

Investigating Novel Methods to Child-Centered Design of Classroom Robots

by

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Investigating Novel Methods to Child-Centered Design of Classroom Robots

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ABSTRACT

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Robots are entering every aspect of our lives to make our lives easier, and educational settings, specifically classrooms, are one of them. As one of the main user groups of classroom robots, children's contributions to the design of these robots are very valuable. However, their lack of knowledge on state-of-the-art of classroom robots, and the means of communication issues between the child and the designer makes the process challenging. To ease these hurdles, a tangible classroom robot prototyping toolkit for children is developed to be utilized with other design activities while designing classroom robots with children. This thesis presents the development process of the toolkit – from design to evaluation, discusses children's requirements for classroom robots, and compares the use of toolkit with other design activities used in classroom robot design processes with children. An exploratory research approach and user-centric design methods were employed throughout the thesis.

Keywords: Robo2Box; classroom robots; design process; toolkit; children; child-centered design; design requirements; order switch; prototyping; storytelling.

ÖZETÇE

Sınıf İçinde Kullanılacak Robotların Çocuk Merkezli Tasarımında

Yeni Yöntemlerin İncelenmesi

Güncel Kırılma

Tasarım, Teknoloji ve Toplum, Yüksek Lisans

Aralık 2020

Robotlar hayatımızı kolaylaştırmak için hayatımızın her alanına girmektedir. Eğitim alanları, özellikle de sınıflar bunlardan biridir. Sınıf içinde kullanılacak robotların başlıca kullanıcılarından biri olan çocukların bu robotların tasarımına katkıları çok değerlidir. Ancak, sınıf içinde kullanılacak robot teknolojisi hakkında çocukların yeterli bilgiye sahip olmayışları ve çocuk ile tasarımcı arasındaki iletişimsel yetersizlikler tasarım sürecini zorlaştırır. Bu engelleri hafifletmek için çocuklarla birlikte sınıf içinde kullanılacak robotları tasarlarken diğer tasarım etkinlikleriyle birlikte kullanılmak üzere bir sınıf içi robotu prototipleme araç seti geliştirilmiştir. Bu tez, araç setinin tasarımdan kullanıcı değerlendirmesine geliştirme sürecini sunmakta, çocukların sınıf içinde kullanılacak robotlar için gereksinimlerini tartışmakta ve araç setinin kullanımını, sınıf içi robotların çocuklarla tasarım süreçlerinde kullanılan diğer tasarım etkinlikleriyle karşılaştırmaktadır. Tez boyunca keşifsel bir araştırma yaklaşımı ve kullanıcı merkezli tasarım yöntemleri kullanılmıştır.

Anahtar sözcükler: Robo2Box; sınıf içi robotları; tasarım süreci; araç seti; çocuklar; çocuk odaklı tasarım; tasarım gereksinimleri; sıralama değiştirme; prototipleme; hikâye anlatımı.

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ABBREVIATIONS

R2B	Robo2Box
HCI	Human – Computer Interaction
HRI	Human – Robot Interaction
CRI	Child – Robot Interaction
UCD	User – Centered Design
PD	Participatory Design
RB	Robot Building Phase
ST	Storytelling Phase

Chapter 1:

INTRODUCTION

Robots are being integrated into many aspects of humans' lives, and educational settings are one of them through the use of classroom robots. As one of the primary users of classroom robots, children's contributions in the design process of this new technology is very valuable to suit their needs for the design product. However, it is very challenging to get design inputs from them, mostly because of their lack of state-of-the-art knowledge, as well as means of communication issues between the child and the designer. To ease these hurdles, a toolkit has been developed: Robo2Box is a robot design toolkit, containing tangible robot body parts to design classroom robots with children. The toolkit is meant to be used with other design activities such as storytelling and sketching. The toolkit consists of 3D printed body elements (head, torso, arms, legs), that are based on a robot feature taxonomy coming from literature (Woods, 2006), classroom robot drawings of interaction designers and children with and without robotic knowledge (Obaid et al., 2015), and material specimens (metal, plastic, fur, eva).

The starting point of this thesis is the work of Obaid et al. (2015, 2016, 2017). Based on the findings of these previous research work, the Robo2Box toolkit was designed, and was developed further by using research through design approach. To involve children in the design process of classroom robots, this thesis aims to introduce Robo2Box, and share methodological implications coming from the exploration of various methods by (i) employing Robo2Box in two different user studies, first to examine the toolkit, and second to examine the order of the design activities employed in the study, (ii) comparing Robo2Box with two other methods used for the same purpose as Robo2Box, drawing and clay. The thesis begins with the development of Robo2Box, followed by the studies conducted with it to elicit children's requirements on classroom robots and the results of these studies, and ends with discussion on results and comparison on methods.

1.1 Motivation

Robots are not only in sci-fi movies anymore, they are here in our daily lives. While hoping for them to not start ruling the world, it is always amazing to see how

they can get our work done in factories, entertain us, assist us at home or in the classroom, or even inform us. As of today, the ongoing research on robots is not only on hardware and software related features of the robots; the social robotics domain aims at studying the behavioral features of the robots and their interaction with humans. One of the focal points in social robotics research is the use of robots in children's learning processes, which has been proven to be beneficial to the pupils (Belpaeme et al., 2018; Benitti, 2012; Johnson, 2003; Rogers & Portsmore, 2004). This emerging area of research led me to study the use of robots in learning environments. In the recent studies on social robots, they are being used in classrooms in various roles, such as a tool, an assistant, or a teacher (Mubin et al., 2013), and they are mainly tested with children to evaluate their teaching capabilities. However, even though children are the main user group, they are left out of the earlier stages of the design process of the classroom robots. Oftentimes, the research either focuses on how children behave towards robots (Shin & Kim, 2007), or uses off the shelf robots (Goodrich & Schultz, 2007), rather than investigating children's requirements for classroom robots. Even though these approaches make the researchers in relevant fields learn about children and their behaviors around robots, they do not involve children in the design process of the robot itself.

The advantages of including the target user of a product or a solution in the design process has long been proven in the field of interaction design (Norman, 1986). Even though they are one of the main users of robots in classrooms, including children in the design process is however very challenging for the researchers because children often lack the knowledge about state-of-the-art robots, and they have difficulties explaining what they want and need. Hence, this thesis focuses on the exploration of novel methods and tools to inform the classroom robot design process with children, and children's requirements for a classroom robot.

1.2 *Aim*

Over the past decades, research on robots have evolved, and the fields of interest have expanded; one of which is education. The researchers aim to explore the ways in which to integrate robots and robotics in the classroom, since the positive effects of their use have been supported by literature (Belpaeme et al., 2018; Benitti, 2012;

Johnson, 2003; Rogers & Portsmore, 2004). Despite the benefits, the children are left out from the design processes of these classroom robots in most of the cases (Komatsubara et al., 2014; Lyk & Lyk, 2015; Madyal et al., 2020) even though they are one of the main stakeholders of the design product.

There are a limited number of examples of research on educational robots that involve children as the contributors of the design process (Alves-Oliveira et al., 2020; Kırılancı et al., 2020; Obaid et al., 2015; Obaid et al., 2016; Obaid et al., 2017). Including the children in the design process is a very challenging task, and the methods to elicit children's requirements for future technologies have been studied by many researchers over the years (Bumby & Dautenhahn, 1999; Druin, 2002; Scaife & Rogers, 1999). Advancing the research on involving the children in a design process is still needed because there is always room for improvement, and classroom robot design is one of the many use cases to consider. Thus, the aim of this thesis is to explore the methodological learnings throughout the process of developing an interaction design tool for designing classroom robots with children, and compare it with some other methods used in the literature. While doing so, as a side product of this study, I will share the insights for the design of a classroom robot that were collected from the participant children.

1.3 Research Questions and Contribution

With the above-explained perspective, I hereby share my research questions:

1. How can children be involved in a classroom robot design process using a tool that provides them a starting point to think without limiting their creativity?
2. What do children envision in terms of a classroom robot's appearance and functions?
3. How does children's demographic background affect the requirement they define for the classroom robot?

This thesis contributes to the Human-Computer Interaction field (HCI), and Child-Robot Interaction (CRI) subfield by:

- Proposing a new tool for informing the design process of a classroom robot that will be envisioned and used by the children in their classrooms,
- Comparing the differences in the design processes assisted by the new tool proposed (Robo2Box toolkit) and two other methods from the literature with the same use case (drawing and clay),
- Reporting children's thoughts on classroom robots' form factor and behaviors,
- Reporting how the differences among children on their socio-economic background and robotic knowledge affect children's requirements for a classroom robot.

1.4 *Research Universe and Scope*

The main research universe of this study relates to child-robot interaction from an interaction design perspective. Furthermore, this study is associated with human-centered design and its methodologies to incorporate children in the design process. The scope of this study consists of (i) designing a robot design toolkit to involve children in classroom robot design process, (ii) eliciting children's requirements for classroom robots, (iii) comparing different methods that were used to involve children in classroom robot design process with the toolkit, (iv) exploring different requirements of the children that were coming from disadvantaged backgrounds. Meanwhile, this study focuses on the look and feel of classroom robots, along with their behaviors within the classroom context. The study excludes hardware and software development of classroom robots, use of robots outside and at home, the perspectives of designers and teachers on classroom robots, and the use of robot building and coding within a learning perspective.

1.5 *Thesis Outline*

The thesis has 6 parts: Part 1 is this introduction. Part 2, "Background", reviews the interaction design literature on classroom robots and methods for designing with children. Part 3, "Method", explains the methodology I employed during this study and R2B toolkit content. Part 4, "Study", defines and details the user tests with R2B and the

findings of the tests. Part 5, “Discussion”, interprets and compares the test results and methodological alternatives. Part 6, “Conclusion”, summarizes learnings from this study.



Chapter 2:

BACKGROUND

In this section, I will present a literature review on three topics: (1) children's involvement in the design process, (2) social robots employed in education, (3) design tools used for robot design.

2.1 *Involving Children in the Design Process*

Involving users in the design process has shown its benefits over the years, and has been recognized by many researchers today, especially in Human-Computer Interaction (HCI) and Human-Robot Interaction (HRI). In these communities, there are two main design approaches that include the user within the design process: user-centered design (UCD) and participatory design (PD). The UCD approach positions users as reacting agents rather than initiators, meaning that they are control mechanisms for designers as assessment services to show whether the user needs are met, along with positive and negative feedback about the design (Muller et al., 1993; Norman, 1986; Rubinstein & Hersh, 1984). Whereas the PD approach positions users more as design partners, gives them a more responsible and equal status and lets them work together with the designers within the design process so that the outcome can suit their needs best (Muller et al., 1993; Schuler & Namioka, 1993).

Abovementioned design approaches are also practiced within children oriented design studies, yet children's involvement in design is still very challenging, as the roles they can play in the process are highly different from those of the adults. Based on her research and literature analysis, Druin (2002) categorized four main roles that the children could play when it comes to technology design: user, tester, informant and design partner. In the user role, children use technology while adults observe or test for skills to understand the effects of existing technologies on children so that they can shape the future technologies accordingly. The children have a mostly passive role in this design process. Meanwhile in the tester role, children use prototypes of technologies before they are released, while adults observe and/or ask for comments about the experience. With the tester role, children contribute to the future iterations of the technology with their test results and comments. In the informant role, children contribute to several stages in the design of technology with the combination of the

previous two roles and inputting on the sketches and early prototypes. In the design partner role, children are equal stakeholders in the entire design process and experience. Being one of the pioneers in the field, Druin and their research show strengths and challenges of each role that a child can play in a design process.

Another important and pioneering research on children's involvement in technology design is done by Scaife & Rogers (1999). By employing a case study on the design of a multimedia application for and with children, they categorized the questions that were raised during their design research with children about a kid-centered framework, and commented on those questions, which were grouped under selection, focus, dialogue, individual, authoring and single method titles. These titles cover the concerns about (1) whether there should be a line in children's contribution to the design, and if yes, where to draw it, (2) how to acquire children's contribution to design, as their conceptual framework and terminology in talking is different than adults, (3) whether it is possible to come up with a "one size fits all" design, and (4) whether the kid-centered methods can be used in other areas. While some of these questions are raised in adult-centered design approaches as well, they are all very critical topics to elaborate.

Having all the above questions in mind, my main focus on this thesis is especially around the second question mentioned above, how to acquire children's contribution to design, as their conceptual framework and terminology in verbal communication are different from adults, by making use of a robot design toolkit. The relevant and detailed examples involving the children in design are given in the titles below, as they are focused more on robot design, and more related to the general scope of the thesis.

2.2 Social Robots

The research explained within this thesis is oriented around "social robotics", thus it is important to explain this terminology. A good definition of social robots was proposed by Dautenhahn and Billard as follows (1999):

"Social robots are embodied agents that are part of a heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other."

The significant characteristics of a social robot are “social learning and imitation, gesture and natural language communication, emotion, and recognition of interaction partners” (Fong et al., 2003). From pets to tutors and assistants to companions, social robots now cover a wide range of application areas. However, this thesis is only limited to the social robots designed for educational settings, therefore other application areas will not be covered in the literature review.

2.2.1 *Social Robots in the Educational Settings*

Nowadays, there is an increasing tendency to implement robots and robotics into the schools as educational tools. As a part of education, integration of robotics into the curricula (either within school hours or as an extracurricular activity) has been shown that it has major benefits on education at all levels by improving educational achievements and student development, and increasing motivation and excitement (Benitti, 2012; Johnson, 2003). Most of the studies about the integration of robotics into education are focused on the education of STEM (science, technology, engineering, mathematics) subjects through robotics with the aim of increasing academic achievement (Barker & Ansorge, 2007; Rogers & Portsmore, 2004). Art and creativity are other focuses in research, aiming to increase students' excitement about learning STEM subjects and robotics (Barnes et al., 2019; Rusk et al., 2008) and boost creativity (Alves-Oliveira et al., 2020). Use of already built robots is a common practice in language teaching and has a potential to increase the achievement scores of students (Han et al., 2008; Kanda et al., 2004; Saerbeck et al., 2010).

My primary focus in this research is on the design requirements of robots that are physically placed in the classroom. The research examples that place robots directly in classrooms utilize robots either as social entities, namely peers, assistants or tutors, or as tools. Examples include robots that help the teacher to silence the class (Lyk & Lyk, 2015), that aims to increase science understanding by quiz-style conversation (Komatsubara et al., 2014), that help students to separate waste (Madyal et al., 2020), that include students - who cannot attend school due to medical conditions - virtually in the classroom via telepresence (Newhart et al., 2016), or that teach drawing and writing with haptic feedback to students with visual impairments (Neto et al., 2020). While those robots can be commercial robots such as Nao and Pepper (Softbank, 2020a,

2020b) altered to fit the research requirements, some of them are built by the respective researchers of the studies, such as Pomelo by Nasi et al. (2019).

2.2.2 *Children in Robot Design*

Actively involving children in different design stages and topics is more common than before, including the design of new technologies. Yet, as mentioned above there is a limited number of studies on robots that involve children in their design process, even though robot(ic)s are one of the trending areas in technology design today. One of the early examples of robot design research with children is by Bumby & Dautenhahn (1999), aimed to discover the children's perception of robots, and how they would behave when interacting with one. They employed the activities of drawing and storytelling to discover the perceptions, and observation to learn more about children's behaviors while interacting with a robot. Taking into account the year the study was conducted (1999), this study was one of the pioneers in the HCI and HRI area by studying the children's perception on robots, while the majority of the robots known by people were either in the factories used as autonomous machinery, or in fiction portrayed as alien or evil creatures that aimed to take over the world. However, robots can be designed and built to fit in human social context, while satisfying the social and cognitive needs of humans, thus allowing more humane interactions between them, as the authors suggested. With this research, they made a first step by discovering the existing perceptions, stereotypes and tendencies about robots, from the perspective of children.

Thereafter, several studies investigated children's perceptions of and expectations from robots. In their study, Woods et al. (2005; 2006) aimed to explore children's attitudes towards robots in terms of robots' physical attributes and personality traits such as appearance, mode of locomotion, gender, by making use of a questionnaire. Their study showed that children's contribution when designing robots for their use, e.g. educational contexts, was very valuable, since children's perception of and attitudes towards robots were different from adults. Woods (2006) also stated that "[...] children use a combination of robot features to form an opinion about the personality of a robot and do not solely focus, e.g. on its face." and argued that robot designers should

combine several physical attributes, instead of isolating features from one another while designing robots.

Shin & Kim (2007) interviewed children to explore their attitudes towards learning about, from and with robots. Even though the children had positive attitudes towards having robots in learning environments, most were not in favor of having robots as teachers because of their lack of emotions. Benitez Sandoval & Penaloza (2012) focused on revealing children's expectations and knowledge about robots to help design better future robots. The researchers used a mixed-methods approach by using surveys and free drawings performed by 296 children. The findings of their study showed that the children participating in their study had some knowledge on robots, and some of them had a deeper understanding of robots. An algorithm based analysis of the free drawings of the robots showed that the strongest stereotype for the robots drawn was mechanical anthropomorphic, described as "with rigid lines, straight angles, vertical geometric organization (i.e. square-shape head over squared-shape body, etc.)". Their study also showed that 79.81% of the participating children would like to see robots employed in education (Benítez Sandoval & Penaloza, 2012).

Lastly, Sciutti et al. (2014) explored children's preferences on robot features, and it was studied with an evaluation experiment by asking children and young adults to rank 14 robotic features (walking, hearing, seeing, having two hands and two feet, having two eyes, having hair, having a mouth, having a head, talking, grasping objects, able to smell, able to feel pinches, able to move, able to stand) from most important to least important for them, both before and after interacting with a robot, and compared the results. The study showed that young children were inclined to pay more attention to the robot's appearance than its functions as older children and adults did, and interaction with a robot affected younger children to pay more attention to the robot's perception and motor abilities compared to their results before the interaction. This study suggests that children's design requirements for a robot may be influenced by age and actual experience with a robot, or at least having seen some examples of robots.

There are also examples in literature about designing robots for children and with children. Obaid et al. studied children's needs and wishes for classroom robots, by using drawing (Obaid et al., 2015), a robot design toolkit made out of 3D printed parts (Obaid et al., 2016; 2017), and clay (Obaid et al., 2017). Apart from showing what children would like from a robot which would be used in a classroom, they also compared

different methods in design research with children (Obaid et al., 2017), along with presenting the differences among interaction designers, children with and without robotic knowledge on the desires for classroom robots (Obaid et al., 2015). Another example is by Alves-Oliveira et al. (2017, 2018), in which they conducted various co-design activities with children to develop a robot to boost creativity in children, called YOLO.

2.3 Tools in User-Centric Robot Design Practices

Robot design is a multidisciplinary area, requiring knowledge of several fields such as programming, engineering, psychology and design. Such a field is thus already challenging to work in, and working in it with a user-centric approach is even more challenging, especially when exploring the needs of user groups without any prior knowledge and experience in social robots and/or robotics. There are multiple methods the researchers use to collect insights and involve users in the robot design practices. While listing all of these methods is beyond the scope of this thesis, I would like to share some of them and present some research examples to give an idea about the user-centric activities in robot design practices.

Most of the time, user-centric design processes employ qualitative methods, along with some quantitative ones to learn more about user needs, involve the users in the ideation process, or get feedback from them. To get feedback for their robot design, Chowdhury et al. observed the users interacting with their robot and made a small interview with them afterwards (2020). Lee & Jung (2020), and Gordon et al. (2015) also employed the same in-the-field observation method for their robot to learn from the users by their interactions with the robot. Both De Graaf & Allouch (2014), Lee & Sabanović (2014), and Jiang et al. (2019) used questionnaires to learn from the users about their perceptions on, preferences of, and expectations from the robots. To learn the user needs and involve the users in the ideation process for the robot design, along with the designers, a common approach used by the researchers is forming a focus group with several design activities. Wu et al. (2012) had discussion sessions and a card-sorting activity with the elderly to learn more about their perceptions of robots and their preferences on robot appearance, to design assistant robots for them. Feng et al. (2015) and Azenkot et al. (2016) studied with visually-impaired designers and non-

designers by making use of discussion sessions for ideation, and then prototyping and Wizard-of-Oz for the user feedback. Visualization methods are another way to get user insights, and generally used with other tools as well. Lee et al. (2012) used drawing as their main method to elicit user requirements in combination with interviews, whereas Rose & Björling (2017) and Lee et al. (2017) employed drawing and storyboarding with discussion sessions and prototyping.

Prototyping toolkits are one of the important approaches for involving users in the robot design process. These toolkits are developed to be used by researchers, designers, and developers working in the social robotics field. Different types of robot prototyping toolkits are presented by researchers: Framework based robotic toolkits were developed for the programming needs of developers by Lane et al. (2012), Henkel et al. (2011), Skantze & Al Moubayed (2012) and Huang & Mutlu (2012). Fossdal et al. (2020) and Kato et al. (2012) developed toolkits with software and hardware support to simplify development and production phases in robotics on the user's behalf. These toolkits are not aimed to elicit design requirements of the users.

Since the incorporation of robotics within the educational curriculum has been shown beneficial for students on STEM and creativity related subjects (Alves-Oliveira et al., 2020; Barker & Ansorge, 2007; Belpaeme et al., 2018; Benitti, 2012; Johnson, 2003), several robotic toolkits for children also exist. These toolkits are either research oriented or commercial, and they mostly aim to inform children about the basics of robotics, namely programming and mechatronics, through play. By being one of the pioneers on the commercial side, Lego Mindstorms offers children to build their own robots with Lego blocks and program them with the in-built interface (LEGO, 2020a). Targeting children of all ages, robots Dash and Cue and the creativity kit Dot focus on enhancing children's problem-solving skills in an inventive way (WonderWorkshop, 2020). On the research-oriented side, SoRo Toolkit aims to educate preschoolers about programming and computational thinking (Gordon et al., 2015). KIWI toolkit, including support on hardware with its software called CHERP, has been incorporated into many research studies with a purpose of integrating technology and engineering into the educational curriculum of ages 4-7 (Sullivan & Bers, 2016). The toolkit system named ModBot focuses on informing children about the fundamentals of underwater robots and the water environment (Liu et al., 2020).

There are robotic prototyping toolkits for children that are not aiming for the educational development of the children as well. Robo2Box is a prototyping toolkit for designing classroom robots, aimed to be used in the classroom robot design process with children to elicit their needs (Obaid et al., 2016; Obaid et al., 2017). The parts in the toolkit were designed based on the data coming from relevant literature (Woods, 2006), and the study conduction with children with and without robotics knowledge and interaction designers (Obaid et al., 2015).

2.4 Background Discussion

Most of the research focuses on the educational benefits of robots & robotics, and educational development and achievements of the children, rather than on the topic of having robots in classrooms as a physical space where children learn, play and socialize - a place where children spend most of their time in a day.

Since the decisions are made by adults (such as teachers, developers or designers) when it comes to designing a classroom robot that the children will use, adults always consider the educational needs of the children in a pedagogical perspective. Most research doesn't involve classrooms thoroughly as a physical space, apart from the teaching/learning activities conducted in it; yet children use this physical space to play and socialize as well, for example. I believe that when the children can contribute to the design process of a classroom robot, the design requirements of the children would also be influenced by their spatial and emotional connection with their classrooms, which shapes their needs and desires for a classroom robot accordingly. Hence, with this motivation, I aim to study different ways to include children in classroom robot design processes.

Chapter 3:

METHOD

This thesis presents an exploratory study on classroom robots, both in methodology of the design process and needs and desires of children. I followed the research through design approach (Frayling, 1993), by using both qualitative and quantitative methods for acquiring and analyzing data, and using primary data coming from the studies I did (Kırlangıç et al., 2020) and secondary data coming from Obaid et al.'s studies (2015, 2016, 2017). I employed storytelling and prototyping as the design activities to be done with the children during the user studies, and I analyzed the resulting data and my own observations during the studies with both quantitative and qualitative approaches. The chosen prototyping method for the research while designing classroom robots with children is a robot toolkit with 3D printed parts, named as Robo2Box. The Robo2Box toolkit derives from Obaid et al.'s (2015) earlier studies on designing for child-robot interaction. This study revealed the necessity of the children's contribution to the designs targeting them. While children's contribution is important, providing them a means of communication, as a tool or method, is a challenge. Robo2Box toolkit is developed to respond to the needs of researchers on communication with children on the same level during the classroom robot design process.

The remainder of this section explains the design process of Robo2Box and its content in detail, while briefly mentions the studies done with the toolkit that aim to understand and evaluate the children's interaction with it.

3.1 *The 1st Version of Robo2box*

There have been two phases in the development process of Robo2Box toolkit. The first phase started with building on the outcomes of Obaid et al.'s study (2015), continued with the development of the first version of the toolkit and ended with testing with children (Obaid et al., 2016). This subsection presents the details of the first phase.

3.1.1 *Developing the 1st version of Robo2Box*

In the abovementioned study of Obaid et al. (2015) (See section 3 and 3.1), the views and requests of (i) interaction designers, (ii) children with robotics knowledge, (iii) children without robotics knowledge on a robotic teaching assistant were studied.

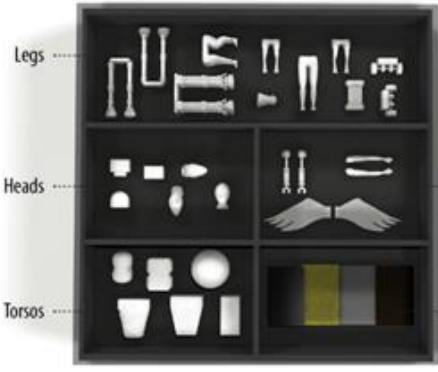
The authors asked the participants to draw the robots that they envisioned as a group, and voice recorded the sessions. As a result, the study showed great differences between the children's and interaction designers' designs for the robotic teaching assistant. Since they would be the target users, children might have a significant contribution to the design process. However, previous research by Scaife and Rogers (1999) shows that the act of drawing keeps children from focusing on other aspects of the interaction, and Obaid et al.'s study supports how children's limited drawing skills hinder them from creating the designs they like. Furthermore, it could also be beneficial to provide children with inspiration from the designs of professionals and more knowledgeable children.

The research by Obaid et al. (2015) led to the idea whether a prototyping tool for designing classroom robots would be helpful for children to imagine and express themselves better in the design process. Hence, the Robo2Box toolkit was designed based on the shapes suggested by the children and the interaction design students' drawings presented in Obaid et al.'s study (2015). Also, some additional elements were added to the toolkit based on the findings of Woods (2006). After setting the baseline for the toolkit, I started my initial design process with a research on the real-life examples and did simple sketches for the parts. The next step was to decide whether to make the parts with moveable joints, and the way of bonding the parts to each other. To prevent restricting the children and their designs by providing some specific areas to bond the parts to one another, the use of adhesive dough for bonding was the final decision of the research team of the project that I was a part of. These decisions were followed by the modelling process, which was made on a 3D modelling software, and I got feedback from the team before finishing it. The finished design of the toolkit was 3D printed with a single material and in white to make all the parts equal in the visual sense and not affect the children's objectivity through visual cues.

3.1.2 The 1st Version of Robo2Box Toolkit Content

The toolkit consists of the elements presented in Figure 3.1. There are 5 groups of elements: heads, torsos, legs, arms, and materials. Similar to Woods (2006) the parts can be categorized as human, animal or machine like (and mixes of these categories). The

different body parts can be connected with adhesive dough, and materials such as fur and rubber can be chosen to indicate a preference, but cannot be physically attached.



Category	Part label	Look	Human	Animal	Machine	Source	Children	Designers	Literature
Head	1 Human head		x				x		
	2 Animal head			x				x	
	3 Rectangular				x		x		
	4 Rectangular with neck		x	x			x		
	5 Spherical				x		x	x	
Torso	1 Sharp-edged distorted rect.		x		x		x		
	2 Curved-edged distorted rect.		x				x		
	3 Sharp-edged square			x	x				x
	4 Curved-edged square			x			x		
	5 Sharp-edged rect.				x			x	
	6 Spherical square				x		x	x	
Legs	1 2 fixed human legs		x				x		
	2 2 fixed animal legs			x					x
	3 4 fixed animal legs			x					x
	4 2 fixed machine legs				x		x		
	5 4 fixed machine legs				x				x
	6 2 fixed wheels		x	x			x		
	7 Thrust engine				x			x	
	8 Tracks				x		x	x	
Arms	1 2 human arms		x				x		
	2 2 wings			x				x	
	3 2 machine arms				x		x		
Material	1 Plastic						x		
	2 Metal						x		
	3 Fur						x	x	
	4 Rubber							x	

Figure 3.1: The 3D model of the 1st version of Robo2Box toolkit on the left; the list of the elements in the toolkit on the right (Obaid et al., 2017).

3.1.3 User Study with the 1st Version of Robo2Box

The aim of the user study in the 1st version of Robo2Box was to evaluate the toolkit's use by the children as a method to elicit children's requirements for classroom robots, by comparing the study's resulting robots with previous research. The study was conducted with 31 school children (8-15 years old, average age of 11 years (SD = 2.3), 16 girls and 15 boys) from Turkey. During the study, each child was asked to build a robot by using the parts in the toolkit first, and place it in the model classroom (robot building and placement phase). The child was then asked to draw or write a story for their robot in a classroom environment, presenting what it would do and how it would behave in the classroom, and this activity ended with a semi-structured interview to elaborate on the story (storytelling phase). Each child participated in the sessions individually in the presence of one facilitator and one observer.

3.2 *The 2nd Version of Robo2box*

The second phase started after the testing of the first version, and continued with modifying the toolkit according to the outcomes of the testing. The second phase ended with testing with children. This subsection presents the details of the second phase.

3.2.1 *Modifications Requested for the 1st version of Robo2Box*

During the testing of the first version of R2B, the children were asked whether they were satisfied with how their robots looked. While the majority of the participants were happy with their robots, there were still several requests for changes and additions to the toolkit and the parts available in it. Based on the requests made by children and the observations of the facilitator during testing, some improvements were distinguished and categorized for the Robo2Box toolkit (Obaid et al., 2016):

Elements. A more human torso was requested, which showed the insufficiency of the current human torso in the toolkit. Another torso request was a cylindrical torso. For the heads, there were requests for heads with a much longer neck, and a more curved neck, and a fully spherical head. A thicker and more rectangular legs and one big wheel were requested for the legs. Separating the hands from the arms to be able to attach various objects like guns to the arms, and separating the feet from the legs to be able to attach other modes of locomotion like wheels to the legs were also requested by the children.

Functionality. There were various types of additions made by the children during the storytelling phase of the tests to add more functionality to their robots. The children added electronic objects like screens, buttons, speakers, microphones and printers, stationary objects like chalks, pens and erasers for in-class use, and storage compartments to put these stationary objects in. A few of them added guns to the hands, or replaced at least one of the hands with a gun for protection purposes. Some children wanted their robots to look like the popular fictional characters in the media, Baymax, Optimus Prime and Captain America, and added body armor or shields to create the resemblance, which is an indication of how media experiences influence the children's robot designs.

Expressiveness. The completely white nature of the toolkit didn't impact the children negatively, but there were several details and comments about creative ways of

expressions in the stories and the interviews, such as adding stickers to the face of the robot, having non-human facial expressions, expressing emotions in the form of symbols, adding colors, facial features and hair to the robots.

In addition to all the change requests and additions stated above, it was observed by the facilitator that the toolkit parts were too small even for a child. It was not easy to bond such small parts to each other, so while trying, some parts were broken during the study. Even though the broken pieces could be glued easily, it was an upsetting moment both for the child and the facilitator. Therefore, the need for the parts to be enlarged were realized.

3.2.2 *The 2nd Version of Robo2Box Toolkit Content*

After distinguishing the needs for improvements, eliminating some of them for the feasibility in the production of the toolkit was decided. Also, some of the changes suggested, like being able to change the sizes of the parts or adding colors, could be accomplished better on a graphical user interface. While a GUI version of the toolkit could be the future study of this research project, it is not in the scope of this thesis, hence the changes that would be better off in a graphical interface were eliminated as well. The changes that were made in the toolkit are listed below with their respective reasons (Kırlangıç et al., 2020), and the diagram of these can be found in Figure 3.2:

- A cylindrical torso, a fully-spherical head, and one big wheel were added to the toolkit based on the suggestions coming from the children in the first user study.
- The thrust engine under legs category was taken out of the toolkit due to being used by only one child during the testing of the toolkit's 1st version, and imagined use of it in a version of the toolkit with a graphical user interface.
- The wings were modeled and printed as the left and the right in the 1st toolkit. Since they were used together all the time during testing of the 1st toolkit, these two parts were modeled into one wing for the 2nd version of the toolkit.
- All the parts in the toolkit were scaled up 10 times to give the feeling of a toy piece and better handling.

- The bonding method of the toolkit was changed from adhesive dough to Velcro to enable a stronger and easier connection between parts. The placement of the Velcro on the toolkit parts were decided based on the most common bonding places from the children's designs in the previous study.

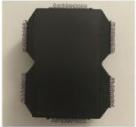
Robo2Box, v1.0	Robo2Box, v2.0	Change	Reason
		Parts added: Torso - Cylindrical Head - Fully Spherical Legs - One Wheel	Parts requested by the children of the first study
		Part taken out: Legs - Thrust engine	Being used only once during the first study Future use in a GUI version
		Seperate wings modeled into one solid piece	Seperate pieces used together all the time in the first study
		Size scaled up to 10 times	To give a feeling of a toy Better handling
		Bonding method changed to Velcro	A stronger and easier bonding between parts

Figure 3.2 The diagram showing the changes and their respective reasons between the two versions of Robo2Box.

The content of the 2nd version of Robo2Box toolkit is presented on Figure 3.3 as a 3D model and list of elements.

LOOK																	
Machine																	
Animal																	
Human																	
SOURCE																	
Literature																	
Designers																	
Children																	
PART TYPE																	
LABEL																	
		Head		Torso		Legs		Arms		Material							
		Human head 1	x	Sharp-edged distorted rect. 1	x	2 fixed human legs 1	x	2 human arms 1	x	Plastic 1	x						
		Animal head 2	x	Curved-edged distorted rect. 2	x	2 fixed animal legs 2	x	2 human arms 2	x	Metal 2	x						
		Rectangular 3	x	Sharp-edged square 3	x	4 fixed animal legs 3	x	Wings 2	x	Fur 3	x						
		Rectangular with neck 4	x	Curved-edged square 4	x	2 fixed machine legs 4	x	2 machine arms 3	x	Rubber 4	x						
		Spherical 5	x	Sharp-edged rect. 5	x	4 fixed machine legs 5	x										
		Fully spherical 6	x	Spherical 6	x	2 fixed wheels 6	x										
				Cylindrical 7	x	Tracks 7	x										
						One wheel 8	x										

Legs

Heads

Torsos

3.2.3 User Study with the 2nd Version of Robo2Box

The first user study with the toolkit was focused on the evaluation of the toolkit with children. The second study was focused more on the structure of the study itself, rather than the toolkit. The toolkit is the main focus in this thesis about eliciting children's requirements for a classroom robot, yet the structure of the study plays a great role while conducting tests with the toolkit. Hence, the aim of this study is to understand how much of an impact the change in the order between robot building and storytelling phases makes on the classroom robot designs of children. The study was conducted with 29 school children in two groups. The first group had 15 children (9-13 years old, average age of 11 (SD=1.45), 7 boys and 8 girls), and they did the study on robot building (RB) - storytelling (ST) order. The second group had 14 children (9-13 years old, average age of 11 (SD=1.67), 6 boys and 8 girls), and they did the study on ST - RB order.

3.3 Design Rationale behind the Decisions

Based on the work of Obaid et al. (2015), Robo2Box was developed and studied to explore the ways to involve children in classroom robot design process. This thesis study aims not only to present the toolkit, but also to show how it can be used in child-centered design of classroom robots. Thus, the developmental process of the toolkit proceeded iteratively, and a research through design approach was followed within the thesis: after the first study with the first version of the toolkit, the changes were made to make the toolkit more playful and durable for children, and to have a wider list of options within the toolkit, so that children could express what they envision for a classroom robot better and in a fun way.

Robo2Box toolkit was designed to be used with other design activities, like storytelling and sketching, to have a full understanding of the classroom robot that a child envisioned. The aim of the first user study was to evaluate the toolkit's use in combination with storytelling and sketching. With the data coming from the first study, the toolkit was modified and used in the second user study. The aim of the second study was to explore more on the user study structure this time; to investigate what would happen if the order of two design activities used in the studies, robot building with Robo2Box and storytelling, were changed. By changing the order of the activities, the

children would either built a classroom robot first with what was available, or they would envision their robots freely, which might have an effect on how a child would think of a classroom robot.



Chapter 4:

STUDY

This section explains the user studies conducted with school children to evaluate the robot-design toolkit Robo2Box and the possible study procedures for its use in detail, and presents the findings from the studies. There are two studies conducted with Robo2Box and presented here: the 1st study's aim was to evaluate the use of Robo2Box, by using the 1st version of the toolkit. The 2nd study's aim was to evaluate how the change in the study procedure impacts the findings of the study conducted with Robo2Box, by using the 2nd version of the toolkit.

4.1 *The User Study with the 1st Robo2Box*

The aim of the user study in the 1st version of Robo2Box was to evaluate the toolkit's use by the children as a method to elicit children's requirements for classroom robots, by comparing the study's resulting robots with previous research. The study was conducted in 2015 in Turkey with 31 school children (Obaid et al., 2016; Obaid et al., 2017). The children were recruited from Fenerbahçe Sailing Club's students, and took place in their club. Before the studies took place, each children's parents were informed by the administration of the sailing club, that also helped to recruit the children, and each child signed a letter of consent before their session. A copy of the consent form was also sent to the families. The study took place in the presence of one facilitator and one observer who was responsible for taking notes and accompanying the children in and out of the study room. Once a child came into the study room for testing, they were introduced to the facilitator and the observer, followed by an explanation of the study and getting their written consent for the participation and video recording. After that, each child was asked about robots, whether they knew anything about them, how they got the knowledge, and if they took any classes on robots and/or robotics. Each session started with such an introductory part as explained, to inform the children about the study and also to break the ice, and consisted of two phases: Robot construction and placement, and storytelling, in the respective order.

4.1.1 Phase 1: Robot Construction and Placement

In the robot construction and placement phase, using the 1st version of Robo2Box toolkit, each child was asked to build a robot which would be used in a classroom setting. During this phase, the facilitator only explained what the element groups were, as heads, torsos, legs and arms, and how the pieces in the toolkit could be bonded using the adhesive dough, then would let the child construct their robot freely. Once the child finished building their robot, they were asked to pick (a) building material(s) for their robot parts from the set of material specimens (plastic, fabric...). Next, they were asked to place their robot in the cardboard classroom model provided. The classroom model was made out of cardboard, having a rectangular shape and closed on two sides as the walls of the classroom. The model wasn't closed on four sides to enable children to see inside clearly. It included 4 student desks, a board on one wall, and two windows on another wall. The teacher and the students were made out of paper (Figure 4.1). There were one teacher and 8 students in the model, 7 students sitting on their desks and the teacher and one student placed each side in front of the board, standing. All the objects and people in the model were sized relative to each other, and the reference point in height was the assembly of human head, curved-edged rectangular torso and 2-fixed human legs from the toolkit to create an adult's height. The children were also asked to comment on the robot's size in relation to the paper people representing a teacher and students inside, and to specify whether their robots were the same size, bigger or smaller than any of the paper models.



Figure 4.1: Items used in the study, Robo2Box toolkit and the classroom model (Obaid et al., 2016).

4.1.2 Phase 2: Storytelling

Once the children were done with constructing their robots with the toolkit, they were asked to draw or write a story of their robots in the classroom, including how the robot would behave and what it would do in a classroom setting. Learning more about the additional features of the robot, such as tools, accessories and colors, was the major goal behind this step. The children were allowed to freely imagine the role of their robot in the classroom. To draw their stories of their robots, a blank A4 paper with four frames, resembling a storyboard, was given to the children along with colored pencils and an eraser. If they preferred to write instead of drawing, they were free to do so, and it wasn't necessary to fill in all the frames on the paper. Once the story was drawn or written, each child was asked to explain their story. The storytelling phase ended with a semi-structured interview, where the child answered some preset questions about their robot to enable the facilitator understand better how they imagined their robot physically and behaviorally.

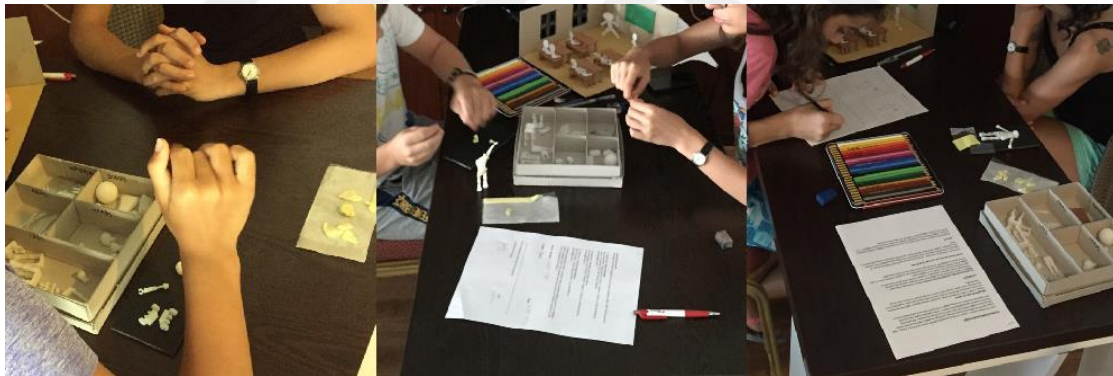


Figure 4.2: Photographs from the study sessions with the 1st Robo2box (Obaid et al., 2016)

4.1.3 Analysis

Each study session was video recorded while the observer took notes and the facilitator took the pictures of the constructed robots. After the study, the recordings of the study sessions were transcribed. The pictures, notes and transcribed recordings were used for the analysis. A single coding scheme was created to code all data gathered in the different phases of the study.

The first phase, robot construction and placement, was coded in a quantitative approach. Coding categories were head, torso, arms, legs, material, gender, placement

and size. Two independent coders first coded all the data coming from 6 out of 31 children in these categories independently. The categories in which the inter-coder reliability was sufficiently high (Cohen's kappa > 0.70) were continued to be coded by a single coder. For other categories, all data was analyzed and discussed by two coders.

The second phase, storytelling, was coded in a qualitative approach. Coding categories were talking style & voice, emotion, tasks and additional features of the robots coming from the stories. One coder was responsible to code and analyze all the data falling under these categories. The comments made by children were grouped according to the categories mentioned above, and those comments were used for analysis.

Video recordings from the study were used for time analysis. Total study time for each session excludes the time spent during the introductory part. Time for robot construction starts once the facilitator finishes explaining how to use the toolkit, and ends when the child states they have finished, and chooses the material(s) for their robots. Time for storytelling starts with the end of robot construction, until the child finishes the study. Please note that the robot placement part was included in the storytelling phase for the time analysis.

4.2 Findings from the User Study with the 1st Version of Robo2box

4.2.1 The First Phase - Robot Construction and Placement

This part presents the findings of the First Phase - Robot Construction and Placement, based on the data coming from the study (Obaid et al., 2016). Below, the results for head, torso, legs, arms, material, gender, placement and size are shared. The overall robots that were constructed with the most chosen body parts by the children can be seen in Figure 4.3.

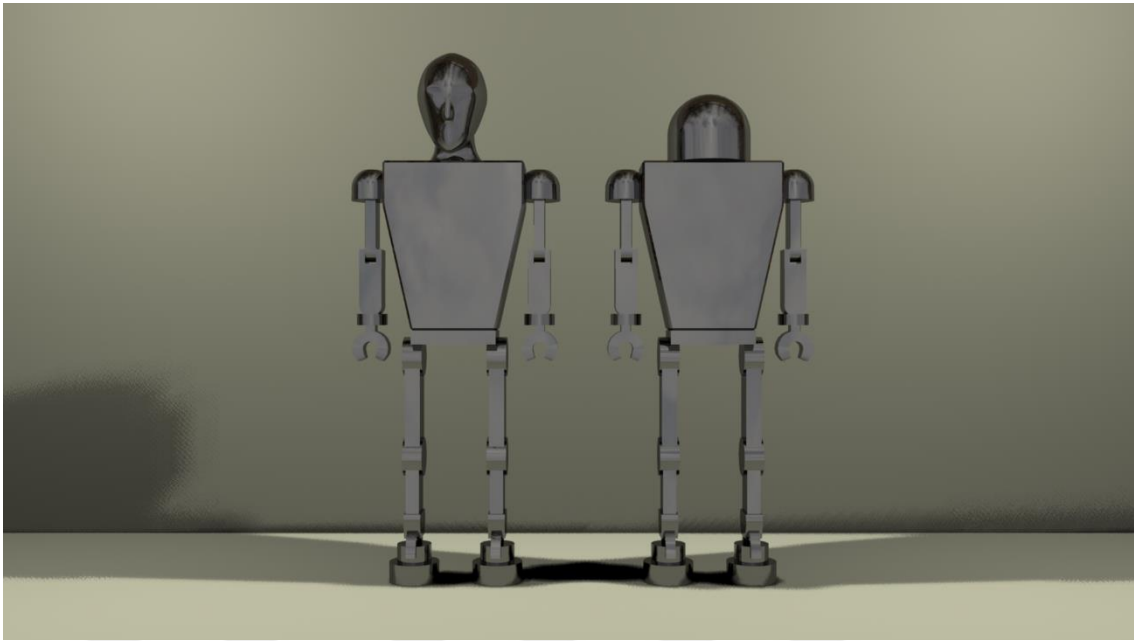


Figure 4.3: The ultimate robots of the 1st user study with Robo2Box (Obaid et al., 2016).

Head. There were 5 types of heads: human, animal, rectangular, rectangular with neck and spherical. 9 children chose human head, 3 children chose animal head, one child chose rectangular head, 7 children chose rectangular head with neck, 9 children chose spherical head and one child didn't choose any head. One child used a torso instead of a head, and was excluded from the results. Figure 4.4 shows the results for the chosen head. The difference between the categories was significant, $\chi^2(5; N = 30) = 14.4$; $p < .05$.

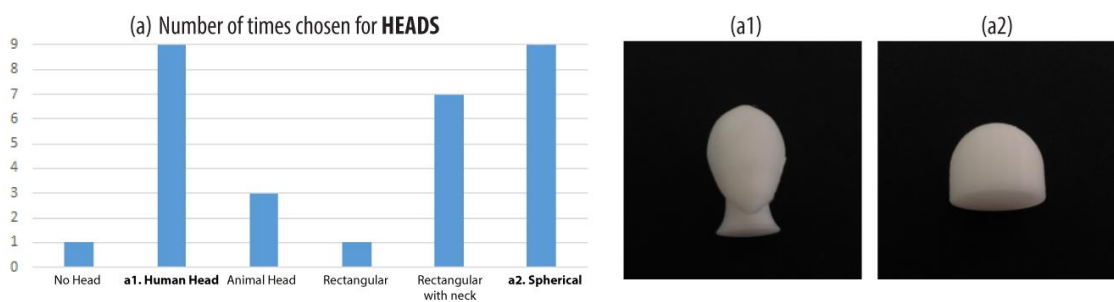


Figure 4.4: Heads chosen by the children during the 1st study (Obaid et al., 2016).

Torso. There were 6 types of torsos: sharp-edged distorted rectangle, curved-edged distorted rectangle, sharp-edged square, curved-edged square, sharp-edged rectangle

and spherical. 10 children chose sharp-edged distorted rectangle torso, 8 children chose curved-edged distorted rectangle torso, 4 children chose sharp-edged square torso, 4 children chose curved-edged square torso, 2 children chose sharp-edged rectangle torso, and 2 children chose spherical torso. One child was confused which parts to use as a torso and was excluded from the results. The most chosen two torsos types were sharp-edged and curved-edged distorted rectangles. Other torso types were less popular among the children than the two distorted rectangle torsos. The choices of the children might show that they were into more human-like forms for the torso of their robots, with broad shoulders and a more defined waistline. The torso results are shown in Figure 4.5. The difference between the categories was not significant, $\chi^2(5; N = 30) = 10.8; p > .05$.

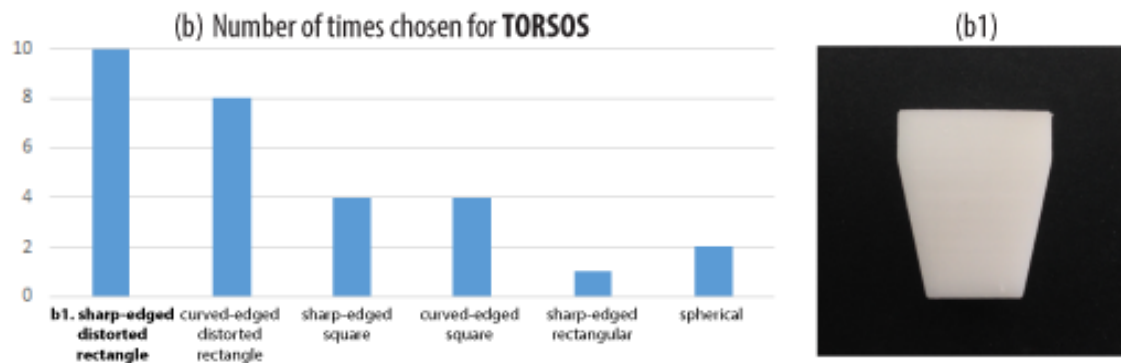


Figure 4.5: Torsos chosen by the children during the 1st study (Obaid et al., 2016).

Legs. There were 8 types of legs: 2-fixed human, 2-fixed animal, 4-fixed animal, 2-fixed machine, 4-fixed machine, 2-fixed wheels, thrust engine and tracks. 7 children chose 2-fixed human legs, one child chose 2-fixed animal legs, one child chose 4-fixed animal legs, 14 children chose 2-fixed machine legs, 2 children chose 4-fixed machine legs, 5 children chose 2-fixed wheels, 2 children chose thrust engine and 3 children chose tracks. The clear preference for 2-fixed machine legs shows that the children desire their robots to have visual machine-like features, as P5 identified them as “having robotic features”. The results of the legs are given in Figure 4.6. The difference between the categories was significant, $\chi^2(8; N = 31) = 39.31; p < .0001$.

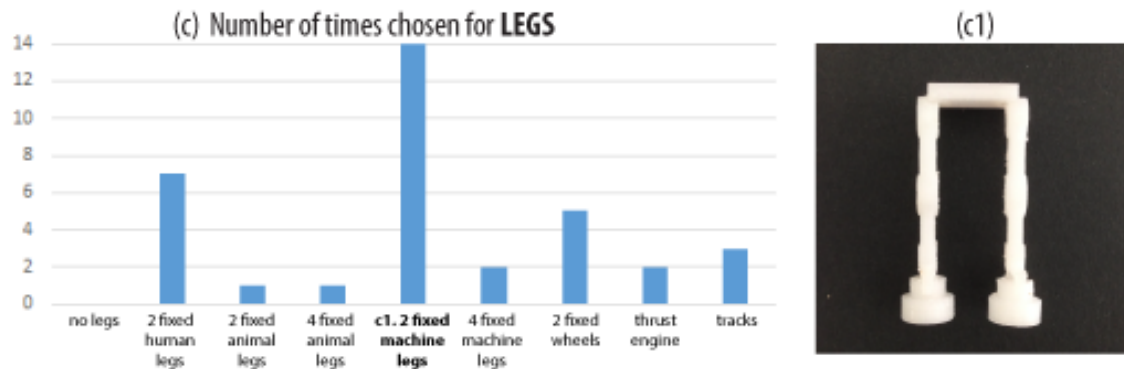


Figure 4.6: Legs chosen by the children during the 1st study (Obaid et al., 2016).

Arms. There were 3 types of arms: human, wings and machine. 9 children chose human arms, 9 children chose wings, 18 children chose machine arms, and one child didn't choose any arms. There were multiple children who selected two different types of arms, one of them being the wings. Among 9 children who chose the wings, 8 of them stated that their robots could fly, and complete some tasks while/by flying. Like for the legs, the clear preference for 2 machine arms shows that the children desire their robots to have visual machine-like features, as P5 identified them as “having robotic features”. Figure 4.7 shows the results for arms. The difference between the categories was significant, $\chi^2(3; N = 37) = 12.19; p < .01$.

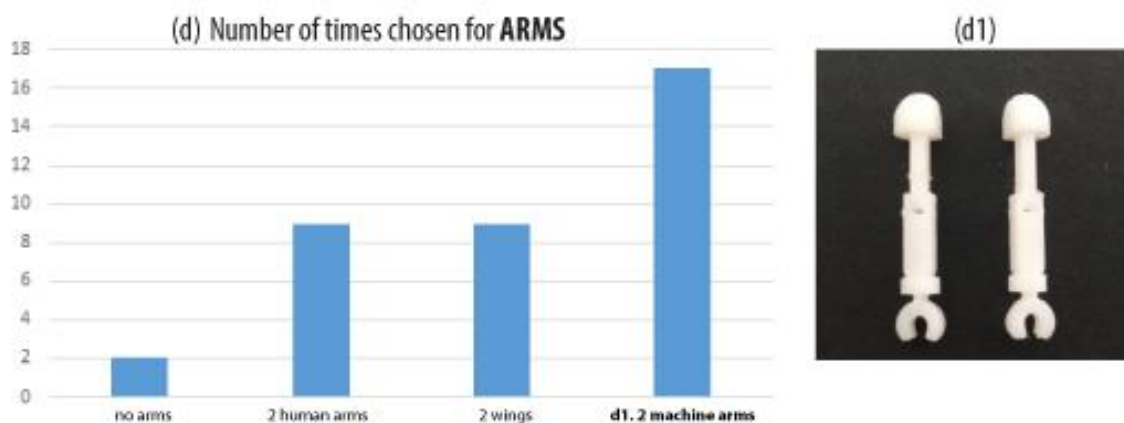


Figure 4.7: Arms chosen by the children during the 1st study (Obaid et al., 2016).

Materials. There were 4 types of materials: metal, plastic, fur and eva. 24 children chose metal as material, 16 children chose plastic as material, 10 children chose fur as material, and 9 children chose eva as material. The children were not required to choose only one material, so several materials were chosen for half of the robots. When the accumulated results for the number of times one material was chosen were examined, metal was the most preferred material because of most children's perception of robots being made out of metal, and the durability and hardness of the material, followed by plastic. As P2 stated "I wanted my robot to appear like a robot, that's why I chose its form and material as such. Also it is metal to protect [the robot]". Other materials were picked up by children for various reasons: preventing the robot from hurting itself or others, "Some children run around without paying attention to their surroundings, and hit the people or things around them. If the robot's material is fur, both the robot and the children wouldn't get hurt." (P4), to cover other parts of the body that are not metal, "I chose eva to cover the [robot's] whole body because it is soft, and plastic to cover eva to prevent wearing away." (P16), and to make the robot more stylish/colorful, "I would use the (yellow) fur for hair because I want my robot to be female." (P1). The latter reason shows the children can get deceived by the color of the materials shown to them to pick, even though they were told the colors of the material specimens did not matter and they could be changed. Figure 4.8 shows the results for the chosen materials. The difference is significant $\chi^2(3; N = 59) = 9.68; p < .05$.

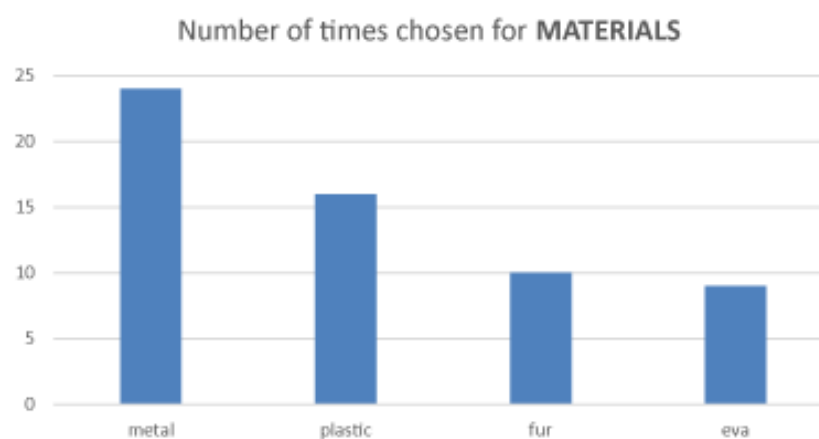


Figure 4.8: Materials chosen by the children during the 1st study.

Gender. There were no predetermined titles for gender during the study, so they were all determined during the analysis. 6 children identified their robots as female, 7

children identified their robots as male and 18 children identified their robots as genderless. More than half of the robots were identified as having no gender. As a child who identified their robot as genderless, P11 explained their reason as such: “I don’t know if my robot has a gender, I mean I have never thought of whether a robot would have a gender. That is why it is genderless. It feels weird for [my robot] to have a gender, it is a robot, not a human.” All the children who gave their robots a gender chose it in-line with their own sex, except one female child who identified her robot as male. The study by Bumby & Dautenhahn (1999) states the same phenomena among the children to assign their sex to the robots or expect them to be the same gender with themselves to communicate with the robots better. P1 (female) and P5 (male) assigned their own sex to their robots, and explained its reason as they didn’t like the opposite sex.

Also, the way the question asked matters for the context of the children’s responses. For his robot’s gender, P13 said “[its gender would be] Male. I haven’t seen many female robots in my life, so actually it might be either of [the two genders]. (when he was told that assigning a gender was not mandatory) Okay then, it doesn’t have a gender.” because he was asked the question “what’s its gender?” instead of “does it have a gender?” It should be also stated that there are no different words for gender and sex in Turkish. The word “cinsiyet” is used for both of them, so it is not possible to tell whether the children in the study knew such a difference and they used it for this particular category. Figure 4.9 shows the results for the gender choices for each robot.

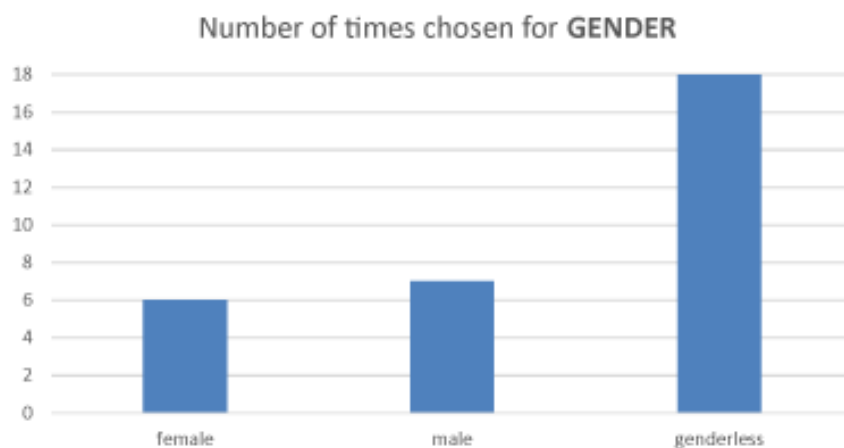


Figure 4.9: Genders stated by the children during the 1st study.

Placement. The children were provided a model classroom with model people in, and asked to place their robots in it during the study. Since the model classroom being used to place the robots in was the same for all the children participating in the study, it was possible to define categories after the study, categorize the answers given according to them and get numerical results. The categories defined were near the teacher, in the teacher's spot, by the door, in the back of the classroom, mobile and other. Some of the answers were categorized under multiple titles. 11 children placed their robots near the teacher, 4 in the teacher's spot, 7 by the door, 4 in the back of the classroom, 4 made them mobile, and 2 of the robots were fallen under "other" category. The children placed their robots based on the roles they have given to their robots: if it was a teacher, it was placed on the spots where a teacher would be, and on one case (P4) it would be outside of the classroom since there was already a teacher placed in the model classroom, or the robot would be mobile because it was a rewarding robot (P21). One of the many reasons given for the robot's placement was making it able to observe the classroom and the students by giving it a broader view by placement, and another was preventing it to block the board, which explains the higher frequency of being placed in the corners or towards the sides of the classroom for the robots. Figure 4.10 shows the results for the placement of the robots.

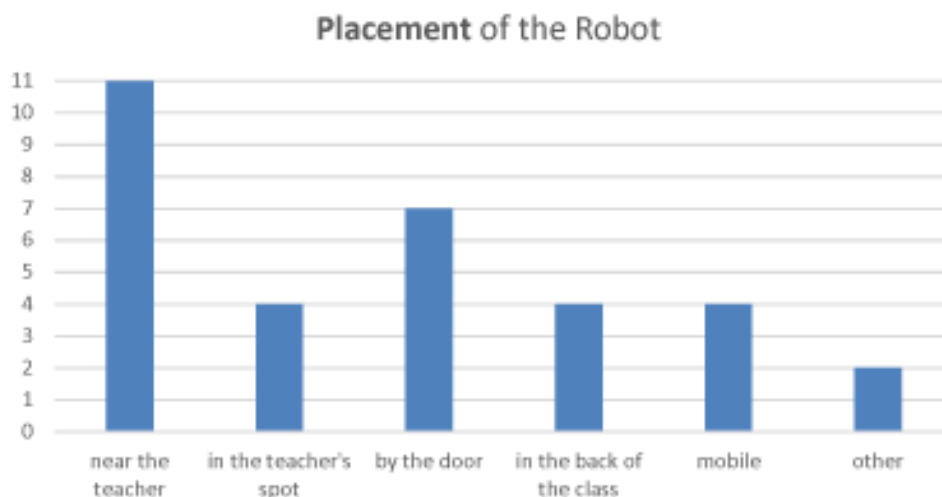


Figure 4.10: Placements stated by the children during the 1st study.

Size. The children were provided a model classroom with model people in, and asked to comment on their robots' size relative to the model people in the model classroom during the study. There were five predetermined categories for the sizes of

the robots: smaller than child, child-size, between child and adult, adult-size, and larger than adult. 3 children wanted their robots to be smaller than child, 2 as child-size, 14 as between child and adult, 6 as adult-size, and 6 as larger than adult. Figure 4.11 shows the results for the size of the robots. The difference between the size categories was significant, $\chi^2(4; N = 31) = 14.32; p < .001$.

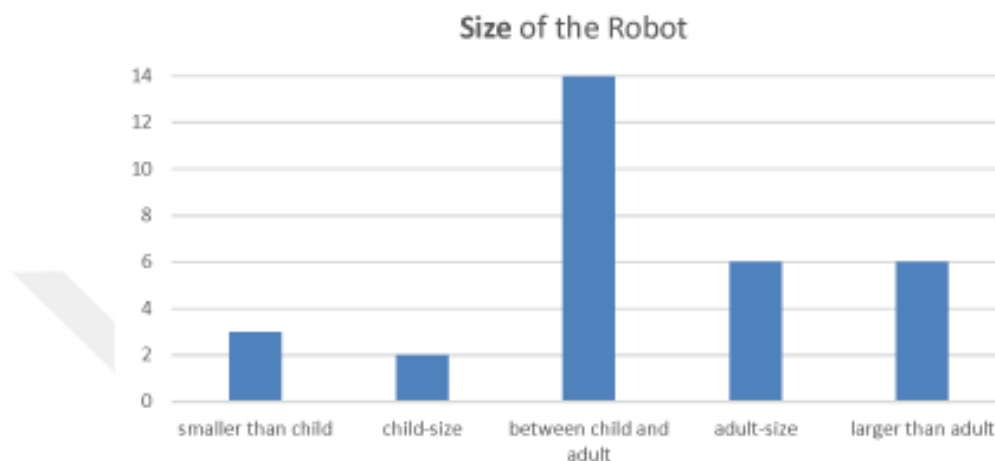


Figure 4.11: Sizes stated by the children during the 1st study.

4.2.2 The Second Phase – Storytelling

This part presents the findings of the Second Phase - Storytelling, based on the data coming from the study. Below, the results for talking style and voice, emotion, tasks and additional features of the robots coming from the stories are shared.

Talking style & voice. Desired talking styles and voices of robots were human-like and machine-like. Only 4 children described their robots as non-verbal. While most of the robots had either human or machine-like features for both their talking styles and voices, only a small number of robots didn't have the same feature for both. These robots all had human-like talking styles and machine-like voices. Except for using the words "human-like" or "robot-like" to describe how their robots' talk and sound, children used "fluent" to describe human-like talking style, "mechanic", meaning with pauses, to describe machine-like talking style and used words "electronic, digital, metallic" for machine-like voice. The children didn't describe human-like voices in detail. Except for one child, no children assigned any genders to their robots' voices, even when the robots had an assigned gender.

Emotion. 17 children stated that their robots' had emotions. 14 children said their robots' had no emotions, however a couple of them added some emotions to their descriptions, such as happiness or anger, when they were giving more details to the question. Emotions that were worded the most by the children were happiness, sadness, anger, joy and crying. Most of the children explained how their robots' demonstrated their emotions in a more humane way, like talking them out, having vocal changes, using body language and mimics, and even crying with tears. For other robots, who didn't have human-like ways of showing emotions, the ways of showing emotions included showing them on a screen, and stopping working for a while or pointing a gun when angry. Some children stated that their robots could empathize with the students in the classroom, even when they were described as having no emotions.

Tasks. The tasks assigned to the robots were divided into 5 categories based on the thematic analysis approach (Braun & Clarke, 2006): serving, teaching, disciplining, entertainment and information services. Serving category includes tasks like carrying or getting materials, cleaning and tidying. Teaching tasks include giving lectures, setting and checking homework, replacing absent teachers and helping out students with lecture-related problems, such as explaining the things they didn't understand or missed. The tasks related to keeping the class order, especially to silence the class fall under the disciplining category. Entertainment category covers tasks that are about entertaining the students, like playing with them or singing to them. Finally, the tasks that are put under the information services category are the ones about providing technology and information, such as printing, answering questions, showing videos and playing music.

Most of the children participated in our study assigned "serving tasks" to their robots, such as providing stationeries to and carrying belongings of both the teacher and the students, cleaning around and fixing things, which is followed by "teaching tasks": giving lectures, giving and checking homework and replacing the absent teacher. There were also a few tasks regarding the other task categories keeping the class order and rewarding the students; playing with the students and providing informational services by answering questions; printing or projecting lecture related information.

The robots were mostly envisioned as having a teaching assistant role in the classroom, either dependent or independent of the teacher, but accompanied by the teacher. While they could help the students as well on various tasks under the serving category, these robots were mostly imagined as an assistant to the teacher. There were

also a couple of children who replaced the teacher with the robot they envisioned, often stating that the robot would do whatever a teacher does, without going into detail on the tasks.

Additional features. The children imagined their robots with various functional and visual features and accessories that they explained during the storytelling phase. For the functional features, the children mentioned electronic devices embedded in the robots, such as screen, button, printer, speaker, camera and projector, and compartments to keep stuff in to give to the students and teacher. Functional accessories included guns, shields and lasers to be used for protection purposes, and chalks, erasers and laser pointers to be used for educational purposes. For the visual accessories, the children assigned colors to the parts of their robots, added hair or wigs, glasses and led lights. The children also mentioned that their robots had facial expressions, and of facial features, like lips, nose, eyes, and especially mouth, since it was a big part of the facial expressions they mentioned in their stories, like smiling.

4.2.3 *Duration of the Study Sessions*

This part presents the duration of each session, along with time spent for robot construction and storytelling. The average duration for building robots was 02:35, the average duration for storytelling was 18:38, and the average duration of total study sessions was 21:13. Figure 4.12 presents the time spent to build a robot, for storytelling, to complete one study session for each child participated, along with the average for the abovementioned durations.

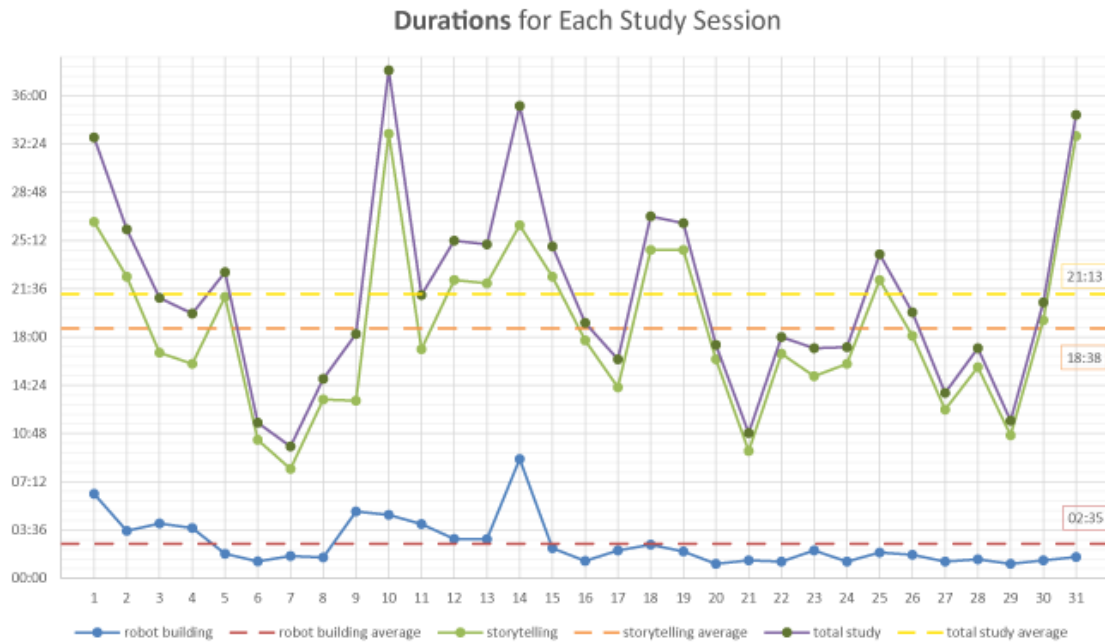


Figure 4.12: Durations of the each study sessions in the 1st study.

4.3 The User Study with the 2nd Robo2box

The first user study with the toolkit was focused on the evaluation of the toolkit with children. The second study was focused more on the structure of the study itself, rather than the toolkit. The toolkit is the main focus in this thesis about eliciting children's requirements for a classroom robot, yet the structure of the study plays a great role while conducting tests with the toolkit. Hence, the aim of this study is to understand how much of an impact the change in the order between robot building and storytelling phases makes on the classroom robot designs of children. The second study with the modified Robo2Box toolkit was conducted in 2019 in Turkey with 29 school children (Kırlangıç et al., 2020). The children were recruited from TOÇEV, Tuvana Okuma İstekli Çocuk Eğitim Vakfı, a foundation in Turkey that gives financial and moral support to the children from disadvantaged families to go to school. The study took place in a classroom of the school that TOÇEV has close relations with. Each child's family was informed about the study by the administrative members of TOÇEV, and their consent was taken verbally. The children who participated in the study were also informed in detail about the study at the beginning of their session and signed a consent form. Out of 29 children, 15 children took the test in robot construction -

storytelling order (control group), and 14 children took the test in storytelling - robot construction order (switch group). Once a child came into the study room for testing, they were being introduced to the facilitator, followed by the explanation of the study and getting their written consent for the participation and voice recording. After that, each child was asked about robots, whether they knew anything about them, from which source they learned about them, and if they took any classes on robots and/or robotics. Each session started with such an introductory part as explained, to inform the children about the study and to break the ice, and consisted of two phases: Robot construction, and storytelling, in changing order.

4.3.1 Phase A: Robot Construction

In the robot construction phase, using the 2nd version of Robo2Box toolkit, each child was asked to build a robot which would be used in a classroom setting. The facilitator only explained what the element groups were, as heads, torsos, legs and arms, and how the pieces in the toolkit can be bound using the Velcro, then would let the child construct their robot freely. Once the child finished building their robots, they were asked to pick building material(s) for their robot parts from the set of material specimens (plastic, fabric...). Since the study took place in a real classroom, the model classroom was not used in the 2nd study, and the children were expected to comment on the placement of their robots in the storytelling phase as a part of their stories.

4.3.2 Phase B: Storytelling

In the storytelling phase, each child was asked to create and tell (either verbally or by drawing based on their preference) a story of their robot in the classroom, summarizing how the robot would behave and what it would do in a classroom setting. Learning more about the additional features of the robot, such as tools, accessories and colors, was the major goal behind this step. The storytelling phase ended with a small interview, where the child was expected to answer some preset questions about their robot verbally, including its size, place in the classroom, its face, voice and emotions, and whether it gives homework or punishments. Since the study took place in a real classroom, the child was asked to show the placement of their robot in the classroom,

instead of using a paper model as used in the 1st study, and they were asked to explain their robot's size verbally.



Figure 4.13: The 2nd version of Robo2Box toolkit on the left, a frame from a study session during the 2nd study on the right (Kırlangıç et al., 2020).

4.3.3 Analysis

Each study session was voice recorded by the facilitator. During the study, the facilitator took notes of the stories and interviews, and took pictures of the constructed robots. After the study, the voice recordings of the study sessions were transcribed. The pictures, notes and transcribed recordings were used for the analysis. The coding scheme for this study was based on the one from the previous study.

Phase A, robot construction, was coded quantitatively. Coding categories were head, torso, arms, legs, material and gender. Two independent coders first coded the data coming from 6 out of 29 children in these categories independently. The inter-coder reliability calculations for these categories were reasonably high (Cohen's kappa > 0.70), therefore only one coder continued to code the rest of the data in these categories.

Phase B, storytelling, was coded qualitatively. Coding categories were talking style & voice, emotion, placement, size, tasks and additional features of the robots coming from the stories. One coder was responsible to code and analyze all the data falling under these categories. The comments made by children were grouped according to the categories mentioned above, and those comments were used for analysis.

Voice recordings from the study were used for time analysis. Total study time for each session excludes the time spent during the introductory part. Time for robot

construction starts once the facilitator starts explaining how to use the toolkit and ends once the child chooses the material(s) for their robots. For the control group that first constructed a robot then told a story, time for storytelling starts with the end of robot construction, until the child finishes the study. For the switch group that first told a story then constructed a robot, time for storytelling starts with the end of introductory part, until the facilitator starts explaining how to use the toolkit.

Since the children were expected to construct only one robot during the study, the data of one child from the control group was excluded from the results because she constructed three different robots to be used in the classroom environment. The voice recording of another child from the control group was corrupted, therefore their data was coded based on the notes and the picture of the constructed robot, but their time analysis could not be completed.

4.4 Findings from the User Study with the 2nd Version of Robo2box

4.4.1 Control Group (First build - Later tell a story)

Phase A - Robot Construction

This part presents the findings of Phase A - Robot Construction, based on the data coming from the control group (Kırlangıç et al., 2020). Below, the results for head, torso, legs, arms, material and gender are shared. Fig. 4.14 shows the overall robot constructed with the most chosen body parts by the children in the control group.

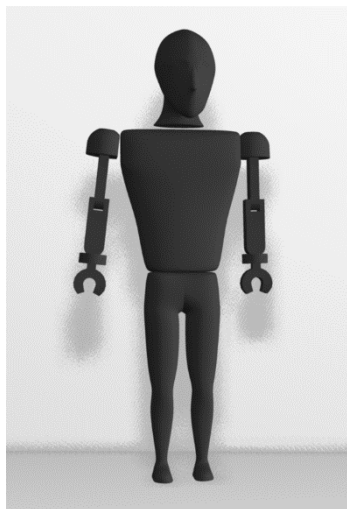


Figure 4.14: The ultimate robot of the control group from the 2nd user study with Robo2Box (Kırlangıç et al., 2020).

Head. There were 6 types of heads: human, animal, rectangular, rectangular with neck, spherical and fully spherical. 6 children chose human head, 1 child chose animal head, 3 children chose spherical head, and 4 children chose fully spherical head. None of them chose the rectangular head and rectangular head with a neck. The mostly chosen heads by the children in the control group show that the children preferred more organic-shaped heads with curvy form. Figure 4.15 shows the results for the chosen head type. The difference between the categories was significant $\chi^2 (5, N = 14) = 12.5$, $p < .05$.

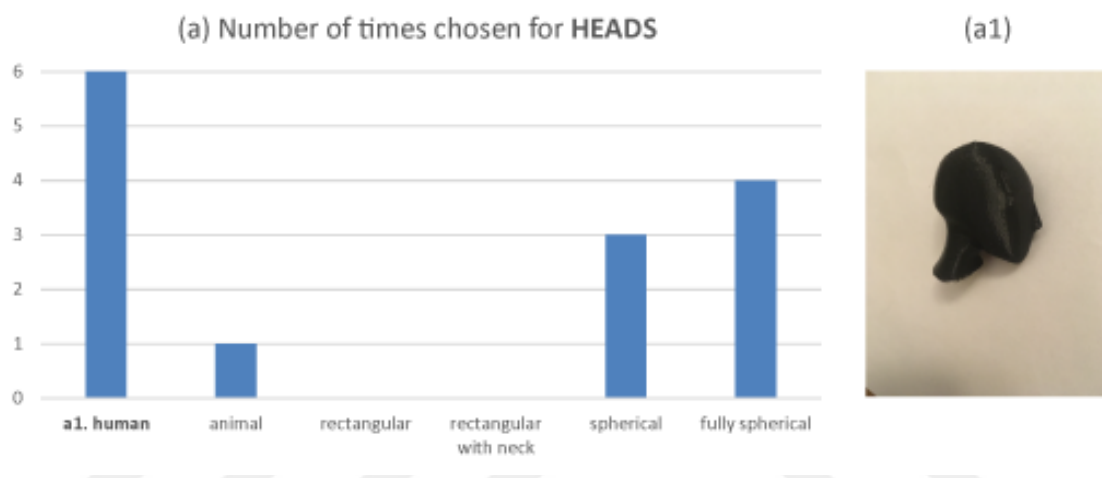


Figure 4.15: Heads chosen by the control group during the 2nd study (Kırlangıç et al., 2020).

Torso. There were 7 types of torso: sharp-edged distorted rectangle, curved-edged distorted rectangle, sharp-edged square, curved-edged square, sharp-edged rectangular, spherical and cylindrical. 3 children chose sharp-edged distorted rectangle torso, 5 children chose curved-edged distorted rectangle torso, 3 children chose sharp-edged square torso, 4 children chose curved-edged square torso, and 1 child chose sharp-edged rectangular torso. No child chose spherical torso and cylindrical torso. One child used three torsos but was not excluded from the results. The most chosen torso is curved edged distorted rectangle, which is one of the human-like torsos with wide shoulders and small waist. When accumulated results of torsos are taken into account, the highest four torsos might be the most human-like for the children. Figure 4.16 shows the results for the chosen torso. The difference between the categories was not significant $\chi^2 (6, N = 14) = 10.25$, $p > .05$.

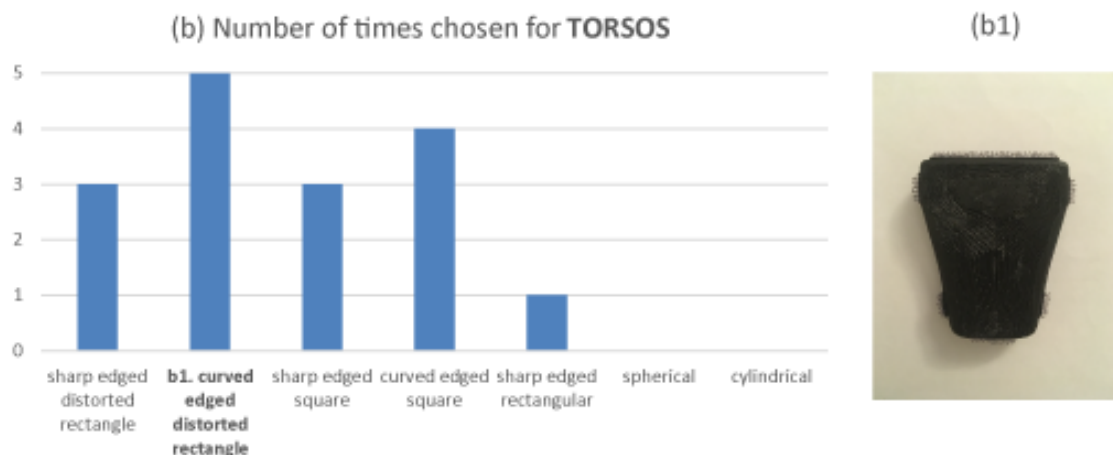


Figure 4.16: Torsos chosen by the control group during the 2nd study (Kırlangıç et al., 2020).

Legs. There were 8 types of legs: 2-fixed human, 2-fixed animal, 4-fixed animal, 2-fixed machine, 4-fixed machine, 2-fixed wheels, tracks and one wheel. 6 children chose 2-fixed human legs, 3 children chose 2-fixed machine legs, 2 children chose 4-fixed machine legs, and 5 children chose 2-fixed wheels. No child chose 2-fixed animal legs, 4-fixed animal legs, tracks and one wheel. 2 children used two different types of legs for their robots, but were not excluded from the results. The children in the control group mostly preferred human legs and two wheels. There might be two reasons behind these selections: (1) the children in this group didn't take any robotics classes, and they knew robots only from the media. This fact might have caused them to relate walking only to human legs, since they didn't choose any of the animal legs either. They also stated robots as “technological humans” (C4) or “like humans, but with battery” (C10). (2) As related to the first reason, the children who chose 2 fixed wheels might have thought that the robots couldn't walk with legs, as stated by C7, because of the children's lack of robotics knowledge. Figure 4.17 shows the results for the chosen legs. The difference between the categories was significant $\chi^2(7, N = 14) = 18.7, p < .01$.

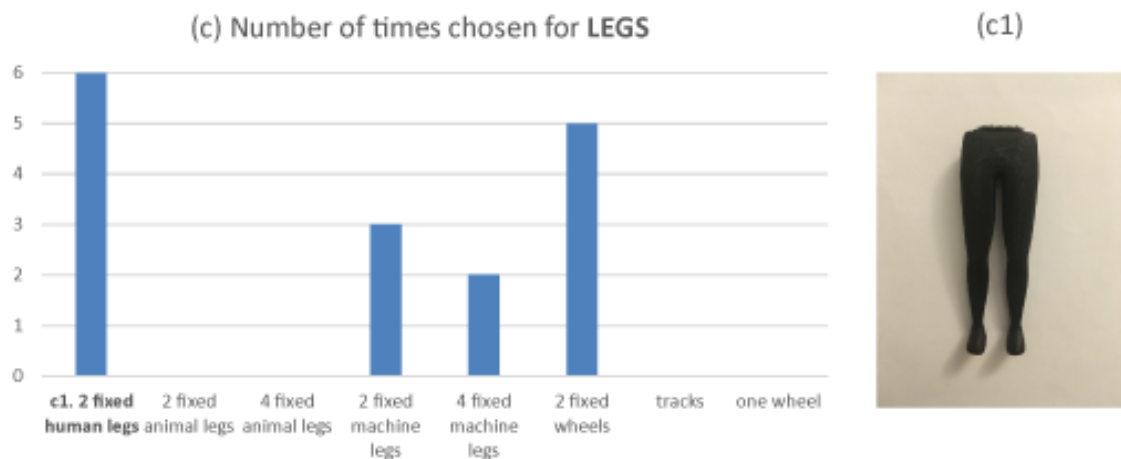


Figure 4.17: Legs chosen by the control group during the 2nd study (Kırlangıç et al., 2020).

Arms. There were 3 types of arms: human, wings and machine. 5 children chose human arms, 6 children chose wings, 7 children chose machine arms and one child didn't use any arms for their robot. One child used torsos for arms and was excluded from the results. There were multiple children who selected two different types of arms, one of them being the wings. Among the 6 children who chose the wings, only two of them stated that their robots could fly. The children might have liked the way the wings looked when they saw them in the toolkit, therefore they might have ended up using the wings even though their robots didn't have/weren't planned to have any flying skill. Figure 4.18 shows the results for the chosen arms. The difference between the categories was not significant $\chi^2(3, N = 14) = 4.4, p > .05$.

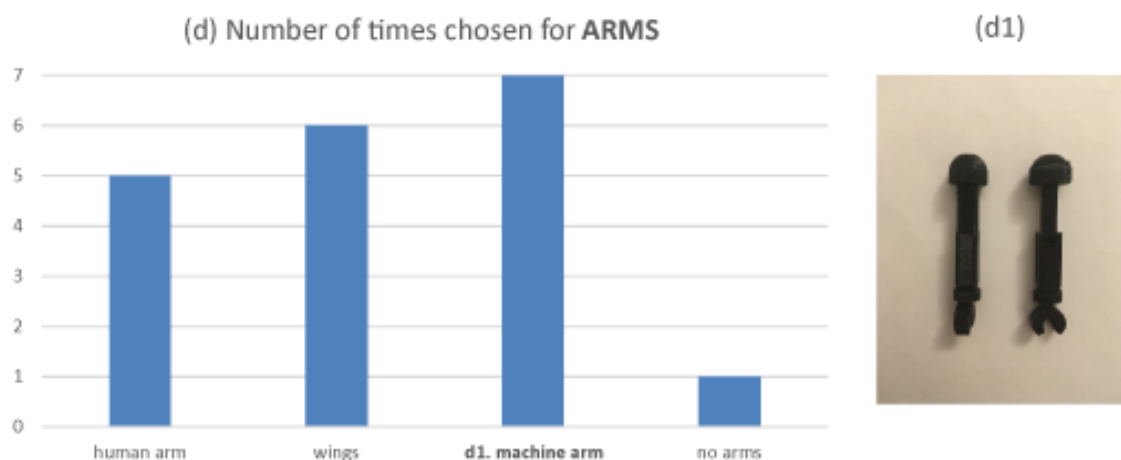


Figure 4.18: Arms chosen by the control group during the 2nd study (Kırlangıç et al., 2020).

Material. There were 4 types of materials: metal, plastic, fur and eva. 10 children chose metal, 6 children chose plastic, 4 children chose fur and 5 children chose eva. The children were not required to choose only one material, so several materials were chosen for more than half of the robots. When the accumulated results for the number of times one material was chosen were examined, metal was the most preferred material. “Robots are [made out of] metal.” (C2) and wanting their robots to be durable and hard were the children’s main reasons for choosing metal for their robots’ material. Other materials were picked up by children to prevent the metal from scratching and the possible injuries on humans that might be caused from metal, or just to make the robot more stylish/colorful. The latter reason shows the children can get deceived by the color of the materials shown to them to pick, even though they were told the colors of the material specimens did not matter and they could be changed. Figure 4.19 shows the results for the chosen materials. The difference between the categories was not significant $\chi^2(3, N = 14) = 3.3, p > .05$.

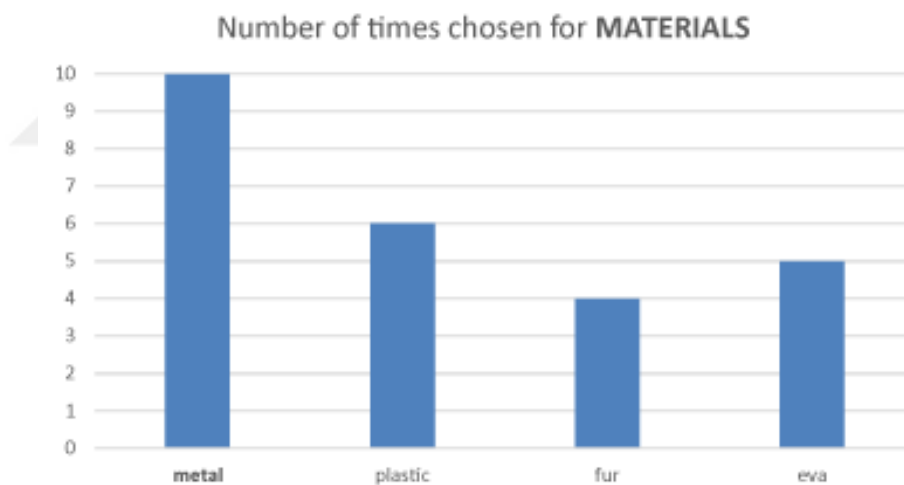


Figure 4.19: Materials chosen by the control group during the 2nd study (Kırlangıç et al., 2020).

Gender. There were no predetermined titles for gender during the study, so they were all determined during the analysis. 5 children identified their robots as female, 4 children identified their robots as male, 4 children identified their robots as genderless, and 1 children stated that their robot’s gender wouldn’t matter. Half of the children in the control group chose their robots’ genders in-line with their own sex. The study by Bumby & Dautenhahn (1999) states the same phenomena among the children to assign

their sex to the robots or expect them to be the same gender with themselves to communicate with the robots better. C7 stated this same-sex preference for such a classroom robot explicitly: “I can get along with the female teachers better.” C12 gave a similar reason for his robot: “My robot is male because I am male too.” C15 was already aware of the possibility of such preference, “the gender of the robot doesn’t matter, it can be either boy or girl. The students might ask [a question like] ‘why is it a girl but not a boy?’.” Also, the way the question asked matters for the context of the children’s responses. For his robot’s gender, C4 said “its gender would be male. I have never seen a robot with gender, normally robots are genderless.” because he was asked the question “what’s its gender?” instead of “does it have a gender?” It should be also stated that there are no different words for gender and sex in Turkish. The word “cinsiyet” is used for both of them, so it is not possible to tell whether the children in the study knew such a difference and they used it for this particular category. Figure 4.20 shows the results for the gender choices for each robot.

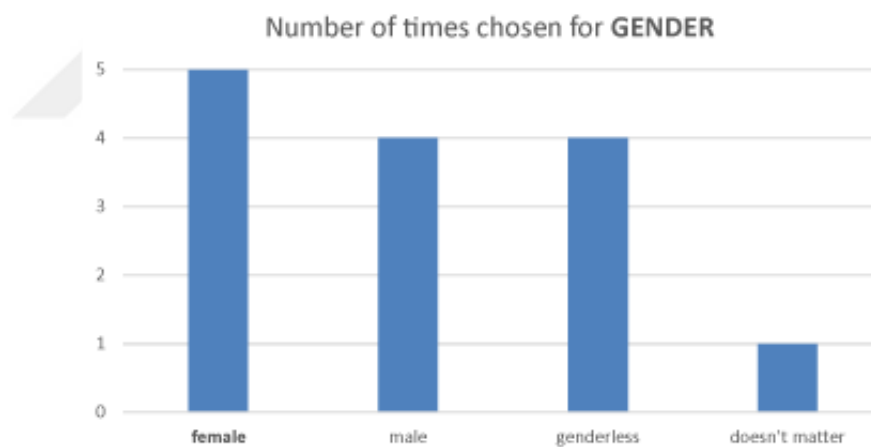


Figure 4.20: Genders chosen by the control group during the 2nd study.

Phase B – Storytelling

This part presents the findings of Phase B - Storytelling, based on the data coming from the control group. Below, the results for talking style and voice, emotion, placement, size, tasks and additional features of the robots coming from the stories are shared.

Talking style & voice. The choices on the talking styles and voices of the classroom robots made by the control group, the children had two distinctive preferences: either

human-like or machine-like. The children who wanted their robots to have human-like speaking features explicitly stated them as “like [a] human’s”, and they already had a perception on how a robot speaks, as told by C3: “its voice is like regular humans’, [and] high-pitched, it doesn’t talk like a robot but like us.” They described their robots’ speaking with details, like “it has a mellifluous voice appealing to people. It talks excitedly. [I’d want it] to talk a little bit loudly to make the students listen and be a little bit afraid of it [to establish authority in the classroom].” (C7).

On the other hand, the robots with machine-like speaking were all given the same talking style by the children in the control group. Both C2 and C4 commented that their robots would talk with pauses, and both of them vocalized their definitions in the same manner. However, the vocal features of their robots were not as detailly described as the robots with human-like speaking features. These features were described as “mechanical” (C4), or “not human-like, an unusual voice” (C12). C10 described her robot’s voice as “wavy”, and associated it to how the human voice sounds when talked to an air cooling fan. This description later became very helpful for the study moderators when they wanted to learn from a child who was trying to describe a machine-like robot voice but couldn’t find the proper words.

The children also considered the genders of their robots and assigned high-pitch or low-pitch vocal characteristics to them.

Emotion. The children from the control group mainly constructed robots with emotions by mostly using the words happy and sad, and the words related to them like crying, heartbroken and joy. The way these robots showed emotions were varying. Some wanted their robots to make human-like mimics as C5: “We [can] see the change on its face, [it’s] like a human [when it gets happy and smiles].” Some stated more machine-like expressions, such as having an electronic face with a pixelated screen and showing smileys (C12), or singing longer and louder when it likes the children and having fun from being with them (C15). On the other hand, there was a small group of children who did not assign any emotions to their robots. C2 stated her robot’s lack of emotion as “it wouldn’t show its emotions because I don’t think a robot could have emotions.”

There were also children who were confused about showing emotions. When asked about their robot’s emotions and the way it shows emotions, C3 said: “it can show its emotions, the emotions can’t be shown but told. I mean, it could’ve told its emotions.

For example, if it saddens, it could stop itself immediately, like a car, or like its battery has died. [But] then, it actually shows its emotions.”

Placement. The children in the control group put their robot in dissimilar places in the classroom depending on their role in the classroom, hence they couldn't be examined in patterns. Each robot was placed depending on their tasks in the classroom, so they should be all analyzed in relation with their tasks. Such an analysis can be found in Section 4.6.2.

Size. The sizes of the robots constructed were mostly within a range from child size to adult size. Asking the children to comment on their robots' sizes verbally in a classroom opened up the possibility to comment on the robot size precisely, since the children knew their height, they used this knowledge to comment. When they couldn't, they basically showed it saying “this tall.”

Tasks. The tasks assigned to the robots were divided into 5 categories based on the thematic analysis approach (Braun & Clarke, 2006): serving, teaching, disciplining, entertainment and information services. Serving category includes tasks like carrying or getting materials, cleaning and tidying. Teaching tasks include giving lectures, setting and checking homework, replacing absent teachers and helping out students with lecture-related problems, such as explaining the things they didn't understand or missed. The tasks related to keeping the class order, especially to silence the class fall under the disciplining category. Entertainment category holds tasks that are about entertaining the students, like playing with them or singing to them. Finally, the tasks that are put under the information services category are the ones about providing technology and information, such as printing, answering questions, showing videos and playing music.

The control group mainly assigned serving tasks to their robots, expecting them to carry or bring materials in class both for the teacher and students. For the tasks that were about teaching, while some robots were expected to lecture, the robots were mainly depicted as a “teaching aid/assistance” for students, by explaining the parts of the lecture they couldn't understand or missed, and revising the lectures. As for setting homework, most of the children stated that their robots would set homework especially to make the students learn the subject better, and these homework would mostly be set independent from the teacher, meaning that the robot would take the initiative. Most of the children stated that their robots wouldn't punish the students, as they “[...] wouldn't

like the robot to shout (us).” (C3), or simply the robots would try to show the students’ mistakes by talking to them (C5).

Additional features. There were not a lot of elements added to the robots in the stories. A bit of clothing, some indications on facial features like hair and eyes, addition of functional elements such as tablet, sound equipment, button, projector, compartment in the body and screen as a face. All of the functional elements were added by different children.

Duration of the Study Sessions

This part presents the duration of each session, along with time spent for robot construction and storytelling. The average duration for building robots was 05:13, the average duration for storytelling was 10:13, and the average duration of total study sessions was 15:25. Figure 4.21 presents the time spent to build a robot, for storytelling, to complete one study session for each child participated, along with the average for the abovementioned durations.

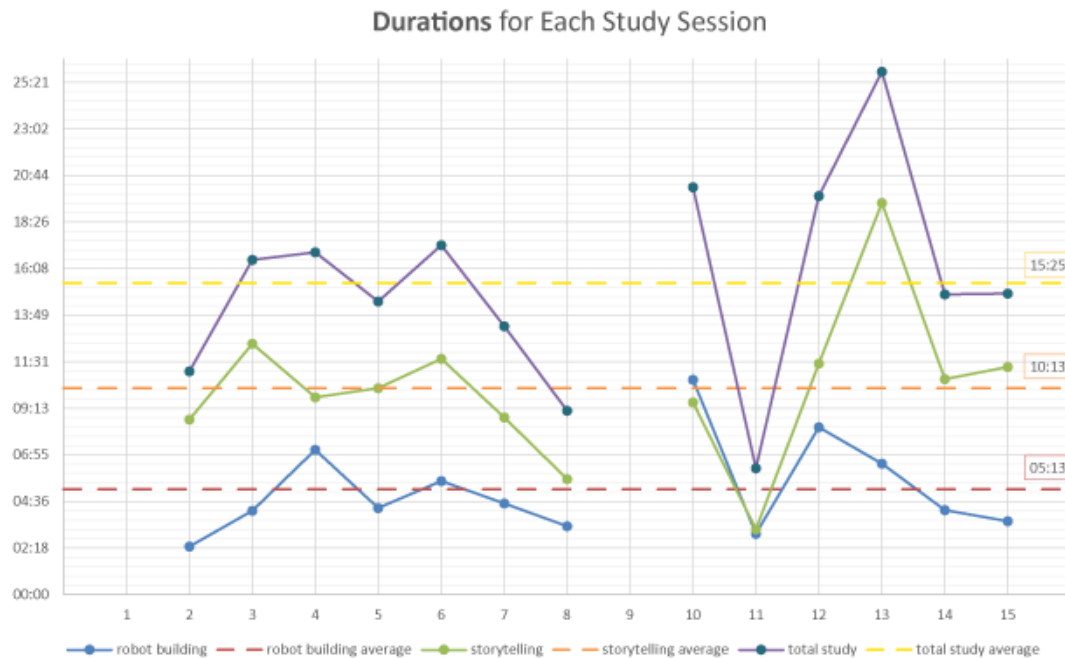


Figure 4.21: Durations of the each study sessions of the control group in the 2nd study.

4.4.2 Switch Group (First tell a story - Later build)

Phase A - Robot Construction

This part presents the findings of Phase A - Robot Construction, based on the data coming from the switch group (Kırlangıç et al., 2020). Below, the results for head, torso, legs, arms, material and gender are shared. Fig. 4.22 shows the overall robot that is constructed with the most chosen body parts by the children in the switch group.

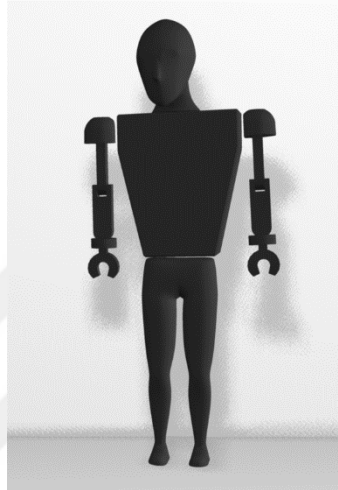


Figure 4.22: The ultimate robot of the switch group from the 2nd user study with Robo2Box (Kırlangıç et al., 2020).

Head. There were 6 types of heads: human, animal, rectangular, rectangular with neck, spherical and fully spherical. 5 children chose human head, 4 children chose rectangular head with neck, and 2 children chose fully spherical head. No child chose animal head, rectangular head and spherical hand. 3 children used a torso for head and were excluded from the results. Figure 4.23 shows the results for the chosen head. The difference between the categories was significant $\chi^2(5, N = 14) = 13.5, p < .05$.

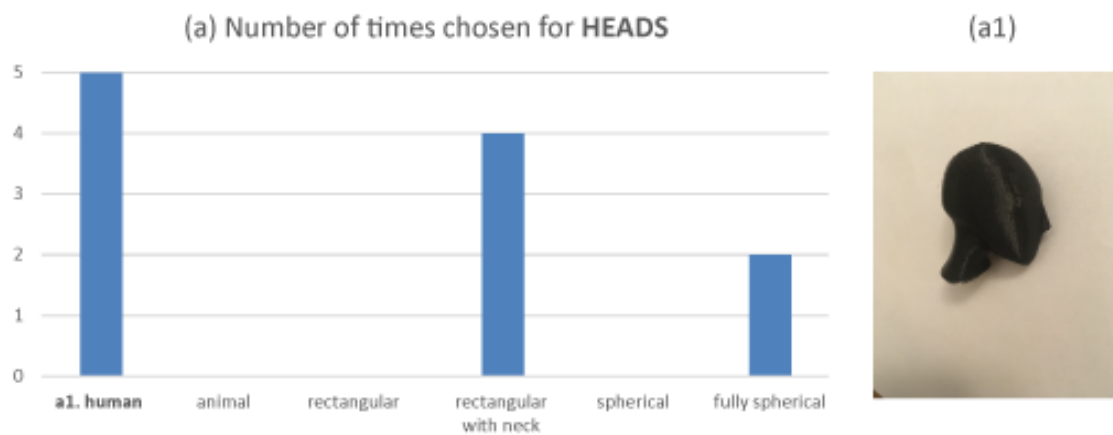


Figure 4.23: Heads chosen by the switch group during the 2nd study (Kırlangıç et al., 2020).

Torso. There were 7 types of torso: sharp-edged distorted rectangle, curved-edged distorted rectangle, sharp-edged square, curved-edged square, sharp-edged rectangular, spherical and cylindrical. 5 children chose sharp-edged distorted rectangle torso, 3 children chose curved-edged distorted rectangle torso, 3 children chose sharp-edged square torso, 2 children chose sharp-edged rectangular torso, and one child chose cylindrical torso. No child chose curved-edged square torso and spherical torso. The most chosen torso is the sharp edged distorted rectangle for the switch group, which has wide shoulders and a small waist, having a more human-like form. When accumulated results of torsos are taken into account, the highest three torsos might be the most human-like for the children, yet the accumulation has a more sharp-edged form than the accumulation of the control group's torsos. There is also use of rectangular and spherical torsos, which have more machine-like forms. Figure 4.24 shows the results for the chosen torso. The difference between the categories was not significant $\chi^2(6, N = 14) = 10, p < .05$.

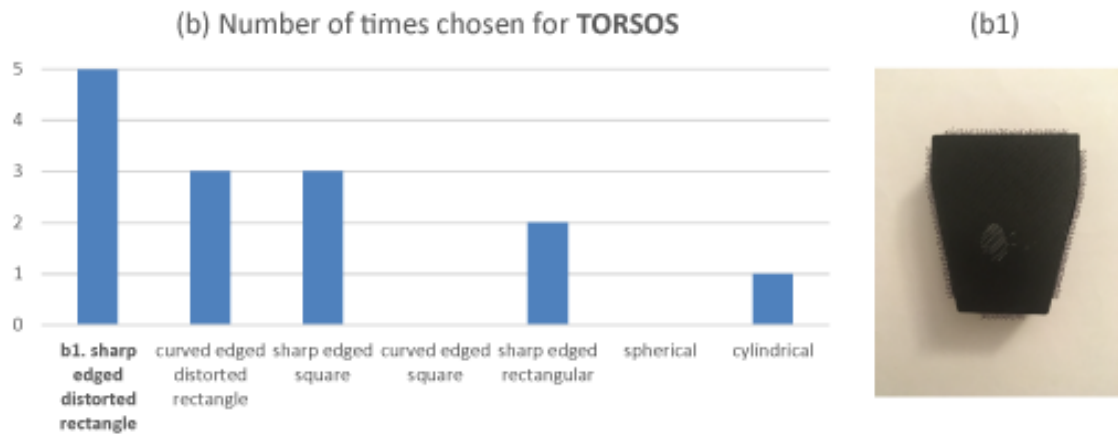


Figure 4.24: Torsos chosen by the switch group during the 2nd study (Kırlangıç et al., 2020).

Legs. There were 8 types of legs: 2-fixed human, 2-fixed animal, 4-fixed animal, 2-fixed machine, 4-fixed machine, 2-fixed wheels, tracks and one wheel. 5 children chose 2-fixed human legs, one child chose 4-fixed animal legs, 3 children chose 2-fixed machine legs, one child chose 4-fixed machine legs, 3 children chose 2-fixed wheels, one child chose tracks, one child chose one wheel, and one child didn't choose any legs. No child chose 2-fixed animal legs. 2 children used two different types of legs for their robots, but were not excluded from the results. The most chosen leg is 2 fixed human legs for the switch group, as it is for the control group. However, it can be observed that other choices of the children are more varied in this group, mainly with machine-like functions and forms. Figure 4.25 shows the results for the chosen legs. The difference between the categories was not significant $\chi^2(8, N = 14) = 11, p < .05$.

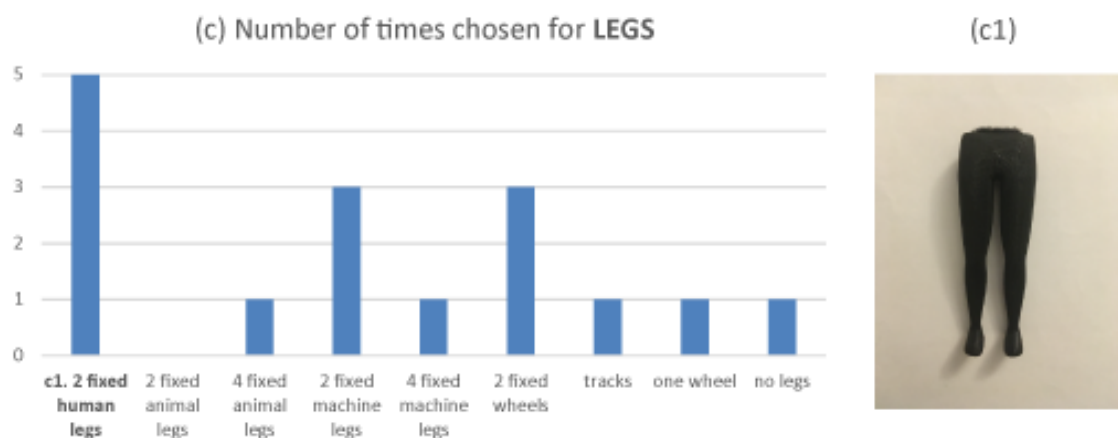


Figure 4.25: Legs chosen by the switch group during the 2nd study (Kırlangıç et al., 2020).

Arms. There were 3 types of arms: human, wings and machine. 8 children chose human arms, 3 children chose wings, and 9 children chose machine arms. There were multiple children who selected two different types of arms in this group, one of the arms chosen is the wings. Among the 4 children who chose the wings, only one of them stated that their robots could fly, and it was after constructing the robot with the parts and putting the wings. 3 out of 4 children who used the wings in the switch group stated that they liked wings in general, and when they saw them in the toolkit, they decided to use the wings. Figure 4.26 shows the results for the chosen arms. The difference between the categories was not significant $\chi^2(2, N = 14) = 2, p < .05$.

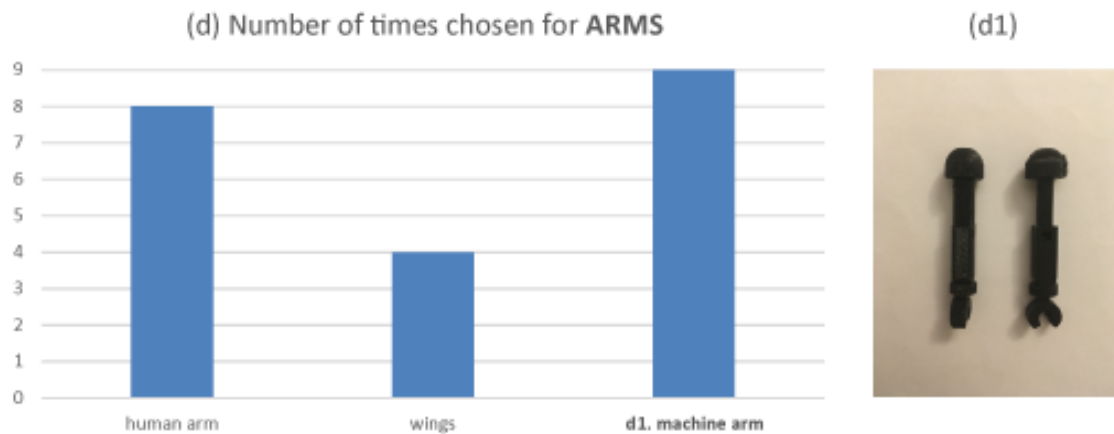


Figure 4.26: Arms chosen by the switch group during the 2nd study (Kırlangıç et al., 2020).

Material. There were 4 types of materials: metal, plastic, fur and eva. 10 children chose metal as material, 3 children chose plastic as material, 3 children chose fur as material, and 6 children chose eva as material. The children were not required to choose only one material, so several materials were chosen for the half of the robots. When the accumulated results for the number of times one material was chosen were examined, metal was the most preferred material in the switch group as well. “My robot is metal because [robots] are hard, so [they are] metal.” (S9). The children in the switch group as well wanted their robots to be mostly metal because of the durability and hardness of the material, which was satisfying the children’s perception of a robot. Other materials were picked up by children for various reasons: preventing the robot to hurt itself or others, to cover other parts of the body that are not metal, such as wheels, and to make the robot more stylish/colorful. The latter reason shows the children in the switch group

too can get deceived by the color of the materials shown to them to pick, even though they were told the colors of the material specimens did not matter and they could be changed. Figure 4.27 shows the results for the chosen materials. The difference between the categories was not significant $\chi^2(3, N = 14) = 6, p < .05$.

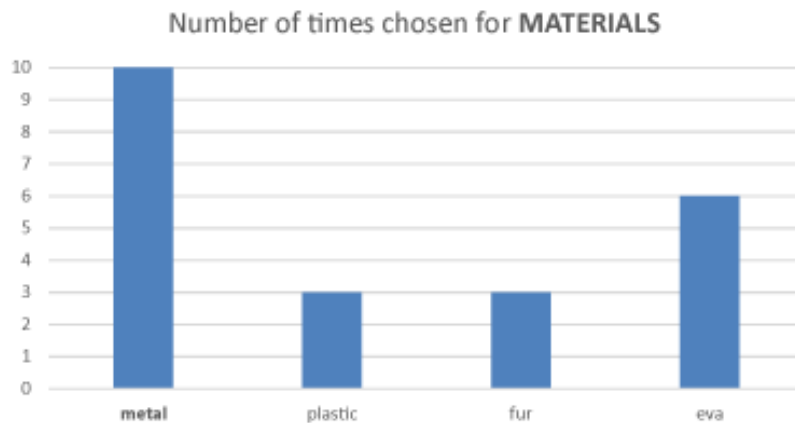


Figure 4.27: Materials chosen by the switch group during the 2nd study (Kırlangıç et al., 2020).

Gender. There were no predetermined titles for gender during the study, so they were all determined during the analysis. 4 children identified their robots as female, 4 children identified their robots as male, and 7 children identified their robots as genderless. One child stated that one half of their robot would be female and the other half would be male, and both choices were added in the results. In the switch group, some children chose their robots' gender the same as their own sex, however, the number of genderless robots was much higher than the control group. S7 commented on her decision as the robot wouldn't have a gender but it could be set by its owner later on. S14 stated that if the robot would have a gender, then it could create segregation between boys and girls; a boy may not use a robot just because it's a girl. Figure 4.28 shows the results for the gender choices for each robot.

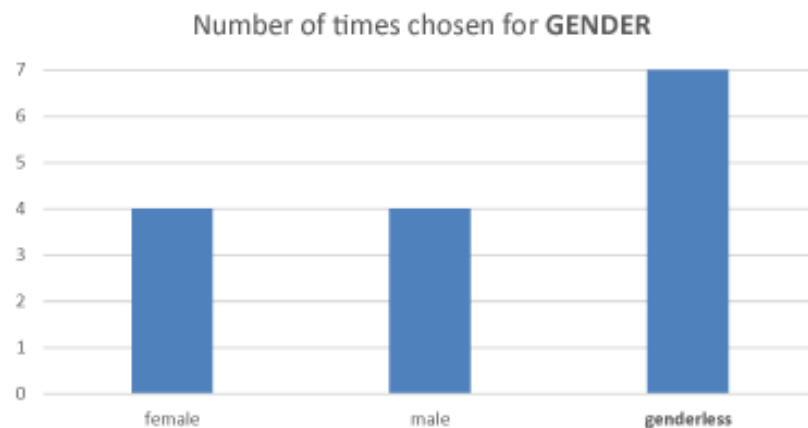


Figure 4.28: Genders chosen by the switch group during the 2nd study.

Phase B – Storytelling

This part presents the findings of Phase B - Storytelling, based on the data coming from the switch group. Below, the results for talking style and voice, emotion, placement, size, tasks and additional features of the robots coming from the stories are shared.

Talking style & voice. The children in the switch group desired their robots to have talking styles & voices human-like, machine-like, or a mixture of both. While describing human-like features, the children used either high-pitch or low-pitch for the voice, and fluent for the talking style. The machine-like features were mostly described with various words like “unusual, digital, like an electronic device, strange”, whereas especially for the talking style one description was used in common: with pauses.

Emotion. In the switch group, only half of the children assigned emotions to their robots and made them show their emotions. S4 explained why his robot had emotions as “I believe robots should have emotions because humans have emotions too.” S2 stated her reason as “If it talks, it has emotions.” The ways the robots show their emotions were rather mixed. While some described the expressions in a more humane way, like crying when sad or blushing when ashamed, others combined the expressions with the functional elements of their robots: the robot of S2 could project its emotions with its glasses, S7’s robot could show its emotions with emojis in a special place on its body, and S14’s robot had emotion buttons on its body.

Similar to the children in the control group, the children in the switch group who didn't assign emotions to their robots claimed similar reasons; "Since [my robot] was made out of technology, it doesn't have emotions." as told by S13.

Placement. The robots constructed by the switch group were mostly placed in front of the classroom, either around the teacher, or in front of the board. The placement decisions were made by the role of the robot in the classroom. The ones around the teacher had an assistant role, they ran errands for the teacher or watched over the students. The robots were placed either on or near the teacher's desk, or moving with the teacher in the classroom. The ones in front of the board had a lecturer role, they were either replacement teachers or lecturers.

Size. As in the control group, the sizes of the robots constructed by the switch group were mostly within a range from child size to adult size. Asking the children to comment on their robots' sizes verbally in a classroom opened up the possibility to comment on the robot size precisely, since the children knew their height, they used this knowledge to comment. When they couldn't, they basically showed it saying "this tall."

Tasks. The tasks assigned to the robots were divided into 5 categories based on the thematic analysis approach (Braun & Clarke, 2006): serving, teaching, disciplining, entertainment and information services. Serving category includes tasks like carrying or getting materials, cleaning and tidying. Teaching tasks include giving lectures, setting and checking homework, replacing absent teachers and helping out students with lecture-related problems, such as explaining the things they didn't understand or missed. The tasks related to keeping the class order, especially to silence the class fall under the disciplining category. Entertainment category holds tasks that are about entertaining the students, like playing with them or singing to them. Finally, the tasks that are put under the information services category are the ones about providing technology and information, such as printing, answering questions, showing videos and playing music.

The robots in the switch group were envisioned for teaching, mainly dependent on the teacher and when the teacher is absent, and would provide information to the students when they asked a question or needed help. These robots were more like "teacher's assistants", as they were expected to help the teacher when they would need an extra hand (S11 & S13). Half of the robots set homework, and would do so mostly on behalf of the teacher. Punishment was more common in the switch group, including

setting more homework to the punished student, shouting, and making them stand in a corner or run around the school.

Additional features. There were not a lot of elements added to the robots in the stories. The most common features mentioned by the children were facial ones like nose, eyes and mouth. Added functional features included projector, screen, compartment, button, pencil sharpener and laser gun that were embedded to the robots' bodies. Addition of clothing and glasses were mentioned for more visuality. Also, some children pointed out the use of remote controls on their robots, and charging features. Even though there were various features indicated in the stories, there were no commonalities between the children who indicated them.

Duration of the Study Sessions

This part presents the duration of each session, along with time spent for robot construction and storytelling. The average duration for building robots was 04:30, the average duration for storytelling was 17:19, and the average duration of total study sessions was 21:50. Figure 4.29 presents the time spent to build a robot, for storytelling, to complete one study session for each child participant, along with the average for the abovementioned durations.

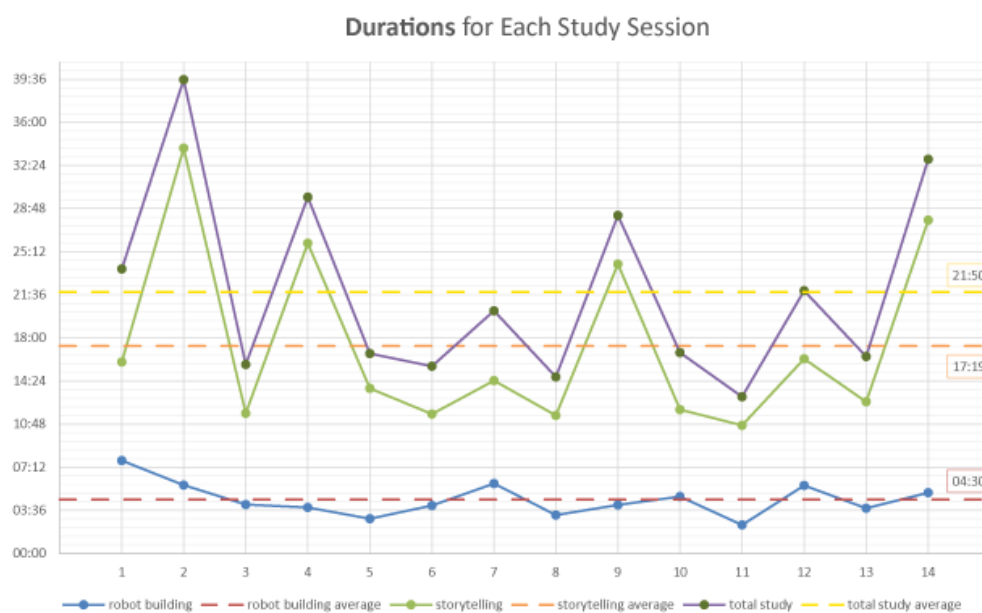


Figure 4.29: Durations of the each study sessions of the switch group in the 2nd study.

4.5 Comparison of the 1st and 2nd Studies

The 1st user study with the 1st version of the Robo2Box toolkit showed how children interacted with a tangible, toy-like toolkit to express themselves on the design process of classroom robots. This study suggested that the Robo2Box robotic toolkit was functional and helpful for design researchers and children, in the classroom robot design case. However, the project Robo2Box was not limited to the physical toolkit. The aim was to design and develop a methodology able to include children into the design processes in order to produce solutions in which the children would be the end/target users, as in this case, for classroom robots. Hence, the user study organization for Robo2Box should bear scrutiny as well.

The 2nd study was designed to investigate how the structural changes in the study method impact the children's interaction with the toolkit and the results of the study. The changes for the comparison were: (i) switching the order of the phases in the study, (ii) implementing a real world classroom setting in the study for children to comment on the placement and size of their robots. However, after the 1st study, some physical changes for the 1st version of the toolkit were also determined based on the children's suggestions and the study facilitator's observations. Those changes were minor, and they were a side product of the study in the context of change for comparison, except for the change in the parts' sizes and bonding method. Even though it wasn't in the scope of the 2nd study's focus, the change in size and bonding method was worth exploring, without interfering with the main focus.

A detailed comparative explanation for each title of changes in the study structure that were stated above can be found in part 5, Discussion.

4.6 Comparison of the Control and Switch Group Results

4.6.1 Phase A - Robot Construction

This part presents the comparison between two groups on the results of the robot construction phase. Each title analyzes the differences between two groups related to the title, with visual representations of the results.

Head

Both groups chose the human head the most. Overall results for chosen heads showed that the control group preferred more organic shaped heads and the switch group preferred more sharp-edged heads. The comparison chart can be seen in Figure 4.30 below.

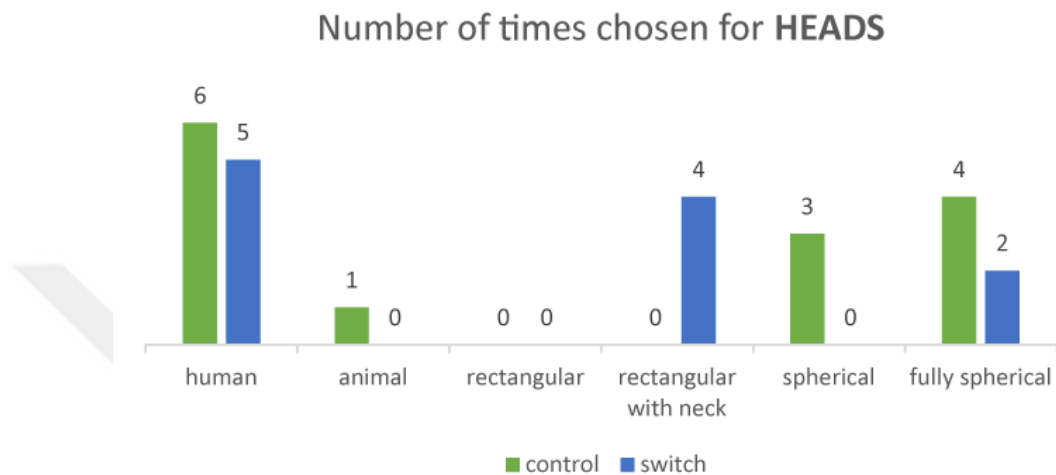


Figure 4.30: Comparison of chosen heads between control and switch groups.

Torso

The control group favored organic shaped torsos whereas the switch group favored sharp-edged torsos, as in the results for the heads. The comparison chart can be seen in Figure 4.31 below.

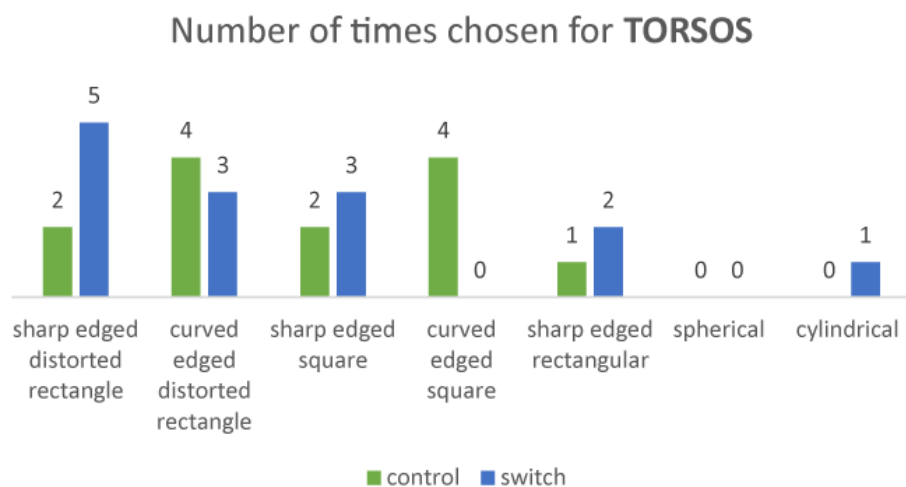


Figure 4.31: Comparison of chosen torsos between control and switch groups.

Legs

Both groups chose the human legs the most. However, the comparison of the overall results shows that the switch group was much more diverse on their leg preferences than the control group. The comparison chart can be seen in Figure 4.32 below.

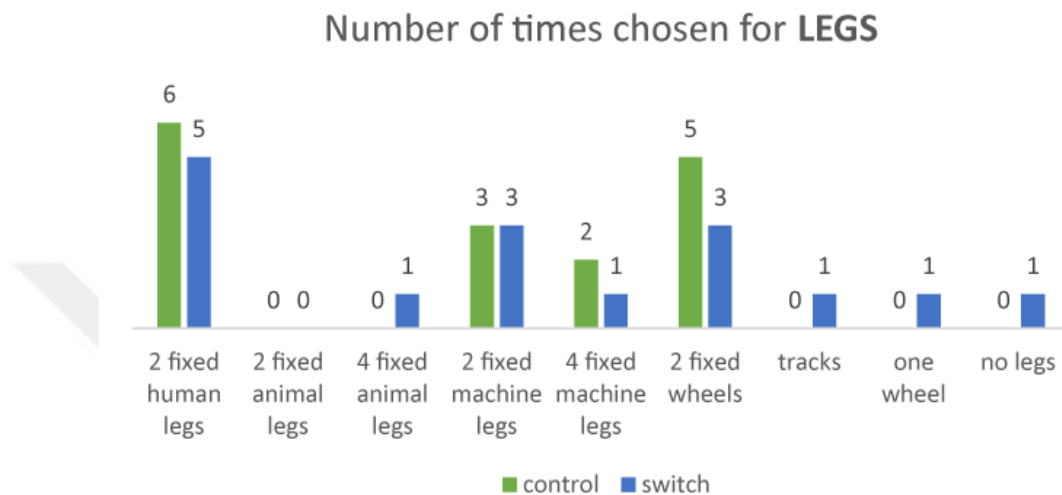


Figure 4.32: Comparison of chosen legs between control and switch groups.

Arms

Both groups chose machine arms the most. In comparison, the control group used wings on their robots more than the switch group, yet most of these robots were not mentioned to have flying skills. The comparison chart can be seen in Figure 4.33 below.

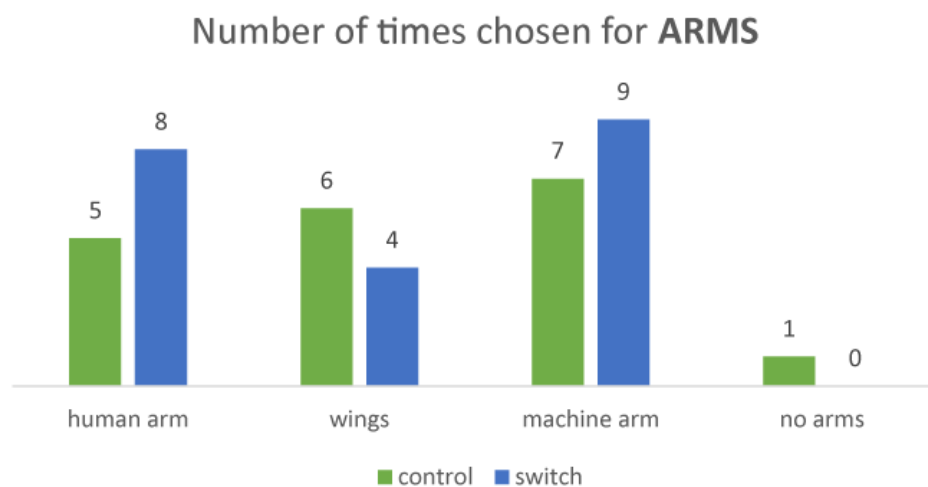


Figure 4.33: Comparison of chosen arms between control and switch groups.

Material

Both groups chose metal as the material because the children stated that "the robots are [supposed to be] metal". The control group chose plastic more than the switch group, which might be explained by the fact that the control group interacted first with the plastic toolkit parts as the study started. The comparison chart can be seen in Figure 4.34 below.

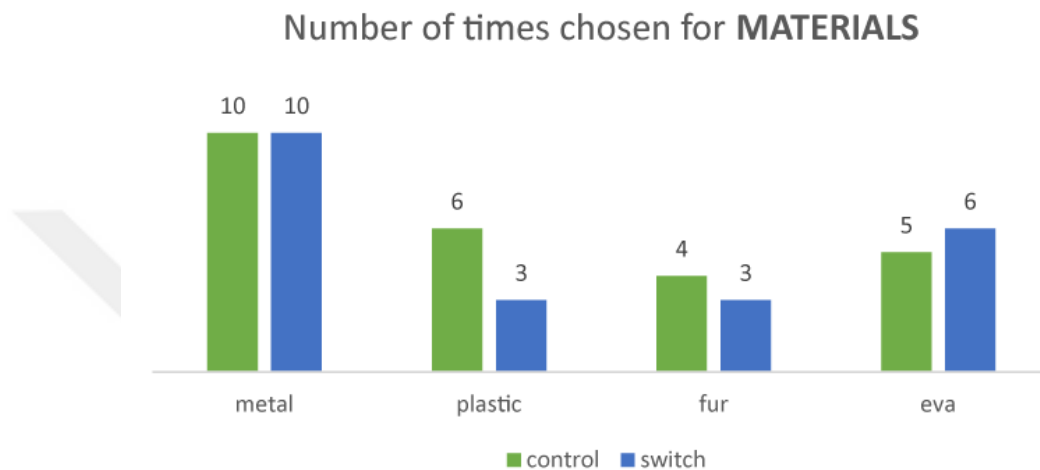


Figure 4.34: Comparison of chosen materials between control and switch groups.

Gender

Number of associated female and male genders with the built robots were similar in both study groups, mainly affected by the gender of the child who built the robot. However, for the switch group, not associating any gender to the robots was chosen the most, because the children stated that "the robots do not have any gender". The comparison chart can be seen in Figure 4.35 below.

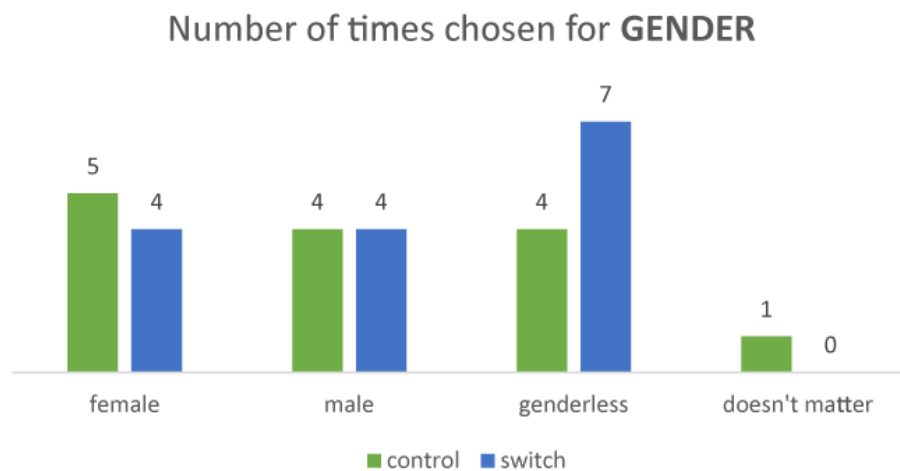


Figure 4.35: Comparison of chosen genders between control and switch groups.

4.6.2 Phase B - Storytelling

This part presents the comparison between the two groups regarding the results of the storytelling phase. Each title analyzes the differences between the two groups related to the title, with visual representations of the results when possible.

Talking Style & Voice

Most of the participating children in both groups of the 2nd study stated that their robots could talk, and they described the way their robots talk and the robots' voice in similar ways. Both the talking style and voice of the robots were characterized as human-like or machine-like. Human-likeness was depicted as high-pitch or low-pitch for the voice, fluent for the talking style, and the children started their descriptions mostly with the words "like a human's". Machine-likeness was depicted as digital, unusual, wavy, or "like an electronic device" for the voice and "with pauses" for the talking style.

Emotion

While most of the children in the control group envisioned their robots with emotions and stated that the robots would show them, only around half of the children in the switch group gave emotions to their robots. The children who did not assign any

emotions to their robots in both groups justified their decisions by stating that the robots wouldn't have any emotions.

Size

The children from both groups stated that their robots would be between child size and adult size.

Placement & Tasks

The control group envisioned their robots more in the servant position, as carrying or getting materials and belongings, and cleaning, and as a teaching assistant, mainly aimed at assisting the students by providing teaching aids and helping them with their classes, and often taking the initiative on how and when to help. Because of their roles, the robots were located mostly around the teacher or among the students. Whereas the switch group envisioned their robots more as a teaching assistant that mainly assisted the teacher by silencing the class, helping out the students that the teacher couldn't, or lecturing when the teacher was absent. These robots were mostly dependent on the teacher while doing teaching responsibilities, and many of them were expected to dole out punishment when the students misbehaved. The robots were located mostly in the spots in the classroom where they could observe the students - on the teacher's desk, around the board or the teacher, and facing the students in all permutations.

Additional Features

When the added features were considered, there was a lack of commonalities between the children in both study groups for the features added to the robots constructed. Addition of facial features and clothing was indicated in both groups, along with functional features such as buttons, compartments, screen and projectors. The functional features added to the robots were more varied in the switch group than in the control group.

4.6.3 Duration of the Study Sessions

The charts of durations for the phases and each study session in total showed that the average time spent in the robot building phase was slightly (43 seconds)

shorter for the switch group than the control group. The average time spent in the storytelling phase and for the whole study were much shorter for the control group than the switch group, 7 minutes 6 seconds difference between storytelling phases, and 6 minutes 25 seconds difference between the study totals. Figure 4.36, 4.37 and 4.38 represent the comparison charts for robot building, storytelling and total study session, respectively.

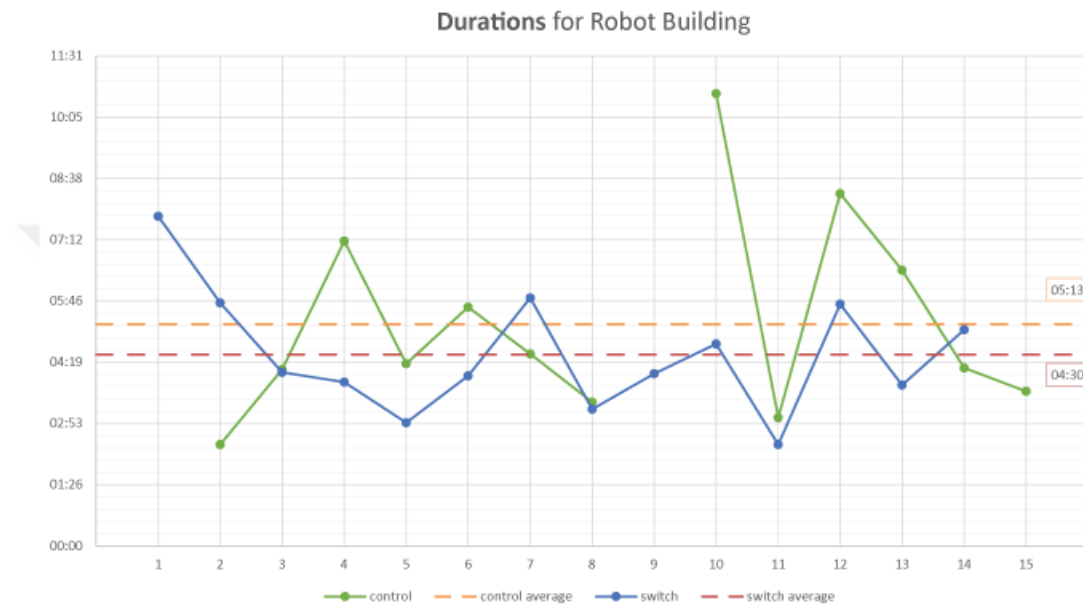


Figure 4.36: Comparison of robot building phase durations between control and switch groups.

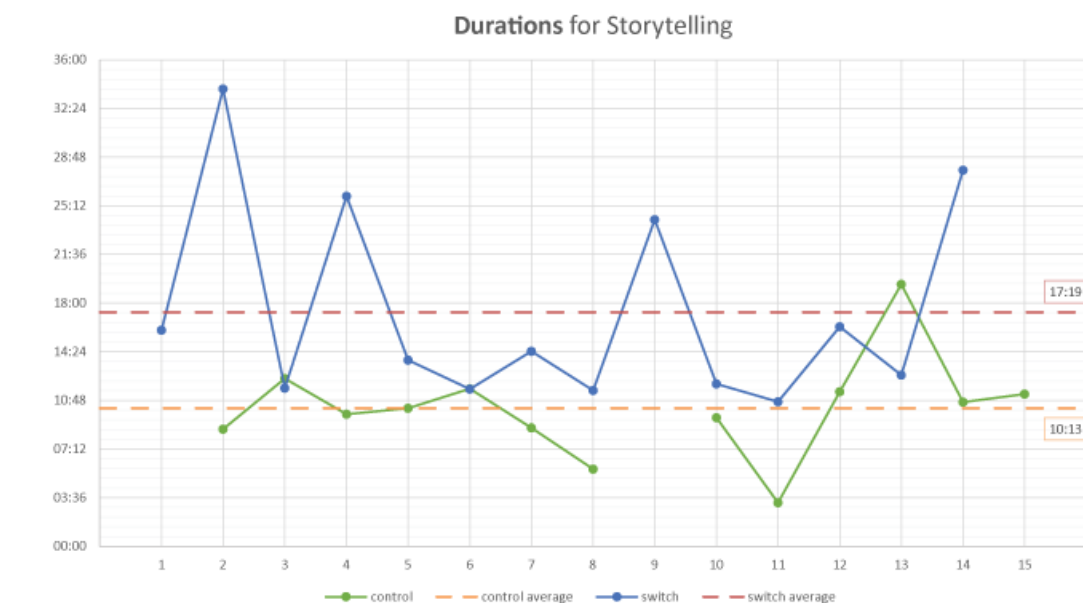


Figure 4.37: Comparison of storytelling phase durations between control and switch groups.

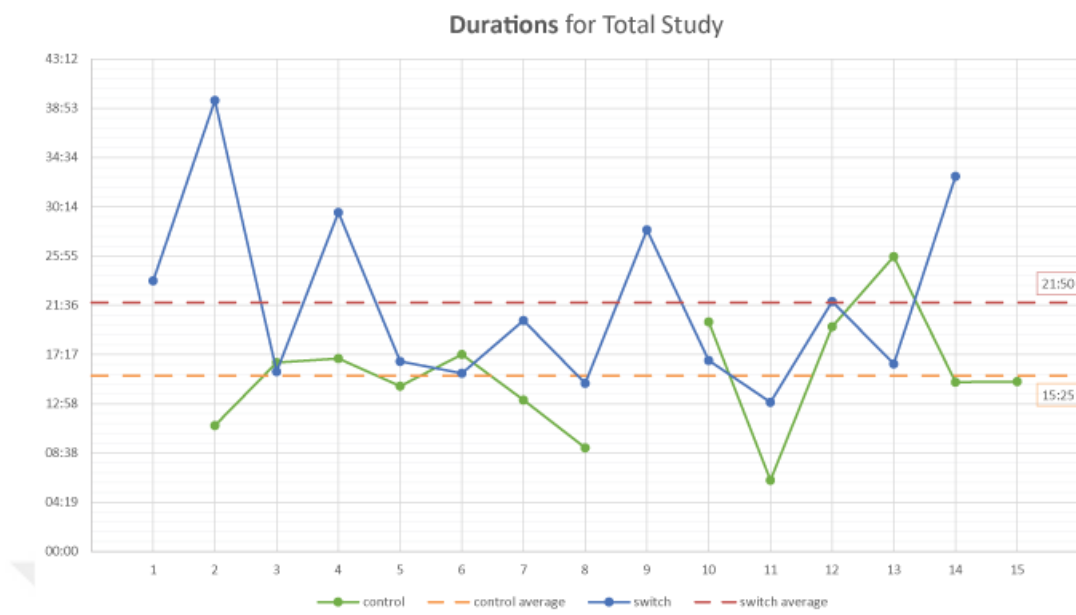


Figure 4.38: Comparison of total session durations between control and switch groups.

Chapter 5:

DISCUSSION

In this section, I discuss the overall findings of the thesis, categorized under; (1) Expression modes, (2) Phase switching, (3) Impact of minor differences between studies, (4) and Impact of children's backgrounds on robot design.

5.1 *Different modes of expression: free or limited?*

Drawing and clay building are two of the many free-thinking methods used in the literature to explore children's requirements for classroom robots, and have been studied (Obaid et al., 2015; 2017) as possible design activities to help children express their needs and desires during the design process. They are both used as free-thinking tools of expression compared to the Robo2Box tool which we suggest in this thesis study, developed for providing a starting point for children to imagine and design robots. This part aims to state the similarities and differences between the use of these manipulable, free-thinking methods; drawing and clay, with a more limited method, Robo2Box, while designing classroom robots with children.

5.1.1 *Drawing*

As an elicitation method, drawing provides freedom for children to express their needs for a classroom robot, yet it is highly possible for children to focus on creating nice drawings more than expressing themselves, which takes time. One of the reasons why the storytelling phase for the switch group during the second study took much longer than the storytelling phase of the control group was participating children's preference on drawing their robots. Scaife & Rogers (1999) and Obaid et al. (2015) also observed the tendency of children to create nice drawings that took time in their studies.

When Robo2Box was employed in the classroom robot design study for the first time, one main advantage was to provide a starting point and being able to shorten the time spent to visualize the imagined robot. The average robot construction time in the first Robo2Box study was 2:35 minutes, whereas in Obaid et al.'s study (2015) the children drew their robots in around 20 minutes. In Scaife & Rogers' work (1999), they experienced a similar thing with drawing; children spent their time to create nice details rather than thinking about the interaction models they were also asked for. Hence, the

researchers decided to use props, so that the children could focus on interaction rather than the visual details. By reducing the time required to imagine the form factor of a robot, the researchers can have more time to explore the characteristics and tasks of the robot.

5.1.2 *Clay*

In a more recent study, Obaid et al. investigated children's involvement in the classroom robot design process by using both Robo2Box and clay (2017). Their aim was to compare and contrast a predefined prototyping toolkit to a free-form prototyping material while designing classroom robots with children. In this study, half of the participating children constructed their robots using first the toolkit and then clay, and the other half completed the same study in the reversed order. Unlike the study with drawing (Obaid et al., 2015), the time spent to construct a robot with Robo2Box and shape one with clay were similar: with Robo2Box it was 2:43 min, and with clay it was 3:01 min. On the other hand, the study showed that the type of prototyping tool didn't affect children's decision of having human-like or machine-like robots, and all robots constructed in the study had a head, a torso and at least two arms.

Along with the similarities, the researchers also spotted some differences between the robots designed with the clay and the toolkit. First, some of the children who used the wings only included this part after seeing them, even though they didn't give any flying skill to their robots. This attitude by children about the wings was spotted in the other studies conducted only with the toolkit as well. Hence, the wings might be considered either as an inspiration or a limitation for children's imagination in classroom robot design, so the researchers should be aware of this possibility when deciding whether to include or not-include wings when they use the toolkit. While there might be some other parts in the toolkit that have an inspiring or limiting effect on children's imagination along with the wings, some parts were used in unexpected ways by several children, such as use of torso as head, or use of head as a piece in hand. The use of toolkit parts in ways that they were not labeled as was also observed in the other studies with the toolkit (Obaid et al., 2016; Kırılancı et al., 2020). I believe that this might be an indication of the toolkit as being not so limiting on children's creativity. Even though the parts were labeled as head, torso, arms and legs, some children didn't

follow the labels and tried to express what they were imagining instead. Second, when using clay to design their robots, the children could add some elements that were not a part of the toolkit, like buttons and hair, which could be considered as an advantage of using a free manipulable tool. Overall, Obaid et al. concluded as (2017):

“[...] although clay provides a free material to elicit some different form factors and affordances from the children, the toolkit helps designers to code and distinguish the form factors more accurately than clay does.”

Therefore, employing other materials like clay, or design activities like drawing in conjunction with the toolkit might be an appropriate approach to give children both more flexibility to design their classroom robots while also providing them possibilities on robot design, helping them focus on the issue, and allowing for rigor in the analysis of the robots.

5.2 Switching phases in the study: which comes first, tangible design or envision?

The 1st study with the toolkit was structured in two phases: first robot construction, second storytelling. This structure let the children design their classroom robots with the toolkit first and envision them in a classroom setting within a story later. The 2nd study investigated the effects of switching the order of these two phases, how the outcome would be if the robots were envisioned first and then designed with the toolkit. Hence, the control group completed the study in robot construction - storytelling order, and the switch group completed the study in storytelling - robot construction order. This section presents the differences between the results of control and switch groups, and comments on them.

5.2.1 Choices of the body parts & materials

The overall results of the 2nd study showed that the participating children envisioned a robot with human-machine look in both groups. Both groups chose the human head, human legs and machine arms the most, and for torso the control group chose a curvier version of the same torso than the switch group. The difference in the torso preference makes the control group's aggregated robot slightly more human-like than of switch group's. When the overall results on body part preferences are examined in detail, especially for heads and torsos, there is a trend for sharper forms in the switch

group, and more organic forms in the control group. This trend can be explained by the control group's preference for human-likeness and the switch group's preference for machine-likeness. I believe that the switch in the order of the study phases caused such a difference: At the beginning of the study sessions in both groups, most of the children described robots as "technological, metallic, having rectangular/square heads/torsos", probably based on the stereotypes they had seen, especially on media. By starting with the storytelling phase, the switch group might have kept the stereotypes in mind while envisioning their robots, and the result was more machine-like robots. Whereas by starting with the robot construction with the toolkit, the control group had seen a whole list of other options, and the result was more human-like robots, even though they might have the same stereotypes in mind as the switch group.

Between the results of two study groups, the leg parts were more diversely selected in the switch group. This difference might have been caused either by the search for a more machine-like robotic look, like for the choices of heads and torsos, or more flexible thinking, because their imagination was not affected by the toolkit parts. The research on whether seeing examples on the related topic affects creativity is controversial (Marsh et al., 1996; Smith et al., 1993). Thus I cannot reach a conclusion as to whether the toolkit limits creativity or not, but I believe that the possibility is worth considering when the children are expected to contribute to classroom robot design processes by using the R2B toolkit.

Since the parts in the toolkit were labeled as heads, torsos, legs and arms, they were expected to be used in the places as their labels suggested. However, there were examples of using the parts in unexpected ways and places, especially in the switch group. Envisioning their robots before constructing them with the toolkit, the switch group might have tried to build their robots as close to how they imagined them with the parts they had. Among the participants in the switch group, two of them used torsos as heads, which were very similar to the heads but bigger in size. It might suggest that these children prioritized the size of the robot's head. One used 2-fixed machine legs as eyes, stating that they were binocular like eyes that could go in and out. Another one used machine arms in the reversed way and the shoulders became hands. This child stated that the robot would have clenched hands when idle, but when the hands were in use, there would be human fingers. Lastly, one placed a torso and an arm on the robot's

body to indicate that these parts were coming out of the robot. These examples show how the toolkit can trigger lateral thinking when it is used after storytelling (Figure 5.1).



Figure 5.1: Example robots from the switch group, showing use of parts in unexpected ways.

Finally, metal was the most chosen material for the constructed robots in both groups, but plastic was chosen more in the control group than the switch group. It's possible that the control group might have been affected by the toolkit's material, which was plastic, while choosing material(s) for their robots, since they did the study in robot construction - storytelling order.

5.2.2 Differences in the robot characteristics & tasks

There are slight differences in the robot characteristics between the control and switch groups: a majority of the robots from both groups could talk, with either human-like or machine-like characteristics in their talking styles and voices. The words used to describe these characteristics were very similar between two groups. Most of the robots in the control group had emotions, whereas there were more robots in the switch group that didn't have emotions compared to the control group, because "the robots wouldn't have emotions." as stated by the children. Justifying not having emotions as being robots in the switch group might be also an indication for this group's desire to have more machine-like robots in the classroom, as it could be indicated from the results of body choices.

The differences in the tasks and the roles of the robots in both groups are more visible than the robot characteristics. The control group envisioned robots more with serving tasks, such as carrying materials and cleaning, and assisting the children on learning more than assisting the teacher during teaching, while being more independent from the teacher and punishing the children less. As a result, the robots were placed mostly among the children or around the teacher by the control group. Whereas in the switch group, the robots were envisioned more like an extra hand for the teacher and assisting them both on teaching and serving, while being mostly dependent on the teacher and punishing the children when needed. These robots were mostly located in the spots where they could observe the whole classroom, like around the board or teacher, and facing the classroom.

As for the choices of body parts, one possible explanation for the differences might be the effect of robot stereotypes on children. Both groups had a similar idea of a robot in mind while talking about them at the start of the study: technologic, metallic, square/rectangular shaped. By having seen a list of human-like body features at the beginning, the control group ended up constructing more human-like robots, thus giving them more of a servant, or a peer-like character. Whereas the switch group kept that idea of robot stereotypes by not seeing the parts of the toolkit, and envisioned their robots accordingly: their designs were more machine-like, and the characteristics of the robots were less human-like, the roles were more controlling and strict; possibly due to the villain roles the robots often fulfill in the media.

5.2.3 *Differences in duration of the studies*

As stated in part 5.1.1 R2B vs. Drawing, an outstanding advantage of using the toolkit was shortening the time spent by the children during the robot construction phase, which was shown with the completion of the 1st study. The 2nd study with the toolkit was designed to explore the testing structure more, including the effect of the order change on the time spent by the children to complete the phases in the study. The comparison between the control and switch groups on average duration of the study phases showed that the switch group spent slightly less time during the robot building phase, whereas for the storytelling phase, the control group spent significantly less time

than the switch group. Figure 5.2 shows the average time spent on robot building, storytelling and the whole study session.

	robot building	storytelling	total
control	05:13	10:13	15:25
switch	04:30	17:19	21:50

Figure 5.2: Comparison of average times spent on robot building, storytelling, and total session, between control and switch groups.

The children in the control group completed the study in robot building - storytelling order, hence they spent more time and did most of the thinking on their robots' visual and functional characteristics while they were building their robots with the toolkit, which might have lengthened the robot building phase duration slightly for the control group, but shortened the storytelling phase considerably since the children already had an idea of what they wanted during that phase. Whereas the children in the switch group completed the study in storytelling - robot building order, so they imagined their robots and talked about them at the same time, which might have made the storytelling phase much longer compared to the control group. However, having decided their robots' characteristics, both visually and functionally, might be the underlying reason as to why the time spent in the robot building phase decreased in the switch group, even slightly.

The comparison between the average durations of the study phases showed that doing such a study in robot building - storytelling order was remarkably faster than doing it in storytelling - robot building order. It also showed that the researchers can take the time spent during the study into consideration while deciding on the structure for such a study, since the difference in average time was significant. However, I believe that grounding the user studies into a change-in-order structure as in the 2nd study makes the outcome more diverse since it would contain different thinking processes of the children as mentioned above.

5.3 *Impact of Minor Differences between the Studies*

5.3.1 *The size of the toolkit parts & the mode of bonding*

In the 1st version of the toolkit, the size of the parts were determined based on human LEGO minifigures (LEGO, 2020b): once the parts were bonded, the outcome was expected to be around the same height of a human LEGO minifigure. LEGOs were used as a reference point for size since they are well-known toys, and the toolkit was envisioned to be toy-like. Adhesive dough was chosen as the mode of bonding due to its ease of use, especially by the children since it was like playing dough, also since it could bond the parts strongly enough to be held together but allowed the parts to be easily separated and disassembled, as well as its reusability.

The study of the toolkit's 1st version, demonstrated that the parts were too small and too weak even for a child. The children tried to bond the parts as best as they could, but there were times when it didn't hold up properly. In one or two sessions, the child tried so hard to bond, it caused the part to break. The broken pieces of the parts were easy to be glued together with a strong liquid adhesive instantly, but the moment was very upsetting especially for the child since they broke something they didn't own. Additionally, because the parts were small and couldn't be bonded well, it was hard to make the constructed robot stand upright, which was also a problem for the children who wanted them to be standing. Hence, even though it was a functional toolkit for children to design classroom robots, it wasn't as playful as it was expected to be based on observations. None of the children could/did play with the robots that they constructed with the R2B toolkit because of the reasons stated above.

The size of the toolkit parts and the mode of bonding were changed after experiencing the difficulties during the 1st study as stated above. The parts were scaled up 10 times, and the bonding method changed from adhesive dough to Velcro (See Figure 5.3 for the examples. The material specimen was the same in both studies, it could be referred for the size.) The designed robots with the parts from the toolkit's 2nd version were much more stable and more likely to be able to stand upright. While handling, the constructed robots were like plastic doll-like toys, which enabled children to play with their robots like a toy. It was observed in the children from the switch group that the children who were shy and tend to not talk much or answer the questions

as “I don’t know” became more lively and talkative once they saw the parts and started constructing a robot. It was also observed that the children in the 2nd study interacted with the parts and played with their resulting robots more than the ones in the 1st study, which was a result of enlarged parts and the change in bonding method.

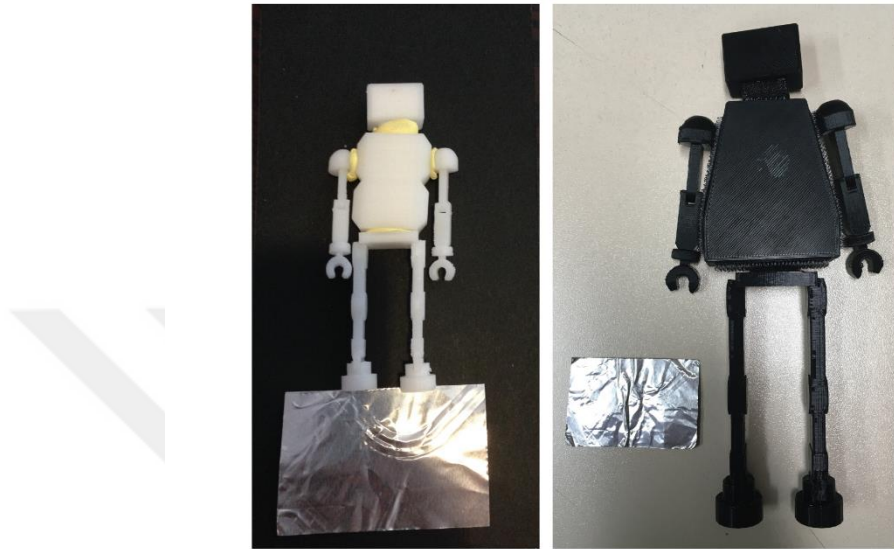


Figure 5.3: Examples of constructed robots; with toolkit's 1st version on the left, with the 2nd version on the right.

The only theorized drawback to changing the bonding method from adhesive dough to Velcro was restricting the children on the placements of the parts. While bonding the parts with each other, the children were free to bond any part to others from any point they wanted to with the use of adhesive dough on the 1st version. However on the 2nd version, the Velcro pieces had to be glued to specific points on the parts, which might have limited the free expression of the children, even though the points of Velcro were determined based on the bonding preferences of the parts in the 1st study.

5.3.2 Use of a model classroom with paper-modelled humans

After the production of the toolkit's 1st version, it was decided by the research team that using a model classroom with a teacher and a couple of students inside during the user tests would be beneficial for children for imagining and expressing their robots' place in the classroom and their size. The model classroom is explained in detail in section 4.1.1, and the model is presented in Figure 4.1.

During the 1st study, once the child was done with the construction of their robot, they were asked to comment on its size by looking at the model people in the classroom setting. In the sessions, every child was told that they should imagine the smaller model human as a student and the bigger model human as a teacher in a real world setting, then asked about their robot's size, whether it was shorter, the same height or bigger than the human models standing in the classroom setting. After that, they were asked about the robot's placement in the classroom.

When faced with a question that required imagination to answer about their robots' sizes, and presented predetermined answers to select from, the children observed to be giving their answers straight away, such as smaller than a child or in between a child' and an adult's size. Presenting children preset answers for their robots' size eases the coding process. However, to be able to answer the size question, the children required to imagine their robots' sizes, and comment on them relative to the model human that they were provided with. On the researcher side, this might have limited the clear understanding of the results on robot size, since it was not known what the height of an adult was for the children, for example. For placement, the children answered in a freer manner than the sizing question, without any predetermined answers provided by the researcher. Providing a model classroom for placement helped children by letting them point out and describe the location they wanted to place their robots in, and it also helped the study facilitator and coders more since the classroom was defined and the same for all children.

In the 2nd study, the model classroom with model humans inside was discarded to let children think and express themselves freely, and the study already took place in a classroom. When answering the size question, the children either gave the answer as an exact height, such as 119 cm, since they knew their height, or with some descriptive words, such as "like a toy". With this approach, some children gave very concrete answers as exact height of the robot in centimeters, but some of them described their robots' size as "smaller than a child" or "height of a teacher", which was not very clear for the facilitator and the coder because of the use of both height in cm or with a comparative description by children. As stated above, the image/height of an adult or a child in the child's mind was an unknown for the facilitator and the coder, especially combined with the answers in centimeters in the same study. While placing their robots in a classroom setting, the children were inside the classroom provided, rather than

looking at a small replica of it, hence they could think about the embodiment of their robot better. Instead of pointing out the locations, the children only described the placement of their robots inside of the real classroom setting. This way was also clear for the facilitator and the coder, except for the very few times when a child described the place by using the words left or right. The lack of modelled humans placed at certain points in the classroom let children give their answers freely: for example, the teacher's place wasn't shown to the children as predetermined, so there were alternating places for the teacher among answers, when the robot's place was described as dependent on the teacher.

Both using and not using a model classroom with model humans inside have benefits. While a model classroom with model humans can provide accurate answers which are easier to code since the defined classroom and relative sizes of humans create rather preset answer categories, a real classroom setting (with real humans inside) can let children imagine freely with the sense of embodiment. The only drawback of not using relative/predetermined sizes for the robots as in the 2nd study is getting the answers for the heights described both in centimeters and with comparisons, which creates confusion while trying to reveal children's desires. Hence, it is advised to ask the sizes of the robots either in a unit of measurement if the children know their height, or comparing to real-world or scaled models. Therefore the researchers should choose the appropriate settings for their study depending on what they want to achieve as an end result.

5.4 *Impacts of children's backgrounds on their classroom robot preferences*

The first R2B study took place in Fenerbahçe Sports Club's sailing facility in Istanbul, and all the children were the attendants of the sailing courses that take place there during summer time. Sailing is a relatively expensive sport in Turkey that low income families cannot financially afford, and being able to take sailing classes for their children in one of the best sports clubs in Turkey shows that the child has enough financial support coming from their family for their education and development. For the second study with R2B, the children were recruited with the help of a Turkish non-governmental organization called TOÇEV, Tuvana Okuma İstekli Çocuk Eğitim Vakfı. TOÇEV aims to provide both material and immaterial means for education to children

who want to get more education but are unable to access it because they come from disadvantaged families that do not have sufficient financial means to do so.

The needs and experiences of the children in their educational life affected the robots they envisioned, and created a (slight) difference between the children coming from disadvantaged families and those that did not, which could be mostly observed in the tasks the children assigned to their robots and in the additional elements they added to them. During the second R2B study that was done with the children who came from disadvantaged families, some of the children mentioned how crowded their classrooms were. Thus they assigned tasks to their robots accordingly, such as silencing the classroom during lectures to ease the teacher's job, and to be able to understand the lectures better. Another desire of these children was to be able to reach educational means more easily in and out of class hours. They expressed their need and desire by envisioning their robots as a helping hand to the teacher, so that either the teacher or the robot could help every student during the lecture, or as a teaching aid for the students by providing them extra study materials so that they could be more successful in their courses. On the other hand, the children that participated in the first R2B study who were not coming from disadvantaged backgrounds did not assign such tasks to their robots by stating such underlying reasons. They mostly envisioned their robots as a teaching assistant that gave lectures when the teacher was absent, provided materials, or provided IT services like printing or projecting educational materials. Expecting the robots to provide IT services also increased the amount of elements added, especially the functional ones, to the robots during the storytelling phase in the 1st study. The participating children of the 1st R2B study augmented their robots more with additional elements, like buttons to change the robot's language or to turn the robot on/off, projectors and screens to show visuals and videos, in-body compartments to hold things like stationeries, or color changing body parts to show information or emotions, along with microphones, speakers and cameras. While the use of additional elements pertaining to facial features (eyes, lips, nose, hair) and clothes were similar between the 1st and 2nd studies, the children in the 1st study mentioned on-body accessories such as guns, shield, belt, lights and eraser & chalk more than the ones in the 2nd study.

Growing up in a disadvantaged family also has an effect on how and where the child learns about robots, mostly because of media access. At the beginning of both studies with Robo2Box, the children were asked about their knowledge of robots, what

they knew about them and where they learned it from, and whether they had any robotics classes. In both studies, there were a few children who mentioned having taken robotics classes (3 children in the 1st study, 1 child in the 2nd study), or having done either visual or code-based programming (3 children in the 1st study, 5 children in the 2nd study who took a course organized by the NGO). As to where they learned about robots, children mainly mentioned the media (movies, books, cartoons, news, TV shows) and the internet, along with in school and from family members like parents who were working in a related field such as computer science and engineering.

While the number of children who mentioned school and family members as their source was very low for both groups, there was a big difference in the numbers for the media and internet among the 1st and 2nd study participants. Out of 31 children from the 1st study, 29 of them mentioned having seen robots in the media and/or internet, mostly in movies and cartoons, and many of the children named Transformers. However in the 2nd study, only 16 children out of 28 mentioned having seen robots in the media and/or internet, without giving any names of the shows. Some of these children didn't even mention what kind of medium they had seen the robots in, they only said "on television". As a possible result of the difference in the level of exposure to the robot-related content in the media, the overall robots constructed with the most chosen body parts in the toolkit differed in two studies: the 1st study resulted in a more machine-like robot (Figure 4.3), and the 2nd study resulted in a more human-like robot (Figure 4.14 & Figure 4.22). There were also more inspirations coming from fictional characters for the robots in the 1st study: a shield like Captain America's, a big muscular body like Hulk, voice/talking style like Baymax (Big Hero 6), a body form like R2D2 (Star Wars) and body shape changing into vehicles like in Transformers were some of the examples from the children in the 1st study. There was only one child in the 2nd study who stated that they got inspiration from a fictional character, which was a Dalek from Doctor Who.

In their study on designing teaching assistants, Obaid et al. (2015) showed that there was a difference between the robots that the children with and without robotics knowledge envisioned. Thus they pointed out the importance of taking into account the children's robotics knowledge when involving them in the classroom robot design process. Finding out the differences in requirements for classroom robots between disadvantaged and not disadvantaged children was not the main motivation behind

running the 2nd study. The 2nd Robo2Box study was mainly aimed to be a fun and learning activity for these disadvantaged children apart from being a research study. However, in the light of what Obaid et al. have shown (2015), the differences spotted between the results of the 1st and the 2nd studies were very valuable to share.



Chapter 6:

CONCLUSION

This section concludes the thesis and summarizes the lessons learnt throughout this thesis. First, I will revisit the research questions and list the design implications, then I will talk about the limitations of the thesis that I observed, and future research directions.

6.1 *Assessment of the Research Questions*

This thesis aims to explore novel methods to involve children in the development of classroom robots. With this aim in mind, answers for the research questions are as follows:

How can children be involved in a classroom robot design process using a tool that provides them a starting point to think without limiting their creativity?

To be able to involve children in the classroom robot design process, Robo2Box was developed as a tool. Two separate studies were conducted with different groups of children, first one to examine the toolkit's use, and second one to examine the user study structure. Both studies incorporated storytelling as a design tool, along with prototyping with the toolkit, while in the second study we looked at the effects of order change. The findings show that Robo2Box is a helpful tool for designers to keep children focused on the task of designing classroom robots. The findings also show that classroom robot construction with children by using the toolkit takes less time compared to two other design tools, drawing and clay. Yet, it is worth considering using a combination of tools during the studies to let children express themselves beyond the toolkit. The studies also show that asking children to construct their robots with the toolkit before and after doing storytelling about their robots' action in the classroom has an effect on the resulting robot. Lastly, the size of the toolkit parts and the bonding method for the parts are important for the ease of use of the toolkit for the children.

What do children envision in terms of a classroom robot's appearance and functions?

In the 1st study, the overall robots that the children envisioned were human-machine-like robots, which can be seen in Figure 4.3. The robots were mostly expected to be a teaching assistant, and helping the teacher more than the students. In the 2nd study, the children who completed the study in robot construction - storytelling order envisioned more human-like robots that mostly assisted the students in learning. The children who completed the study in storytelling - robot construction order envisioned more machine-like robots that mostly assisted the teacher in teaching. The overall robots of the 2nd study can be seen in Figure 4.14 for the control group, and in Figure 4.22 for the switch group.

How does children's demographic background affect the requirement they define for the classroom robot?

According to the results obtained from the studies, the children coming from disadvantaged and non-disadvantaged families envision robots differently, mainly on the tasks & roles, and the features added to the robots. These differences are affected by what kind of a learning environment the children are in, what they experience in their learning environment, and how much they are exposed to robots in the media.

6.2 Methodological Implications

This thesis study presents a methodological research on classroom robot design process with children by using a robot prototyping toolkit called Robo2Box. The findings of the user studies have the following methodological implications:

- By definition, a classroom is a place where the children get education. Yet, it is important to consider the whole meaning of and the experience in a classroom for children while designing classroom robots with them, since they also play and socialize, and even eat, in a classroom.
- For a holistic approach to classroom robot design with children, Robo2Box toolkit can be used in combination with some other design activities, like storytelling or sketching, and/or with other free-form prototyping materials,

like clay. When used in combination, these tools can help designers/researchers to have a deeper understanding for the requirements of the classroom robots constructed by the children on both appearance and functions/behaviors.

- For a playful experience for children while designing classroom robots, Robo2Box can be used in the size of the second version of the toolkit, since it gives a doll-like feeling once the parts are assembled into a robot.
- Adhesive dough was used in the first user study as the bonding method for the parts, and was found to be weak as a bonding method, yet scaling up the parts might have a different effect on the strength of the bonding done with it. Velcro was used in the second user study as the bonding method for the parts, and was found to be a more stable bonding method when assembling the parts compared to adhesive dough. However, it needs to be glued onto the parts, hence it might limit the children when constructing their robots.
- Use of a model classroom with replica people and furniture inside was found to be beneficial especially for the designers since it is well-defined and same for all the children, which gives some rigor for the analysis. Having the study in a real classroom can give children flexibility on their design decisions, and the children can give more precise answers for the placement and size of their robots. The designers/researchers should choose which one to use in their studies depending on their needs.
- Changing the order of the phases in the study (starting with robot construction with Robo2Box vs. starting by envisioning the robot) can create a difference in the resulting robots. The resulting robots of the second study were both human-machine like, however the resulting robot of the group that started by envisioning their robots (switch group) had more machine-like features, both for the appearance and functions, than the resulting robot of the group that started with constructing their robots with Robo2Box (control group).
- The duration of the study sessions might be important for some research setting. When the study is conducted in storytelling – robot building order, the robot building phase takes less time than the group in robot building –

storytelling order. However, storytelling phase takes much less time when the study is conducted in robot building – storytelling order.

- In their study, Obaid et al. (2015) showed that the children with and without robotics knowledge envisioned classroom robots differently. Similarly, children's educational experience in a classroom differs depending on their socio-economical background, and it affects how they envision their classroom robots.

6.3 Limitations

There are several limitations to the studies presented in this thesis. First, both studies were performed with only Turkish children. Lee et al. (2014) indicates that cultural differences affect how social robots are envisioned. Even though Robo2Box toolkit was based on the drawn robots of Portuguese children, interaction designers with international backgrounds (Obaid et al., 2015) and literature (Woods, 2006), the findings of this thesis might still be representative of Turkish children only. Second, the children's age range in both studies are rather broad (8-15 in the first user study, 9-13 in the second user study). As Sciutti et al. (2014) states, which robotic features are considered important by the children change depending on the age. Hence, it is possible to reveal different requirements for classroom robots by narrowing the age range of the children, or by analyzing the data based on the age or age groups.

6.4 Future Research

Considering some of the changes requested to the toolkit by the children and the use of toolkit parts in unexpected ways, Robo2Box toolkit can be moved to a graphical user interface in order to give children more means to express themselves. The children can change the part sizes and colors, and add accessories based on the additional features coming from the two studies to their robots in GUI, while still choosing the parts from the content list of the toolkit within the GUI.

Based on the limitations of the studies, the studies can be conducted with (i) children coming from different cultural backgrounds, and possibly different educational systems since these might affect their overall experiences in the classroom, hence their requirements for classroom robots, (ii) children with narrower age range, for example

between 7 and 9, or 9 and 11, to reduce some of the effects that might be caused by the age difference, such as the features that are considered important, on the overall robots of the whole study. Grouping the data coming from the study by the age or age groups might be another way to handle this issue as well.

Another future work with Robo2Box toolkit might be conducting workshops with small groups of children, and let them discuss on their robots collectively. However, the group dynamics might affect the results (Van Mechelen et al., 2015), such as one child might have dominance over others, hence the researcher should be aware of that. With this perspective in mind, there is a possibility to explore the classroom robots designed by the children individually vs. the classroom robots designed by the children in small groups.

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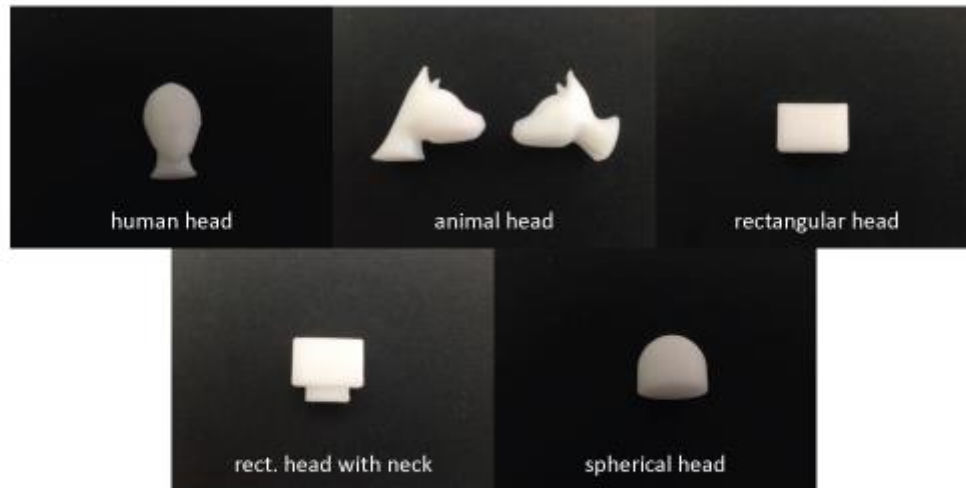
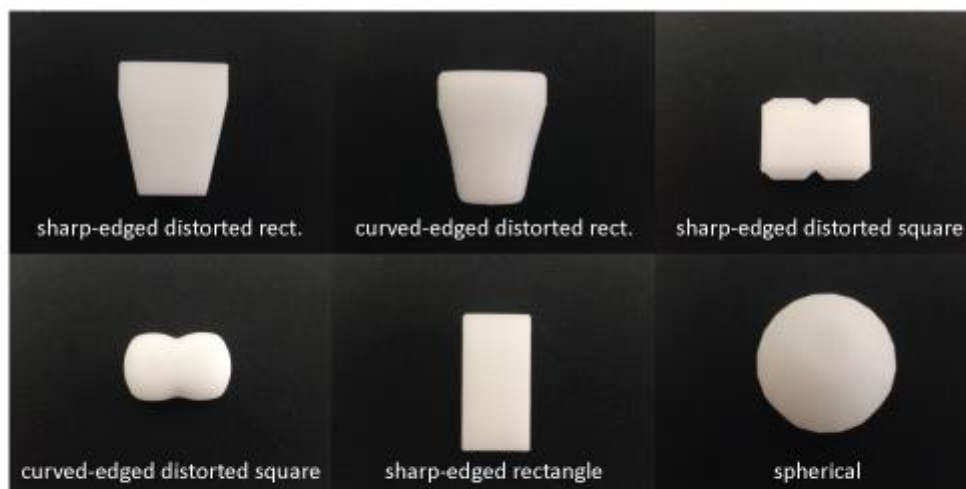
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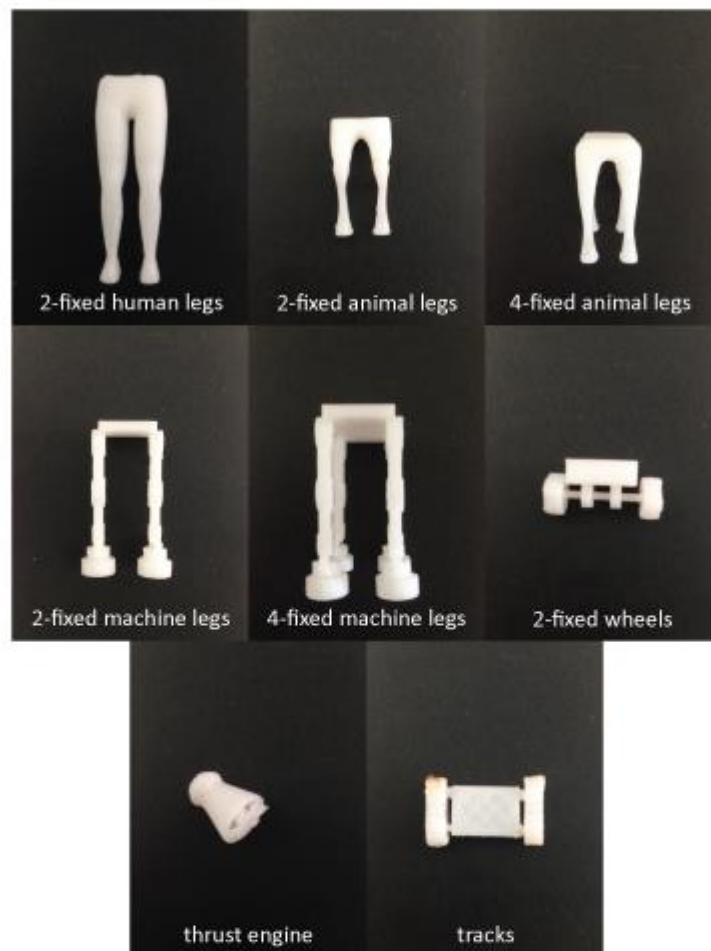
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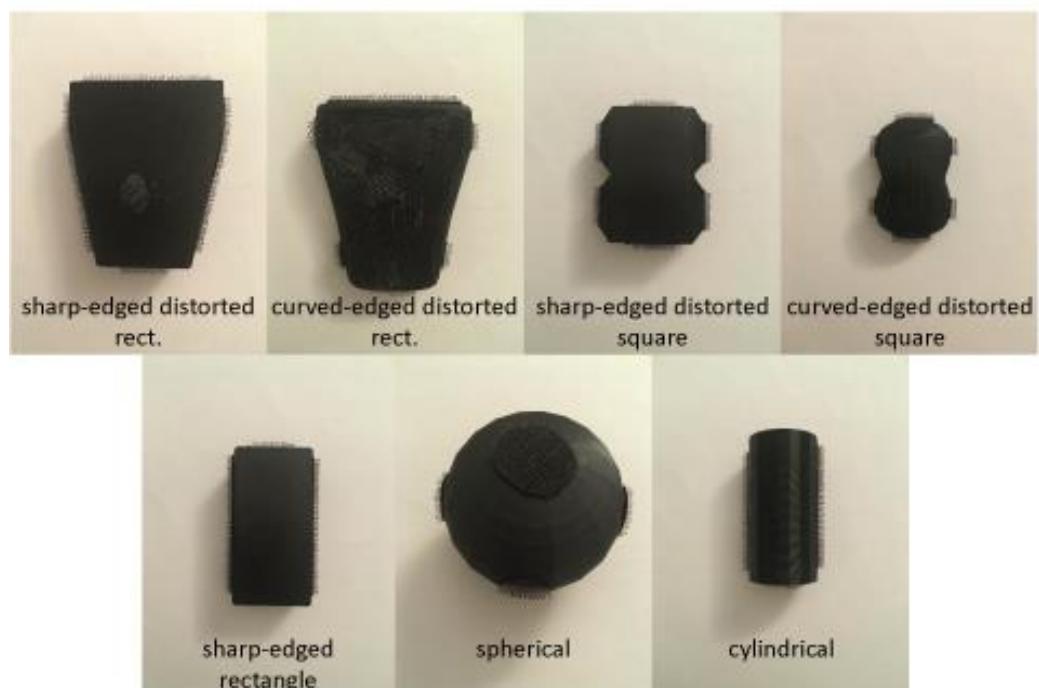
Appendix A: Parts of the 1st Robo2Box**HEADS****TORSOS****MATERIALS**

LEGS



ARMS



Appendix B: Parts of the 2nd Robo2Box**HEADS****TORSOS**

LEGS



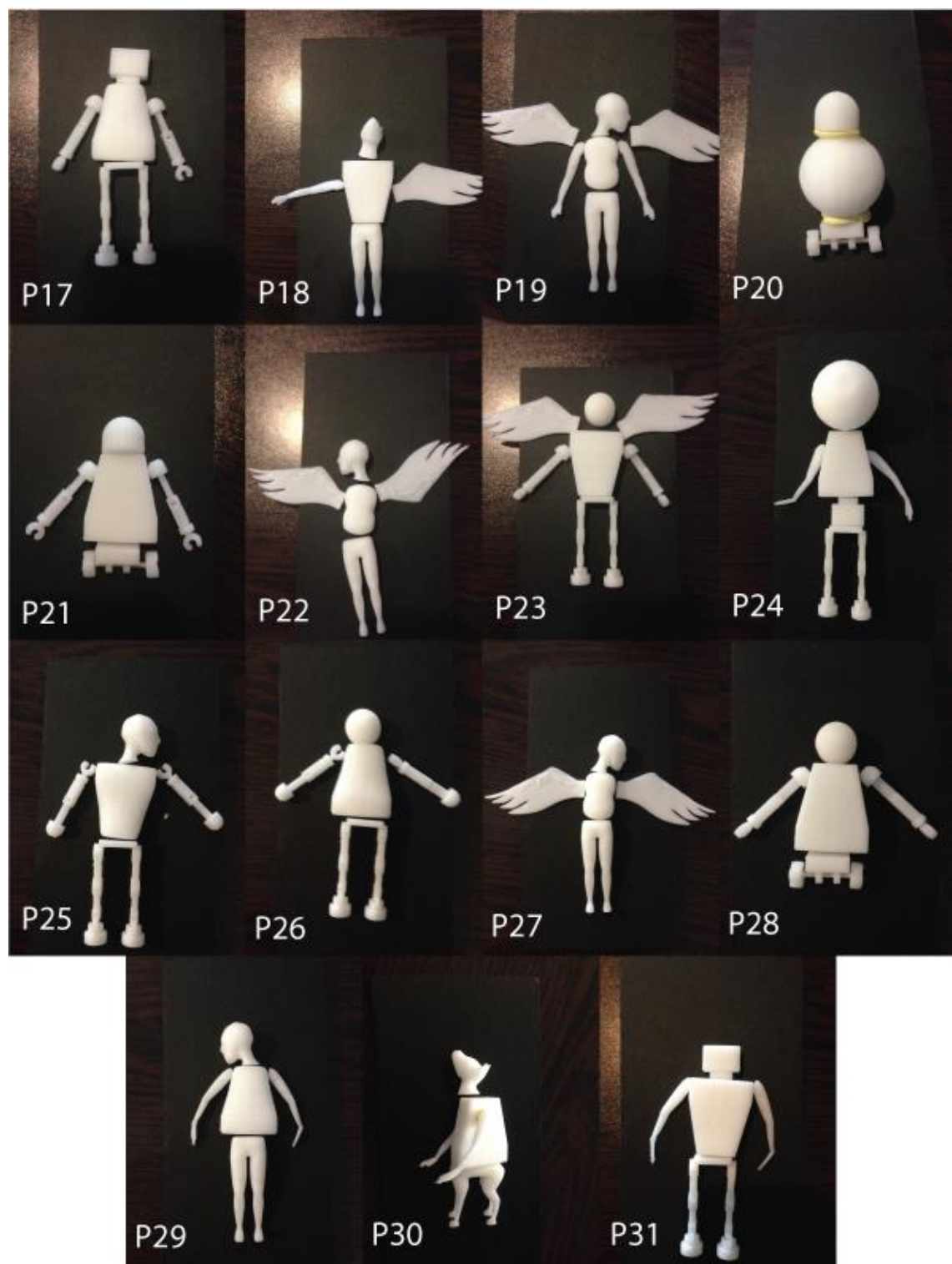
ARMS



MATERIALS



Appendix C: Robots Built in the 1st Study



Appendix D: Robots Built in the 2nd Study

THE CONTROL GROUP



THE SWITCH GROUP



Appendix E: Publications

E.1 Paper published in ICSR 2016

Obaid M., Yantaç A.E., Barendregt W., Kırlangıç G., Göksun T. (2016) *Robo2Box: A Toolkit to Elicit Children's Design Requirements for Classroom Robots*. In: Agah A., Cabibihan JJ., Howard A., Salichs M., He H. (eds) *Social Robotics. ICSR 2016. Lecture Notes in Computer Science*, vol 9979. Springer, Cham.
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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

2 Authors Suppressed Due to Excessive Length

novel ways of imagining about classroom robots. In this paper we aim to 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

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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 Figure 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 Section 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).

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LOOK																	
SOURCE	Human	×	×			×	×			×				×			
	Animal		×					×	×			×	×			×	
	Machine			×	×	×	×	×	×	×	×	×	×	×	×	×	
	Obaid - Children	×	×	×	×	×	×			×			×	×	×	×	×
PART TYPE	Obaid - Designers			×				×	×			×		×	×		×
	Woods - Literature							×	×			×	×				
LABELS		Heads				Torsos				Legs				Arms		Material	
	Human head 1																
	Animal head 2																
	Rectangular 3																
	Rectangular with neck 4																
	Spherical 5																
	Sharp-edged disc, rect. 1																
	Curved-edged disc, rect. 2																
	Sharp-edged square 3																
	Curved-edged square 4																
	Sharp-edged rect. 5																
	Spherical square 6																
	2 fixed human legs 1																
	2 fixed animal legs 2																
	4 fixed animal legs 3																
	2 fixed machine legs 4																
	4 fixed machine legs 5																
	2 fixed wheels 6																
	Thrust engine 7																
	Locks 8																
	2 human arms 1																
	2 wings 2																
	2 machine arms 3																
	Plastic 1																
	Metal 2																
	Fer 3																
	Rubber 4																

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 Figure 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.

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

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

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.

Torso: The torso results are shown in Figure 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

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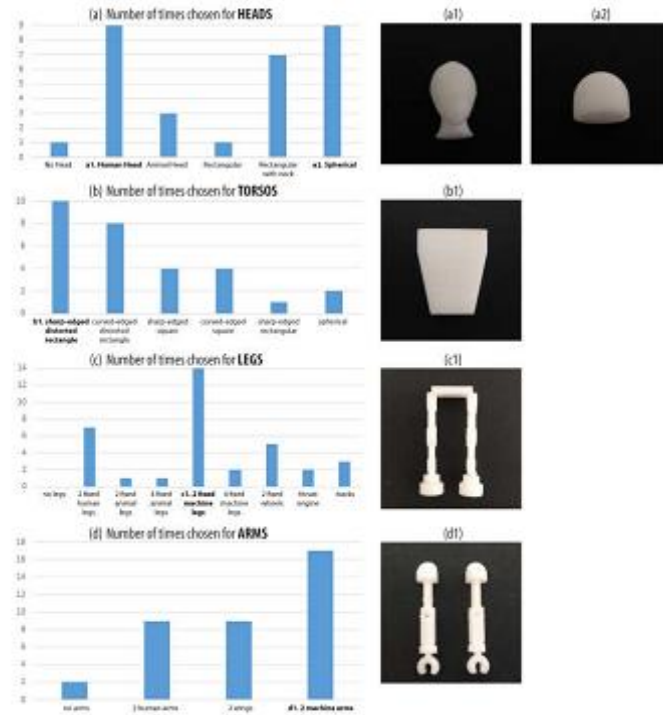


Fig. 3. Head's (a); Torsos (b); Legs (c); Arms (d) chosen by the children.

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 Figure 3(c). The difference between the categories was significant, $\chi^2(8, N = 31) = 39.31, p < .0001$. 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 Figure 3(d). The difference between the categories was significant, $\chi^2(3, N = 37) = 12.19, p < .01$.

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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 $\chi^2(3, N = 59) = 9.68, p < .05$.

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, $\chi^2(4, N = 31) = 14.32, p < .001$. 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.

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6 Discussion

The aim of the work presented here was to develop and evaluate a robot design toolkit, Robo2Box. 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 (Figure 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 the Robo2Box was the time spent on actually constructing the robot. In our previous study it took children around 20 minutes to draw a robot, the average construction time with the Robo2Box toolkit was 2:25 minutes 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

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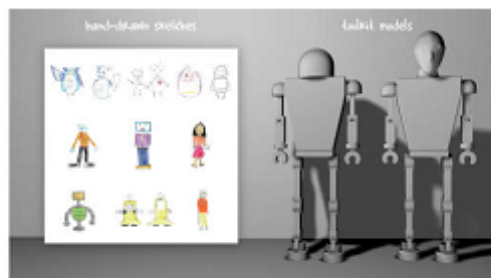


Fig. 4. Drawings (interaction designers = top row, children without robotics knowledge = middle row, children with robotics knowledge = bottom row) and our two Robo2Box prototypes.

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

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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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Storytelling Before or After Prototyping with a Toolkit for Designing Classroom Robots

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ABSTRACT

Storytelling is an effective approach that is used in interaction design to help align users' needs throughout the design process. In this paper, we utilize a storytelling approach with hands-on design toolkit activities to investigate how the experimental order effect can have an impact on the overall outcomes. In particular, we focus on a robotic design toolkit that aims to involve children in the process of designing assistant classroom robotic artifacts. We report the findings of a study conducted with 28 children that designed their own classroom robotic assistance using the toolkit before and after storytelling. We conclude the paper with discussion on the order effect and design findings. This paper aims to contribute to the literature with insights on how to implement storytelling along with a prototyping toolkit; approaches that are highly valued in interaction design research and practice recently.

CCS CONCEPTS

• Human-centered computing → Interaction design process and methods.

KEYWORDS

design process, storytelling, toolkit, classroom robots, children, order switch

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1 INTRODUCTION

Contributions coming from the users in the design process of a new technology is important for the design to suit the user needs, and the children are one of those user groups to be included in this process.

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However, it is challenging for the researchers to include children in the design process because they may lack the knowledge on the state-of-the-art technologies. One of the related technologies is classroom robots. As educational tools, robotic technologies started to enter classrooms since several studies showed that children's learning processes can benefit from these technologies [5, 10, 42]. There is also research focusing on children and how they envision robots in their educational environments [11]. As a type of robot they would be using actively, children's input for the design of classroom robots would be highly valuable. In this context, previous research presented a novel way to inform the design process of classroom robots using their a Robo2Box toolkit [37, 38]. The proposed Robo2Box toolkit was designed to be used with children to let them express themselves in an area they lack the state-of-the-art knowledge, while learning from them about what they want for a classroom robot. In their approaches, Obaid et al. [37] have used several complementary activities to the toolkit to allow for a further understanding of children's user needs in a classroom robot, this includes drawings with a story, clay, and interviews. We believe that storytelling is an activity that can largely complement such a toolkit in the process of acquiring children's needs in the design process. Thus, in this research, we investigate the use of a storytelling approach as a complementing activity to a design toolkit, particularly, making use of the Robo2Box toolkit [37, 38] and combining it with a storytelling approach to elicit children's requirements.

A main question here is the order of executing the combined activities, i.e. using a toolkit and storytelling, and its impact on the design outcomes. For example children can first be engaged in telling stories about their classroom robot/s and then build their robot using the toolkit based on the stories they've created; or they can first build up a body of the robot with the toolkit and later place their robot's body in a story and define roles and tasks. The order here can play a crucial role in revealing children's needs and, to the best of our knowledge, there are no such study the investigate this relationship in the context of a design toolkit and a storytelling approach. Therefore with this study, we are exploring the effects, and sharing what we learned by switching the order of the phases. We will mainly focus on the findings related to form factor, while briefly going through the effects on the behavioral elements of the resulting robots, namely roles and tasks assigned to the robots. We do not have enough space in this paper to share all behaviour related results, which will be the focus of another paper in the future.

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This study aims to contribute to the HCI literature with the lessons learnt from the switching the order of storytelling and a prototyping toolkit in a classroom robot design process with children. We are looking for the answers of the following research questions; (1) What kinds of robots do children design for their classrooms when the order of the phases are switched? (2) Does switching the order of the phases (robot construction with toolkit and storytelling) make a difference in children's thoughts on robots to be used in their classrooms? (3) How does storytelling together with prototyping impact children's thinking about robots to be used in their classrooms? Here in this paper, with the above listed questions in the mind, we share the lessons learnt from a study conducted with 28 children.

2 BACKGROUND

Here in this section, we bring together an overview of HCI literature in robots in educational settings, user-centric robot design studies involving children, prototyping toolkits for robot and robotic design, and finally studies making use of storytelling along with prototyping involving children.

2.1 Robots in Educational Settings

As robots are increasingly getting more involved in our daily lives, they are also taking more place in educational settings since several research showed the learning benefits of using robots in education [8, 10, 22]. Main topic of related research is mostly teaching STEM (science, technology, engineering, mathematics) subjects, especially the integration of robotics in curricula [5, 42]. Other example uses of robots and robotics within educational curricula include art [6, 44], creativity [1], and language skills [19, 23, 45]. There are also robots placed physically in the classrooms for specific functions, such as to help the teacher to silence the class [30], or the students to separate the waste [31], or the students with medical conditions so that they can attend lectures virtually via telepresence [35]. While some of these robots for educational settings are developed from off the shelf robots like Nao [40] or Pepper [41], there are robots that are developed by the research teams as well [34].

The aforementioned research examples generally involve children in the tester role [14], and study how children behave with the robot and while using it. One of the goals in our research project is to explore what kind of a robot the children would like to have in their classrooms by letting them contribute to the design process, since they will be one of the main users of the robot. In order to achieve this goal, the children should have the role of either informant or design partner [14] in the design process.

2.2 Involving Children in the Design Process of Robots

Today, the benefits of including the user in the design process has been well acknowledged by the researchers in Human-Computer Interaction (HCI) field. As more research has been carried with user-centric approaches, more and better methods to get user contributions are established. However, including children in the design process still remains challenging. In their pioneering research, Druin [14] and Scaife [46] address the problems and raise some

questions about the children's contributions in HCI through case studies on designing new technologies with children.

When it comes to defining robotic features with and for children, only a little research has focused on it. One of the early examples about eliciting children's design requirements for robots was presented by Bumby and Dautenhahn [11], in which they explored children's expectations about robots from their stories and drawings of them, and their interactions with the robots. Woods et al. [56, 57] examined children's opinions on robot appearance, gender, locomotion and personality by making use of questionnaires that were to be completed according to robot pictures chosen by the participants. Sciutti et al. [47] studied the children's preferences of the features of a robot that they would play with, by asking them to rank some features according to their importance, both before and after interacting with a robot. Benítez Sandoval and Penaloza [9] explored children's knowledge, expectations, and perceptions on robots with the surveys that were completed either before or after interacting with a robot, and free robot drawings of the children. Finally, recently Obaid et al. [37, 38] made use of a robotic design toolkit with 3D printed parts for children to share their thoughts about classroom robots.

While all of the above mentioned examples mainly focused on discovering and revealing children's existing perceptions of robots, based on their knowledge and expectations with the use of mixed methods, some of the more recent research are oriented around designing the robots for children with children. YOLO is one of the resulting robots on the case, which has been developed to boost the creativity in children, after a series of design activities done with the children [3].

2.3 Prototyping with a Toolkit for Designing Robots

Doing research or designing robots is a challenging subject, requiring a combination of knowledge coming from several fields such as programming, engineering, design, and psychology. One of the main challenges throughout the design and development process in this multi-discipline domain, is learning user needs to feed the design related decisions. Most times, social robots are developed to interact with many different types of users (such as children, older adults, blind people) and not many of these user types have earlier experience with robots in their everyday lives. Researchers [4, 27, 38, 39] have been exploring methods to collect insights to involve users in the process of designing robots.

One approach to involve users in the early stages of designing robots is prototyping toolkits that are being developed and presented for the use of researchers, developers, and designers in the field of social robots. There are various types of toolkits to fit the needs: [21, 26, 48, 51] presents framework based robotic toolkits in their research that aim to satisfy programming needs of developers. Toolkits with hardware and software support are introduced in [15] and [24], which are both aimed on easing the process of development and production for the users, rather than eliciting their design requirements on the subject.

There are also several robotic toolkits that are aimed specifically for children, especially because incorporating robotics within the

curricula as a part of education is a trending topic in both educational and robotics literature. Studies show that making use of robotics as an educational activity has major benefits on students' skills and educational development, both on STEM and creativity related subjects [2, 5, 10, 22]. There are both research oriented and commercial toolkits, and many of them focus on teaching children the fundamentals of mechatronics and programming through play. Lego Mindstorms is one of the commercial pioneers in the field, that enables children to construct their robots by using Lego blocks and program them with an interface [28]. Robots Dash and Cue, and the creativity kit Dot are aimed to help improving problem-solving skills of the children of all ages in a more creative way [58]. On the more research-led side, SoRo Toolkit focuses on teaching preschoolers computational thinking and programming by employing reusable vinyl stickers to "teach" a robot [18]. KIWI toolkit, with hardware and its software called CHERP, which has been utilized in many studies for further development, aims to bring technology and engineering education into the curricula of ages 4–7 [52]. ModBot toolkit system is specialized on teaching children essentials of underwater robots, along with the features of water environment [29].

Some other prototyping toolkits for children to design robots are also present without the goal of educational development of the children. Robo2Box toolkit is one, which has been developed to be used for a design aid to elicit children's requirements for classroom robots [38]. The toolkit parts were designed with the data coming from children with and without robotics knowledge, interaction designers [36] and literature [56].

2.4 Storytelling and Prototyping Together as Design Activities

The power of storytelling has been known in daily life and culture, since it is a very effective tool to introduce matters on values, social roles and skills, and emotions to children [17]. When children are the authors in the storytelling activity, children can benefit from it by developing their skills on creativity, communication and memory [59]. Both as consumers and producers, children advance with storytelling, and that creates a growing body of research in the HCI field for interactive storytelling.

Most of the research on interactive storytelling covers for the development of creative storytelling practices for children, such as inclusion of augmented reality [16], soundscape [20], gesture recognition technology [25], tangible interfaces [53], immersive environments [12, 33], and collaborative use with parents [13, 55]. These research mention prototype as their design product on storytelling, as the outcome of their studies. Another approach for storytelling in the HCI research is using it as a design activity within the design processes with children [7] and [54] introduces their research to children within a storytelling context. Moreover, the presented by Rubegni et al. [43] and Speek et al. [50] are toolkits developed to use storytelling as a design activity in co-design processes with children. Yet, to the best of our knowledge, there are no research investigations that address the impact of the order on combining a storytelling approach and prototyping with a toolkit as a design activity for children.

3 METHODOLOGY

We follow a user-centric approach in this study, to learn about what kind of robots children imagine in their classrooms by using prototyping with a toolkit and storytelling. As mentioned above, we wanted to see if and how the order of applying these two design activities would change the thinking pattern of children. Below, we summarize how we conducted the study.

3.1 Procedure, Recruitment and Setting

The study was conducted with a total of 28 school children from Istanbul, Turkey, and they were recruited with the help from a local NGO, TOÇEV, that worked with children. Their parents were informed during the recruitment process and their consents were taken verbally. The participating children were randomly assigned to two groups: the first group (control group) completed the study in prototyping - storytelling order (P->S) and had 14 children (9–13 years old, average age of 11 (SD=1.44), 7 boys and 7 girls). The second group (switch group) completed the study in storytelling - prototyping order (S->P) and had 14 children (9–13 years old, average age of 11 (SD=1.67), 6 boys and 8 girls). The study was conducted by one facilitator, and each session was voice recorded after getting a verbal consent from the participating child. The study took place in a school classroom. Every study session started with a little introductory phase where the facilitator first introduced themselves, explained the study and got the child's written consent, and then asked the child about robots: what they knew, from where they learned these, and whether they took classes on robots/robotics. Each study session then continued with either prototyping or storytelling phase, depending on which group the child was in.

3.2 Toolkit Preparation

In order to evaluate the effect of applying storytelling before or after prototyping, we derived from an existing prototyping toolkit, namely Robo2Box, developed by Obaid et al. [38]. We made some changes to the original toolkit to suit our needs, and some of them were already suggested by the authors. Hence, an amended version of the toolkit was developed, which we refer to as Robo2Box throughout the paper.

The amendments we made to the toolkit are listed below:

- A fully-spherical head, one big separate wheel and a cylindrical torso were added based on the results of their study [38].
- The thrust engine was taken out of the toolkit based on the results of their study [38].
- The wings that were modeled and presented separately in the original toolkit were combined as one so that it would be easier for children to manipulate.
- All parts in the original toolkit were scaled up ten times so that it would be easier for children to manipulate.
- Velcro was chosen as the bonding method for the parts of the toolkit, instead of double-sided tape, and it was glued on the parts so that it would be easier for children to manipulate.

The list of the parts for the content of the toolkit, with the indication of the parts' visual likeness, is presented in Figure 1.

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Category	Part name	Machine-like	Animal-like	Human-like
Head	1 Human head		x	x
	2 Animal head		x	
	3 Rectangular		x	
	4 Rectangular with neck		x	
	5 Spherical		x	
	6 Fully spherical		x	
Torso	1 Sharp-edged distorted rect.		x	
	2 Curved-edged distorted rect.		x	
	3 Sharp-edged square		x	
	4 Curved-edged square		x	
	5 Sharp-edged rect.		x	
	6 Spherical		x	
	7 Cylindrical		x	
Legs	1 2 fixed human legs			
	2 2 fixed animal legs		x	
	3 4 fixed animal legs		x	
	4 2 fixed machine legs		x	
	5 4 fixed machine legs		x	
	6 2 fixed wheels		x	
	7 Tracks		x	
	8 One wheel		x	
Arms	1 2 human arms			
	2 Wings			x
	3 2 machine arms			x
Material	1 Plastic			
	2 Metal			
	3 Fur			
	4 Rubber			

Figure 1: The content list of the parts in the toolkit.

3.3 Prototyping Phase

In the prototyping phase (P), each child was asked to construct one robot which they would use in the classroom setting by using RoboZBox. The child was informed about the groups of toolkit parts: head, torso, legs and arms, and how the parts could be combined using Velcro, and then asked to construct their robot freely. Once the child finished, they were asked to choose material(s) for their robot from the set of specimens (metal, plastic, fur, eva) included in the toolkit.

3.4 Storytelling Phase

In the storytelling phase (S), each child was asked to tell a story of the robot that they would use in the classroom setting, to learn about the tasks and the roles of their robot in the classroom, provided with the option of drawing the robot and/or the story if they preferred to. This phase was concluded with a small interview that the child was asked some preset questions about their robot verbally, and the goal of the interview was to understand the robot's physical and behavioral features and its attributes in the classroom better, such as emotions, face, dialogue, homework and punishment. Yet, these behavioral features will be the focus of another paper. The whole study took place in a real classroom, so the children were asked to comment on the size and the placement of their robot either by showing in the classroom, or verbally.

3.5 Analysis

In this paper, we only focus on the findings about the forms of the constructed robots, their roles and tasks. The notes taken by the facilitator during the study, transcriptions of the voice records and the photos of the constructed robots were used for the analysis. The robots constructed by the children were coded based on the chosen parts as head, torso, legs, arms and material. To start, two coders annotated data from six children independently and an inter-coder

reliability was in an acceptable range ($\kappa > 0.70$), so one of the coders continued to analyze the rest of the data.

4 FINDINGS

In this section, we will present the findings of our study on the effect of switching the orders between prototyping and storytelling by designing classroom robots with children.

4.1 Control Group (Prototyping - Storytelling Order)

Here we present the findings on form related factors, roles and tasks of the classroom robots that are imagined by the children in the control group (prototyping + storytelling).

4.1.1 *Head*: Figure 3(a) shows the results of the chosen heads. The difference between the categories was significant ($\chi^2(5, N = 14) = 12.5, p < .05$). Human head was the most chosen head. The results show that the children mostly chose heads with curvier forms with the indication of children's preference to more human-like features.

4.1.2 Torso. Figure 3(b) shows the results of the chosen torsos. The difference between the seven categories was not significant



Figure 2: The toolkit and the study setting.

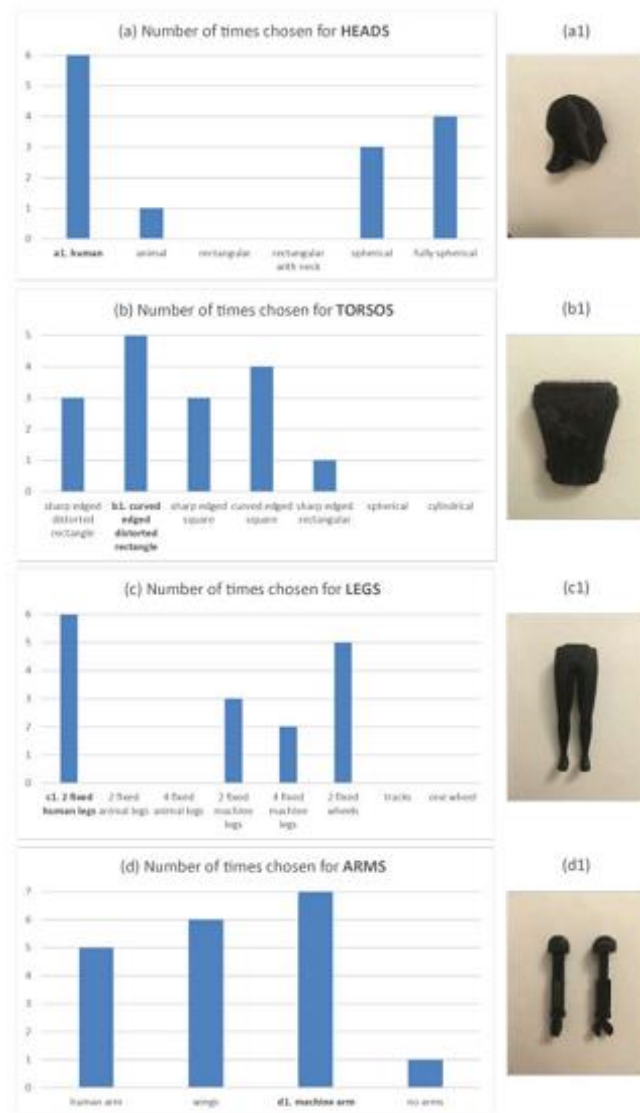


Figure 3: Heads (a); Torsos (b); Legs (c); Arms (d) chosen by the children from the control group (P→S).

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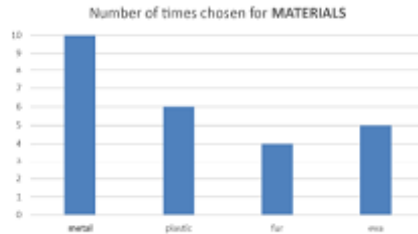


Figure 4: Materials chosen by the children from the control group (P→S).

($\chi^2(6, N = 14) = 10.25, p > .05$). One child used three torsos on their robot but was not excluded from the results, since there were not any limitations on the number of parts to be used. The most chosen torso is one of the human-like torsos with small waist, wide shoulders and a curvy form, and the accumulated number of times the torsos with more organic shape chosen is slightly higher than sharp-edged ones, which shows the preference of children towards more human-like features for their robots.

4.1.3 Legs. Figure 3(c) shows the results of the chosen legs. The difference between the eight categories was significant ($\chi^2(7, N = 14) = 18.7, p < .01$). Two children used two different leg parts for their robots, but they were not excluded from the results. Human legs were the most chosen leg part, which indicates the tendency towards human-likeness for the envisioned robots. However, the children chose 2-fixed wheels as the second most, because "the robots couldn't walk with legs" as stated by one child.

4.1.4 Arms. Figure 3(d) shows the results of the arms chosen. The difference between the categories was not significant ($\chi^2(3, N = 14) = 4.4, p > .05$). One child used torsos as arms and was excluded from the results. The children were not required to choose only one part, so there were several children who chose two types of arms. The most chosen were machine arms, followed by the wings. Only two out of six children who also chose wings for their robots stated that their robots could fly.

4.1.5 Material. Figure 4 shows the results of the chosen materials. The children were not required to choose only one material, so multiple materials were chosen for several robots. The difference between the categories was not significant ($\chi^2(3, N = 14) = 3.3, p > .05$). The accumulated results show that children preferred their robots to be metal because of the hardness and durability of the material, and children's perception of robots: "robots are [made out of] metal."

4.1.6 Roles and Tasks Assigned. Roles and tasks assigned to the classroom robots were extracted from the stories told by children. The task for handling, carrying or bringing things, like pens, books, erasers, chalks and assignment papers, to the teacher or the students was assigned to the robots by almost every child in the control

group (P→S). Most of the robots were expected to help in lecturing, as explaining and revising the lecture, checking the homework, asking and answering questions, repeating the missed parts for better note-taking, and silencing the class. Many of the children stated that their robots would help lecturing related tasks either when the teacher was in the class, or they were absent due to health or personal reasons, but almost none of them replaced the teachers with robots completely. Some of the children wanted their robot to help cleaning and tidying their class and school, and some of them wanted to have fun with the robots, by playing games with them or wanting them to lecture in a more entertaining way, like by singing. The tasks assigned to the robots indicate that the control group (P→S) mostly gave the roles of a teaching assistant and service oriented tool to their robots, along with the indication of them being companions.

4.2 Switch Group (Storytelling - Prototyping Order)

Figure 5 presents the results of the form related factors of a classroom robot that are imagined by the children in the switch group (storytelling - prototyping order).

4.2.1 Head. Figure 5(a) shows the results of the chosen heads. Three children used torsos for head and were excluded from the results. The difference between the categories was significant ($\chi^2(5, N = 14) = 13.5, p < .05$). Human head was the most chosen head, followed by the rectangular head with a neck.

4.2.2 Torso. Figure 5(b) shows the results of the chosen torsos. The difference between the seven categories was not significant ($\chi^2(6, N = 14) = 10, p > .05$). The sharp-edged torso with small waistline and wide shoulders was the most chosen by the children, which had a more human-like form. However, the accumulated results show that torsos with sharp edges were chosen more, which had more machine-like forms.

4.2.3 Legs. Figure 5(c) shows the results of the chosen legs. Two children used two different leg parts for their robots, but they were not excluded from the results. The difference between the categories was not significant ($\chi^2(8, N = 14) = 11, p > .05$). Human legs were the most chosen legs, however the chosen legs were various with more machine-like functions and forms.

4.2.4 Arms. Figure 5(d) shows the results of the chosen arms. The children were not required to choose only one part, so there were several children who chose two different types of arms. The difference between the categories was not significant ($\chi^2(2, N = 14) = 2, p > .05$). Machine arms were the most chosen arms. Only one child out of four children who chose the wings stated that their robot could fly.

4.2.5 Material. Figure 6 shows the results of the chosen materials. The children were not required to choose only one material, so multiple materials were chosen for several robots. The difference between the categories was not significant ($\chi^2(3, N = 14) = 6, p > .05$). Accumulation of the overall preferences of the children shows that metal was the most chosen material. Children's perception about robots, and the material's characteristics (hardness and durability) played a great role on children's preference, as one child

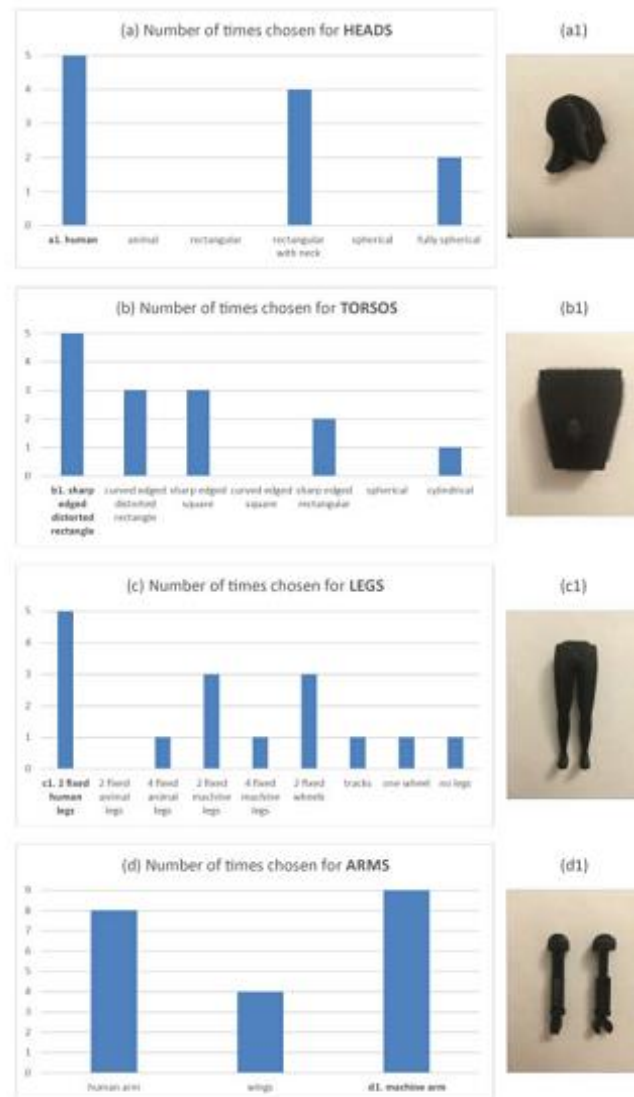


Figure 5: Heads (a); Torsos (b); Legs (c); Arms (d) chosen by the children from the switch group (S→P).

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Figure 6: Materials chosen by the children from the switch group (S->P).

stated: "My robot is metal because [robots] are hard, so [they are] metal."

4.2.6 Roles and Tasks Assigned. In the switch group (S->P), similar tasks were assigned to the robots. Most of the children expected their robots to carry and deliver things to the teacher and students, and help the teacher while lecturing in class directly and indirectly without diminishing their overall existence in education. The robots of the switch group (S->P) also helped students during and after the lectures for revising. Especially because of the robots' tasks on helping in lectures, they were claimed to be observing the class all times to spot the children in need and the situations that needed to be taken care of. For the switch group (S->P), the robots are claimed to be teaching assistants and (serving?) tools as well, however, assistance role is more observed than the tool role, differently from the control group's (P->S) results.

4.3 Comparison of the Results

This section presents the comparison between control (P->S) and switch groups (S->P), within the categories of heads, torsos, legs, arms, materials, and roles and tasks, respectively. Figure 7 shows the numeric data for the comparison on the above mentioned categories, excluding roles and tasks.

4.3.1 Heads. The most chosen head for both groups is human head, however control group (P->S) in overall follows the trend of choosing more organic shaped heads, whereas switch group (S->P) doesn't follow such a trend by having preferred a sharp-edged head.

4.3.2 Torsos. Control group (P->S) had the tendency to choose more organic shaped torsos as in the head category, while switch group (S->P) preferred the torsos with sharp-edges more.

4.3.3 Legs. Both groups' most chosen legs are human legs, however when overall results are compared between two groups, it can be observed that the chosen leg parts in switch group (S->P) are more diverse than control group (P->S).

4.3.4 Arms. For both groups, machine arms are the most preferred arms. The comparison on chosen arms shows that the control group (P->S) used wings more than the switch group (S->P). Yet, most

of these children in both groups didn't mention the acquisition of flying skill in their robots.

4.3.5 Materials. The children in both groups mainly chose metal as their robots' material, because "the robots are [supposed to be] metal" according to the children. The preference for plastic in control group (P->S) is higher than switch group (S->P), which might be due to first seeing the parts that were made out of plastic.

4.3.6 Roles and Tasks Assigned. On tasks and roles assigned to the classroom robots, both groups have very similar trends: using robots as agents for moving class-related things around, like stationery supplies, and expecting them to work as teaching assistants. Yet, the control group (P->S) had a more balanced vision on the robots' roles of assistants and tools, with the addition of companionship. Whereas the switch group (S->P) put their robots more on the assistant role, by making them another control mechanism and authority in class without completely replacing the teacher.

5 DISCUSSION

In this section, we will discuss the results further to elaborate and reflect on the overall research questions of this work.

First, we address the research question on "What kinds of robots do children design for their classrooms when the order of the phases are switched?" The overall look of the robots constructed by the both groups is very much similar when the most chosen parts are taken into account. The general robotic prototypes for both groups choose a human head shape, 2-fixed human legs, and machine arms. The only difference is the torso shapes, where in the control group (P->S) preferred the curved-edged distorted rectangle torso, whereas the switch group (S->P) preferred the sharp-edged distorted rectangle torso. For the choice of material, both groups chose metal the most because of the hardness and durability of metal, stating that "robots are [supposed to be] metal." The complete looks of the robots indicate the desire for a human-machine-like robot on the appearance for both groups. Figure 8 shows the 3D models of the robots of both groups, based on the most chosen parts.

As for the roles and tasks of the robots, both groups expected their robots to assist in the lecturing process, such as being a replacement teacher, or helping the students for the subjects they didn't understand, without replacing the teacher with the robot. They also assigned tasks that positioned the robots as service oriented tools accomplishing tasks such as carrying and handing in the stationary supplies and assignments.

Secondly, we focus on discussing the research question on "Does switching the order of the phases (robot construction with toolkit and storytelling) make a difference in children's thoughts on robots to be used in their classrooms?" The complete look of the robots indicate the desire for a human-machine-like robot on the appearance for both groups, but the general robot of the control group (P->S) is slightly more human-like than the general robot of the switch group (S->P), due to the change of torso type. When the preferences of the children are examined in more detail, we observed this difference more between two groups, by examining the selection of heads and torsos. The comparison on the head and torso choices between two groups presents a trend towards organic forms for the control group (P->S), and forms with sharp lines for

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Control Group	6	1	0	0	3	4	0	2	4	2	4	1	0	0	6	0	0	3	2	5	0	0	0	5	6	7	1	1	10	6	4	5
Switch Group	5	0	0	4	0	2	3	5	3	3	0	2	0	1	5	0	1	3	1	3	1	1	1	8	4	9	0	0	10	3	3	6
Part name	Human head	Animal head	Rectangular	Rectangular with neck	Spherical	Fully spherical	Excluded	Sharp-edged distorted rect.	Curved-edged distorted rect.	Sharp-edged square	Curved-edged square	Sharp-edged rect.	Spherical	Cylindrical	2 fixed human legs	2 fixed animal legs	4 fixed animal legs	2 fixed machine legs	4 fixed machine legs	2 fixed wheels	Tracks	One wheel	No legs	2 human arms	Wings	2 machine arms	No arms	Excluded	Plastic	Metal	Fur	Rubber
Category	1	2	3	4	5	6		1	2	3	4	5	6	7	1	2	3	4	5	6	7	8		1	2	3		1	2	3	4	
	Head							Torso							Legs								Arms				Material					

Figure 7: The table for showing the number of times chosen results on heads, torsos, legs, arms and materials comparatively.

the switch group (S→P). This can be elaborated as more human-like preference in control group (P→S), and more machine-like preference in switch group (S→P). We believe that having the storytelling phase before building prototypes affected how they approached the robot designing process. The general stereotypes on robots set the ground for the switch group (S→P), which resulted with more machine-like forms while on the other side the toolkit parts were the starting point for the control group (P→S), and the presence of organic forms within the parts showed children the possibility of having more human-like robots. One could think that children's imaginations of robots would be effected from what they watch on the media. For example they might be inspired by sci-fi content when using machine-like forms, however, we observed that starting with the toolkit and seeing a whole list of other options might help them with lateral thinking and leading to building options such as a more organic form.

The difference between two groups on human vs. machine likeness can be also observed on the roles and tasks of the robots. We think that by starting with a more human-like robot form in hand,

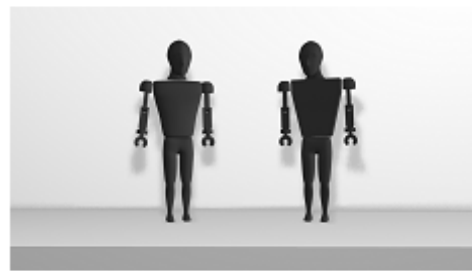


Figure 8: 3D images of the robots constructed by the control group (left) and switch group (right).

control group (P→S) imagined these robots in a more serving role and as being more like companions to the children, compared to the switch group (S→P). However, the idea of a stereotypical robot in mind caused the switch group (S→P) to create more controlling robots, as another authority in classroom, by making the robots observe the children more, and assigning them less service oriented tasks.

Even though the children in both groups chose metal as material the most, the control group (P→S) chose plastic as a material to be used for their robots more than the switch group (S→P). Since the control group (P→S) completed the prototyping phase before storytelling in their study, and constructed their robots with the toolkit parts that were made out of plastic, they might have been affected by the material of the toolkit itself when assigning material(s) to their robots.

Finally, we will discuss the question of how storytelling together with prototyping impact children's thinking about robots to be used in their classrooms.

More diverse choices on leg parts was noticed in the switch group (S→P). We observed that the children in this group wanted their robots to look like what they had in mind, since they thought of the appearance of their robots before using the toolkit. Having a more diverse selection of chosen leg parts might be an indication of either the search for a more machine-like desire on the appearance of the robots, in accordance with their preferences on head, torso and roles and tasks, or more flexible thinking, because the toolkit pieces didn't limit their imagination. There are controversial research results on the topic, whether seeing examples affects the creativity or not [32, 49], so we cannot have a definite idea on that.

Since the switch group (S→P) imagined their robots before using the toolkit, they tried to construct their robots as similar as how they imagined them with the available parts. That's why there are more examples of using parts in the ways or places they were not expected. Two children used torsos as heads, even though there were heads resembling these torsos very much in the toolkit but smaller than the torsos, indicating that these children prioritized

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the head size of their robots. One child used machine arms reverse, making the shoulder side hands, because they wanted their robot's hands to be clenched when idle, but have human fingers when the robot used their hands. One child used 2-fixed machine legs to indicate their robot had eyes that could get in the shape of binoculars when needed. Lastly, one child used extra torso and arm because of their shapes on their robot's torso to be able to show the parts imagined to be coming out of the robot's body. This is sign of how the toolkit can trigger lateral thinking.

Two children in the control group (P→S) constructed more unconventional robots than the others, by using extra parts to indicate functional features. One child put the rectangular head to their robot's torso as the tablet on the body. Another child created a robot using multiple torsos bonded to one another, stating that the torsos were functioned as compartments for the cleaning task of the robot. This shows that the children might possibly use toolkit parts not just as how they were labeled, like body parts in our toolkit, but as functional elements. This is an indication of the importance of both/either designing a prototyping toolkit in a more flexible fashion to let children express themselves better in the design processes with children, and/or the use of storytelling with prototyping together in a design process with children to be able to understand their needs and wishes better.

Lastly, we observed that the toolkit was perceived as a toy and the whole activity as a game by some children, which made the design activity more playful for them, as we aimed to do so by scaling up the size of the toolkit parts and letting them having more hands on control over the robots they build. Some children in the switch group (S→P), who were being shy, non-talkative, and mostly refused to answer, became more active when they saw and interacted with the toolkit. Also, some children from both groups not only constructed robots by using the toolkit, but played with the robots they made as well during the sessions.

6 CONCLUSION

Using a storytelling approach and a design toolkit, we have presented a study that investigates the order effect on the design of classroom robots via a child-centered approach. Twenty eight children participated in our study and from the results we concluded that complementing the robotic design toolkit with a storytelling approach is to some extent impacted by the order the activities are presented; thus, having an impact on how children imagine their robotic form. While we observed that both methods are engaging and effective in fostering the thinking process of children, playing with the order makes changes in their ways of thinking. But we do not say that one is more effective than the other.

One limitation of this study is that due to space limitation we did not largely analyse the stories presented, which may include a rich amount of data on how the toolkit is impacting the stories of children. Future work can be directed at analysing the stories presented by children to see how the toolkit impacts the stories.

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