Investigating the Effects of Demographics and Framing on the Robot-Theater Program

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While STEAM (Science, Technology, Engineering, Arts and Mathematics) education programs have shown promise in increasing students' interest in STEM and arts & design fields, the effects of demographic and other contextual factors have not been thoroughly investigated yet. While conducting robot-theater summer youth sessions with forty participants of the TechGirls international summer exchange program, we explored these factors. Participants in teams of four to six students created a script for a theater play that required the use of programmable robots. Results seem to suggest the influence of demographic factors such as nationality, as well as the effect of framing on participant attitudes towards robots and STEAM education. Subsequent validation of these effects in other studies is expected to contribute to refining the design of robot-theater and other STEAM education programs.

INTRODUCTION

Advancements in emerging technologies, from robotics to artificial intelligence, have brought about new ways for human-computer interaction (HCI) to support users. This progress has led, in the case of educational technology, to the development of new concepts for the promotion of STEM education. Notably, STEAM (Science, Technology, Engineering, Arts, and Mathematics) education programs have gained traction in recent years. The integration of arts and science provides individuals with more creativity to enrich one's way of thinking and grasp STEM concepts, leading to STEM innovation (Land, 2013). On the other hand, the increasing use of robots in daily life, starting as autonomous agents (Floreano & Mondada, 1994), has opened up opportunities for human-robot interaction that can improve user engagement, learning, and experience. Robots have proven to be a valuable partner as nurses for the elderly (Wada, Shibata, Saito, & Tanie, 2004), a dancing partner for children (Michalowski, Sabanovic, & Kozima, 2007), and a multitude of other roles.

The integration of robots in a STEAM education setting can thus combine benefits to both approaches. Robot-Theater programs have shown promise in effectively engaging users to practice and learn STEAM skills (Barnes, FakhrHosseini, Vasey, Park, & Jeon, 2020; Jeon et al., 2016). Additionally, such programs have also been found to reduce social anxiety and improve social interaction in children with Autism Spectrum Disorder (ASD) (Kaboski et al., 2015; Sartorato, Przybylowski, & Sarko, 2017; Zhang, Jeon, Park, & Howard, 2015). However, many factors can affect user acceptance of social robots, and in turn lead to decreases in participants' engagement, trust, and motivation in STEAM education programs. Studies have shown that demographic factors such as users' previous exposure to relevant technologies, age, and culture influence users' perceptions and acceptance of social robots (Flandorfer, 2012; Reich-Stiebert & Eyssel, 2015).

In view of past implementations of the Robot-Theater program, and in the interest of exploring demographic trends amongst youth, the present study conducted Robot-Theater summer youth programs with female high school students as part of the TechGirls program. TechGirls is an international summer exchange program, including female students between the ages of 15 and 17 years old from the United States as well as Central Asia, the Middle East, and North Africa (MENA) who are interested in science and technology.

Other objectives of this research included introducing robotics to the participating students, practicing and promoting STEAM skills while programming and integrating robots into a theater play. Students were asked to program or train at least one of those robots to act as a character in their own theater play. Results of their created scene were recorded in videos and a post questionnaire was administered for participating students to express their opinions and perceptions about robots and the program activity.

METHOD

Participants

Forty female participants were all part of the TechGirls summer program, and their age ranged from 15 to 17 years old (M = 16.13, SD = 0.686). The participants came from the United States as well as eight countries from Central Asia, North Africa and the Middle East (Uzbekistan, Kazakhstan, Tajikistan, Kyrgyzstan, Lebanon, Palestine, Tunisia, Algeria). The TechGirls program had various activities planned for participants over its duration (one and a half weeks during summer), and the Robot-Theater program was conducted in two separate sessions on a single day. For each session, twenty participants took part in the three-hour program, for a total of forty participants. In each session, participants were asked to separate into four separate teams.

Robots

In our Robot-Theater program, we provided four different robots. Nao and Pepper were the two primary robots with the following characteristics:

Nao-V6: height: 574 mm (22.6 in), depth: 311 mm (12.2 in), width: 275 mm (10.8 in).

Pepper-V10: height: 1.20 m (4 ft), depth: 425 mm (17 in), width: 485 mm (19 in)

Both robots possess programmable functions, such as text to speech, and moving body parts that are accessed through Choregraphe, a software that enables drag-and-drop programming features. This ease of use made Choregraphe a conducive medium for participants to program robots in a theater play setting. Two additional robots were also provided, in the form of Aibo (ERS-1000), a dog-like robot, and an Alexa device (Amazon Echo Dot 3rd generation). While Aibo was not scheduled to be programmable during the activity, the robot could perform many dog tricks that could be triggered with specific keywords. Alexa could likewise be programmed to voice out specific lines prior to the start of each team's play.

Procedure

The Robot-Theater program took place in a classroom environment in Virginia Tech's university campus. The room was arranged in a way to encourage group cooperation with desks placed in clusters close to one another.

Preliminary phase: The session started with a brief introduction of the program and the Mind Music Machine Lab's research interests. The four robots used in the session were then introduced to participants through short demonstrations of each robot. Demonstrations sought to highlight important interactions each robot was capable of. Aibo's abilities were demonstrated by performing tricks, such as kicking a ball or sitting down after being prompted to do so. Nao's demo had the robot perform a Tai Chi dance, highlighting its ability to move its arms and legs, and the range of physical maneuvers it could execute. Instructors briefly demonstrated to participants how Pepper could be programmed to engage in a conversation through the same software as Nao (as seen in Figure 1). Participants were also informed that Alexa could be programmed to respond to select statements. Twenty minutes were spent in this phase.

Figure 1: The preliminary phase of the Robot-Theater session

Choregraphe tutorial: Once each robot was properly introduced, the instructors presented Choregraphe and its functions in a step-by-step live tutorial. The participants followed the tutorial along with laptops provided by the TechGirls program. The two main instructors for the session were female undergraduate members of the Mind Music Machine Lab. Three more assisting instructors, graduate students from the same group, were also present around the room to help anyone who may seek further help with the software. Participants first learned how to connect to each robot, with instructors ensuring all participants could achieve this step. For the purposes of the program, participants were instructed to use virtual renditions of the robots and their actions so the main robots could be controlled by the instructors. Additional functions that were presented to participants included activating and deactivating an autonomous mode, as well as utilizing various movement options for both robots. As participants would have to integrate either of the two robots into a theatrical play, conversation functions such as "Say" and "Speech Recognition", that can be used to have the robots speak, were extensively discussed during this phase. The instructors actively answered participants' inquiries and ensured all participants could program all showcased features. This phase lasted thirty minutes in total.

Team formation and script creation: Once participants felt comfortable with using Choregraphe, instructors started explaining the group activity. Participants were instructed to divide into four teams of four to six students and would create and act out a script for a theatrical play. Requirements for the script each team would create were as follows:

- Every group member must have more than one line.
- At least one programmable robot, Nao or Pepper, must be used in the play.
- Robots must have at least ten lines.

Story scripts could revolve around any specific topic. The instructors suggested sample themes: human-robot collaboration in work, study, or research, interactions with robots for emotional support, or collaboration on accessibility issues. Additionally, a sample play made by the researchers was shown to participants. This play showcased both Nao and Pepper interacting with the instructors as classmates and served to help participants visualize and grasp instructors' expectations as for the length and content of user-created scripts. Participants were given thirty minutes to collaborate, brainstorm, and create their scripts as a team. Once a group claimed that they were done scripting their production, an instructor checked the script to ensure all script requirements were met. Finally, each team provided the script to the instructors who categorized the theme of each play and the role assigned to robot actors.

Robot programming phase: In this half hour phase, TechGirls participants programmed voice lines and commands for robots they chose as actors in their play. Teams collectively worked on testing programmed features with the virtual robot (as seen in Figure 2). The instructors in this phase helped teams navigate programming errors and other related inquiries.

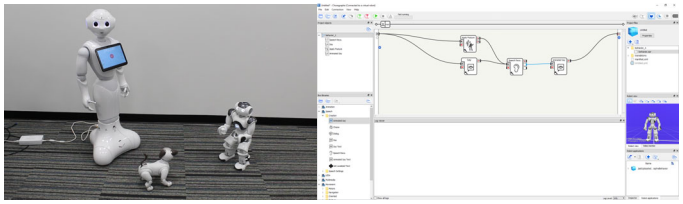

Figure 2: First image: from left to right - Pepper, Aibo, and Nao. Second image: screenshot of Choregraphe software, with a virtual robot in bottom right side of the screen.

Live theater performance: Each team was given the chance to practice the live theater play at least once. Following a successful rehearsal, each team performed again while being recorded by the instructors. Consent for recording was obtained prior to the session by the TechGirls program. The final run of the play took each team an average time of 1 minute and 39

seconds, with a standard deviation of 41 seconds. The instructors ensured that robots ran at the correct times during each run of the play so that participants could focus on acting. Once every team's project was filmed, the lab staff played the recordings on the overhead projector for participants to watch one last time. While the participants watched their creations unfold, they were each asked to fill out a survey regarding their experience at our Robot-Theater program. Rehearsing, performing, and watching all four plays took thirty minutes.

Closing comments and subjective questionnaire: The instructors passed subjective questionnaire forms to participants. Demographic measures collected included participant age, grade, nationality, and exposure to robots prior to the program (coded as 0-No past interaction, 1-Past interaction). Participants were then asked to choose their favorite robots from the theater session, the gender pronoun used for each robot (they, he, she), and comment on ways the activity could be improved. Finally, participants were asked to rate seven statements on a seven point Likert scale (from 1-Strongly Disagree to 7-Strongly Agree) (Participating in this activity increased my interest in learning (1) programming, (2) robotics, (3) theater production; Working in a team helped me learn (4) theater production, (5) to program robots; (6) Increased my comfort with having robots in my daily life; (7) I would like to have robots in future teams). After participants filled out the questionnaire form, the instructors delivered closing comments on the activity and answered any comment from participants.

RESULTS

Participant Nationality and Grade

Out of forty participants, ten students were domestic US students, twenty eight were international students, and two remaining students did not disclose their nationality. Participants were in grades 9 to 12. One participant was in grade 9, seven participants were in grade 10, twenty three participants were in grade 11, and nine participants were in grade 12.

Twenty three students reported having interacted with robots and seventeen reported no prior interaction with robots prior to our program. For past exposure to robots, a likelihood ratio test showed a statistically significant difference between US and international students, $\chi^2(1)=7.513$, $p=0.0061$. International students were more likely to have no prior interaction with robots (53% with no interaction) when compared to US students (10%) in this program.

Robot Usage and Preference

Nao and Pepper were the only robots used by all teams (37.5% and 100% usage frequency respectively, seen in Table 2). Pepper was the most favorite robot, whereas some participants chose Aibo, Alexa, or multiple robots as their favorite (as seen in Table 1). Reasons provided differed depending on the robot, with examples such as:

- *Pepper:* "Pepper is practical because it can make moves, interact, and speak. It also has a big, suitable size to work with.", "She was very responsive and the biggest robot."
- *Nao:* "Has lots of joints. Was nicer to program because you could see what he was saying."
- Aibo: "It looks so familiar and interactive", "I wish this robot was a cat but aibo was so adorable."

Favorite Robot	Count	% of Participants
Pepper	12	30
Multiple or all	11	27.5
Aibo	7	17.5
Nao	7	17.5
Alexa	2	5
Not reported	1	2.5

Table 1: Favorite robot chosen by our participants

Robot Gender

Eleven participants assigned a gender pronoun to Pepper (2 neutral, 2 female, 7 male). A likelihood ratio test showed a statistically significant difference between US and international students, $\chi^2(2)=10.431$, $p=0.0054$. Two US students referred to Pepper as a female robot, and international students viewed Pepper as a male or gender-neutral actor. Only four and seven participants answered questions regarding the gender of Aibo and Nao respectively (Aibo: 3 male, 1 neutral; Nao: 7 male).

Robot Perceived Standing

The role, or perceived standing, attributed to each robot in theater play put them on equal, lower, or higher footing with the participants. A distinction was made when the robot was an antagonistic agent in participants' theater play (seen in Table 2).

Team	Theme of the play	Robot used	Robot act	Robot role
1	Time travel	Pepper	Emotive robot	Ordinary figure / Equal Footing
2	First day of school	Nao, Pepper	Students	Equal Footing
3	Urgent surgery	Pepper	Surgeon	Authoritative figure / Higher Footing
4	Superhero	Nao, Pepper	Civilians in need	Dependent figures / Lower Footing
5	Criminal case	Pepper	Criminal	Antagonist
6	Court Case	Nao, Pepper	Thief (Nao), Judge	Antagonist, Higher Footing
7	First day of school	Pepper	Student	Equal Footing
8	First day of school	Nao, Pepper	Students	Equal Footing

Table 2: Summary of each team's play by theme, robot used, as well as role and role attributed to the robots

Subjective Likert Scale Responses

Average participants' response to the Likert-scale questions were positive (score above 4, as seen in Figure 3). All groups of data were analyzed with a factorial analysis of variance (ANOVA), with grade, nationality, robot interaction, and role of Pepper (as the one robot that all teams used) considered. Post hoc analysis was conducted with a student t test.

For the "Interest in Robotics" scale, a significant effect was found for nationality, $F(1, 29)=8.381$, $p=0.0071$ (US domestic $M=4.87$, $SD=0.43$; International $M=6.04$, $SD=0.29$), grade, $F(3, 29)=3.983$, $p=0.0172$, and role of Pepper, $F(3, 29)=5.398$, $p=0.0045$. For grade levels, grade 9 ($M=3.614$, $SD=0.96$) showed significantly lower rating of "Interest in Robotics" than grade 12 ($M=6.633$, $SD=0.34$; $p=0.0065$) and grade 10 ($M=6.093$, $SD=0.36$; $p=0.0183$). Grade 12 showed significantly higher rating of Interest in Robotics than grade 11 ($M=5.493$, $SD=0.29$; $p=0.0113$). For robot role, Antagonist ($M=4.078$, $SD=0.53$) showed significantly lower rating of "Interest in Robotics" than Equal Footing ($M=6.170$, $SD=0.29$; $p<0.001$),

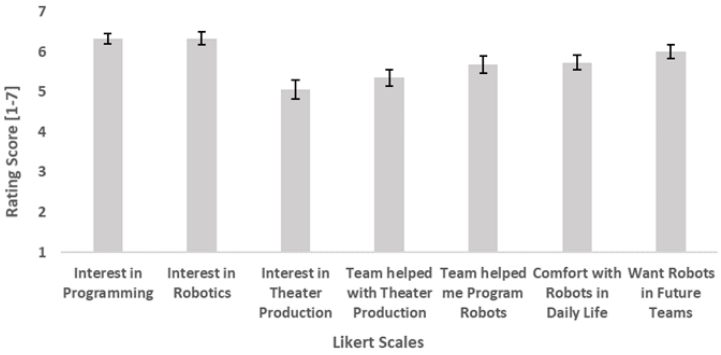

Figure 3: Average response to Likert-scale statements (Error bars represent standard errors in all graphs.)

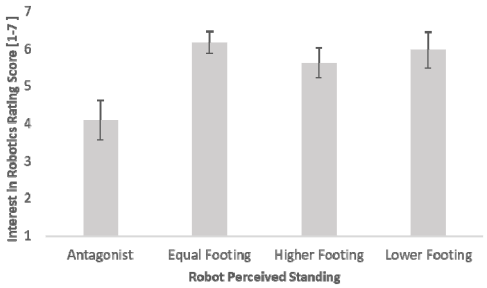

Figure 4: Mean expressed interest in learning robotics after the sessions based on robot's role

Higher Footing (M=5.623, SD=0.40; p=0.0061), and Lower Footing (M=5.963, SD=0.48; p=0.0038).

For the "Team helped with Theater Production" scale, a significant effect was found for the role of Pepper, $F(3,29)=3.233$, p=0.0366. Antagonist (M=3.841, SD=0.65) showed significantly lower rating of "Team helped with theater production" than Equal Footing (M=5.410, SD=0.35; p=0.0214), Higher Footing (M=5.666, SD=0.49; p=0.0079), and Lower Footing (M=5.801, SD=0.59; p=0.0121) (as seen in Figure 5).

For the "Comfort with Robots in Daily Life" scale, a significant effect was found for past interaction, $F(1, 29)=6.470$, p=0.0166 (no interaction M =5.964, SD=0.38; prior interaction M=4.990, SD=0.39), grade, $F(3, 29)=4.949$, p=0.0068, and role of Pepper, $F(3, 29)=5.380$, p=0.0045. For grade levels, grade 10 (M=4.556, SD=0.40) showed significantly lower rating of "Comfort with Robots in Daily Life" than grade 12 (M=6.722, SD=0.38; p<0.001) and grade 11 (M=5.722, SD=0.32; p=0.0201). Grade 11 also showed a significantly lower score than grade 12 (p=0.0407). No statistical differences were found for comparisons with grade 9 (M=4.909, SD=1.06).

For robot role, Higher Footing (M=4.710, SD=0.44) showed significantly lower rating of "Comfort with Robots in Daily Life" than Lower Footing (M=6.510, SD=0.53; p=0.0038) and Equal Footing (M=6.059, SD=0.32; p=0.0038). Antagonist (M=4.635, SD=0.59) also showed a significantly lower score than Equal Footing (p=0.0211) and Lower Footing (p=0.086), as seen in Figure 6.

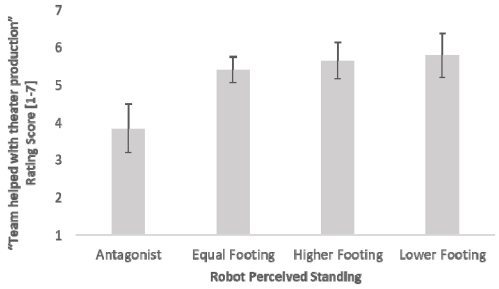

Figure 5: Mean perceived benefit of team in theater production after the sessions based on robot's role

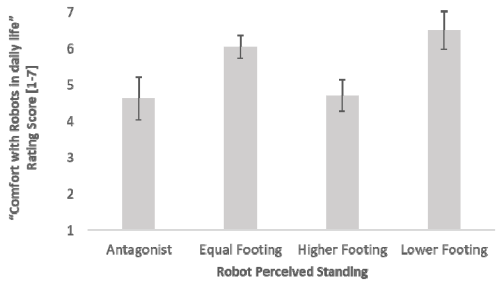

Figure 6: Mean perceived comfort with robots in daily life after the sessions based on robot's role

DISCUSSION

To promote interest in STEM fields and facilitate STEAM education, we conducted robot-theater summer youth sessions with the TechGirls program. In this exploratory study, female high school students from the US, Central Asia and MENA worked in teams to perform a short theater play while programming robots. The results of this study seem to indicate the need to consider certain demographic and framing factors when designing a robot-theater program, although a confirmation in studies with a formal experimental setting is required.

Trends regarding nationality observed seem to suggest different patterns of exposure to robot technology between US and international students from the countries present in this study. Nationality also influenced participants' interest in learning robotics after the session, with international students expressing greater interest in the matter. This may indicate a ceiling effect regarding the novelty of the programming task presented to participants, with more experienced individuals feeling less inspired by the end of the activity than others. A similar effect was observed for participant exposure to robotics on perceived comfort with robots and seems to support this point. The implications of this effect, should it be confirmed in subsequent studies, would influence the design of STEAM education programs according to participant demographics.

Another potential significant factor observed in this study lies in the role of the robot actor within the theater setting. Results seem to suggest that portraying the robot as a higher authority figure or an antagonist decreased subjective ratings for

the activity. Related literature on the status of robots indicates that, when collaborating on a work task, users were more critical of robots that were designated as a supervisor (Hinds, Roberts, & Jones, 2004). This may partly explain results observed in our study, specifically related to comfort and acceptance of robots (as seen in Figure 6). However, literature has focused on the perception of a robot's agreeableness and personality based on visual appearance (de Borst & de Gelder, 2015) or expressions (Bethel & Murphy, 2008), discounting the effect of the perceived morality of a robot. Framing a robot as a trustworthy agent, either as an equal, a benevolent authority figure, or a dependent other, as opposed to an antagonistic robot, may be advisable for fostering acceptance of robots in STEAM education programs.

CONCLUSION

To summarize, the current paper discusses demographic and framing factors that could be of interest when designing robot-theater or other STEAM education programs. The current study explored these considerations in a summer youth program setting with high school female participants from the TechGirls program.

Future work can include (1) validating the suggested effects through a randomized experimental study; and (2) exploring the influence of cultural factors on STEAM education programs using social robots (Reich-Stiebert & Eyssel, 2015). The inclusion of these additional elements into the setting of robot-theater programs, or within the larger human-robot interaction field, has the potential to enrich user experience and bring a new level to such programs.

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