Robo2Box: A Toolkit to Elicit Children's Design Requirements for Classroom Robots

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Abstract. We describe the development and first evaluation of a robot design toolkit (Robo2Box) aimed at involving children in the design of classroom robots. We first describe the origins of the Robo2Box elements based on previous research with children and interaction designers drawing their preferred classroom robots. Then we describe a study in which 31 children created their own classroom robot using the toolkit. We present children's preferences based on their use of the different elements of the toolkit, compare their designs with the drawings presented in previous research, and suggest changes for improvement of the toolkit.

1 Introduction

Nowadays, children's design input is considered very valuable for the design of various technologies because it may help designers to focus on children's needs from an early stage in the process [2]. Robots as a new kind of technology are likely to enter children's lives, especially in the form of classroom educational robots, so therefore, involving children in the design of classroom robots is a logical step in a human-centered design process. However, there are also some hurdles when involving children, or even adults, in the design of future technologies. People find it hard to imagine the use of future technologies since they haven't experienced them yet and they are not always aware of the state-of-the-art developments in areas such as robotics. In our previous work [4], we have explored how classroom robots are envisioned by children (age 10–14 years) and interaction design students. We found that children without robotics knowledge envisioned the classroom robot as a human teacher with some additions and modifications, while the interaction design students imagined it as a small and rather cute teaching assistant, and children with some robotics knowledge imagined a more technically inspired classroom robot. Those findings clearly point out the need to involve children in the design of classroom robots, but more importantly the need to enable them to broaden their design views as there were major differences between children with and without robotics knowledge.

We extend our work by providing children with a toolkit giving them access to design tangible materials (Robo2Box) that can express different and possibly novel ways of imagining about classroom robots. In this paper we aim to

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answer the following: **RQ1**: What kind of robots do children design for the classroom using the Robo2Box toolkit? **RQ2**: When using the Robo2Box, do children design classroom robots similar to just drawing robots? **RQ3**: What changes should be made to the Robo2Box for children to express their design ideas?

2 Related Work

The Human-Robot Interaction (HRI) community has focused on defining the design requirements and implications for physical and behavioural aspects of robots. In general, such investigations are conducted based on laboratory studies using commercially available robots [3]. Little work has focused on human-centered design approaches to define robotic features; in particular, approaches to define robotic features with and for children. Below, we will provide an overview of the work performed in this and closely related areas.

An early relevant study into children's design requirements for robots was performed by Bumby and Dautenhahn [1]. They conducted a series of design sessions with 38 children between 7 and 11 years old in which the children were asked to draw a robot in small groups, write a story about the robot, and thereafter observe and interact with two rather simple robots. They found that the drawings were mainly based on geometric forms, but with human heads and feet. The robots in the drawings usually didn't carry any weapons, didn't have lights or a battery and didn't have a gender. The interaction with the robots showed that children anthropomorphized the robots and talked to them like pets.

Thereafter Woods et al. [8,9] investigated children's views on robot appearance, movement, gender, and personality. Children between 9 and 11 were asked to choose a robot picture and fill out a questionnaire. The pictures displayed different robot attributes: mode of locomotion, body shape, looking like an animal, human or machine, the presence or absence of facial features, and gender. Woods identified two dimensions in children's evaluations termed 'Emotional expression', ranging from happy to sad, and 'Behavioral intention', including friendliness, shyness and fright versus aggressiveness, bossiness and anger. Human-machine robots were considered the most friendly, shy and frightened types of robots. Woods argued that robot designers should *"consider a combination of physical characteristics rather than focusing specifically on certain features in isolation"* [8]. Furthermore, children were positive towards robots that were more human-machine like instead of purely machine-like, but showed a sharp drop in positive attitude towards robots that were very human-like.

In a recent study, Sciutti et al. [6] asked children to order 14 pieces of paper with robotic characteristics, from most important to least important. They were asked to imagine building a robot they could interact and play with. The researchers found that age had an effect on which features the children considered important. Furthermore, they found that robots should have some human-like properties to make them more readable. Finally, Shin and Kim [7] interviewed 85 school students from three school levels (with an average age of 14 years) to investigate their attitudes towards learning about, from, and with robots. Their results showed a positive attitude towards learning from robots, but not in favor of having them in schools due to robots lacking emotion.

In summary, when involving children in the design of classroom robots, we need to use methods that help them to focus on the aspects of interest. The process of involving children in the design of classroom robots can benefit from many different inclusive methods such as sketching, storytelling, bodystorming, role-playing and design with prototypes. Yet the design problem comes with the need for covering many different properties; form factor, gender, material, and behaviour. The robot design toolkit described in this paper can serve as the basis for eliciting children's design requirements for classroom robots.

3 Robo2Box Toolkit

Our previous study [4] indicated that children may have an important contribution to make in the design of a classroom robot. However, children's limited drawing skills might hinder them from creating the designs they like. Scaife and Rogers [5] even claim that the act of drawing might keep children from focusing on other aspects of the interaction. Furthermore, it could also be beneficial to provide children with inspiration from the designs of professionals and more knowledgeable children. Therefore we decided to base the Robo2Box toolkit on the physical elements of the drawings by the children and the interaction design students presented in our previous work [4]. However, we also added additional elements to the toolkit based on the findings of Woods [8].

The toolkit is 3D printed and consists of the elements presented in Fig. 1. There are 5 groups of elements: heads, torsos, legs, arms, and materials. Similar to Woods [8] the parts can be categorised as human, animal or machine like (and mixes of these categories). The different body parts can be connected with double-sided tape and materials, such as fur and rubber, can only be chosen to indicate a preference but they cannot physically be attached.

4 Study

The aim of the study is the development and evaluation of a robot design toolkit that can be used as part of a human-centered design approach to involve children in the design of classroom robots. While we are also interested in understanding behavioral requirements for classroom robots that can be elicited through the use of this toolkit in combination with other elicitation approaches, this paper will focus on the use of the toolkit itself as a human-centered design tool.

We conducted a study to address the main questions raised in Sect. 1 with 31 school children (8–15 years old, average age of 11 years (SD = 2.3), 16 girls and 15 boys) from Turkey. Most children (25) did not have any robotics knowledge, while four had little robotic knowledge, and two had attended some robotics classes. Each child was asked to first construct a robot for the classroom and place it in a cardboard model of a classroom (Robot construction and placement).

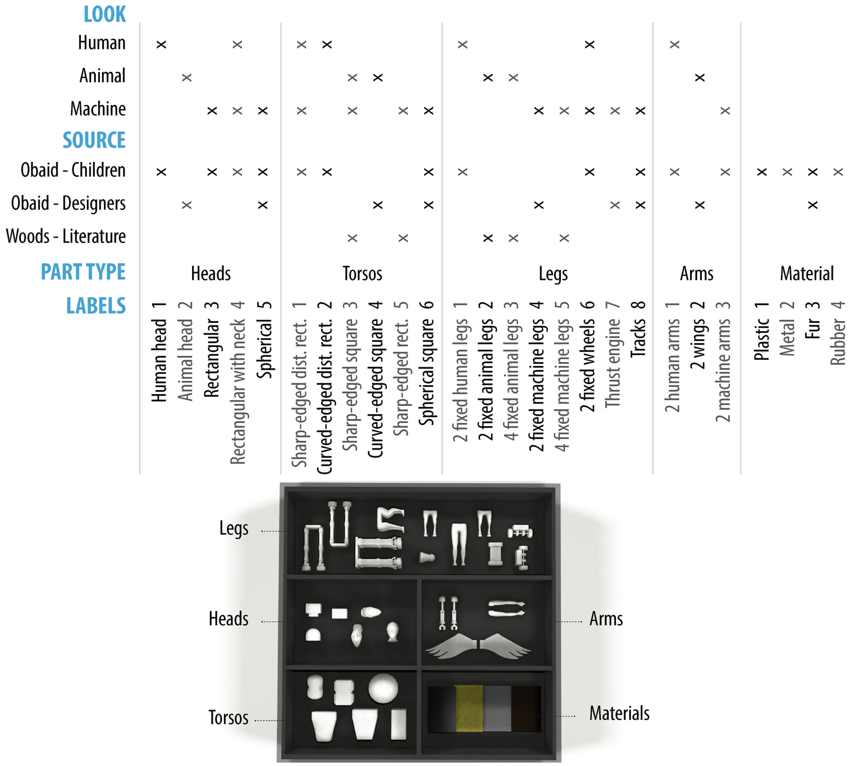

Fig. 1. A list of the proposed elements in the robot-design toolkit, based on elements from our previous study [4] and the study by Woods' et al. [8].

Then the child was asked to write or draw a story about this robot in the classroom and elaborate on the story in an interview (Storytelling). The study was conducted individually with the presence of a facilitator and an observer and were recorded with a video camera after getting informed consent.

Phase 1 - Robot construction and placement: in the robot construction phase, each child was provided with the Robo2Box set that included 3D printed model pieces and material specimens as shown in Fig. 2. During this phase, the facilitator only gave the instructions to freely construct a classroom robot and the observer took notes. When the child finished, they were first asked which materials they wanted to use for their robot. Thereafter they were asked to place their robot in a classroom model. The classroom model had paper people representing a teacher and students inside it to help children understand the relative sizes. We then asked the children to indicate whether their robot should be the same size, bigger or smaller than each of the paper models. The children were allowed to freely imagine the role of their robot in the classroom.

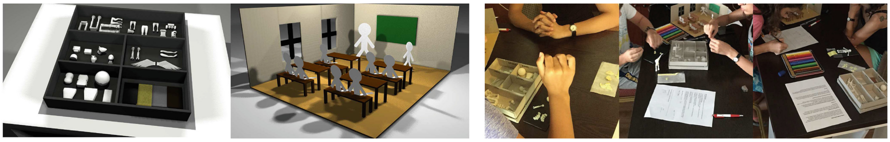

Fig. 2. Items used in the study including a Robo2Bbox and a classroom model.

Phase 2: Storytelling: after building a robot with the toolkit, the children were asked to write or draw a story about how this robot would behave in a classroom. The main idea of this phase was to learn about the additional appearance features (such as color, attachments, tools etc.) of the robot in addition to some extra information on how the children imagined the robot's behaviour in the classroom. But we did not focus on the behavioral aspects of the robot design. This approach is similar to the approach taken by Woods et al. [9] where they asked children to write a story about the robot of their choice (based on pictures). In our study, children were provided with a blank A4 paper with four sequential frames on it, along with colored pencils, to draw their stories. They were free to write down their stories if they preferred not to draw, and they were not required to fill in all the frames on the paper. Once the story writing phase was over, each child participated in a semi-structured interview, in which they were asked to explain their story. This explanation part was followed by some questions from the interviewer to gain a better understanding of how the children imagined their robot physically and behaviorally.

5 Analysis and Results

In this paper we focus on the use of the Robo2Box toolkit and the physical characteristics of the robots designed by the children. Other aspects related to the analyses of the interviews and stories will be presented in another paper. The only interview part that we will report on is the size of the robot and whether the children wanted to add or change anything in the toolkit.

5.1 Children's Designs

Head: Figure 3(a) shows the results for the chosen head; where one child was confused and used a torso and was excluded from the results. The difference between the categories was significant, $X^2(5, N = 30) = 14.4, p < .05$. The children typically chose a human head or a sphere. If we compare the elements here with the elements found in our previous study, it is clear that there is a preference for the elements that are based on children's drawings. Having no separate head, or an animal-like head was not popular among the children. According to Woods [8] children associate robots with no face to negative behaviors (e.g. aggression), which can explain this tendency.

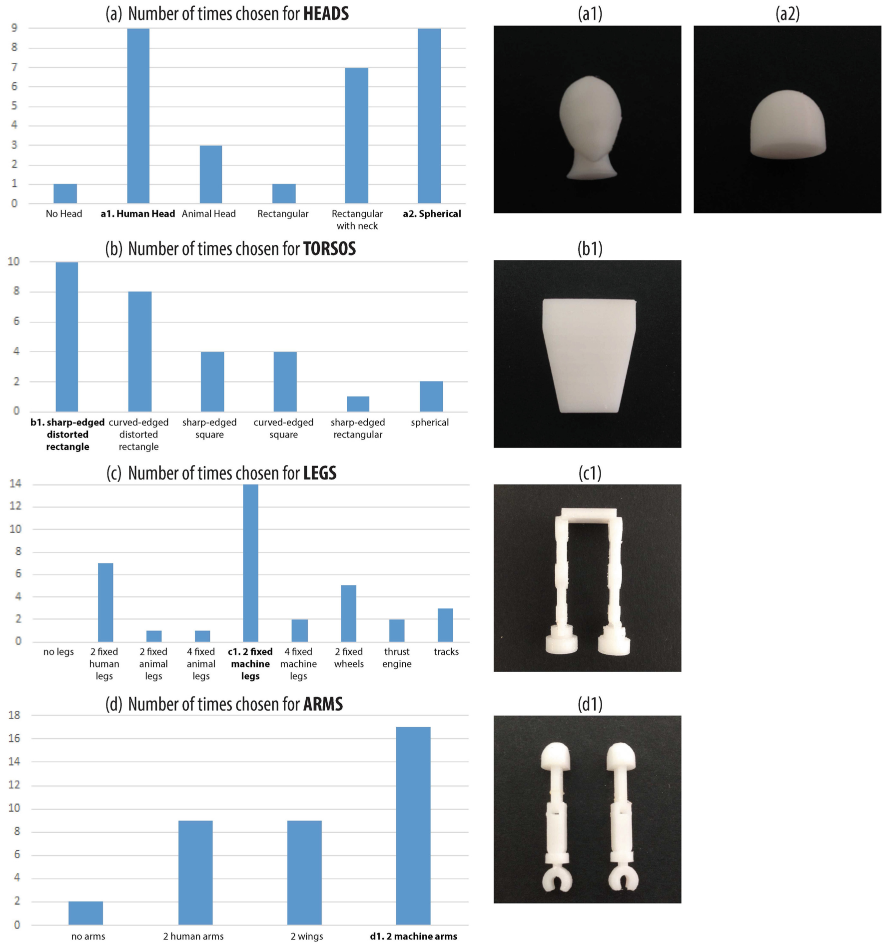

Fig. 3. Head's (a); Torsos (b); Legs (c); Arms (d) chosen by the children.

Torso: The torso results are shown in Fig. 3(b). One child was confused which parts to use as a torso and was excluded. The difference between the categories was not significant, $X^2(5, N = 30) = 10.8, p > .05$. The two torso parts most often chosen were the sharp-edged and curved-edged distorted rectangular torso, which can be mapped as both human- and machine-like. Squared, rectangular, or spherical torsos were less popular, which may indicate that children are looking for a slightly more human-like form with broad shoulders.

Legs: The results of the legs are given in Fig. 3(c). The difference between the categories was significant, $X^2(8, N = 31) = 39.31$, $p < .0001$. Children in our previous study often drew human-like legs, while in our study children showed a clear preference for two fixed machine-like legs. A possible explanation is that children found it difficult to imagine and/or draw machine-like legs, therefore the physical form helped them to express their design more.

Arms: The two machine-like arms were preferred, see Fig. 3(d). The difference between the categories was significant, $X^2(3, N = 37) = 12.19, p < .01$. Their choice confirms that children do imagine a classroom robot with two mechanical arms as exhibited also in our previous study.

Materials: The results show that children choose several materials for different parts of the body. However, when accumulating the number of times each material was used, it is clear that metal was chosen most often, followed by plastic. This difference is significant $X^2(3, N = 59) = 9.68, p < .05$.

Size: The majority of the children indicated the size of the robot to be between a child and an adult and the difference between the size categories was significant, $X^2(4, N = 31) = 14.32, p < .001$. In general, children expected their robot to be larger than a child size, certainly not smaller or equal to a child size.

5.2 Changes to the Robo2Box

During the interview we asked children whether they were happy with their robot. 24 children indicated that they were satisfied with it, while 6 children were not completely satisfied with it. In addition, there were several requests for changes or additions, in terms of additional elements, additional functionality for the robot, or creative ways of expression.

Additional Elements. One child wanted to have a torso that was more human, meaning that the human torso included in the toolkit was not sufficient. Regarding the head, there were several requests: a taller neck like an ostrich, a more curved shape in the neck area, a fully spherical head instead of a half one. One child wanted a cylindrical torso instead of a spherical one, and one child wanted thicker more rectangular legs. Finally, one child wanted two legs, but with wheels instead of feet, and one child wanted one big wheel.

Additional Functionality. Seven children wanted to add a screen on the torso and one child wanted the robot to be able to turn into a television. Five children wanted to add buttons, for example to open and close or stop the robot, and two children wanted the robot to have a way to keep pens and erasers, for example in a storage compartment or in the hands. Two children wanted to add guns to the robot's hands. In addition, requests were also related to elements present in existing fictional robots or action figures. Three children wanted an appearance more similar to the popular Baymax figures, while one child wanted his robot to look like the Optimus Prime transformer figure, and another wanted the robot to look like Captain America. This indicates that indeed, experiences with robots in the media influence children's designs.

Additional Expressiveness. One child wanted to have the possibility to add stickers to the robot's head and another wanted the head to have facial expressions, but different from a human being. One child wanted the robot to be able to express emotions, but only in the form of symbols. While all drawings of the children in our previous study were rather colorful, the Robo2Box toolkit only provided the children with white elements. Although children in general did not comment on this negatively, they usually added many details about colors and other elements of the robot in their stories and mentioned them in the interviews. This might be an indication that some more ways for creative expression would have been appreciated.

6 Discussion

The aim of the work presented here was to develop and evaluate a robot design toolkit, Robot2Box. Here we answer our three main research questions:

What kind of robots do children design for the classroom using the Robo2Box toolkit? The Robo2Box toolkit appeared to be easy-to-use for the children. All the children except one understood how the different elements could be combined to construct a robot. By combining the robot elements chosen we constructed general robotic prototypes (Fig. 4) that children envisioned as a robot for use in the classroom. The robots have bodily characteristics that are similar to humans but with a robotic flavor, e.g. made out of metal, slightly more rectangular, and with machine-like arms and legs. This kind of robot was identified in previous research as the robot that children find the most friendly and that they think is able to understand them [8]. Interestingly, in general the children envision the classroom robot as bigger than a child. This strengthens the image of a classroom robot close to a human adult. It also suggests that children are not immediately afraid of a relatively large robot in the classroom.

When using the Robo2Box, do children design classroom robots similar to drawings? Figure 4 shows the drawings from our previous study alongside the prototypical robot designs made with the Robo2Box.

If we compare the robots created with the Robo2Box toolkit with the drawings made by children and interaction designers, we see that they resemble the drawings of the children most, especially the drawings made by children without any robotics knowledge (middle row). In general, the children in our study did not have much robotics knowledge either. In comparison to the interaction designers' robots the children's classroom robots were bigger, more similar to humans, and didn't include many animal parts.

The findings are interesting in several ways. First of all, the elements incorporated in the Robo2Box toolkit based on children's drawings enable children to construct designs for classroom robots that are similar to those they draw. Second, the additional elements based on interaction designers' drawings do not change children's views considerably. This indicates that their views are rather stable. Finally, it means that children really have different requirements for classroom robots than those who may be designing them, and are not just limited by their drawing skills. Involving children in the design of classroom robots, for example through the use of the Robo2Box presented here, is thus important to let them express their own views. In addition, a main advantage of using

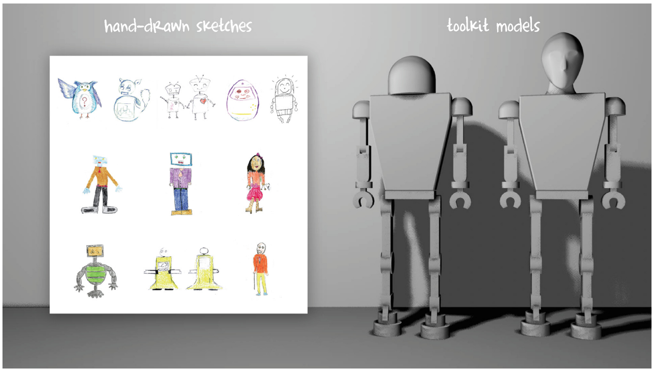

Fig. 4. Drawings (interaction designers = top row, children without robotics knowledge = middle row, children with robotics knowledge = bottom row) and our two Robo2Box prototypes.

the Robo2Box was the time spent on actually constructing the robot. In our previous study it took children around 20 min to draw a robot, the average construction time with the Robo2Box toolkit was 2:25 min for forming the body and then the rest of the time was spent on elaborating on other details. Limiting the time needed to envision a robot may allow researchers to allocate more time for discussing the behaviour of the robot.

What changes should be made to the Robo2Box for children to express their design ideas? Based on the storytelling activity and the interviews we were able to distinguish improvements for the Robo2Box toolkit, including separating the arms from the hands and the legs from the feet. This will allow children to add for example wheels to the legs, or tool-like hands to the arms. We will probably also expand the toolkit with some of the suggestions of the children (such as tools, armor, buttons and screens, and stickers or pens to create a more lively face). While the reliability and detail level of the toolkit are important, feasibility and low-cost production of the toolkit are also needed.

There are several limitations to this study that need to be mentioned. One of the limitations might come from performing the study with Turkish children only. It is possible that our findings are only representative for Turkish children. However, the drawings on which the elements of the toolkit are based come from other cultures. The fact that the children in our study often chose the toolkit elements that were based on other children's input indicates that findings may be generalised over different nationalities; this however needs further investigations. Another limitation might come from the actual sizes of the toolkit elements, since we did not provide the children with differently sized parts, however, we asked children to imagine it within a model of a classroom. Finally, the age range of the children in this study was rather broad. Focusing on specific age ranges could possibly reveal different preferences for the different age groups.

7 Conclusion and Future Work

We have described the reasons for developing a robot design toolkit, Robo2Box, as part of a human-centered design approach involving children in the design of robots for use in the classroom. We have also described the development of this toolkit based on previous literature. Through a study with 31 children from Turkey using the Robo2Box toolkit we conclude that (1) the classroom robots created by children are rather human-machine like, (2) the Robo2Box toolkit enables children to create classroom robots similar to freely drawn robots in a short time. This indicates that the robot design toolkit is a relatively fast and easy way for children to imagine a robot through a tangible experience, (3) the Robo2Box could be expanded and improved, by allowing more functionality, expressiveness, and additional elements, However, the benefits for a human-centered design process should also be considered. We thus argue that the Robo2Box can be a good basis for a human-centered design approach in which children are involved in the design of robots for the classroom.

Future work will focus on a more interactive toolkit with moving parts and means to join them. This might even lead to a toolkit where the design of some issues such as color, actions, behaviour and size can be left to accompanying software synchronized with the physical toolkit.

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