Informal STEAM Education Case Study: Child-Robot Musical Theater

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ABSTRACT

STEAM education fuses arts with traditional STEM fields so that the diverse disciplines can broaden and inform each other. Our eight-week STEAM afterschool program exposed elementary school children to social robotics and musical theater. Approximately 25 children grades K-5 participated over the course of the program with an average of 12 children attending each week. The program covered acting, dancing, music, and drawing with the robots in two-week modules based around the fairy tale, "Beauty and the Beast". The modular design enabled children who

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could come to only a few sessions to participate actively. The children demonstrated enthusiasm for both the robots and the musical theater activities and were engaged in the program. Efforts such as this can provide meaningful opportunities for children to explore a variety of arts and STEM fields in an enjoyable manner. The program components and lessons learned are discussed with recommendations for future research.

1 INTRODUCTION

STEM (Science, Technology, Engineering, and Mathematics) education has expanded over the years to STEAM (Science, Technology, Engineering, Art, and Mathematics). Among numerous others, our focus is to combine robots and musical theater in an afterschool program for elementary school children in rural areas, and more specifically, socio-economically underprivileged students. We believe that this combination offers an unusually rich and engaging means of introducing groups of children to the core ideas of STEAM education. Robotics can easily lead into discussions of programming, math, physics, human-robot interaction, animation, etc. Musical theater meanwhile lends itself to discussions of music, singing, acting, drawing, painting, costume design, and more. Our modular program design is both flexible and extensible. Other groups with access to a robot or multiple robots should be able to modify the program to suit different ages, skill levels, timeframes, and productions. Our program contributes to demonstrating a new format of STEAM program and providing a structured process that others can easily follow. We hope that sharing our experiences and recommendations can promote "robots for all" efforts and other STEAM activities.

2 RELATED WORK

Using robots in classroom environments for educational purposes has been proposed by a number of researchers and commercial entities [e.g., 1]. The LEGO Mindstorms program teaching robotics and programming could be considered relatively mainstream in the United States at this point. Robotics is particularly attractive in an educational context because it has potential to help narrow the gender gap in STEM fields by increasing girls' interest in STEM careers and their perception of their own abilities [2]. Unlike most previous work using robots in the classroom, our project does not focus on teaching particular skills, but on general exposure to STEAM fields with a heavy emphasis on robotics and the arts. Robots have been used in theater productions by a number of research groups [e.g., 3]. The focus of these projects tends to be improving the social interaction of robots and producing art. Theater is an attractive test bed for HCI research in that it incorporates numerous aspects of social interaction in a relatively constrained environment. Furthermore, most robot theater projects thus far have focused on robots interacting with adults, though [4] included some theater activities within a STEAM education program for children. Unlike the existing adult theater, our focus is not on developing novel techniques to improve robot interaction, but on educating toward elementary school children with musical theater.

3 METHODS

The eight-week program was divided into four two-week self-contained modules to allow children

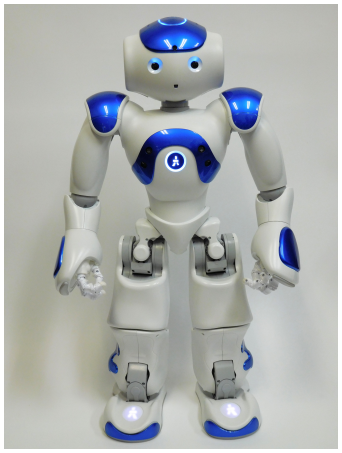

Figure 1: NAO, a humanoid robot.

Figure 2: Pleo rb, a dinosaur robot.

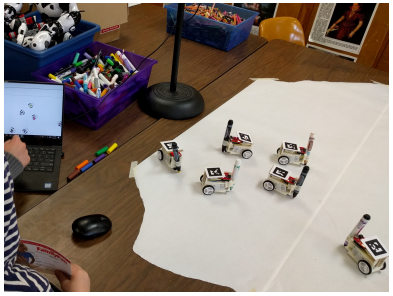

Figure 3: Swarm robot with markers.

who did not attend consistently to participate in our program. We approached teaching using techniques based on situated learning [5] and cognitive apprenticeship [6]. Using the context of the "Beauty and the Beast" story, children learned about different aspects of musical theater and how to interact with the robots as needed for the individual activities. During both planned activities and free play sessions, researchers discussed and demonstrated the processes of programming the robots, writing scenes, creating sound effects, etc. giving the children opportunities to observe successful efforts and strategies for troubleshooting.

3.1 Participants

The Dollar Bay Elementary School hosted our afterschool program. Twenty-five children total attended over the course of the program. An average of 12 kids participated each week. Twenty-one participated to at least some degree in the consent process. As most research studies involving children, we required both parental permission and the children's verbal assent to participate in the study. The research protocol and supporting documents were approved by the Institutional Review Board. We collected demographic information from 16 participants via a verbal questionnaire. The children had an average age of 7.69 years (*SD* = 1.70) with 12 female participants and 4 males. Their grade levels ranged from kindergarten to 5th grade. Race and ethnicity data were not collected as the questions could be confusing for young children.

3.2 Story

Rather than using a published play, we used the fairy tale "Beauty and the Beast" with an emphasis on the 1991 Disney version. The story was attractive in large part because of its familiarity and the familiarity of its music. Having young children write their own scripts had proven difficult in the previous research and a familiar story had the benefit of being easier for infrequent participants to pick up. The timing of the program also allowed us to capitalize on the excitement surrounding the release of the live action version of "Beauty and the Beast".

3.3 Robots

Our primary robot was Nao (Figure 1), a small humanoid. It was particularly well suited for use in a theater context because of its size, text-to-speech engine, relative ease of animation, and friendly appearance. Besides, we also used Pleo rb (Figure 2), a dinosaur robot and small vehicle swarm robots (Figure 3) for the drawing module. A variety of other robots, including Mindstorm EV3, Romo (mechanical), Robosapien, Darwin OP2 (humanoid), and Zoomer (animal) were included as references for characters and for playing (Figure 4).

3.4 Modules

Four modules were designed based on the needs of the story, the abilities of the robots, and the time available. Each module lasted for two consecutive weeks. The planned activities were followed by free, supervised play with the robots.

3.4.1 Acting. The first week of the program included an introduction to the program, the research, and the robots. Further goals of the acting module included having the children understand the basic characteristics of the different robots and begin to learn how to control the robots' behavior and speech. We also gave an oral retelling of an early version of the tale and discussed some of the

Figure 4: Researchers with robots at school.

Figure 5: Collaborative scenery drawing by swarm robots and children.

story's variations. This prepared the children to consider a new version of the tale including robots. They were then split into groups. Each group was asked to cast themselves and the robots as characters in the story. After casting, each group was tasked with writing the dialogue for a scene in the story. Then, they took the time to begin rehearsing the scene they had written. The second week of the module began with viewing a clip of Disney's "Beauty and the Beast" wherein Belle met the Beast for the first time. After several of the robots and researchers acted a modified version of the scene, the children also played roles in the scene with the robots. For several repetitions, children rotated parts.

3.4.2 Dancing. The goal of the module was to have children learn some of the finer points of robot control and animation, while also learning about types of dance and how movement is coordinated with music. The discussion of dance was started by watching the "Beauty and the Beast" scene where Belle and the Beast waltz and by talking about various types of dance, i.e., ballet, tap, ballroom, swing, etc. We transitioned from discussing all dance to ballet and introduced the basic positions for arms and legs. The Nao humanoid robot was used to demonstrate the arm positions (leg positions were infeasible). The children practiced both. The following week began by watching the animated dance again briefly and then comparing it to a live-action video of a formal waltz. We then split the children and taught their respective parts of the waltz box step. With all the children together again, we had them match brief segments of the robot dancing to music clips to demonstrate the relationship between dance choreography and music. Finally, we animated the children's song, "I'm a Little Teapot" with the traditional movements using the Nao robot. The physical manipulation of the robot and the programming was handled by one of the researchers with the children watching the proceedings and directing the actions. The children sang the song and also danced themselves. They made Nao dance using the remote-control we had developed.

3.4.3 Music & Sound. The music & sound module was intended to teach children about the role of sound in art and how to produce their own sounds. A video clip of the classic cartoon, "Tom and Jerry" introduced the children to sound effects and was followed by a documentary clip describing Foley design. Once the concepts had been introduced, the children recorded their own sound effects on sound cards. Then, they split into groups and used the sound cards to record sounds for the characters of "Beauty and the Beast". In the following week we played the character sounds that had been recorded in the previous week and discussed which sound should belong to which character. We also had the kids sing part of the song, "Beauty and the Beast" in chorus and recorded it on one of the sound cards. Finally, we had notes of the theme programmed to correspond with poses of the Nao robot. The children ordered the movements to play a brief snippet of the song.

3.4.4 Drawing. For the drawing module, we wanted children to express themselves through visual media and robots. The section began with an overview of character designs seen in various productions of "Beauty and the Beast". The children were then asked to draw one of the robots as one of the characters in the story with each child being assigned a particular combination. When that exercise was completed, another collection of images depicting real and imagined castles was shown and set design was discussed. Then, we moved on to an explanation of basic three-

Table 1: Perceived roles of robots by kids after the program

	Helper	Friend	Teacher	Superhuman	Pet	Toy
1	v	v	v		v	v
2		v	v	v	v	
3	v	v				
4		v	v			
5	v	v				
6		v	v			v
7	v	v				
8	v	v	v			
9		v	v	v	v	
10	v	v				
11	v	v				
12						
13	v			v	v	v
14	v	v		v		v
15		v			v	v
16	v	v				
17	v	v		v		
18						
19	v					
20	v	v	v	v		
21	v	v	v	v		

Table 2: Kids' responses about the swarm robots

• **How the swarm robots followed your drawing**: **close understanding** - "camera is tracking the little cars and camera is connected to the computer", **conceptual understanding** - "they are programmed", "connected to computer", "robots were programmed", "a person teaches how to draw and show the lines, and robots can remember and draw them", **no understanding** - "I don't know"
• **How the swarm robots are different from other robots**: **appearances** - "smaller", "they have numerous", **functions** – "can color", "draw", "need a computer [but] others didn't", "working as a group", "they can talk", "programming is different, less complicated"

dimensional geometric shapes and how they might be used to draw buildings. The children used the shapes to draw Beast's castle. The final week of the drawing module started with a discussion of modern art with a focus on geometry-based pieces in particular. We then began discussing the swarm robots. Attaching markers to the robots with masking tape, the swarm robots could be made to draw on a piece of banner paper to create background scenery. The children took turns planning paths for the robots and making them draw. Once all the children had a turn, they were given crayons and markers to draw on the paper themselves (Figure5). We returned following the conclusion of the program to conduct final interviews.

3.5 Design & Procedure

The research took place in the art room and library of the elementary school. Both rooms were familiar to the children. Rather than desks, the rooms had tables so that the children could sit in groups and there was safe operating space for the robots. The demographics questionnaire was very brief. Children were pulled aside to talk one-on-one with a researcher for the assent procedure and demographic questionnaire, which were completed verbally. These initial conversations took place in the same room as the main activities to maintain appropriate levels of supervision by the program staff. Subsequent interviews took place during the session following each module. Similar procedures were followed with children having one-on-one interviews with a researcher off to the side while the main activities continued in the room. The final interviews were conducted after the conclusion of the program. The staff of the program were interviewed at various points during the program depending on availability. The core objective of the program was to increase interest and awareness of arts and technology while highlighting their complementarity and leveraging the familiar aspects of each to introduce and motivate new content. We were also curious if and how children could grasp the facts, processes, or mechanisms in robotics. We considered observed and reported interest, as well as engagement in the program and activities as indicators of success in reaching this objective. In addition, we were interested in the practicalities of the program and how it might be improved for the future.

4 RESULTS, CRITICAL REFLECTION AND DISCUSSION

Overall, this program was successful in getting and keeping the children excited about our robot- theater program. The staff reported that the children were still talking positively about it months after the study concluded. The children were excited when we arrived with the robots and frequently asked their parents to let them stay longer if they were picked up before the session wrapped up for the day. They particularly enjoyed the free play time with the robots. Touching the robots held special interest, e.g., Pleo, the dinosaur covered in a soft coat, and Zoomer, the canine robot. Nao's text-to-speech engine allowed it to say some of the children's names and that also received a very positive response. The staff remarked that the children were as engaged as could be expected for the age group. During both the structured activities and the free play, we observed peer-to-peer interactive learning with students explaining to each other how to operate the robots or complete a task. When asked to select their favorite robot, most children chose Nao (humanoid) and Pleo (animal), which is in line with previous iteration. However, it was also because that

Table 3: Recommendations for future research

• **Use a familiar story rather than making a new one**: more comfortable and easier to manage fluctuating attendance.
• **Use scaffolding and explicit instructions**: less frustration than the problem-solving approach
• **Use the modular curriculum**: easier to manage given the program's attendance constraints than having one continuous project.
• **Use detailed planning and a variety of activities** (e.g., free play): giving the flexibility to vary the time allotted to planned activities as needed and allowing researchers to observe the children as they explore the robots for themselves.
• **Balance groups**: (collaborating with school staff) organize effective groups for the activities taking personality, age, and social dynamics into account.
• **Ensure child-friendly communication** (images instead of text, tangible artifacts to manipulate): simple and short enough for the children to follow well.
• **Make the environment kid-friendly and safe:** familiar and comfortable to the children
• **Do not make the research a test** (designed to be ungraded and did not have any sort of pass/fail standard): avoiding peer-pressure issues.

specific robot was randomly assigned to the children in a previous activity, which suggests that children form emotional bonds with robots quite quickly. Of the individual activities, several stood out as favorites both from behavior during the session and from interview responses: acting out the script with the robots, recording sound effects on the sound cards, and for the girls, learning the waltz steps. On the other hand, the children had difficulty with generating dialogue in the initial script writing exercise and struggled to draw the robots as characters in the play. From the interview data, we examined the roles children believed robots could play (Table 1). The most common role was "friend" with 17 children indicating they believed a robot could be their friend. The second most common with 14 recordings was "helper", which included tasks such as assisting with washing dishes and babysitting. "Teacher" came up for 8 children. Flying around the world and time travel were both mentioned as "superhuman" feats children wanted robots to perform for them. Seven children wanted a superhuman robot. "Pet" and "toy" came up with 5 of the children each. One specific success in familiarizing children with robotics was having them learn about the swarm robots. Some of them understood the mechanisms behind the drawing swarm robots and the differences from other robots (Table 2). Our efforts tie in with recommendations for working with children in literature [7]. Based on our experience, we listed our recommendations for future research (Table 3). Currently, programming the robots has to be done by the research team either in advance or while demonstrating the process for the children. This is partly due to the difficulty of programming the robots, but also simply because of the high child-to-robot ratio. There has been significant work done on making coding more accessible to children, so even if we cannot have the children program the robots themselves, it would be interesting to use child-friendly tools on PCs and tablets, or even to use tangible blocks to explore programming, perhaps using a simulated robot. Musical theater with robots provides an engaging way to expose children to STEAM fields. While it may not be suitable for exploring any one field in depth, the variety offers its own benefits. Our modular scheduling was well suited to a weekly afterschool program. We hope that this structure provides the flexibility required for other research groups to use their resources in similar endeavors to bring STEAM education to more students.

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