AC 2012-5376: A LOW-COST MANUFACTURING OUTREACH ACTIVITY FOR ELEMENTARY SCHOOL STUDENTS

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A Low-Cost Manufacturing Outreach Activity for Elementary School Students

Many postsecondary manufacturing programs across the country are exploring ways to reach out to K-12 students to help attract the next generation of students into Science, Technology, Engineering and Mathematics (STEM) careers. One effort to increase students' interest in such careers involves exposing them to STEM concepts through field trips to science centers, space centers, universities, etc. Unfortunately, with ever-tightening budgets many school districts are cutting back on field trips and extra-curricular activities that often accompany STEM outreach activities. This paper describes a research project in which we measured the effectiveness of a very low-cost robotics-related manufacturing outreach activity that was conducted with elementary school students. Existing educational robot kits such as LEGO® MINDSTORM® and Boe-Bot® were not used in this study in order to reduce costs and to allow the research team to investigate an outreach activity that is easy replicate because it does not require programming expertise or special equipment to deliver.

The principal investigators in this study were a faculty member from the Department of Psychology with expertise in cognition and child development and a faculty member from the Engineering Technology program with expertise in manufacturing and industrial automation. Graduate and undergraduate psychology and technology education majors helped deliver the outreach activities to the children.

Participants were 143 students (82 male), aged 6 to 10 years, from an elementary school in the Midwestern United States. A subset of students from second-grade (n = 29; mean age = 7.6; SD = .49) were exposed to in-class targeted instruction on robots and industrial robotics. First-, second- and third-grade students were used as a control group.

Data measures

For several decades, the "Draw-a-Scientist Test" (DAST)[1] has been used to understand stereotypes about scientists. Finson's[2] review describes the stereotypical image (i.e., white, male, lab coat, eye glasses) as consistent across ages, races and gender but also shows how this task has been used to demonstrate the effects of targeted interventions (e.g., exposure to alternate role models in science). Taking inspiration from the DAST, we created a "Draw-a-Robot Task" (DART) to determine the "stereotypes" about robots that may exist, and whether such conceptions may change as the result of instruction[3, 4].

All students completed the DART, which is a single-page assessment with the instruction, "In the box below, please draw a picture of a robot doing something robots often do." Below the drawing, students completed the following sentence: "My robot is doing ____." The students exposed to the intervention (i.e., robotics outreach instruction) also completed the DART the day after the intervention, and again three months later. These students also completed a brief journaling activity that asked them to describe what they learned about robots.

Description of outreach activity

The outreach activity was designed to introduce the elementary school students to industrial robotics and various topics related to programming industrial robots. As part of the outreach activity, the research team visited the elementary school on two occasions spaced one week apart. Before the students were told about the planned visit of the research team, they were asked to complete their first DART assessment.

The initial visit was broken into three 40 minute sessions. During the first session, two classes of second-grade students met with the project team to discuss robots. During this session, students were introduced to: (a) industrial robots and the tasks they often perform, (b) task planning and communication with robots (programming concepts), and (c) robotics-related jobs and the importance of studying math and science in school. Several short video segments (2-5 minutes each) showing industrial robots performing interesting tasks were also shown to the students during this session.

After the initial 40 minute session, the research team met with each of the second-grade classes separately for a robot programming activity. The goal of this activity was to engage the children in a fun, hands-on activity that would introduce them to the concepts of task planning, robot programming, and the coordinate grid. Since the students had not yet been introduced to the X-Y coordinate system, a grid utilizing the cardinal directions of north, south, east and west was used (see Figure 1). The grid was comprised of 3" squares which made it easy for groups of 4 or 5 students to work together. Using a simple robot programming language developed for this task (see Figure 2), students were asked to work with their group members to write a program that would cause an industrial robot to move five 2" square wooden blocks, each having one letter written on them, to designated grid locations to spell "ROBOT". Small font size letters printed on the grid helped the students place the blocks at the same grid location at the start of each program, and large font size letters showed where the blocks should be placed by the robot. One research team member worked with each group of children to document the program they developed, answer questions, and help the students stay on task. The research team did not make corrections to the programs developed by the students, and the student groups were limited to 20 minutes to create their programs. Figure 3 shows students working with research team members on this task.

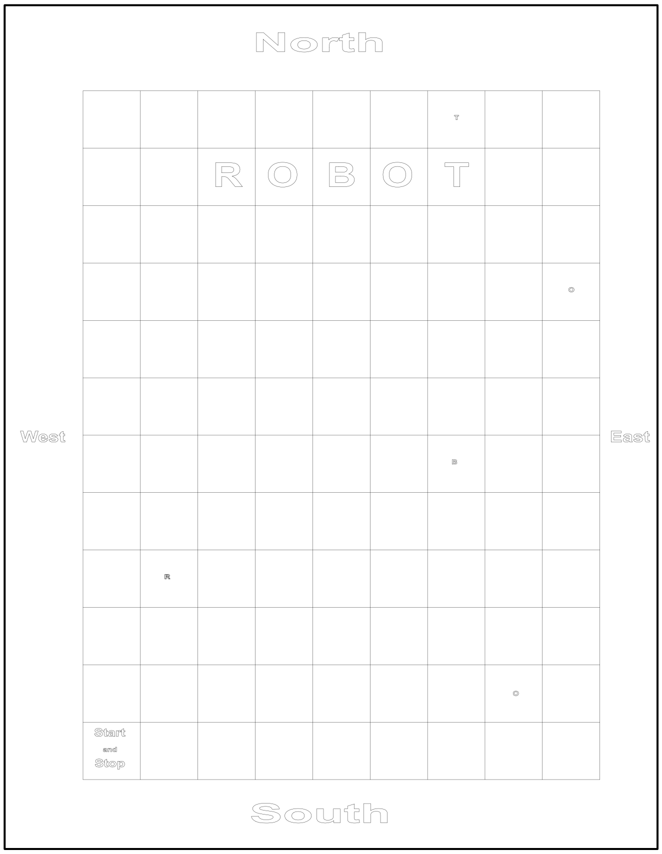

Figure 1. Robot programming grid

Instruction	Sample Program Statement
MoveNorth x;	MoveNorth 3;
MoveSouth x;	MoveSouth 2;
MoveEast x;	MoveEast 1;
MoveWest x;	MoveWest 5;
ArmUp;	ArmUp;
ArmDown;	ArmDown;
HandOpen;	HandOpen;
HandClose;	HandClose;

Figure 2. Robot programming instructions

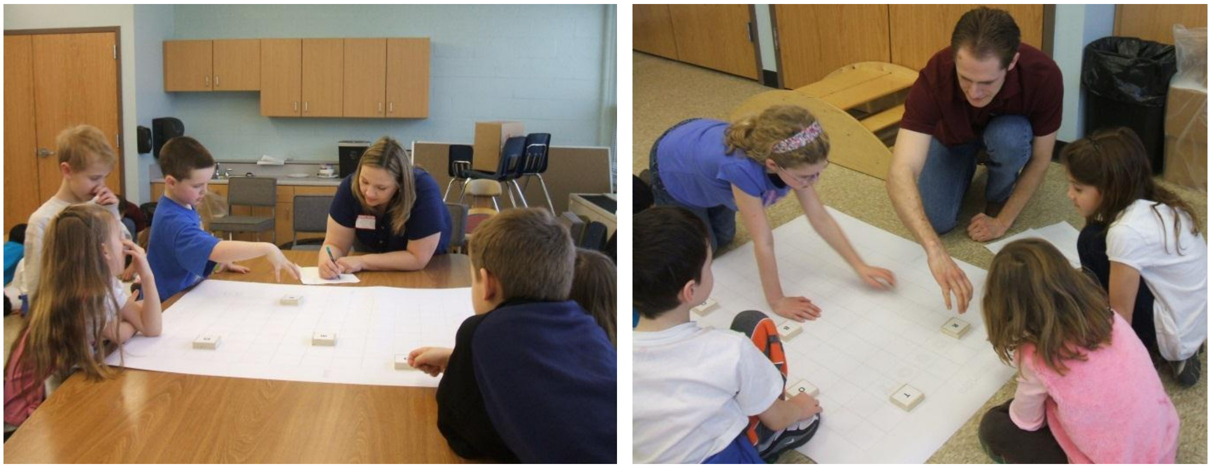

Figure 3. Students working to create a robot program

After the groups of students finished creating their programs using the 3”grid paper, a larger grid was laid-out on the floor using the 12” square floor tiles as the grid. For this activity, the 2” lettered wooden blocks were replaced with 8” cardboard boxes. During the remaining time in the 40 minute session, each group read their robot program out loud to the class while a student volunteer acted as a robot to complete the tasks as programmed. If a robot program contained errors, as many did, the “human” robot would move unexpectedly and would not successfully complete the task of spelling “ROBOT” on the floor. This led to problem-solving sessions that required the children to work together to determine what was wrong with the program how the program could be corrected (i.e., real-time “debugging”). It also helped students better understand the concept that robots do not have human intelligence and humans must plan and write error-free programs for industrial robots to complete a task properly. Figure 4 shows the “human robot” executing a robot program.

Figure 4. Students running their programs using a “human robot”

During the week between the research team visits to the school, the second-grade teachers showed several additional short robot videos to the students. These videos were selected to show industrial robots performing tasks the students could relate to. For example, robots where shown decorating cakes, packaging pancakes and candy, and making shoes and toys. An annotated bibliography of the videos was provided to the teachers to help them choose videos they thought would be of interest to the class and to help explain what was happening in the video.

On the final visit to the school, the research team met with the two second-grade classes separately for a second hands-on programming session. The programming session made use of the same 3” grid paper and programming language used in the first session. This time, however, the programming task required the robot to manipulate five 1” diameter wooden dowel pieces that were 2” long. On the end of each dowel an upper- or lower-case letter was printed. The dowels were placed on the grid with lower-case letters facing up spelling “robot”. The students were instructed to program the robot to move the dowels to new locations with the upper-case letters facing up to spell “ROBOT”. At first the students thought this would be an easy task since it was quite easy for them to pick up a dowel with their hand, flip it over, and set it down in a new position. The researchers asked the students to imagine if a robot would be able to rotate the dowel using a gripper as they did with their hand. To help illustrate the limited dexterity of a robot, the students were given a pair of kitchen tongs and asked to flip the dowel using the tongs rather than their hands. The students quickly understood that the limited dexterity of the robot would need to be overcome in order to complete their assigned task. The students were then given a Vee-Block but not shown how it could be used to help with this task. With the help of their peers and some guiding questions from members of the research team, the students figured out that the dowel could be temporarily placed in the Vee-Block and picked up again in another orientation to complete the programming task. Figure 5 illustrates the dowels, Vee-Block, and kitchen tongs used in this programming activity. A new programming instruction called “FlipIt” was added to the list of programming instructions to help students complete this programming task.

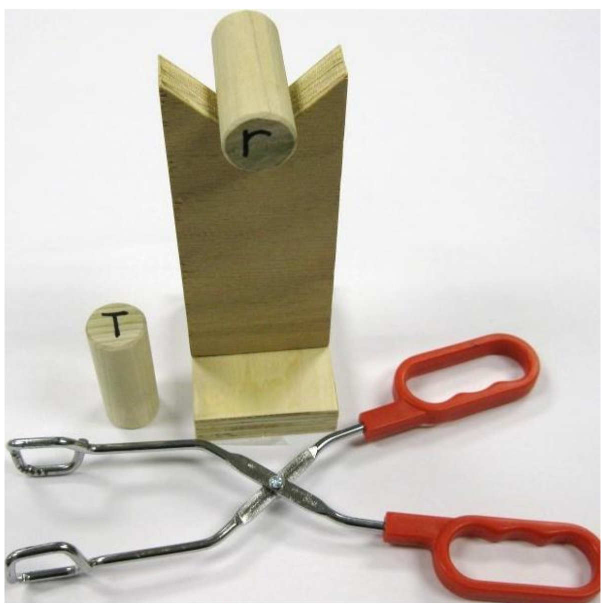

Figure 5. Vee-Block, Dowels and Kitchen Tongs

Results

Coding schemes for the DAST focus on physical characteristics of the scientist and symbols of knowledge and research[2]. We developed an initial coding scheme for the DART to account for both physical characteristics and the robot activities, beginning with our knowledge about real and fictitious robots. The coding scheme was refined in a data-driven way. Recurring characteristics were noted and added (e.g., “multiple limbs” and “dancing” were unexpected). Some categories were collapsed for characteristics (e.g., “smile” and “smile with teeth”) and activities (e.g., sports and leisure activities were grouped together).

Coding of the pre-intervention and control group DART assessments (n=143) showed that 91% of the children thought the typical robot had a humanoid appearance and performed tasks such as work/helping activities (32%), dancing (28%), fun/leisure activities (13%), and fighting/battle (9%). For the students who participated in the outreach activities, drawings at post-test and after a 3-month delay showed that the students’ conception of robotics had changed from naïve to realistic. Figure 6 illustrates sample pre- and post-intervention student drawings and Figure 7 provides a summary of the coded DART assessments.

Figure 6. Sample DART assessments showing a pre-intervention humanoid robot (left) and post-intervention industrial robots (right)

	First drawing (n=143)	**First Post-Intervention drawing (n=29)**	**Second Post-Intervention drawing (3 month delay) (n=29)**
Industrial	1%	90%	86%
Humanoid	91%	3%	14%
Rover	8%	7%	0

Figure 7. Summary of coded DART assessments

The students exposed to the intervention (i.e., robotics outreach instruction) also completed a brief journaling activity that asked them to describe what they learned about robots. The journal entries were analyzed and salient themes were noted. Figure 8 provides a summary of the post-interview journal entry themes.

Sample Journal Entry Categories	**n**	**%**
It can do specific tasks (e.g., surgery, makes cakes, work in a factory, build cars, cut things, make shoes, etc.)	29	100%
You have to give it directions/tell it what to do	16	55%
Speed (it can move fast or slow)	15	52%
You must program it (with computer)	11	38%
Moves in specific directions (cardinal directions)	11	38%
Size (some are large and some are small)	8	27%
It does "dirty jobs"	7	24%
Won't harm humans/safety	5	17%

Figure 8. Summary of post-intervention journal themes (n=29)

Conclusions

This study revealed that the elementary students' conceptions of robots changed from naïve to realistic with instruction, and this change was reflected in their drawings both immediately and after a 3-month delay. Furthermore, student journal entries and teacher comments clearly indicate that the students enjoyed the outreach activity. Anecdotal comments from the teachers also suggest that the robot programming activities facilitated student learning in mathematics later in the school year during an introduction to the coordinate system grid.

Key characteristics of the outreach activity include the following features: (a) it is very low-cost; (b) it minimizes the impact on the children's school schedule; (c) it engages the children in hands-on learning in small groups; and (d) it has a measureable impact on students' conception of industrial robots immediately and after a 3-month delay. Taken together, the features of the student activities and the positive results make this an ideal outreach activity to be implemented by postsecondary manufacturing programs.

Acknowledgements

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