2023 32nd IEEE International Conference on Robot and
Human Interactive Communication (RO-MAN)
August 28-31, 2023. Paradise Hotel, Busan, Korea

Participatory design of a social robot and robot-mediated storytelling activity to raise awareness of gender inequality among children

Romain Maure*[1], Barbara Bruno*[1]

***Abstract*— Gender inequality is a widespread problem in our society. It can manifest itself in many ways and contexts, and starting as early as primary school. While an increasing number of initiatives aim at tackling gender biases and inequalities, few of them are aimed at raising awareness of gender (in)equalities among young children, i.e., at the age in which such inequalities appear in their lives. The potential shown by social robots in teaching non-curricular topics is a promising motivation for exploring their use in this context. Indeed, a social robot could offer children the possibility to discuss gender (in)equality with an intelligent entity that is neither male nor female, but rather a credible outsider with respect to mankind. In this article we present the design process of a social robot, named PixelBot, and associated robot-mediated storytelling activity aimed at raising awareness of gender (in)equality among children. We used a participatory design approach involving 20 children aged 10-13 to acquire (i) their opinion on how a robot should look like and (ii) stories featuring robots and gender (in)equality. Finally, we conducted a study involving 8 children aged 9-10 to test the co-designed robot and robot-based storytelling activity. Results suggest that social robots are a promising avenue to promote gender equality and respect in children.**

***Index Terms*— social robotics, human-robot interaction, participatory design, gender equality**

I. Introduction

"*Gender inequality* refers to the unequal treatment or perceptions of individuals based on gender" [1]. It can affect anyone, but it primarily affects women and gender minorities. Gender inequality can manifest in many different ways. In the professional field, it can take the form of unequal pay for the same work, or unequal career opportunities. In the private sphere, it can manifest with imbalances in the amount of housework. On the educational front, gender inequality can exhibit itself as unequal access to education. Sexual exploitation, violence and discrimination against specific gender minorities are also part of gender inequalities [2].

Efforts to promote gender equality and address gender inequality can be traced back to the '70s and are still ongoing. Olivares et al. demonstrated in their review that gender inequality is not only learned in the socialization process that starts at home but is also present in the school environment from the very early years [3]. As a result, many tried to solve the problem of gender inequality through education [4]–[6]. Hilke and Conway-Gerhardt proposed to introduce in the curriculum a cyclical model for eliminating gender inequality, incorporating the stages of awareness, analysis, action and assessment [4]. Koblinsky et al. explored how the exposure to non-sexist curriculum could reduce sex stereotyping among children [5], while Flerx et al. showed how egalitarian sex role models in illustrated stories and films could help reducing stereotypic thinking in children [6].

When it comes to gender inequality, *Robotics* stands in a rather peculiar position. On the one hand, as a field within the STEM (Science, Technology, Engineering, and Mathematics) domain, robotics suffers from significant gender imbalances [7]. On the other hand, as an activity to engage in, it was found to be an effective mean to tackle those same imbalances [8], [9]. For example, Gomoll et al. explored how an after-school robotic club can provide informal STEM experiences that inspire students, with a particular focus on girls, to engage with STEM in the future [8]. Similarly, Sullivan et al. provided preliminary evidence that a developmentally appropriate robotics curriculum can increase girls' interest in engineering [9].

A common trait of the works mentioned above is that robots are used to address gender inequalities *implicitly*, by teaching STEM concepts. To the best of our knowledge, no work has investigated the use of robots to address gender inequalities *explicitly*, i.e. by making respect and gender equality the focus of a robot-based educational activity. We argue that the robot, by being genderless and non-human, could be seen as a credible and impartial outsider with respect to mankind, thus bringing in a novel perspective that no person could as believably bring. More formally, this work tackles the Research Question (RQ):

Can social robots be used in a learning activity explicitly aiming to raise children's awareness of gender inequality?

As a first step towards this end, we conducted a participatory design study to acquire children's opinions on how a robot should look like and stories that feature the robot and relate to gender (in)equality. Participatory design is an approach attempting to actively involve all stakeholders in the design process of a product [10], to ensure that the product meets most of the intended users' needs and promotes long-term adoption and satisfaction [11]. We thus built the robot and robot-based learning activity on the basis of the suggestions provided by the children in the participatory design. Finally, we conducted a user study to evaluate the effectiveness of the robot intervention on children[1].

*Majority of the work was conducted while the author was employed at the Computer-Human Interaction in Learning and Instruction (CHILI) Lab, Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland.

[1]Socially Assistive Robotics with Artificial Intelligence (SARAI) Lab, Karlsruhe Institute of Technology (KIT), Germany. Corresponding authors' email: firstname.lastname@kit.edu.

[1]All resources developed for this study can be found at: https://github.com/RomainMaure/PixelBot.

II. Related Work

A. Social robots for education

Social robots can support learning in a variety of ways [12]–[16]. In curricular education, social robots can offer personalized and adaptive learning experiences, which can help meet the individual needs and abilities of students. For example, Hood et al. explored the use of the NAO robot as an autonomous teachable robotic partner to engage children in handwriting practice and improve their self-esteem [12]. Björling et al. explored the importance of adding culturally responsive appearance and behaviour to a robot's dialogue to improve the quality of language learning activities for children [13].

In non-curricular education, social robots can provide children with innovative learning experiences helping them to develop a wide range of skills and abilities. Alves-Oliveira et al. co-designed a robot named YOLO aimed at stimulating creativity in children [14]. Prabha et al. presented a participatory design of a robot promoting healthy habits, such as hand hygiene, among children [15]. Sanoubari et al. explored the use of social robots and role-playing to foster anti-bullying peer-support [16]. The variety of topics for which social robots have been successfully used supports our idea of using them to raise awareness of gender inequality.

B. Participatory design

The methods used in participatory designs of social robots vary according to the target population.

When considering middle-aged adults and the elderly as the target population, focus groups, interviews and questionnaires are generally used [17]. Conversely, when considering children as the target population, combinations of more playful methods tend to be preferred. In their study focusing on fostering anti-bullying peer-support among children, Sanoubari et al. used a combination of drawings, 3D prototyping using recycled materials and storytelling [16]. Neto et al. proposed a robot design supporting inclusive classroom experiences for visually impaired children [18]. In combination with 3D prototyping, they developed and used a toolkit allowing the children to describe the attitudes and physical characteristics of their ideal robot. Guided by these examples, we structured our participatory design as a combination of drawings and storytelling.

C. Joint design of robot and robot-mediated activity

Lastly, it is interesting to notice how several studies in non-curricular education and remediation relied on participatory design to jointly design a robot and the robot-based activity [14], [15], [17], [19]. Specifically, this seems to be the case whenever it is not straightforward to define the characteristics and abilities that a robot would need to have in order to be effective towards a particular purpose. As an example, O'Brien et al. developed a robot called TACO to address symptoms of loneliness, anxiety and social isolation in hospitalized children [19]. The robot's characteristics (non-anthropomorphism, cuddly shape) are envisioned to help trigger behaviours in children (cuddling and stroking) that are essential for the success of the robot's intervention (to reassure and calm the hospitalized children). This insight motivates us to design our robot jointly with the learning activity aimed at raising children's awareness of gender (in)equality.

III. Participatory Design

A. Participatory design toolkit

In line with the findings from the literature review, we carried out a participatory design with two objectives. The first objective was to gather children's thoughts on the physical appearance and main characteristics of social robots. These opinions would assist us in the robot design process. The second goal was to collect stories that feature the robot and relate to gender (in)equality to gain insights into how a robot could act in such situations and inform the design of the robot-based learning activity.

To design the first part of our participatory design toolkit, focusing on the robot's physical appearance and characteristics, we took inspiration from the toolkit developed by Neto et al. [18]. In their toolkit, children can describe the main features of their idealised robot. "Feature cards" are given for each feature and children have to choose one among them. For example, the "communication" feature includes cards for "Writes", "Body movement", "Speaks", "Sound", and "Facial expressions". Blank cards are also provided for children to specify their own ideas. On the basis of the feedback provided by a colleague with a primary school teaching background, we substituted the card concept with a multiple-choice-like format, in which children could select and rank the preferred option describing the robot's feature. While this format may seem less engaging for children, we believe it to be easier and faster for them to use. We also included a section where children could make a drawing of their ideal robot, which would give us a more visual representation of what the children envision for their robot.

Concerning the second part of the participatory design toolkit, which focuses on stories featuring the created robot and gender (in)equality, we took inspiration from Sanoubari et al. [16], who used storyboards. Children would create their stories by drawing in each frame of the storyboard (see Figure 1), possibly adding textual descriptions in the empty lines underneath. Following a discussion with our colleague with a teaching background, we also decided to include a story map alongside the storyboard, which would be filled out by children beforehand and would aid them in establishing the setting for their story.

To test the envisioned participatory design approach and see how the toolkit would be used by children, we conducted a first iteration of the participatory design[2]. Two subsequent iterations were then conducted to collect children's feedback concerning the robot and stories.

[2]Ethical approval for this study was granted by the EPFL Human Research Ethics Committee (HREC) via decision HREC No: 082-2022.

Fig. 1: Example of a story made during the participatory design. A robot is tasked to observe the different gender-based inequalities present in a city and report those to a judge to help him create new laws to solve the inequalities.

B. Participants

The first iteration took place during the public day of a robotic-related event. A stand in an open space was allocated to us, and interested children were free to come and participate in the activity (see Figure 2a). In total, fifteen children, mostly accompanied by their parents, participated in the activity (9 males and 6 females, age=10.43, SD=2.96). The experiment took place during the afternoon and lasted approximately four hours, with no time constraints for children to finish the activity. Alongside minor improvements in the robot-design part of the toolkit, our main takeaway from the first iteration was the observation that children seemed to struggle with the creation of the story. To tackle this issue, we added to the toolkit a sheet of questions related to gender (in)equality, aimed at providing children with avenues for reflection and inspiration. In the second and third iterations, children used the refined toolkit.

The second iteration of the participatory design occurred in our laboratory (see Figure 2b). Eight children participated in the activity (4 males and 4 females, Age=11.37, SD=0.99) and were separated into two groups. Each group performed the design activity for 30 minutes.

The third iteration took place in a private school in the region and involved a class of twelve children (4 males and 8 females, Age=10.91, SD=0.64) under the sole supervision of their teacher. This iteration lasted 90 minutes.

(a) First iteration (b) Second iteration

Fig. 2: Setup of the first two iterations of the participatory design. The third one took place in a school under the sole supervision of a teacher.

C. Participatory design results

While the results of the robot design part of the toolkit are presented in Section IV-A, together with the robot design, the analysis of the stories created by the children deserves a particular attention. The stories created by the children participating in the second iteration were discarded from the analysis, as either unfinished or unrelated to the subject of gender inequality. Additionally, one story from a child in the third iteration had to be discarded because it did not include the robot. This left us with 11 valid stories to consider.

The contexts and types of inequalities discussed in the analysed stories were various. Four of the stories discussed inequalities in sports, namely differences in visibility and "physical strength" between men's and women's sports. Two children focused their stories on the topic of salary inequalities. Three children tackled inequalities in the sharing of house chores, unequal employees' distribution to specific jobs or unequal career opportunities. Finally, the remaining stories respectively described gender inequality as a societal problem to be solved and as a subject of debate between men and women. Considering the ending of the stories, nine had the issue resolved, while the remaining two did not.

To better analyse the stories, we followed the approach proposed by Rubegni et al. [20], which envisions the use of five lenses: *Role, Agency, Embodiment, Personality*, and *Emotion*. Since we are interested in the role children attribute to the robot and its relation with the other story characters, we give a particular attention to the *Role* lens. Conversely, the *Emotion* lens had to be discarded due to incompatibility with the French language in which the stories were written.

The *Role* lens aims at identifying the relationship between a character's gender and function according to the fairy tale functions proposed by Propp [21]: Protagonist, Antagonist, Antagonist Helper, Protagonist Helper, and Magic Object. The Magic Object and Antagonist Helper roles did not appear in any of the created stories. Conversely, we added the role *Protagonist Being Helped* to make a clear distinction between (i) the Protagonist, whom we consider to be the main character of the story; (ii) the Protagonist Helper(s) who help the Protagonist in achieving their goal and (iii) the Protagonists Being Helped, who are mainly passive characters being defended by the Protagonist.

The results of the *Role* lens analysis are shown in Figure

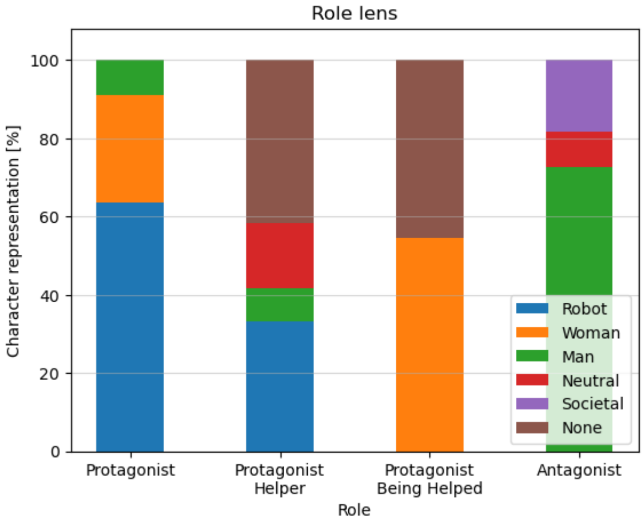


Fig. 3: Role lens analysis: relationship between a character's gender and its function in the story. "Neutral" refers to a human character whose gender could not be identified, while "None" refers to stories in which a role does not appear.

3. As the Figure shows, the robots were always envisioned by the children as either the Protagonist or a Protagonist Helper, which suggests that children see the robot as a strong and positive figure whose role is to help humans in solving problems and not the other way around. Women were mostly represented as Protagonists Being Helped, while men mostly played the role of Antagonists. This finding informs us that children envision gender inequality as a problem mainly caused by men and mostly affecting women. Indeed, 100% of the Protagonists Being Helped were women, showing that children are probably unaware that men too can experience and be affected by gender inequality. Finally, some children did not represent the Antagonist of their story as a single individual but rather as the society as a whole, suggesting that they view gender inequality as a societal problem which requires societal changes to be solved.

The *Agency* lens, which attributes to each character a level of agency from 1 (low) to 3 (high), allows us to conclude that 81.8% of the Protagonists and Antagonists exhibit high agency and drive the plot of the story[3]. The Protagonists Being Helped exhibit low or medium agency, undergoing events rather than driving them, while 71.4% of the Protagonist Helpers are successful in providing assistance.

Concerning the *Embodiment* lens, eight of the stories represented men and women with a clear gendered look (women drawn with long hair and a skirt and men drawn with short hair and pants). Conversely, in nine of the stories the robot was represented with a neutral look, while the other two stories feature robots displaying male characteristics.

Lastly, the *Personality* lens requires to base the analysis on the adjectives used to describe characters' actions and beliefs. The robots appear to be "calm" and "determined" characters favouring discussion over violence, while women are depicted as emotionally expressive and positive characters (denoted by adjectives such as "serious" and "hardworking", or smart, independent and persevering). Conversely, men are typically negatively connotated ("jealous", "mocking", "lazy"), although several stories also represented them to be calm, listening and able to reflect on their mistakes.

IV. Robotic Platform and Learning Activity

A. Robotic platform

The first element taken into consideration for the design of the robot was its overall shape. Two-thirds of the children who participated in the third iteration of the participatory design showed a preference for human-like forms while 62.5% of the children who participated in the second iteration preferred zoomorphic robots. We thus designed a robot (see Figure 4) whose overall shape is humanoid, but with animal characteristics (antennae).

With regard to the robot's communication, the children deemed the ability to move to be the most vital method for a robot to communicate. We thus chose to motorize the robot's arms and antennae. Sounds and facial expressions were also considered to be important features for a robot to have. To this end, we designed the robot's torso to incorporate a speaker, and the robot's head to incorporate a Liquid-Crystal Display (LCD) that would act as the robot's face. Lights, the least desired feature according to children, were not included.

Concerning the robot's mobility, 57.9% of the children from both the second and third iteration showed a preference for legs over wheels, which fitted nicely with the choice of giving the robot a humanoid shape. To comply with the suggestion while keeping a low mechanical complexity, we decided to just give the robot a semblance of walking, achieved by moving the arms in a "walking-like" gesture.

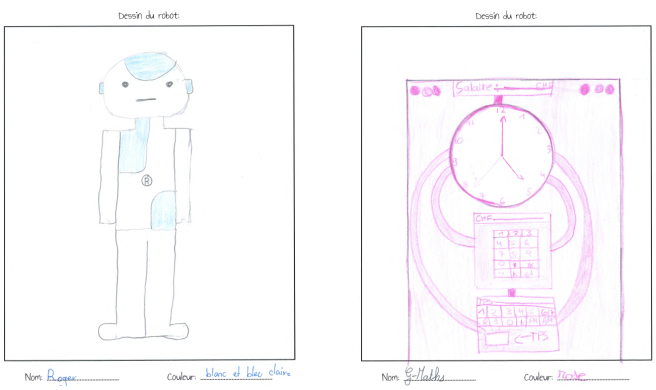
With respect to the robot's ability to sense its surrounding, vision was considered the most important, followed by hearing. Concerning touch sensing, the opinions were mixed. Some children considered it as important as vision, while others considered it the least needed sense. For the sake of design simplicity and robustness, we made the choice to provide the robot with touch sensing only, via two buttons located in the robot's torso.

Regarding the material the robot should be made of, 84.2% of the children from both the second and third iterations expressed a preference for metal. However, we chose to use plastic to leverage fabrication technologies such as 3D printing, which is cheap, accessible and allows for rapid prototyping. Additionally, 3D printing offers the possibility to use plastic filaments of various colours, which was an important aspect in our case. The robot has been completely printed using white filament, as it was one of the two most mentioned colours (along with blue) by the children.

Considering electronics, the robot is equipped with a Raspberry Pi 4 (model B with 8 GB of RAM), which supports USB, Ethernet, and HDMI ports, as well as Bluetooth and WiFi connectivity. The actuation of the robot's arms and

[3]One Protagonist tried but failed in solving the gender inequality, while another did not put a strong effort. Two stories feature society as Antagonist.

Fig. 4: PixelBot: the robot co-designed with and for children.



(a) Roger: humanoid-like robot.

(b) G-maths: machine-like immobile robot.

Fig. 5: Examples of robot drawings from the participatory design iterations.

antennae is done by four SG90 servo motors, connected to the Raspberry Pi via a PCA9685 controller. The two push-pull buttons, 5" LCD and speaker are directly connected and managed by the Raspberry Pi.

The Raspberry Pi runs Ubuntu 22.04 LTS and ROS2: the software architecture of PixelBot is structured as a hierarchy of ROS2 packages[4].

B. Robot-based learning activity

The robot-based learning activity follows an interactive storytelling approach inspired by four stories created by children during the third iteration of the participatory design:

- **Unequal house chores distribution story:** Alice and Hugo live together in a flat. However, Alice does all the house chores and is not helped by Hugo. The robot Roger (shown in Figure 5a) intervenes to promote an equal sharing of household tasks.
- **Unequal salary story:** In a ski resort, several men and women work as lifeguards. However, men are paid more than women. The robot G-maths (shown in Figure 5b) intervenes to compute salaries equally.
- **Unequal career opportunity story:** Marie is a female engineer who dreams of becoming an astronaut. She goes to the NASA, but is refused to become an astronaut because of her gender. With the help of her turtle-like robot Tika, Marie builds a rocket and goes to the moon.
- **Gender inequalities observation story:** The humanoid robot Bob is tasked by a judge to observe the different gender-based inequalities present in a city. After doing so, the robot reports back to the judge to help him create new laws aiming at solving the inequalities (the full story is shown in Figure 1).

The main plot of the developed storytelling activity is based on the fourth story. PixelBot narrates the story in first-person perspective, as the robot that has been tasked to observe the gender inequalities present in a city and report to a judge to help him create new laws promoting gender equality. The story then implements a mise en abyme (i.e., the technique of inserting a story within a story): on its journey, PixelBot visits three places and unveils the gender inequalities happening therein, which correspond to the situations described by the first three stories listed above. It is interesting to mention that the robot, as a genderless non-human being, acts as an impartial observer and brings in a perspective that no person could as believably bring.

The first three stories were selected as they highlight distinct instances of gender inequality (at home, at work and in career opportunities), providing the children with a broad overview of the various types of gender inequalities affecting our society. They also provide variety in the magnitude of the problem presented and the hierarchical relations between the characters. The first story describes a domestic situation involving two persons only, on an equal footing. The second story involves two groups, and the third one involves a person fighting against an organization.

During the activity, after the description of each case, the robot stops speaking and lets the teacher discuss the case of gender inequality with the students. The teacher first asks them questions related to the case of gender inequality, as well as their feelings toward it. Then, the teacher suggests two options for the robot to solve the situation, which are consistently either talking to the protagonist or talking to the antagonist. Once a consensus is reached, the children validate their preferred solution by pressing one of the two robot's buttons. The robot replies by acknowledging the children's choice and then resumes its storytelling. The activity has no wrong answers: all solutions proposed by the teacher would lead to the resolution of the situation. The story script can be found on our GitHub repository[1].

[4]The components list, 3D printed parts, electronics schematics and control packages of PixelBot are available at: `https://github.com/RomainMaure/PixelBot`.

The storytelling activity, robot characteristics and capabilities were concurrently refined, also with input from the teacher who participated in the third participatory design iteration, to ensure they align with each other. The robot tells its story via its speaker, and its motion capabilities are used to make the storytelling more lively and engaging. At the beginning, the robot performs a greeting gesture with its arms when presenting itself and the mission it has been given. When moving from one place to another, the robot uses its arms to mimic a walking gesture. When confronting a case of gender inequality, the robot exhibits emotions using its LCD and antennae.

V. Experimental Evaluation

A. Objectives

The main objective of this evaluation was to preliminarily assess the suitability of Pixelbot and the proposed interactive storytelling activity for raising children's awareness of gender (in)equality (RQ). We measured children's perception of Pixelbot via the Godspeed questionnaire [22] and assessed the suitability of the activity by quantitatively measuring the children's engagement with the activity and the topic, as well as via qualitative feedback from the teacher who led it.

B. Participants

The co-designed robot and robot-based learning activity were tested in two iterations, in the same school where the third iteration of the participatory design was carried out. They were led by the same teacher, while the researcher observed but did not actively participate in the activity. To avoid any bias, none of the children involved in the participatory design took part in the experiment. The first evaluation iteration involved seven children (4 males and 3 females, Age=9.57, SD=0.49) and lasted approximately 18 minutes (Figure 6). Due to seasonal flu, the second evaluation iteration was conducted with only one child (female, age=9) and lasted approximately 11 minutes. Audio recordings were collected during the iterations, which were then transcribed[1] and anonymized. The Godspeed questionnaire was filled by the children who participated in the first evaluation iteration one week after the experiment took place, in class, under the guidance of the teacher. On this day, two children were absent, thus yielding only five valid responses (3 males and 2 females, Age=9.4, SD=0.49).

C. Results

1) Robot-based learning activity: To assess the children's engagement with the activity we start by defining as a *comment* any intervention made by a child during it. While the most common type of comment is an utterance, we also consider a response provided by a child in the form of a mimic (such as a head movement to express agreement or disagreement) or an onomatopoeia as a comment. Then, we only take into account individual comments (i.e., disregarding comments made by multiple children simultaneously). The analysis of the individual comments reveals that all children participated in the activity by making at least one comment, which indicates their involvement in the activity. In the first iteration, the children made 0.81 (SD=0.48) comments per minute each, while the only child participating in the second iteration made 2.5 comments per minute.

Fig. 6: Setup of the first iteration evaluating the co-designed robot and robot-based learning activity for raising awareness about gender (in)equality.

We also analysed the number of comments *about gender equality* made by the children, which we define as comments belonging to any of these classes:

- **Description:** A comment describing a case of gender (in)equality, either referring to the ones described in the storytelling activity or others ("Women do all the housework and boys do nothing.").
- **Solution:** A comment providing a solution to a case of gender inequality ("The girl and the boy should be given tasks. Both of them.").
- **Emotion:** A comment expressing an emotion about the topic of gender (in)equality ("This is just injustice!").
- **Agreement/Disagreement:** A comment expressing an agreement or disagreement with another comment made on the topic of gender (in)equality ("Not necessarily!").
- **Answer:** A comment answering a teacher's question related to the cases of gender (in)equality ("Sweep the floor.", "Do the dishes.").

We argue that comments of the classes listed above imply that the child engaged in a moment of reflection over an aspect of gender (in)equality (e.g. ways in which it can manifest, possible solutions, effects it has on the people affected by it...) and thus contribute to raising awareness about it. Based on the above definition, 86.8% of the comments made by the children who participated in the first iteration were about gender equality. Similarly, 100% of the comments made by the child who participated in the second iteration were about gender equality. These results support the effectiveness of the activity in stimulating children to reflect on the topic of gender (in)equality.

Concerning the choices taken by the children to solve the cases of gender inequality, the children from the first iteration suggested the robot to speak to the antagonist in two of the three stories (the unequal house chores distribution story and the unequal career opportunity story), while the child in the second iteration always asked for the robot to speak to the antagonist. This finding, which nicely aligns with the personality attributed by the children involved in the participatory design to the Antagonists of their stories, suggests that children view inequalities as solvable through dialogue, especially when they involve single individuals.

Finally, we qualitatively analysed the comments about gender equality belonging to the Solution class, with the aim of investigating the "constructiveness" of the solutions provided by the children. Concerning the case of the unequal distribution of household tasks, constructive comments promoted mutual help, sharing and discussion (*"The girl and the boy should be given tasks. Both of them."*, *"We help each other."*, *"Talk to them."*). Conversely, the less constructive solutions would promote inaction or quarrel (*"I would do nothing."*, *"We get angry."*), with some even revealing the gender biases in the language spoken [23] (*"We hire a cleaning lady."*). In the case of salary inequality, children did not make any nonconstructive comments, while the constructive comments promoted equality, sharing and discussion (*"They should be paid exactly the same, as they do exactly the same thing."*, *"We share."*, *"Speak to the director."*). Finally, the constructive comments about the case of unequal career opportunity promoted perseverance and focused on the unfairness of the situation (*"Humm, persevere."*, *"We say that it's unfair."*). As in the previous case, the children did not make any nonconstructive comments.

The teacher who led the activity reported that the robot's emotions, movements and sounds were key to keeping the children's attention, while its visual appearance, especially its animal features, had a positive impact on its likeability. In addition, the teacher recommended balancing the overall scenario of the activity by including cases where men would be the subject of gender inequality.

Albeit preliminary, the results suggest that the proposed robot-mediated activity is a promising avenue to engage young students in reflection and discussion of gender (in)equality and thus raise their awareness of the topic.

2) Co-designed PixelBot robot: Figure 7 reports the average scores of the Godspeed questionnaire items, with 95% Confidence Intervals (CI).

PixelBot obtained an average score of 2.68 (CI=$\pm$1.0) on Anthropomorphism, suggesting that the children considered the robot halfway between human and non-human. This result is consistent with our intention to design a robot featuring both human (human shape with legs, arms, torso, etc) and animal characteristics (antennae).

The average score obtained by PixelBot on Animacy was 3.5 (CI=$\pm$0.49), which suggests that the children viewed the robot as more animated than inanimate. Indeed, while storytelling, the robot used a combination of speech, arm and antennae movements and facial expressions, giving it a lively appearance. Conversely, during the discussion moments, the robot would simply wait for one of its buttons to be pressed,

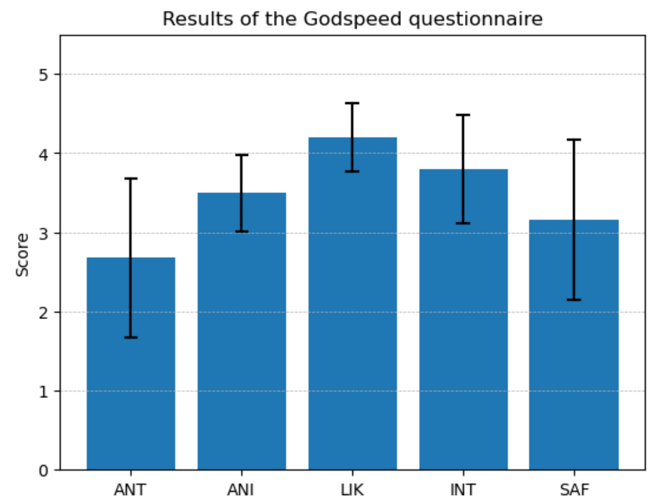


Fig. 7: Results of the Godspeed questionnaire (abbreviations: ANT -anthropomorphism, ANI -animacy, LIK -likeability, INT -perceived intelligence, SAF -perceived safety.)

rendering it mostly inanimate. Indeed, we deem it crucial for the robot to remain unobtrusive during discussions, to not distract the students from their teacher.

PixelBot obtained the highest score among the questionnaire items on Likeability (4.2, CI=$\pm$0.43), indicating that the children had a positive impression of the robot. This result suggests that the co-design with and for children was successful, although the score might have been positively influenced by the novelty effect.

The average score for PixelBot on Perceived Intelligence was 3.8 (CI=$\pm$0.68), which suggests that the children viewed the robot as more intelligent than not. According to Bartneck et al., the perceived intelligence of a robot corresponds to its ability to adapt its behaviour to varying situations [22]. Although PixelBot's behaviour was mainly pre-programmed, it was able to adapt slightly its speech based on the children's responses, which might have contributed to raise its perceived intelligence. On the other hand, the robot's reliance on the children's assistance in resolving the issues that arose in the stories may have led to a lower perception of its intelligence. Considering that recent studies suggest the existence of an inverse correlation between a robot's perceived intelligence and the amount of feedback given by the children interacting with it [24], future work should be devoted to fine tuning the robot's perceived intelligence to maximise the children's engagement with the activity.

Finally, PixelBot obtained a score of 3.16 (CI=$\pm$1.01) on Perceived Safety, which indicates that several children felt the robot more unsafe than not. A possible reason for this score might lie in the robot's movements, which may have been perceived as too rapid. Efforts should be made in the future to identify possible causes of discomfort and improve the children's perceived safety of the robot.

Although no conclusion can be drawn due to the low number of respondents, the results of the Godspeed questionnaire suggest that further studies can and should be made with and on PixelBot, to better assess its Likeability, optimize its Perceived Intelligence and improve its Perceived Safety.

VI. Conclusion

In this work we used a participatory design approach to develop the social robot PixelBot and an associated robot-mediated storytelling activity. The robot acts as a tool whose aim is to confront learners with cases of gender inequality and to encourage discussion, under the guidance of their teacher. We conducted an experimental evaluation to assess the suitability of PixelBot and the proposed interactive storytelling activity for raising children's awareness of gender (in)equality (RQ). The analysis of the discussions that took place during the activity shows that all children engaged in the activity and reflected on the topic of gender (in)equality (more than 85% of their interventions were on the topic). These findings, combined with the children's apparent liking of the robot, suggest that social robots can be successfully used in a learning activity that explicitly aims to raise awareness of gender inequality.

The main challenge encountered was an unexpected consequence of the subject being tackled: gender inequality is a sensitive and high-profile topic, which led many parents not to allow their children to participate in the activity. This challenge demonstrates the importance of involving parents in the participatory design of technologies for children, to improve acceptance and spread knowledge about the research objectives. Besides the preliminary nature of the study and the small pool of participants, a number of limitations of this work are worth discussing. We only examined the involvement of the children in talking about gender (in)equality through the analysis of the discussions. It would have been interesting to use a quantitative instrument in a pre-post-test design to assess the extent to which the children learnt about gender (in)equality. The seeming lack of valid measurement instruments for this purpose made it unfeasible to pursue this goal. Additionally, while we envisioned our co-designed robot as a genderless non-human being, which, we argue, helps in bringing in the activity a perspective that no person could as believably bring, we did not investigate the validity of our hypothesis, nor the robot's perceived gender, although it is known that humans tend to anthropomorphize robots by attributing them a gender and associated stereotypes [25].

Acknowledgments

We would like to thank all the children and adult stakeholders who contributed to this research.

References

[1] "Gender discrimination defined | Langston University," https://www.langston.edu/title-ix/gender-discrimination-defined.

[2] J. Lorber, "Gender inequality," *Los Angeles, CA: Roxbury*, 2001.

[3] R. A. Olivares and N. Rosenthal, "Gender equity and classroom experiences: A review of research." 1992.

[4] E. V. Hilke and C. Conway-Gerhardt, *Gender Equity in Education. Fastback 372.* ERIC, 1994.

[5] S. A. Koblinsky and A. I. Sugawara, "Nonsexist curricula, sex of teacher, and children's sex-role learning," *Sex Roles*, vol. 10, no. 5, pp. 357–367, 1984.

[6] V. C. Flerx, D. S. Fidler, and R. W. Rogers, "Sex role stereotypes: Developmental aspects and early intervention," *Child Development*, pp. 998–1007, 1976.

[7] E. Regan and J. DeWitt, "Attitudes, interest and factors influencing stem enrolment behaviour: An overview of relevant literature," *Understanding student participation and choice in science and technology education*, pp. 63–88, 2015.

[8] A. Gomoll, C. E. Hmelo-Silver, S. Šabanović, and M. Francisco, "Dragons, ladybugs, and softballs: Girls' stem engagement with human-centered robotics," *Journal of Science Education and Technology*, vol. 25, no. 6, pp. 899–914, 2016.

[9] A. Sullivan and M. U. Bers, "Investigating the use of robotics to increase girls' interest in engineering during early elementary school," *International Journal of Technology and Design Education*, vol. 29, pp. 1033–1051, 2019.

[10] Wikipedia contributors, "Participatory design — Wikipedia, the free encyclopedia," https://en.wikipedia.org/w/index.php?title=Participatory_design&oldid=1113634369, 2022.

[11] M. Steen, M. Manschot, and N. De Koning, "Benefits of co-design in service design projects," *International Journal of Design*, vol. 5, no. 2, 2011.

[12] D. Hood, S. Lemaignan, and P. Dillenbourg, "When children teach a robot to write: An autonomous teachable humanoid which uses simulated handwriting," in *Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction*, 2015, pp. 83–90.

[13] E. A. Björling, B. Louie, P. Wiesmann, and A. C. Kuo, "Engaging english language learners as cultural informants in the design of a social robot for education," *Multimodal Technologies and Interaction*, vol. 5, no. 7, p. 35, 2021.

[14] P. Alves-Oliveira, P. Arriaga, A. Paiva, and G. Hoffman, "Children as robot designers," in *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*, 2021, pp. 399–408.

[15] P. Prabha, S. Sasidharan, D. Pasupuleti, A. Das, G. Manikutty, and R. Sharma, "A minimalist social robot platform for promoting positive behavior change among children," in *ACM SIGGRAPH 2022 Educator's Forum*, 2022, pp. 1–2.

[16] E. Sanoubari, J. E. Muñoz Cardona, H. Mahdi, J. E. Young, A. Houston, and K. Dautenhahn, "Robots, bullies and stories: A remote co-design study with children," in *Interaction Design and Children*, 2021, pp. 171–182.

[17] I. Zubrycki, I. Szafarczyk, and G. Granosik, "Participatory design of a robot for demonstrating an epileptic seizure," *Advanced Robotics*, vol. 33, no. 7-8, pp. 338–349, 2019.

[18] I. Neto, H. Nicolau, and A. Paiva, "Community based robot design for classrooms with mixed visual abilities children," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 2021, pp. 1–12.

[19] C. O'Brien, M. O'Mara, J. Issartel, and C. McGinn, "Exploring the design space of therapeutic robot companions for children," in *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*, 2021, pp. 243–251.

[20] E. Rubegni, M. Landoni, A. De Angeli, and L. Jaccheri, "Detecting gender stereotypes in children digital storytelling," in *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, 2019, pp. 386–393.

[21] V. I. Propp, *Morphology of the Folktale*. University of Texas Press, 1968, vol. 9.

[22] C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, "Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots," *International journal of social robotics*, vol. 1, no. 1, pp. 71–81, 2009.

[23] P. Zhou, W. Shi, J. Zhao, K.-H. Huang, M. Chen, R. Cotterell, and K.-W. Chang, "Examining gender bias in languages with grammatical gender," *arXiv preprint arXiv:1909.02224*, 2019.

[24] L. L. Wright, A. Kothiyal, K. O. Arras, and B. Bruno, "How a social robot's vocalization affects children's speech, learning, and interaction," in *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 2022, pp. 279–286.

[25] G. Perugia, L. Boor, L. van der Bij, O. Rikmenspoel, R. Foppen, and S. Guidi, "Models of (often) ambivalent robot stereotypes: Content, structure, and predictors of robots' age and gender stereotypes," in *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*, 2023, pp. 428–436.