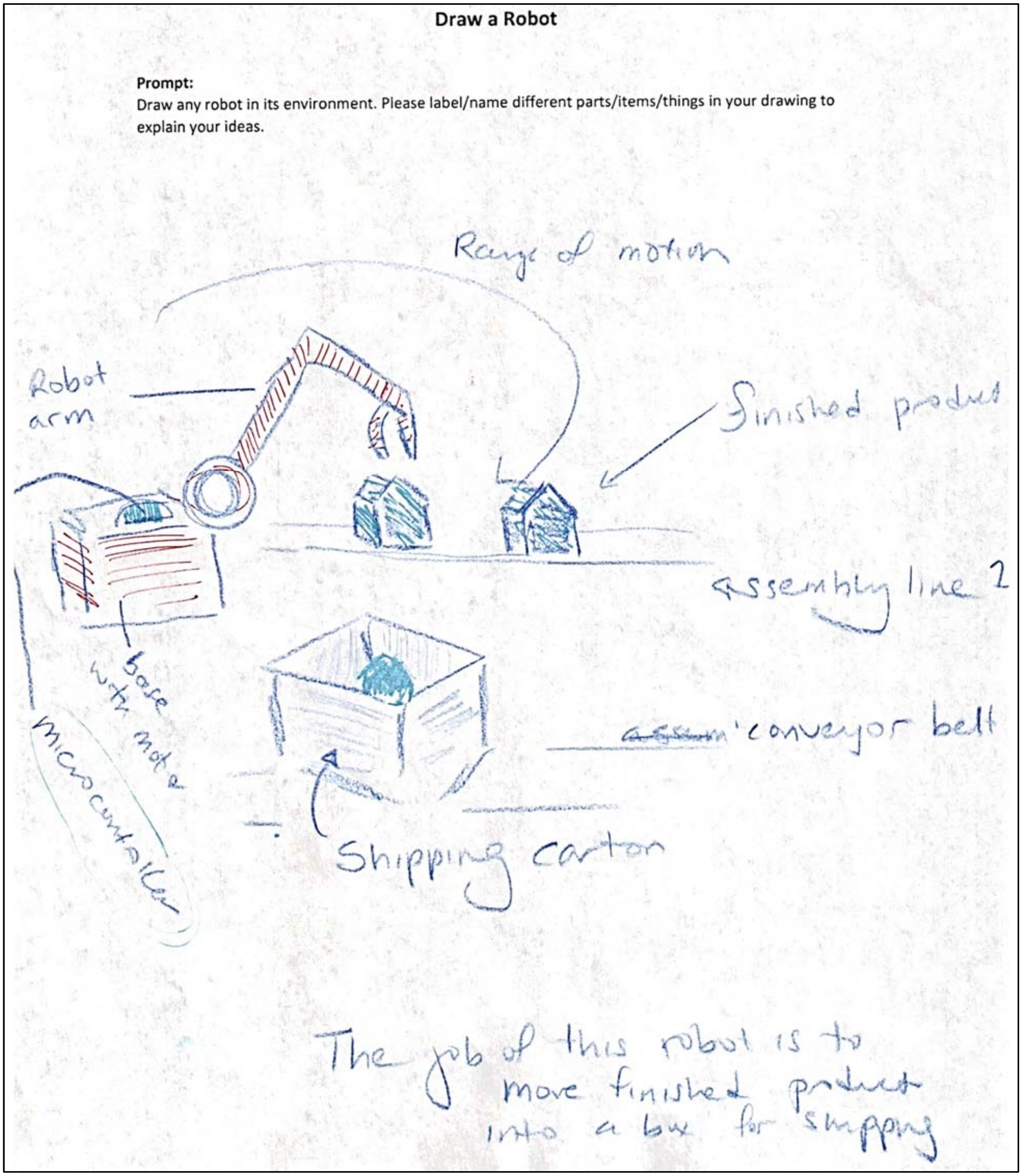

Figure 4: (b) Posttest robot drawings of teacher B

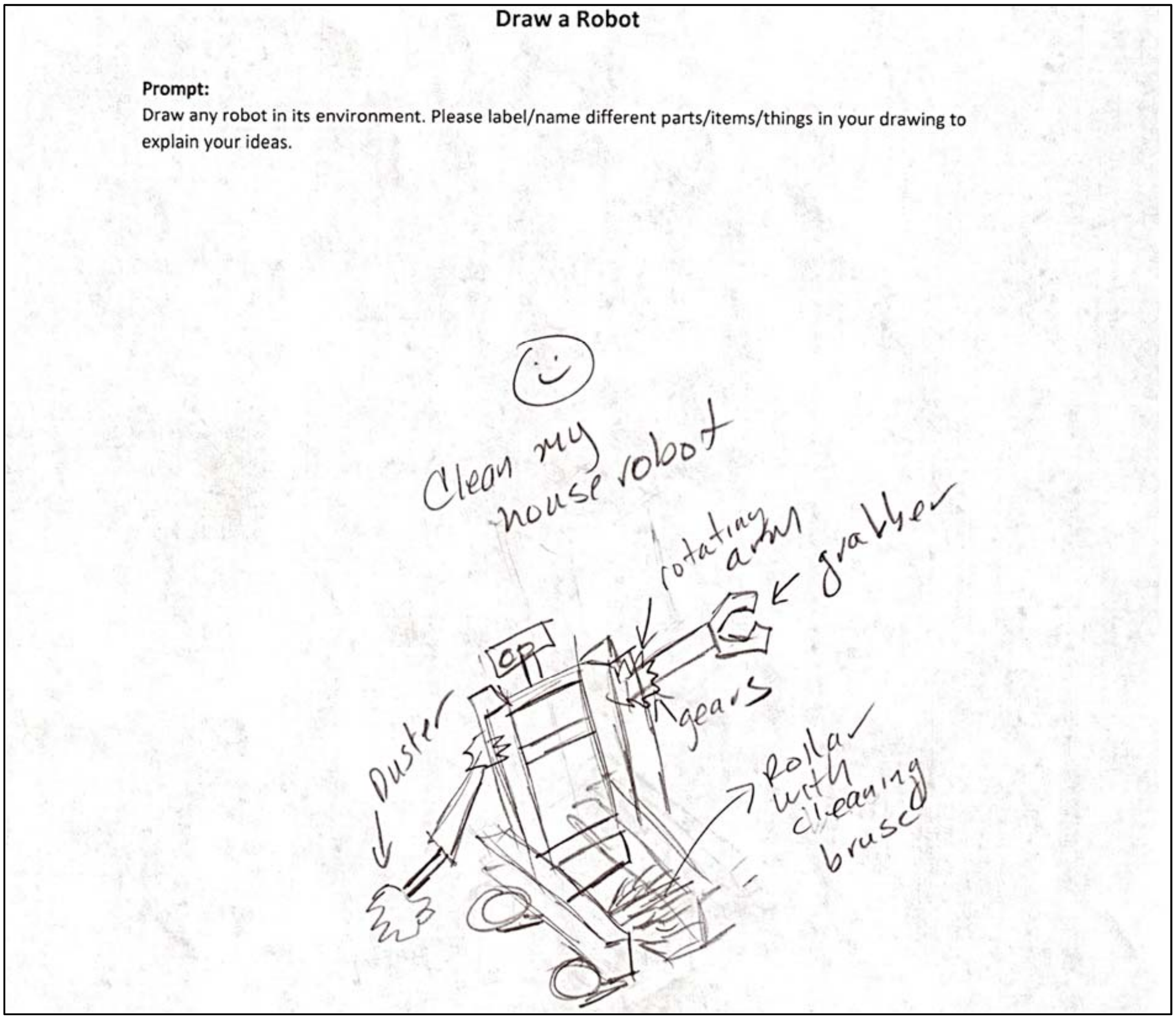

Figure 5: (a) Pretest robot drawings of teacher C

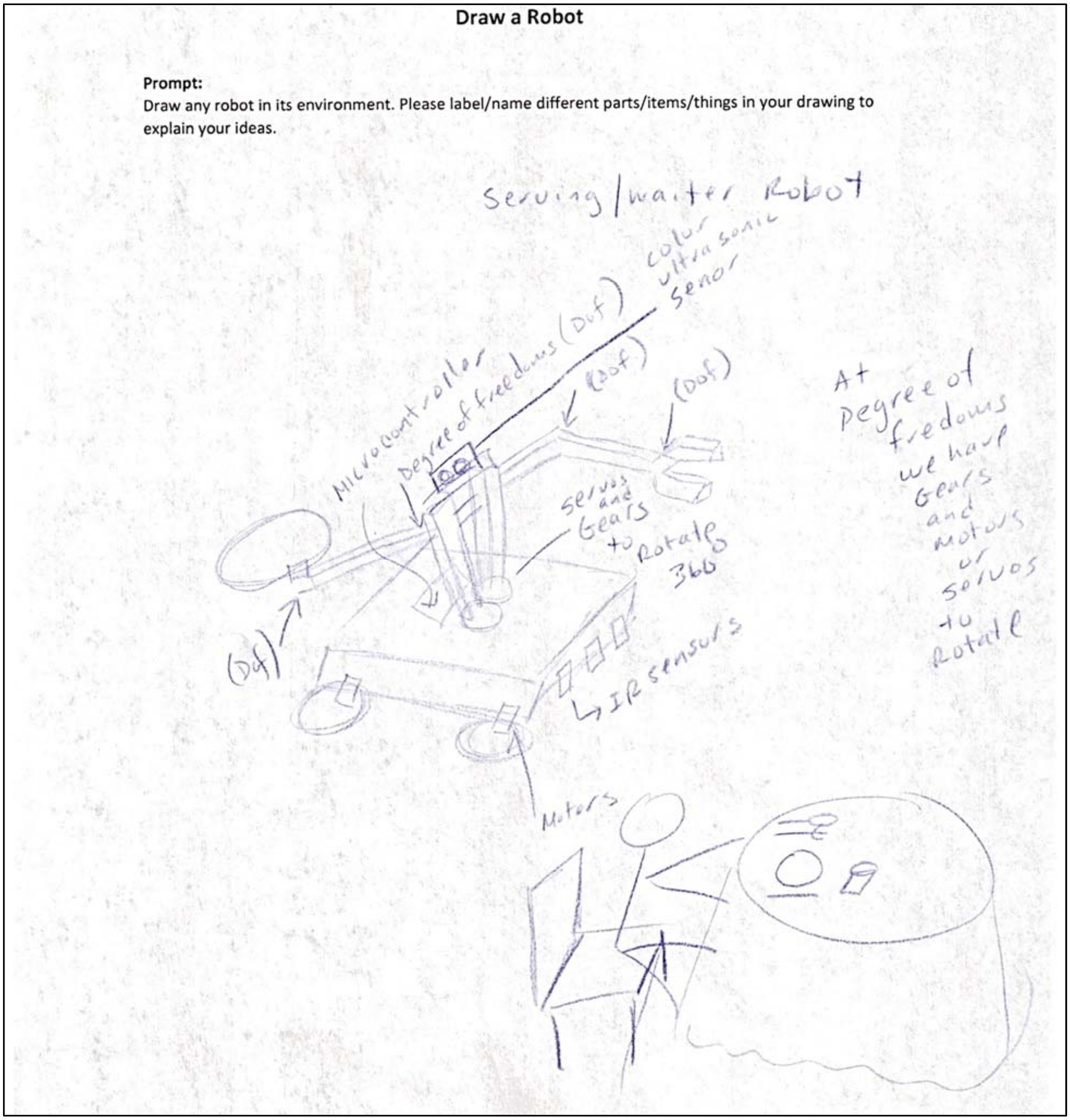

Figure 5: (b) Posttest robot drawings of teacher C

6. Discussion

Robotics engineers are aware that misconceptions about the field of engineering are pervasive [10,34,35]. However, there is less information about these misconceptions, in particular among teachers and about robotics. In this study, we used the draw a robot test to understand teachers' views and possible misconceptions that they may hold about robotics. Additionally, the study aimed to see if there was any relation between teacher gender and race in terms of robot perception and changes in their perceptions after attending the workshop. Even though we had a small number of teachers in our workshop, we were able to identify some trends among teachers as they entered the program. In the pretest, teachers drew robots, mostly in a human form, performing some daily tasks (e.g., cleaning, lawn mowing, grading) or assisting with lifting and organizing objects. All except one teacher did not specify any technical parts of their robots such as sensors or motors. Instead, they described the functions and tasks that their envisioned robot would perform (e.g., identifying on-time homework submission). Even though at the end of the workshop some teachers still drew fantasy humanoid robots, all of them used specific technical terms to label their robots. We argue that adopting a technical language for describing their drawing, even for the fictional robots, demonstrates teacher learning resulting from the workshop. Moreover, compared to the beginning, when teachers drew some imaginary form of robots, by the end of the workshop most of them were able to picture a realistic form of a robot.

7. Conclusion and Future Directions

In this exploratory study, we had a small sample group (10 teachers), thus further investigations are needed to claim that the themes observed in teacher drawings in our study are transferable to larger groups of teachers. In addition to choosing a larger group of participant, for future studies, we suggest using individual and focus group interviews with participants to further understand their perceptions about robotics, why they choose drawing certain types of robots, and what might have inspired their ideas. The researchers can use images drawn by students and teachers in other studies (e.g., current study) and ask participants if they identify the images as robots and why. These methods can generate more in depth data about student and teacher perceptions about robots and any misconceptions held by them.

Even though we had a limited number of participants, we believe that the findings of this exploratory study are not an exception. In our multi-year experience in working with teachers through various projects, we have learned that teachers have scant information about what robots are, what they can do, and what it takes to design, build, and operate them. We posit that given the limited direct experience in working with or observing robotics engineers, teachers (and students) mostly form their ideas about robots based on representations in media (e.g., science fiction books and movies). As shown in this paper, most of the teachers envision robots as sophisticated humanoid machines. When teachers convey such advanced and fantastical visions of robots to their students, it may cause students to believe that robotics engineering represents a highly sophisticated field in which a career for them may be unattainable. Thus, students may decide not to consider and pursue the field as their future profession. Another possible implication can be that learners with fictional views of robots might be disappointed as they enter the field where the reality of the work is different from their imagination.

Further investigations are required to understand dominant stereotypes and misconceptions about robots and develop approaches to correct them. Additionally, we propose that exposing students and teachers to robotics projects and robotics engineering work can serve as an effective intervention for them to develop more realistic and attainable views of robots and their capabilities. Finally, we argue that the draw a robot test has the potential to serve as an assessment tool for similar workshops and PD programs.

Acknowledgments

This work is supported in part by the National Science Foundation grants ITEST DRL: 1614085, DRK-12 DRL: 1417769, and RET Site EEC: 1542286; and NY Space Grant Consortium grant 76156-10488. The authors thank the high school teachers and their students for their participation in this study.

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