Robot-Theater Programs for Different Age Groups to Promote STEAM Education and Robotics Research

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ABSTRACT
Issues with learner engagement and interest in STEM and robotics fields may be resolved from an interdisciplinary education approach. We have developed a robot-theater framework using interactive robots as a way to integrate the arts into STEM and robotics learning. The present paper shows a breadth of our target populations, ranging from elementary school children to college students. Based on our experiences in conducting four different programs applied to different age groups, we discuss the characteristics, lessons, design considerations, and implications for future work.

CCS CONCEPTS
• Social and professional topics~Computer science education

KEYWORDS
Robot Theater; STEAM Education; Multiple Generations

ACM Reference format:

FirstName Surname, FirstName Surname and FirstName Surname. 2018. Insert Your Title Here: Insert Subtitle Here. In *Proceedings of ACM Woodstock conference (WOODSTOCK'18). ACM, New York, NY, USA, 2 pages.* https://doi.org/10.1145/1234567890

1 INTRODUCTION
Robot-theater is a new paradigm utilizing interactive robots for educational purposes through creating and performing live theater plays. It has arisen with the educational needs for teaching interdisciplinary subjects and facilitating STEAM (STEM + arts and design) education [1-2]. The main motivation is to support students' learning by integrating unfamiliar contents (e.g., STEM and robotics) with familiar formats (e.g., arts) to make the whole process more accessible [1]. Also, the full embodiment of robots offers an opportunity for students to engage more in the task and educational environment [3]. Under this paradigm, we conducted four different robot-theater programs with students of different age groups. The present paper compares these four programs and provides lessons and design considerations for future work.

HRI '20 Companion, March 23–26, 2020, Cambridge, United Kingdom

ACM ISBN 978-1-4503-7057-8/20/03. https://doi.org/10.1145/3371382.3378353

2 ROBOT-THEATER PROGRAMS
The features of the four programs are briefly depicted in Table 1. Across the four programs, a variety of robots were used, including programmable robots (humanoid: Nao, Darwin, and Pepper; animal: Pleo rb and Aibo; imaginary creature: Romo and Mindstorm EV3), non-programmable toy robots (humanoid: Robosapien; animal: Zoomer; mechanical: BB-8), a voice-controlled smart speaker (Amazon Alexa), and open-source swarm vehicle robots (MICROMVP).

2.1 Child robot-theater afterschool programs
The child robot-theater program was developed to promote STEAM education to socio-economically underprivileged children by using interactive robots and different forms of arts. The first and second afterschool programs were held at the same elementary school in a rural area of the U.S. (Fig.1.(a)) [4-5]. The second program was different from the first one in that (1) it was composed of four different modules so that students who were not able to continuously attend could catch up the program easily and thus, there was no final performance and (2) instead of creating a new story by children, a well-known familiar story was used for theater.

(a) (b)

Fig.1. (a) Performance in the afterschool program (b) Robot demo in the summer youth program

Table 1. Four robot-theater programs across different age groups

Program	Elementary Afterschool Program	Elementary Afterschool Program	Highschool Summer Youth Program at University	Research Workshop at University
Students	Socio-economically underprivileged students in a rural area	Socio-economically underprivileged students in a rural area	Highschool students from Central Asia, Middle East, and North Africa who are interested in science and technology	Graduate and undergraduate students who are interested in robotics and HRI research
Objectives	Promote STEAM Education	Promote STEAM Education	Promote STEAM & Robotics Education	Promote Robotics & HRI Research
No. of Participants	12	25	40	8
Average Age	6	7.7	16.1	Above 20
Period (Total Hours)	11 weeks (11 hours)	9 weeks (9 hours)	1 day (2.5 hours)	1 day (3 hours)
Main content	Introduction, Robot Demo, Scenario Writing, Clay Character Making, Scenery Drawing, Rehearsal, & Performance	Introduction, Robot Demo, Acting, Dancing, Music and Sound, & Drawing Modules	Introduction, Robot Demo, Robot Programming, Scenario Writing, Rehearsal, & Performance	Introduction, Robot Demo, Research discussion, Robot Programming, Scenario Writing, Rehearsal, & Performance

2.2 Robot-theater programs for youth and college groups

The third iteration was planned as a part of a summer youth program for high-schoolers to promote STEAM and robotics education (Fig.1.(b)). The program was an international summer exchange program for ages 15-17 girls from all over the world who are interested in science and technology. We conducted two sessions with 20 participants in each session on the same day. The last program was conducted on a college level to promote robotics and HRI research. College students from Industrial and Systems Engineering and Computer Science participated in the program. This program was similar to the third one, but related academic research in HRI with presented robots was briefly introduced in the beginning part so that students can be motivated to engage in HRI research more. Different from the previous programs, the robot taxonomy (e.g., anthropomorphic- and zoomorphic robots), physical constraints, and the debugging process were instructed. Since the time schedule for these programs was much shorter and the participants' age range was different from the elementary school students, we made the programs much more compact.

3 OBSERVATIONS AND LESSONS

Four programs were designed with different goals and expectations. For the first two afterschool programs, we fused different forms of arts (e.g., theater, drawing, music, and dance) with STEM contents (physics, math, psychology, geometry, etc.) since arts are easier to approach and fun to learn for kids. Our summer youth students and college students already pursued STEM in their career, but the robot-theater program still promoted robotics and HRI research by providing new opportunities to imagine, conceptualize, and enact robotics research topics.

The entire time scale was different. We conducted the elementary afterschool programs for 9-11 weeks, while we conducted the summer youth program and college student workshop within 2-3 hours. Elementary school students had to spend a couple of weeks to memorize their lines, but it was not necessary for high school and college students. From the first testbed project, we have learned that we have to create our programs considering students' age and developmental stage [6]. For example, in the first program we had our students write their own script, which turned out too difficult for 5-6 years old children. In the second program, instead, we used a well-known story for our robot theater program. However, high school students and college students could easily compose their own story line even though they had to complete the writing part within 20-30 minutes. In line with this, our approach to programming was also different. For elementary school students, we played the Simon Says game to teach the "if-then" concept and children used the remote to control robots. In contrast, the high school and college students learned robot programming to control their robots for their play. This art and technology integration project was also a great way to promote STEAM to female students. All 40 students were female in the summer youth program and more than half participants were female students in other programs as well. Moreover, the first two afterschool programs were designed and led by two female PhD students and the summer youth program was designed and led by two female undergraduate students.

4 CONCLUSION AND OUTLOOK

We have developed the robot-theater framework for the use of interactive robots in STEAM and robotics education for different generations. All four iterations of the robot-theater program have shown promise in increasing learner engagement and interest in STEAM and robotics research fields. That could only be successful when we considered participants' different developmental stages and leaning skills. We believe that this robot theater program can also serve as a great catalyst to implement various robotics and HRI research topics, such as robots' autonomy, mobility, facial expression, and speech-based emotion recognition. Involving older adults in future robot-theater programs would be of interest to see its effects on the new population. We hope that this robot-theater program can be more broadly used as an educational program and research tool.

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