Children at the centre: designing technology for literacy with and for children

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I certify that except where due acknowledgement has been given, the work presented in this thesis is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; and the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program.

Sveva Valguarnera
Lugano, 13 June 2024

*To each and every child who lent me their experience,
creativity and imagination during this journey*

Every child is an artist

Pablo Picasso

Abstract

As children are exposed to technology at increasingly younger ages, the issue of their involvement in the design of innovations meant for them is at the forefront of the field of Child-Computer Interaction. This doctoral thesis explores the extent of children's involvement in the design of technology, exposing gaps in the literature and proposing guidelines to widen children's participation, empower them and improve their agency, as well as delving into the practical application of participatory design with preschoolers for the design of a storytelling tools. This dissertation is structured into three main parts: (1) Children in a world shaped by technology, which represents the theoretical foundation of this thesis, and discusses children's perception and expectations of technology, and the extent of their involvement in design. (2) Co-Designing a storytelling tool for emergent readers, which described the collaborative design process of a storytelling tool for children, offering both methodological and practical insights into the topic of collaborative design. (3) Discussion and Conclusions, in which research questions are addressed, and limitations, challenges and possible future avenues of research are discussed. In this work, children are placed at the centre of the design process: while the opinion and points of view of other stakeholders, such as parents and teachers, are considered to elicit user requirements, children's needs, wishes and preferences are at the forefront. This doctoral dissertation contributes to the field of Child-Computer interaction by providing theoretical and methodological insights, as well as practical applications for the co-design of technology for emergent readers.

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Thank you all for being a part of this significant milestone in my life.

Contents

Figures

Tables

Glossary

PD Participatory Design

UN United Nations

CCI Child-Computer Interaction

IDC Interaction Design & Children

R&D Research & Design

WIP Work in Progress

ASD Autism Spectrum Disorder

ADHD Attention Deficit Hyperactivity Disorder

Chapter 1

Introduction

This doctoral research was undertaken to understand how to involve young children in the design of technology to support them in learning pre-reading skills. While originally focused on children's learning in a school context, its scope has evolved to include parent-child shared reading experiences, and children's interaction with storytelling tools alone or with peers. To this end, all relevant stakeholders were included - parents, teachers, experts - and especially children, who were involved in all stages of design following a participatory design approach, and whose involvement in research has also been researched on a theoretical level. This introductory chapter presents the background and motivation behind my research, starting from the definition of "child", and outlining my research questions and goals. In this chapter I will also provide an overview of the structure of this dissertation, and of my publications.

1.1 Background and motivation

Defining what a child is is not univocal and unambiguous by any means; while many dictionaries describe a child as an human being between birth and puberty, according to the UN Convention on the Rights of a Child [1], "*a child means every human being below the age of eighteen years unless under the law applicable to the child, majority is attained earlier.*". While this is, by nature, an arbitrary cut-off, this definition has also been the one commonly accepted by the Child-Computer Interaction community [255]. During their first years of life, ~~however,~~ children develop very rapidly, with different ages having different needs, characteristics and stages of development which needs to be taken into consideration by researchers.

Unlike designing for adults, who often focus on goals, designing for children means meeting needs, expectations and desires [16]. While children are not the only stakeholders when it comes to technology use - as parents, teachers and caregivers are the one who, ultimately, choose to give them access to it - they can and should have a significant role in creating it, designing it and shaping it to their wishes and preferences.

This has not always been the case: as technology became commonplace both at school and at home, children began to use it, but initially they were not involved in its design. Whenever a new product was developed, it was the parents and teachers who were asked what the children might need, like or want [83]. This began to change at the turn of the century, when children were involved in the design process in various roles, e.g. as users, testers, informants and design partners [83].

This also aligns with the principles expressed by the United Nations' Convention on the rights of the Child, according to which "*States Parties shall assure to the child who is capable of forming his or her own views the right to express those views freely in all matters affecting the child, the views of the child being given due weight in accordance with the age and maturity of the child*".

Since then, co-design with children has become commonplace. Many studies have not only advanced the state of the art - with new methods, reflections on ethical issues, experiences and theoretical contributions - but have also applied existing co-design techniques to investigate children's likes, dislikes and preferences in different areas.

In the late 1990s, when co-design with children was gaining popularity in research, it was believed that children aged 7 to 10 were the most effective design partners [83] as they could discuss their ideas verbally and were capable of abstract thinking while not having too many preconceived ideas about technology. However, times have changed a lot since then. Technology is becoming more widespread and children are starting to use it earlier and earlier: in 2010, a Dutch study reported that the majority of pre-school children (4 years old) were already able to start and play a game on a computer on their own or with the help of an adult [207], while a 2014 Turkish study reported that although pre-school children did not own smartphones, they regularly used their parents' devices, with some children using them to play games for up to 3-4 hours a day [110]. In 2020, the situation had changed drastically: according to an English study, 35% of children aged 3 to 5 already owned their own device (smartphone or tablet) and used it for an average of almost 2 hours a day [250].

On the other hand, the COVID-19 pandemic showed the other side of the coin: the worldwide school closures prompted educators to take measures to avoid disruption in children's education by using technological platforms and internet-based tools to enable students to learn remotely. However, not all children had the same opportunities to access remote learning platforms and tools. There was a significant digital divide not only in majority world countries such as Nigeria, Brazil, Pakistan, Kenya, South Africa and Turkey [21, 182], but also in developed countries such as the UK and the US [62, 187].

Just as children's use of technology has changed over time, co-design has had to change and evolve to keep up with the times. Research now includes not only children of all ages, but also children with different special needs and from different socio-economic backgrounds.

While building on participatory design as a technique and as a philosophy, my research focuses more specifically on the design of technology to support the acquisition of literacy skills in emergent readers. Learning to read is one of the most important milestones in young children's lives, as it influences their learning outcomes in later life, with different pre-reading skills such as naming speed and phonological awareness being predictors of reading development in later years ([88, 170]).

Children's learning happens both in formal (school) and informal context (home and library, among others); while the formal context is important and necessary, it is not enough for children to successfully learn how to read - especially as preschool education is not compulsory in many parts of the world.

Shared child-parent reading is an important bonding activity, and part of a complex set of intimate practices at home. In this regard, [336] report three points of tensions that can be used as opportunities for design: parents' busy schedules that cause them to have little time to organise and perform shared reading activities, the different level of engagement between parents and children, with the former preferring more complex and layered stories, and the negotiation regarding book choices.

In my research, I build on the first of these three themes, while also considering the importance of dialogic reading ([354]) - a form of interactive reading in which children answer questions and reflect on the reading, that has shown to be effective in developing pre-reading skills ([162, 221, 357]) but that many parents do not know or cannot perform effectively.

As I started my doctoral studies just a few months before the COVID-19 pandemic, my perspective has been shaped by the way lockdown impacted not only my research, but the lives of the children with whom I would be working. School closures, while providing an unique opportunity to study how technology can impact learning, significantly increased teachers' workload and made it harder for them to find time to participate in the research project with their students, as had been the original goal.

This was a significant factor in the evolution from designing for group reading experiences in school to designing for a more intimate setting, in which the child interacts with technology on their own or with an adult caregiver.

1.2 Proposed Research

My research explores the design space of technology to support the acquisition of pre-reading skills by preschool children, while also researching the relationship between children and technology on a broader level.

In this dissertation, I begin to focus on children's involvement in the design of technology on a methodological and theoretical level: First, starting from the analysis of a dataset of children's drawings, in which they share their ideas for future technology to solve real-world problems, I analyse their perception and expectations of technology, and how they change as children grow. Then, I discuss the role of the CCI community, focusing specifically on the IDC conference, in empowering children and helping them inspire future research, Finally, I review the extent of published research that involves children in the design process. This constitutes the first part of this dissertation, "Children in a world shaped by technology".

At the core of my research then stands the practical application of the participatory design approach, which aims to involve children in each step of the design process, according to their stage of development and abilities; this approach was instrumental in the design, evaluation and successive iterations of ROBIN, an interactive storytelling prototype that represents the main artifact of my work, whose design process allowed me to delve into the topic of collaborative design with children, and enabled me to run a proof of concept with the direct involvement of children, to get answers to my research questions. This constitutes the second part of this dissertation, "Co-designing a storytelling tool for emergent readers".

The third part of this dissertation, "Discussion and conclusions", summarises the findings of the previous parts and addresses the research questions, discusses potential avenues for future work and offers reflections on the work described in this thesis.

Figure 1.1 shows an overview of the structure, content and main publications of this dissertation, as well as showing the chapters in which the main research questions are answered.

This dissertation contributes to the field of CCI by offering methodological and theoretical contributions, as well as design guidelines. Moreover, it presents

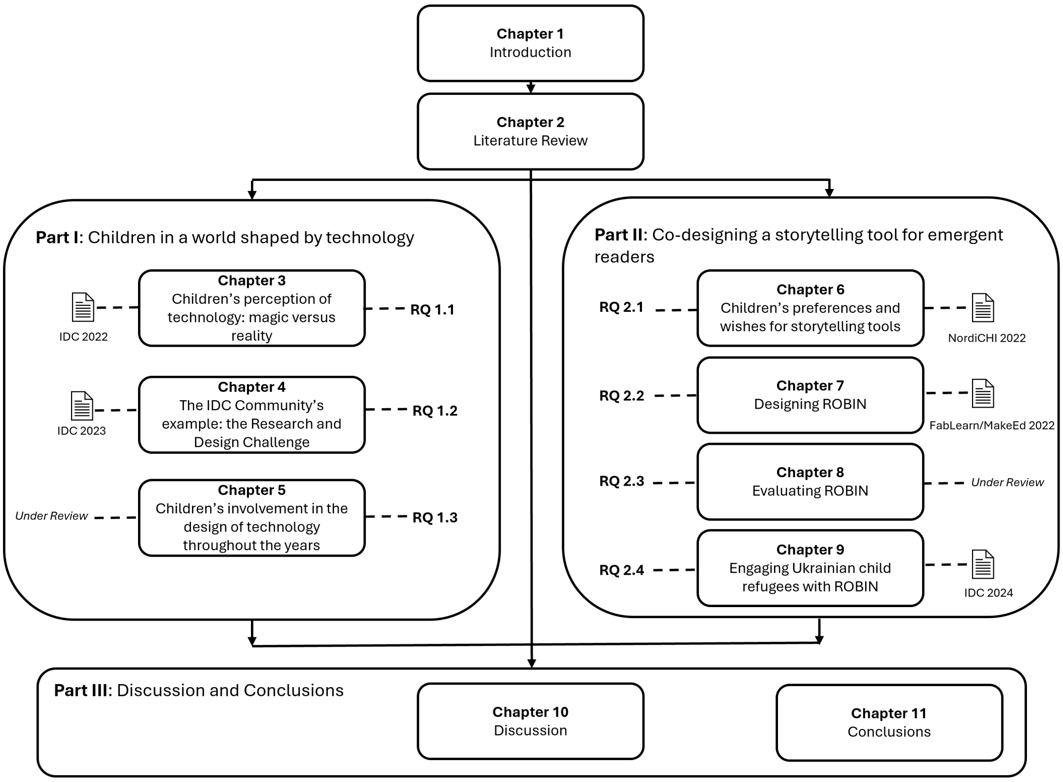

Figure 1.1. Diagram outlining the structure, content, main publications and answers to research questions of this dissertation.

a Wizard of Oz prototype as an artifact designed and evaluated with preschool children, using a participatory design approach.

In this work, I employ the first-person singular in the Introduction, Discussion and Conclusions sections, as they reflect my personal insight and reflections. In the remaining chapters, I employ the first-person plural to reflect the collaborative nature of my work, that would not have been possible without my colleagues, peers and mentors.

1.3 Research Questions

In this dissertation, I will address several research questions. The main research questions are:

- **RQ 1.** How can children contribute to shape the design of new technology?
- **RQ 2.** How can technology foster young children's literacy skills?

To effectively address these questions, I segmented them into smaller questions, which allowed me to delve deeper into the insight gathered from my research. Figure 1.1 shows how each chapter contributes to answer my research questions.

- **RQ 1.1** What are children's perception, understanding and expectations about technology, as expressed in their drawings?
- **RQ 1.2** How can the CCI community empower children to participate in research and inspire researchers through design challenges and other initiatives?
- **RQ 1.3** What is the extent of published research focused on collaborative design with children, in terms of methods, diversity and inclusion?
- **RQ 2.1** What kind of storytelling activities can engage emergent readers and meet their needs and wishes, and what design insight can we learn from that?
- **RQ 2.2** How can we co-design a storytelling toy for emergent readers, to use in an informal context at home?
- **RQ 2.3** What are the main design dimension of a storytelling toy for emergent readers?

- **RQ 2.4** How can a storytelling toy engage child refugees who are learning a new language?

To answer these research questions, I will use several methodologies, such as the analysis of children's drawings, interviews with adult stakeholders, a review of the literature, and several co-design and evaluation techniques with children, with the aim of designing and evaluating a Storytelling toy as a proof of concept.

1.4 Dissertation Outline

1.4.1 Chapter 1

In this chapter I introduce the background, motivation and context of the research presented in this dissertation; I discuss the definition of "child", and present an overview of the structure of this thesis. Then, I present the research questions, and list the publications produced during my PhD, some of which are still under review.

1.4.2 Chapter 2

In this chapter, I review the literature on several topics related to this dissertation: I start from an analysis of children's role as users and stakeholder of technology, which includes a discussion regarding the main theories on children's cognitive development, as well as an analysis on how drawings can be used to assess children's opinions and preferences and a discussion on magical thinking in children. From there, I delve into the topic of children's participation in design and innovation, focusing on participatory design with children and on the evaluation of technology with children; this aspect will however be furtherly discussed in Chapter 5. Finally, I explore the topic of designing for literacy, analysing the design space of shared reading, and discussing storytelling tools and interactive toys for children, both for language acquisition and for learning a second language.

The chapter ends by highlighting and discussing the gaps found in the literature regarding the topic of this dissertation.

1.4.3 Chapter 3

This chapter, along with Chapter 4 and Chapter 5, forms the theoretical part of this dissertation; here I analyse a dataset composed of 166 drawings by children from all over the world, resulting from the Research and Design Competition held at the IDC conference in 2022, and discuss how drawings can help researchers understand children's perception and expectations for technology, and how younger children tend to perceive technology as magical. Here I also discuss the design implications of such a perception. This chapter answers RQ 1.1.

1.4.4 Chapter 4

In this chapter I delve more specifically on the Research and Design Competition, already mentioned in the previous chapter: I discuss its history and compare it with similar competitions from all over the world, then analyse the complete dataset of all the 351 drawings submitted from 2016 to 2023. I then discuss children's participation in the challenge throughout the years, and highlight issues and limitation that emerge from the current dataset. Finally, I propose guidelines and best practices for the competition, to promote inclusion among children and help children's voice inspire researchers. This chapter answers RQ 1.2.

1.4.5 Chapter 5

In this chapter I review the literature on the topic of collaborative design with children. The aim of the review is to analyse the current state of research on co-design with children, both in terms of the inclusion of children and methods, techniques and practical applications, in order to identify gaps and identify opportunities for future research. This chapter answers RQ 1.3, and concludes the theoretical part of this dissertation.

1.4.6 Chapter 6

This chapter opens the practical component of this dissertation, which will continue in Chapters 7, 8 and 9. Here, I discuss a collaborative design study conducted with children aged 3-6 years old, aimed at understanding young children's preferences and wishes for storytelling tools. I discuss the setting and the activities, and analyse the data obtained during the study, comparing interactive vs. non-interactive toys, and traditional vs. digital storytelling. This chapter answers RQ 2.1.

1.4.7 Chapter 7

This chapter employs the insights obtained from the collaborative design sessions described in the previous chapter, together with the results of a series of interviews with adults stakeholders such as parents and teachers of preschoolers. The aim of this chapter is to discuss user requirements for ROBIN, the prototype which is the main artifact designed during this dissertation. This chapter answers RQ 2.2.

1.4.8 Chapter 8

In this chapter, I report on the evaluation of a Wizard-of-Oz prototype of ROBIN, that we conducted with 36 preschoolers in Portugal and Switzerland. Here I discuss the challenges of evaluating technology with young children, and use the results of our analysis to build on our previous work and provide guidelines for the design of storytelling tools for children. This chapter answers RQ 2.3.

1.4.9 Chapter 9

This chapter ends the applied part of this dissertation. Here, I discuss a novel use case for ROBIN: supporting the acquisition of Italian as a second language for child refugees from Ukraine. While originally co-designed with and for preschoolers, ROBIN shows its potential even with older children who are learning a second language. In this chapter we also propose a second iteration of ROBIN, based on the feedback obtained from the participants. This chapter answers RQ 2.4.

1.4.10 Chapter 10

In this chapter, I sum up the results and the achievement of my work. I discuss the answers to my research question, my contributions to the field of CCI, as well as the limitations and challenges that I faced during my research. I also suggest future directions to address these issues, and expand upon my findings.

1.4.11 Chapter 11

This chapter offers final considerations and remarks, and concludes this dissertation.

1.5 Publications Overview

In this section, I present the list of publications in chronological order; two additional publications are under review.

1.5.1 Publications in this Dissertation

- [323] **Sveva Valguarnera** and Monica Landoni. 2022. ROBIN - Designing a ROBot for Interactive Narratives to engage preschool children. In 6th FabLearn Europe / MakeEd Conference 2022 (FabLearn Europe / MakeEd 2022). Association for Computing Machinery, New York, NY, USA, Article 8, 1-5.

- [325] **Sveva Valguarnera**, Cristina Maria Sylla, and Monica Landoni. 2022. Magic and Reality: what children's drawings tell us about their perception of technology. In Proceedings of the 21st Annual ACM Interaction Design and Children Conference (IDC '22). Association for Computing Machinery, New York, NY, USA, 498-503.

- [322] **Sveva Valguarnera** and Monica Landoni. 2022. "This book is magical!": exploring emergent readers' preferences and wishes for storytelling tools. In Nordic Human-Computer Interaction Conference (NordiCHI '22). Association for Computing Machinery, New York, NY, USA, Article 28, 1-9.

- [326] **Sveva Valguarnera**, Cristina Maria Sylla, and Monica Landoni. 2023. The IDC Research and Design Challenge throughout the years: achievements, reflections and next steps. In Proceedings of the 22nd Annual ACM Interaction Design and Children Conference (IDC '23). Association for Computing Machinery, New York, NY, USA, 423-434.

- **Sveva Valguarnera** and Monica Landoni. 2024. Exploring the use of an interactive storytelling toy to engage Ukranian child refugees in learning Italian. *Accepted for publication in the 23rd Annual ACM Interaction Design and Children Conference (IDC '24)*

1.5.2 Additional Publications

- [320] **Sveva Valguarnera** and Leandro Soares Guedes. 2020. Two in a Pod: promoting sustainability and healthy eating in children through smart gardening. In Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts (IDC '20). Association for Computing Machinery, New York, NY, USA, 241-246.

- [5] **Sveva Valguarnera**. 2021. EPPics: Enhanced Personalised Picture Stories. In Proceedings of the 20th Annual ACM Interaction Design and Children Conference (IDC '21). Association for Computing Machinery, New York, NY, USA, 620-623.

- [321] **Sveva Valguarnera** and Monica Landoni. 2021. Designing Collective Teacher-Children Personas in Preschool: A Methodological Approach. In Proceedings of the 20th Annual ACM Interaction Design and Children Conference (IDC '21). Association for Computing Machinery, New York, NY, USA, 488-492.

- [324] **Sveva Valguarnera** and Monica Landoni. 2023. Design with and for Children: The Challenge of Inclusivity. In: Antona, M., Stephanidis, C. (eds) Universal Access in Human-Computer Interaction. HCII 2023. Lecture Notes in Computer Science, vol 14020. Springer, Cham.

1.5.3 Under Review

- **Sveva Valguarnera**, Monica Landoni and Cristina Maria Sylla. 2024. "Can you help me tell you a story?" - Exploring children's interactions with a storytelling toy. **Submitted to: NordiCHI 2024.**

- **Sveva Valguarnera**, Monica Landoni. Children's involvement in the design of technology: a literature review. **Submitted to: International Journal of Child Computer Interaction.**

Chapter 2

Literature Review

In this chapter we provide an overview of the literature on the topics of CCI that are of greater relevance to this dissertation. The first section reviews the literature on child development, focusing on the two main cognitive development theories, magical thinking and the use of children's drawings to acquire information. The second section looks at children's involvement in the design of technology. However, this aspect will be explored further in Chapter 5, where I will present a detailed literature review on collaborative design with children. The third and final section looks at the development of technology for literacy. It includes an introduction to shared reading between adults and children and its influence on literacy development, before moving on to storytelling tools and interactive toys for children. These three sections outline respectively the user population, the methodology and the design space of the work presented in this dissertation, and as such they represent the foundation of my work.

2.1 Children as users and stakeholders of technology

2.1.1 Children's cognitive development

There are two main cognitive developmental theories, where "cognitive" refers to the processes of thinking and memory. The first one is Jean Piaget's theory [242], according to whom cognition develops through four distinct states.

1. **Sensorimotor Stage (Birth to 2 years)**
    - In this stage, infants and toddlers learn about the world through their senses, by touching, chewing, looking and listening.

- They also start developing object permanence, the understanding that objects continue to exist even when not visible.

2. **Preoperational Stage (2 to 6 years)**
   - Children start developing language and symbolic thinking, engaging in pretend play and being able to describe things around them.
   - They are egocentric, meaning they have difficulty seeing things from other people's perspectives and can only think of their own.

3. **Concrete Operational Stage (7 to 11 years)**
   - Children start developing their logical reasoning, being able to understand conservation (items and people can be the same even when they look different) and other concrete concepts.
   - While they become less egocentric and more capable of seeing other people's perspectives, abstract thinking is still limited.

4. **Formal Operational Stage (12 years and older)**
   - Children become more capable of abstract and hypothetical thinking, they can use deductive reasoning and understand abstract concepts.
   - They gain the ability to think and plan for the future, as well as think about moral and ethical issues.

While Piaget argues that the stages happen always in the same order and without skipping any of them, different children reach each stage at a different age, with very wide possible variations in the same age range [280].

The second theory is Lev Vygotsky's sociocultural theory of child development [328, 338, 339]: unlike Jean Piaget's emphasis on individual exploration and cognitive development, Vygotsky focused on the role of social interaction, cultural context, and language in shaping a child's cognitive development.

One of the main concepts from Vygotsky's theory is the **Zone of Proximal Development (ZPD)**, which is the space between what a child can do without assistance, and what they can do when collaborating with more capable peers or assisted by an adult; thus, this theory highlights the importance of social interaction and guidance in the learning process. Vygotsky believed that learning and development are inherently social processes, and that interactions with others, especially more knowledgeable individuals, contribute significantly to a child's cognitive development.

While these two theories have often been seen as alternatives to one another, it can be argued that, while both have limits, they complement each other. [279].

2.1.2 Magic and magical thinking in children

Our understanding of magic builds on the concept of magical thinkers and believers in magic [296]. As magical thinkers we can move objects with our thoughts, let inanimate objects become alive, and we can even do much more, with the full knowledge that all this happens in the realms of our imagination and our dreams [296]. People that instead believe that this could happen, are believers in magic. Whereas in ancient times our forefathers were believers in magic, explaining the phenomena they could not understand as magic, the evolution of science has shown us that magic contradicts the fundamental laws of nature. Nonetheless, research suggests that the belief in magic is a fundamental property of the human mind [297], and this is particularly true for children. A comparative study [298] investigating the capacity of discriminating between ordinary and fantastic realities represented in pictures with three age groups, 6-years-old, 9-years-old and adults, confirmed previous research that 6-years-old children performed significantly worse than 9-years-old, and both age groups performed significantly worse than adults on the test. Thus supporting "the hypothesis that there is a developmental progression on the capacity to discriminate between ordinary and fantastic visual realities" [298].

According to [296] children's magical thinking is an important and necessary complement to cognitive development, enhancing creativity and helping to develop coping mechanisms. Magical thinking takes place in emotional domains, and underpins our construction and understanding of meaning [296]. As we grow in age, we gradually change from believers in magic to magical thinkers, and while most four- to six-years-old children still believe in magic [241] [126] [295], by the age of nine most children are aware of the difference between magic and reality [296]. Whether magic thinkers or believers, magic seems to play an important role in human cognition; in children, magic is part of their role-play as it can be seen in their storytelling, and besides helping them to explain the world, it gives them a feeling of power and independence [296].

2.1.3 Children's drawings

Drawings have an historical tradition as a method to evaluate cognitive development. A particularly influential approach is the visual-haptic theory [194], which is still applied in a number of research areas such as: art education, child studies and psychology. Lowenfeld and Brittain [194] see drawing as a process that children use to signify and reconstruct the world around them. This exploitation of the environment has a strong sensory component, involving all their senses, and the way children represent things shows how they understand them, which evolves with time as children become more aware of the world around them.

Children's drawings have been used in Child-Computer-Interaction as a method to involve young children as design partners of technology [?], and to gather information related to user experience [302] [301] [362] [363] [364]. For example, [364] used children's drawings to assess fit and fun of technology, [301] investigated the use of drawings to understand if it is possible to evaluate usability aspects of an interface by looking at children's drawings, and uncover indicators that would reveal children's satisfaction with the interaction. Drawings have also been used to compare the learning benefits of tangible versus graphical interfaces for preschoolers, particularly to assess children's degree of involvement with the interfaces [302]. Nicol and Hornecker [230] studied children's drawings to investigate its effectiveness to elicit children's feedback on interactive museum prototypes. Barendregt and Becker [26] investigated the use of children's drawings to evaluate a game with younger children and its potential as a method to invite children to generate design ideas, and if drawings can be used as a collaborative design method. Vishkaie [337] analysed children's drawings with early elementary school children, K1, to learn about their perceptions with animated and inanimate objects, to inform the design of interactive toys. Overall, children's drawings seem to provide useful information about children's perceptions, however it is not always an easy task to fully interpret the meanings conveyed in children's drawings. Research has also pointed out that the use of drawings may be advantageous for the evaluation of technologies with children over other methods, since at young age children may not yet be able to write proficiently or may have difficulties expressing themselves, or they may feel unsure expressing themselves verbally to a researcher [362].

2.2 Children's participation in design and innovation

2.2.1 Participatory Design with children

Participatory design originated in Scandinavia in the 1970s, and it was originally meant as a way to involve factory workers in the research and design of new software for their workplace ([233]); as such, it concerned the idea of democratising work ([37]). However, it quickly grew and now its concepts are used throughout the world, as it has shown to have many benefits: for example, involving users in the design process has a positive effect on both the success of the system and the satisfaction of its users ([176]). The process of co-design also has inherent ethical qualities, as users can express and share their experiences ([292]). It can be seen as an empowering process, in which users are involved in the design of products that will raise their quality of life ([145]). Because of its ethical and democratic qualities, we chose collaborative design as a way to conduct this doctoral dissertation. While in the past co-designing was mainly performed with adult users, in the last decades children have also started being involved in the design of new technology, first as testers, then as informants and finally, as design partners in their own right ([81]). According to [257], the ideal age for collaborative design is between 7 and 10 years old, as children of that age have a good capacity of abstraction and reflection, but they are still very imaginative, and they lack prejudices and preconceptions. In this age range, both brainstorming and prototyping work well as design methods: while children uncover a higher number of design ideas when prototyping, they provide more detailed criteria when brainstorming ([284]). Many methods to evaluate technology with children, such as the Fun Toolkit, have also been developed for older children, at least 7 years old ([256]).

Some techniques developed for older children, such as the Cooperative Inquiry ([80]), have been successfully adapted for younger children with some changes, such as allowing the children to draw their ideas instead of writing them down and working in smaller groups ([97]). Both [300] and [97] emphasize that children work better in smaller groups. This is also supported by [33], who goes beyond that to present evidence that younger children, aged 4 to 5 years old, have the most difficulty in working collaboratively, and work better in pairs.

Other techniques have been proven to be useful with older preschoolers, but still present challenges with children on the younger side of this age range: for example, [26] used the drawing intervention method to elicit design ideas with children aged 4 to 7 years old, and found that the younger children found it hard to collaborate, and had difficulty using drawings to communicate design ideas. This was also true for [134], who used *Fictional Inquiry* and *Comicboarding*, techniques developed to elicit insights from adults users, with children aged 4 to 6 years old; while 5 and 6 years old were able to successfully generate design ideas, 4 years old children had more difficulties in doing so. However, younger children still participated enthusiastically, suggesting that with more adult facilitation, they could participate fully in the design process. This is also confirmed by

[97], who note "More adult facilitation" as one of the changes to design methods needed to involve younger children. However, [205] report that less structured sessions, that required a small amount of instructions to be given to children, tended to elicit more reliable and valuable data for researchers.

There are also many design methods developed specifically for younger children. For instance, as envisioned by Iversen et al. [156] and following an approach centred on constructive play practice, aimed at creating a story-line and establishing a cooperative process, children can become protagonists in the design process ([286]). Another example is *Mixing Ideas* ([120]) that has been used to foster collaboration among young children. A technique called *Play-based design* has also been developed for younger children, involving make-believe play activities with an adult facilitator ([300]).

2.2.2 Evaluating technology with children

As the role of children as users of technology grew during the last decades, researchers needed to learn how to involve them in the evaluation of the technology they were now using. The first guidelines regarding usability testing with children date back to 1997 [125]. While the world of technology has undergone significant changes in the last decades, most of these guidelines are still useful for researchers wanting to evaluate technology with children, such as the idea of allowing younger children to explore the tools according to their own interest instead of directing them to execute specific tasks, and how to create an environment in which children would feel comfortable.

In the following years, evaluation methods known to work for adults were adapted to children, such as think-aloud and post-task interviews. Both these methods have been used successfully with children aged 9-11 years old [22], and together with observation they allowed researchers to efficiently uncover usability problems. Laddering as an interview technique was also discovered to be useful with children aged 5 years and older [374], although with some differences in the types of ladders created in comparison with adults. Other methods such as Active Intervention, Retrospection and Peer Tutoring were also successful with children aged 6-7 years old, however the Co-discovery method, which relies on collaboration, was less successful as children at that age do not collaborate very well [330].

In time, researchers developed new evaluation methods specifically for children, such as the Fun Toolkit [254], a collection of three instrument that can be used to elicit feedback from children, that was shown to be effective with children aged 5 and older; the Five Degrees of Happiness scale, which was evaluated with children aged 9-11 years old [3], and which sprouted variations such as the Smiley Face Icon creator [163]. Other methods include the Sticky Ladder [10] and its variation, the Paper Ladder [305], which was considered easier and less expensive to adopt for researchers. The advantage of such methods, which is also shared by the Fun Semantic Differential Scale (FSDS) [220] or the UX Scale for preschoolers, which is part of the This-or-That method [373], is that they do not rely on written text, and can be used with children who are still learning how to read and write, and who might be too shy to express their opinion verbally. For the same reasons, children's drawings have been used during evaluation [302]. However, evaluation methods with written prompt have successfully been used with pre-literate children, with the researchers reading aloud the prompts, such as the Giggle Gauge [72]. With children who have limited communication skills, such as children with ASD (autism spectrum disorder), video observation can also be a useful technique to evaluate user experience [200].

However, methods developed specifically for children do not necessarily perform better than methods designed for adults, and adapted for children: for example, Cross-Age tutoring (an older child tutoring a younger one in the use of a specific tool of technology) was shown to elicit fewer verbal comments than either Active Intervention or Peer Tutoring [86], and MemoLine did not offer significant advantages over just conducting an interview [142].

2.3 Designing for literacy

2.3.1 Shared reading and literacy

Shared book reading between parent and child is not only a learning opportunity, correlated with better reading achievements and language growth ([45, 281]), but also a social practice that supports parent-child bonding and foster intimacy ([336]).

Current research also shows that dialogic reading, which consists in reading *with* children, asking questions and interacting with them, is effective in promoting emergent literacy ([77, 162, 221, 357]).

While some research suggests that shared parent-child reading using an electronic format negatively affect children's story comprehension ([175, 239]) and dialogic verbalisation ([224]), multimedia stories are more beneficial in terms of story comprehension and vocabulary than traditional story-books when children read them on their own, and they are on par with shared parent-child reading of traditional books ([307]).

Moreover, the downsides of using technology for shared parent-child can be mitigated and even negated by explicitly designing for shared participation ([135]). One example of such design is TinkRBooks ([54]), a flexible table-based storybook in which both parent and children can alter the text of the story by manipulating the characters on the screen, that was shown to elicit more dialog and dialogic questioning compared to print books.

In this context, multimedia tools for storytelling should not be seen as an improvement over parent-child shared reading, but as an enhancement or a substitute, in cases when a parent is not available or needs help performing the role of orchestrator and narrator during shared reading activities, which is a real point of tension identified by research ([336]).

Robots have also been used to create interactive stories with children: a Wizard of Oz study showed that even young children are able to interact with robots by inserting new content in a story, relating it to the existing story ([299]), while storytelling with a listener robot as a side-participant, together with a reader robot, has proved to be more enjoyable than just reading with a reader robot ([308]). As well as being enjoyable and engaging, storytelling with a robot can also have a positive effect on children's vocabulary: when playing a storytelling game, levelling a robot's language to a child's current abilities resulted in children using a more diverse language and creating longer stories ([353]). Robots' social behaviour is also an important factor in their performance: for example, expressive robots narrating stories to preschool children have an effect on children's recollection of stories that is comparable to expressive humans, and better than static, inexpressive humans ([66]).

However, children are not independent users of technology, and as such, parental expectations and concerns must also be taken in consideration: while an exploratory study suggest a generally positive attitude towards storytelling robots for children ([189]), the attitude of parents towards technology has a strong cultural component and can also change over time.

2.3.2 Storytelling tools for children

Learning to tell stories is a fundamental milestone in children's development because it is how they form a picture of the world around them [71]. While storytelling is a natural activity for all children that usually precedes the use of technology, many toys, tools and technologies have been developed in recent decades to support storytelling with and for children, such as StoryMat [52] and MyStoryMaker [208], which enable collaboration between children and help them develop pre-literacy skills, and KidPad, which was developed in collaboration with children as a learning environment [82]. Some tools, such as StoryBuilder [15], have been developed to support storytelling as an online activity or even to promote collaborative storytelling at a distance, such as The Conference of the Birds [48].

Apart from helping children develop their literacy skills, digital storytelling environments have also been used to promote specific goals, such as detecting - and preventing - gender stereotypes in the stories created by the children [265].

As technology evolved, new forms of storytelling tools emerged, such as storytelling robots [188, 323], chat-bots [375] and conversational agents [365]. As these new forms of technology spread, researchers also had to consider parental concerns and attitude towards robots [189], and how they can be used to help children develop social-related skills [185].

2.3.3 Interactive toys

When we think of technology in our homes, we think of computer, laptops, game consoles, mobile phones and similar items, whose common characteristic is having a screen, that are present in many people's home and available to both adults and children [141]. In fact, many of the aforementioned storytelling tools for children are not tangible, but apps that run on smartphones, tablets, and computers.

However, the availability of technology in the home raised the issue of screen time, for parents and experts alike: while parents often recur to screens to entertain their children, allowing them time to perform independent activities such as working, cooking or cleaning in their home, they know that an excess of screen time can be detrimental to children's health [133]. After the COVID-19 pandemic, during which children's screen time rose as schools transitioned to distance learning, parents also expressed the preference for screen-free educational and entertaining activities for their children [323]. Moving away from screen time to a non-screen activity can be hard for children, but when the technology itself is the one mediating this transition, results can be better [13, 133]. The kind of screen time offered to children is also an important consideration: while children under 2 years old should not be exposed to screens in any circumstance, the preferred screen time for children between the ages of 2 and 5 years old should be active - meaning, not simply watching a video but interacting and engaging with technology such as an app or a game - and it should preferably happen together with parents, fostering active interaction and engagement between parent and child [186]. This also align with children's own preferences: toys and tools explicitly designed for interaction, whether they are digital or not, work better in engaging children aged 3 to 6 years old [322].

The need for children to use screen-free, interactive technology with their carers or peers means that researchers need to design interactive toys for children that are appropriate to their development. For example, some of the recommendations for younger children (3 years and under) relate to the type of interaction to be implemented, the effects the toy should produce and the importance of playing together [140], while when designing for older children (8-10 years), the aim is to encourage engagement and agency by using design patterns that allow them to actively participate in the activity, make choices and express themselves [188]. Interactive toys can also be educationally valuable, for example by enabling children to learn a second language in a fun way [157].

2.4 Conclusions

In this chapter, I reviewed the research on the most relevant topics to this dissertation. The literature shows how children are not "small adults", but individuals who are growing and have specific needs that correlate to their development, and as researchers it is our duty to design technology that can nurture and support their needs, allowing them to grow and thrive.

While children's involvement in the design of technology has grown over the years, preschoolers - the specific demographic investigated in this dissertation - are still underrepresented, with design methods often developed specifically for older children and adapted to the needs of the younger ones.

However, the age between 3 and 6 years old is the age in which children began to explore literacy and gain the pre-reading skills that will influence their success in acquiring literacy, and technology has a role to play in this process, not as a replacement for shared adult-child reading and for actual human interaction, but as a support for parents and caregivers.

The next parts of this doctoral dissertation will build upon this foundation and furtherly explore the themes identified in this literature review, providing answers to the research questions asked in Chapter 1.

Part I

Children in a world shaped by technology

Chapter 3

Children's perception of technology: magic versus reality

3.1 Introduction

In this chapter we explore the potential of drawings to assess children's perceptions, understanding and expectations concerning technology. This chapter is based on our work presented at the IDC conference in 2022, "*Magic and Reality: what children's drawings tell us about their perception of technology*" [325].

To do so, we analysed the drawings and descriptive texts submitted to the Research and Design Challenge (R&D Challenge) for the International Conference on Interaction Design and Children 2022, looking at age and gender as main lenses; more information about the Research and Design Challenge will be provided in the next chapter. Inspired by considerations in [363] on how extra annotations provided by children helped in the interpretation of portrayed elements, we also turned to text submitted together with each idea as well as that included in the drawing, to better understand the ideas conveyed in the drawings. The R&D Challenge theme for IDC2022 was "Connectedness". Children all over the world were invited to imagine and submit "their ideas of how technology can foster connectedness among people who live near and/or far from each other, who are of the same age or from different life spans, who have similar and/or different social and cultural background, etc. In short, how can technology creatively connect people, people and pets, or even people and objects if they have a special role in somebody's life?". In the first phase of the challenge children sent a record of 166 ideas, each composed by a title, an explicative drawing and a brief textual description as requested in the call. Therefore, prompted by the availability of such a rich collection of representations of what technology can

Figure 3.1. Collage of different elements, 8-years-old girl from CH

do for children, we set out to run our study, an exploration into expectations, understanding and preferences children have towards the technology to come; by doing so, we were also able to assess how effective such a drawing based method is in revealing this type of information.

3.2 Submissions

3.2.1 Collection

A total of 166 ideas were submitted, mostly coming from two schools, one in Portugal (PT) and one in Switzerland (CH), with a very few from other sites (USA and Japan). As in the past editions, the majority of submissions were sent from schools already collaborating with researchers in the Child-Computer Interaction community.

For each of the submissions, children wrote a title and the description of their idea, this way they could create and share meaning using two modes: nonverbal, graphic depiction and written, telling the drawing [361]. As suggested by Wright, this “crossover of modes increases children’s capacity to use many forms of representational thinking and to mentally manipulate and organise images, ideas and feelings” [361]. Moreover, the combination of graphic depiction and written explanation provided us with additional information to better understand children’s drawings. However, as the children wrote in their local language, the descriptions had to be translated by the adults responsible for the submission to be included in the RD challenge booklet. Because of this, we have to point out that the resulting descriptions, while useful to understand the chil-

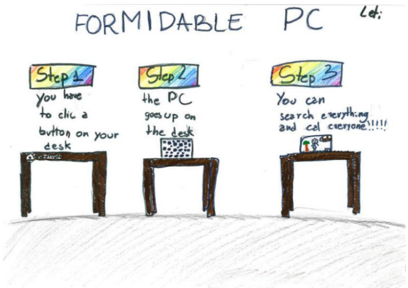

Figure 3.2. Storyboard representing an idea, 10-years-old girl from CH

Figure 3.3. Drawing with embedded text, 11-years-old boy from CH

dren's drawings, may be contaminated by the adult mediators. While this is certainly a limitation, it can also help researchers focus more on the drawings than on the descriptions, in order to capture the children's authentic voices. And even if it might be difficult to understand children's drawings, in fact, studies have also confirmed that despite such limitations drawings seem to have advantages over other methods to access children's perceptions and opinions [362] [26].

To reflect the rich creativity expressed by children, the submissions were divided into those connecting: people; humans, animals and aliens; humans, objects and wishes; connecting places and reducing distances; and connecting times. While most drawings depicted one single piece of technology to support connectedness, few of them were a collage of different elements (Figure 3.1) and others told us a story and represented it in a story board (Figure 3.2) with or without text to help comprehension. Often text was embedded in the drawing too as an essential part of it (Figure 3.3). In the spirit of the challenge, children had total freedom to express themselves and this resulted in a variety of drawings and 3D artefacts (Figure 3.4).

3.2.2 Coding

We started our thematic analysis by defining two major categories to enable us to distinguish between ideas based on magic and those grounded in reality. This distinction was based on Subbotsky's [296] four dimensions of magic, "thought over matter", "coming to life magic", "transformation magic" and "violating fundamental properties of space and time". According to this, the drawing of an app that translated all languages in real time was coded as grounded in reality, while drawings that depicted various forms of teleportation were coded as magic. Figure 6 shows shows two examples of drawings that were coded as magic.

It is however worth noting that even "magic" drawings usually presented elements that can be described as technological, such as buttons, keyboards, holograms and so on (Figure 3.5). Often children would explicitly use the term "magic" either in the title or in the description of their idea.

We also added categories for describing the main theme of the challenge: connectedness, these were communication, translation, time travel, mind reading and transportation, as the main ways children envisaged technology could support different types of connections between humans and animals. As children were invited to think of technology we also added a few categories to let us pick on trends and preferences in terms of the envisaged tools: digital devices to depict everyday items such as smartphones, laptops, and tablets, holograms, wearables and robots as these are becoming more familiar at least in movies and television. As for the context where children envisioned using the technology they were describing, we had school and videogames, covering both education and their spare time. Food, money and space emerged naturally as categories linked to natural needs and curiosity.

Then, we started coding the remaining drawings: a team of three researchers coded the drawings separately, according to each category - as explained below - and then we kept the categories that had two or more votes. So, if for example two researchers coded a drawing as "magical" and one as "grounded in reality", the final code was "magical". If two researchers coded a drawing as pertaining to the "wearables" category, it was coded as "wearables". However, it is worth noting that the inter-rater agreement was over 90%.

Starting with the original dataset of 166 drawings, we excluded from our analysis anonymous drawings and drawings that could not be associated with a specific age or gender (such as group drawings). This led to the exclusion of 5 drawings. Then, we coded whether each drawing and its textual description was related or not to the proposed theme of connectedness. This led to the exclusion of 16 drawings, which were not included in the subsequent analysis.

Figure 3.4. 3d artifact, 7-years-old girl from PT

Figure 3.5. Flying phone, 8-years-old girl from CH

	7yo	8yo	9yo	10yo	11yo	Total
Male	5	28	11	10	15	69
Female	6	31	23	27	25	76
Total	11	59	23	27	25	145

Table 3.1. Distribution of the drawings according to authors' age and gender

The resulting data set was composed of 145 drawings, 69 by male children and 76 by female children. Table 3.1 shows the distribution of age and gender among the children.

Then, we coded the remaining drawings according to the following categories: magic, grounded in reality (mutually exclusive), holograms, humans, animals, cartoon/movie related, digital devices, teleportation, robots, wearables, portal, translation and other. Each researcher furtherly divided the "other" entries according to the content of the drawings; similar categories were then merged, while categories that had three or less entries were removed. We removed the categories human and cartoon/movie related, and added translation, communication, schools, money, video games, food, transportation, space, communication via thoughts. One drawing could belong to more than one category, for example boots that allowed the wearer to travel fast were coded both as "wearable" and "transportation".

We furtherly refined our "wearables" category by coding the drawings according to the type of wearable depicted: the categories were: jewellery, glasses, footwear, headwear, clothing, watches and other. Some drawings were coded as belonging to more than one subcategory, as for example they depicted both shoes (footwear) and a helmet (headwear).

3.3 Results

3.3.1 Analysis

For each category, we created separate contingency tables; one of them is shown in Table 3.2. As the sample size is small, we opted to perform Fisher's exact test with a p-value threshold of 0.05 to examine the significance of the association between the different categories and either gender or age of the children; in accordance with Subbotsky's research [296], who reports that by the age of nine most children are aware of the difference between magic and reality, we divided the children in two groups according to age, "younger" children who are younger than 9 (7-8 years old), and "older" children who are 9 or older (9-11 years old).

	Magic	Grounded in reality
Younger children	47	7
Older children	37	29

Table 3.2. Example of the age-magic versus grounded in reality contingency table

We found a significant association (p=0.0003) between age and the depiction of technology as magical, with younger children significantly more likely to depict "magical" technology such as teleportation or mind-reading. As explained by previous research, by the age of nine children are more likely to be magic thinkers whereas younger children tend to be believers in magic [296].

We did not find any other significant association between the age of the child and the content of the drawing; however, we detected some trends whose significance could be potentially ascertained with a larger sample: specifically, we found that older children's drawings featured wearable technology and holograms more often than younger children's (however, the p-values that we found were respectively 0.0917 and 0.0572, both above the threshold for significance), and that older children also tended towards representing technology for communication (p= 0.1025). While we cannot say that there is a statistical significance, the small size of the sample, coupled with the fact that in all these cases the p-value was near the threshold for significance, suggests that these tendencies could be explored more deeply.

While we expected gender to play a more significant role in the depiction of technology, the only significant association we found was between gender and the depiction of animals (p=0.0381), with girls representing this kind of technology significantly more often.

We also looked for significant associations between the different kinds of wearables depicted and the age and gender of children; however, we did not find any significant associations. While age seems to be a discriminant, gender proved to be not significant, at least when looking at the magic vs realistic dichotomy.

While not relevant drawings were not included in the previous analysis, we also analysed whether the prevalence of off-topic drawings could be correlated either with age; the p-value proved to be above the threshold for significance at 0.1118, however as mentioned above the small size of the sample suggest that further analysis could lead to a different result.

Figure 3.6. On the right, very fast boots from PT; on the left, flying shoes from CH

Looking across all drawings we could also see how certain ideas were more popular than others and could be found in contributions coming from different countries. This was the case of boots that made you travel fast where you wanted to be. We found drawings depicting shoes, trainers and fancy boots, made by girls and boys both in Switzerland and Portugal, as in Figure 3.6. We also encountered other such instances as the headbands for transmitting thoughts to people (PT) or to control an iPad (CH) or even to make the animal you are thinking about appear for real in front of you (CH), or the glasses and contact lenses to control other devices or VR.

3.3.2 Discussion

In this chapter, we aim to answer the following research question: ***RQ1.1*** *What are children's perception, understanding and expectations about technology, as expressed in their drawings?* After coding the children's drawings, two main categories emerged: that of magic versus more realistic proposals with age being as discriminant as to be expected. Magic was either mentioned explicitly in the title and/or descriptive text or inferred from these and mostly resulted in technology behaving in totally unexpected and not realistic ways. Children's magical thinking as explained by [296] is an important and necessary complement to cognitive development, enhancing creativity, and giving children a feeling of empowerment. Children's creativity was visible in their drawings. The significant association between age and the depiction of technology as magical, with younger children significantly more likely to draw "magical" technology, confirms that younger children tend to be believers in magic, whereas older children tend to be magical thinkers. According to [194], the way children represent things shows how they understand them, which evolves with time as children become more aware of the world around them. Gender did not seem to play a role even if we noticed a higher level of anthropomorphism and overall cuteness, difficult to quantify, in submissions made by girls even when portraying similar ideas (such as a collar for speaking with animals). The definition and more importantly the role cuteness could play in design with and for children needs further investigation while literature reporting on studies with adults [196] suggests how anthropomorphic representations of technology results in higher expectations from users, who would express human-like kind of intelligent response. We could also observe how children more exposed to video games, mentioned explicitly in their ideas, produced more realistic proposals, a hint that early playful exposure to technology can equip children with a basic understanding of its functioning and thus with a more down to earth expectation for it.

3.4 Conclusions

Our analysis showed that many children portrayed technological objects that contained, either explicitly or implicitly, references to magic - either in their behaviour or in their appearances, such as teleportation capabilities or wings. In interpreting the drawings, the included descriptive text had an important role, and could sometimes clarify whether an item was magical or realistic in nature, as mentioned also by [363].

However, the impact of viewing technology as magic on designing children's technology is still an open question. We need to further explore whether children behave like adults, and according to [196] if when their expectations - for magic - are not fulfilled, lose their trust in technology and refrain from using it for complex tasks or if on the contrary, their trustworthy approach to life keeps them trying harder to make sense of the tools they have at hand. Or, on the other hand, can principles of magic be used to inspire the design of technology, as defended by [252], and can we get inspiration from children's drawings to design better interfaces? Either way, we feel designers should be careful when using drawings to elicit user requirements and capture this magic versus realistic dimension as a meaningful clue to drive them in the right direction.

The Research and Design challenge was instrumental to our analysis: the ideas submitted by the children proved to be very rich and creative, and represent a worthy dataset to share with other researchers. As a community, we should discuss whether and how to keep it and have it grow over the years. Issues of data protection and confidentiality will need to be addressed, going beyond the current explicit request made at submission time to choose whether and how authors want to be acknowledged by full name, initials or just be anonymous. Age, gender, school and additional information we used in our analysis and their availability should be discussed and possibly kept too.

However, due to the nature of the data set we did not have access to further details about the children who participated, such as their familiarity with technology and with science fiction books, movies and cartoon. We feel that this information might allow for a deeper level of analysis, that we intend to further develop in the future.

We feel that maintaining over time and making such a curated data set more widely available could not only enable researchers to keep the pulse of how children perceive technology but also enable children to explore each other's likes and dislikes and perhaps even help them form a richer sense of what future technology could do for them.

This is why, on top of recognising children as the owners of the submitted ideas, we can truly put them at the centre of the technological innovation process in the true R&D Challenge spirit. We need to point out that in order for this initiative to continue and grow, the whole CCI community needs to engage with it, reach out to children and help them get their voices heard. A coral effort is needed if we want to build a long standing and meaningful initiative.

This will be the focus of the next chapter, in which we will delve deeply into the Research and Design challenge, as it grew and changed throughout the years, and its role in empowering children to participate in the design of technology.

Chapter 4

The IDC Community's example: the Research and Design Challenge

4.1 Introduction

In this chapter we reflect on the achievements of the R&D challenge, introduced in the previous chapter, but also on the issues and limitations that have emerged throughout the years, in terms of participation by children and by adult researchers, and we propose guidelines and best practices for the challenge going forward. This chapter is based on our work presented at the IDC conference in 2023, "*The IDC Research and Design Challenge throughout the years: achievements, reflections and next steps.*" [326].

After a comprehensive description of the current state of the challenge, we will introduce some other competitions and challenges held by different organisations and companies in the world.

Then, we will take a look at how we collected a data set composed of all the submissions to the challenge, from 2016 to 2022; finally, based on the answers, we will propose guidelines and best practices to enhance the benefits for children, teachers and the research community.

4.2 The Research and Design Competition

Since IDC websites are taken down after each conference, we resorted to the Internet Archive: Wayback Machine [18] to find archived copies of previous years' websites, and we were able to find all the R&D competition calls except for 2017.

The Research and Design competition was first introduced in the 2016 edition of IDC with the theme “Let’s invent the future!”. Children all over the world were invited to submit ideas about the “smart things” of 2030, thinking of how children would learn, play and keep in touch with others in the future. During the first edition, submissions were collected by email, with the possibility of also physically mailing them to the track chair. However, the call did not explicitly mention who would judge the submissions, and how the IDC community would use them.

While we were unable to locate the call for the 2017 challenge, we learn from reading the conference proceedings how in that year children submitted written challenges instead of drawings, and it was also the first time that adult researchers’ extended abstracts in response to these challenges were included.

In 2018 the two phases of the competition were explicitly mentioned in the call, with a first phase in which children were invited to submit their ideas for future technology that would “celebrate diversity and foster social inclusion”. The second phase was open to researchers and designers, who were invited to submit design concepts built on children’s ideas. Adult submissions were then judged both by the track chairs and by children who participated in the first phase of the challenge; the finalists’ submissions were then included in the conference proceedings.

The competition was ran in the same way in 2019 and 2020, with the theme for 2019 being “ideas for technology that would help kids feel better physically and mentally”, and for 2020 “technologies that address some of the problems our planet faces today: e.g. climate change, the loss of animal and plant species, inequality between people”.

However, 2020 also saw the first edition of the junior competition, in which children in primary and secondary school were invited to submit a description of a design concept that would address one or more of the ideas submitted during the first phase, not necessarily their own. Children submitted videos and short explanations written in English, that were then judged by a jury made of children, with the help of the adult jury organised by the track chairs.

In 2021 the challenge underwent a drastic change: while there were still two phases, the challenge only involved children and there was no adult track. In the first phase, children were invited to submit ideas - in the form of a description supplemented by a drawing or other materials - in response to the topic “(Re)imagining a world after COVID-19”. In the second phase, children that had already submitted an initial idea were invited to elaborate on a design concept regarding the same topic of their Phase 1 submission, and submit a video of their concept. The videos were then judged by all the children who had participated in phase 1, and by a panel of adult judges, with the three top submissions presented in video form at the conference.

As reported in the previous chapter, in 2022 the theme of the challenge was "Connectedness", with the competition running in the same way as 2020, with an adult track and a junior challenge, however the junior challenge was divided into two categories: up to 12 years old, and 12 to 17 years old, with the three finalists in each category being invited to present during the IDC conference.

In 2023, the theme of the challenge is "Smart Communities: Rebuilding a compassionate world!", with the challenge running in the same way as 2018, 2019 and 2020: a first phase with children submitting ideas in the form of drawing, and a second phase for adult researchers.

It is interesting to note that, throughout the years, the words "challenge" and "competition" have been used interchangeably in the calls.

In order to better frame the R&D challenge, we now describe similar initiatives run by different organisations similarly aiming at discovering how children relate to technologies. For each we report on the participants, the roles played by children and adults, and the setup of the competition.

4.3 Other challenges and competitions

The research and design competition is not the only challenge that aims to involve children in the design of new technology; some other similar initiatives are the micro:bit do your :bit Challenge, the Samsung Solve for Tomorrow: Next Gen, the COBIS Design & Technology Competition and the Raspberry Pi Pioneers initiative.

4.3.1 micro:bit do your :bit Challenge

The micro:bit is essentially a small computer with LED displays, buttons, sensor and many features, that can be programmed in the same way as other microcontrollers such as Arduino. It was originally created in 2014 as part of the BBC's Make it Digital initiative [30], and in 2019 the first do your :bit challenge[217] was introduced.

The challenge has the aim to allow students to design and show ideas to solve real world issues; children choose one of the Global Goals For Sustainable Development agreed by the UN by 2015 [316] and then design and prototype an idea to tackle issues related to those goals.

The challenge is divided into three categories according to age, with a specific category for younger children who only submit a drawing and description of their idea, with no code. Children can compete on their own or in teams; then, a panel of judges chooses winners for each of the six global regions - Africa, Asia and Pacific, Europe, Latin America, North America and Middle East - and for each category, with second and third place in each category also getting a prize. Prizes are micro:bit packages, accessories and merchandise.

While this is not a requirement, many children who join the challenge are involved in micro:bit projects and classes at school or as an extracurricular activity conducted elsewhere, such as code clubs and libraries.

4.3.2 Samsung Solve for Tomorrow: Next Gen

The Solve for Tomorrow: Next Gen Tech Design Competition [271] was launched in 2021 by Samsung UK, addressing children aged 11 to 15 and their teachers. Teachers who participate in the competition receive a video that takes students through the Design Thinking process, a Sprintbook (differentiated by age) and a delivery guide; prizes include smart boards for the schools, and other Samsung Galaxy products for winners and runners-up.

4.3.3 COBIS Design & Technology Competition

This competition [61] is open to all COBIS (Council of British International Schools) pupils aged 11 to 18 (KS3-5); here, students have to identify broken or discarded electro-mechanic products and make them usable again by using innovation and skills to solve a problem. This competition is also teacher-led, and prizes include trophies and mentorship by professionals.

4.3.4 Raspberry Pi Pioneers

In 2016, Raspberry Pi launched the Pioneers program [4], with a series of challenges to inspire young people to develop and share new ideas. The challenges were open to teams of children aged 12 to 15, with each team making a video about their ideas, and the winners getting different kinds of prizes. The first challenge took place in 2017 with the theme “Make us laugh with tech”. However, the challenge has since been discontinued.

We can see across initiatives how there is an emphasis on consistently rewarding children’s participation with prizes, while at the same providing support to the involved adults, teachers and educators. The competitions also involved libraries, coding clubs and other non-school entities, where extra curricular activities take place. Children of similar age groups compete against one another in the respect of various abilities and skills linked to the different stages of development. Organisers rely on a robust network of partners that makes it easier to reach out to young participants.

Even in this brief overview of existing initiatives we can see how children have a central role, and their effort is clearly acknowledged and rewarded. The outcomes of these competitions are often in the shape of drawings and/or early prototypes. Their analysis provides a valid and rich insight into children's expectations when it comes to future technology. On this line in the next section, we present relevant literature regarding the role children have in design, also describing how drawings have been used over time as a method of choice to gather children's feedback. Finally, we discuss ethical considerations in relation to the involvement of school teachers and children in such initiatives.

4.4 Submissions

4.4.1 Data Collection

Our first task was to collect the data from past R&D challenges. We reached out to the chairs from 2016, 2018, 2019, 2020 and 2022, since those are the years in which the challenge was organised, and we were sent copies of the drawings for each year.

The drawings from 2016 were not yet formally organised; upon contacting that year's chairs, we received three PDF files, each containing a collection of drawings. For each drawing, there was also a form filled by the child with their name, class, the name of their "smart thing", what it did, how did you use it, and where did you take it. These drawings were the most challenging to analyse, as children's handwriting was often difficult to interpret, and in some cases not all the fields had been completed.

The drawings from 2018 were organised in a website that is still online [6]; for each drawing, there was a short description in English, the names of the children involved, their ages and the school they attended. Some ideas did not include a drawing, or they included digital drawings - which were not present in 2016.

The drawings from 2019 onwards were organised in PDF booklets, with each drawing including a description in English, the names of the children involved, their age and the school they attended. Some ideas included 3D representations, as artefacts made of cardboard, fabric or other materials instead of a drawing.

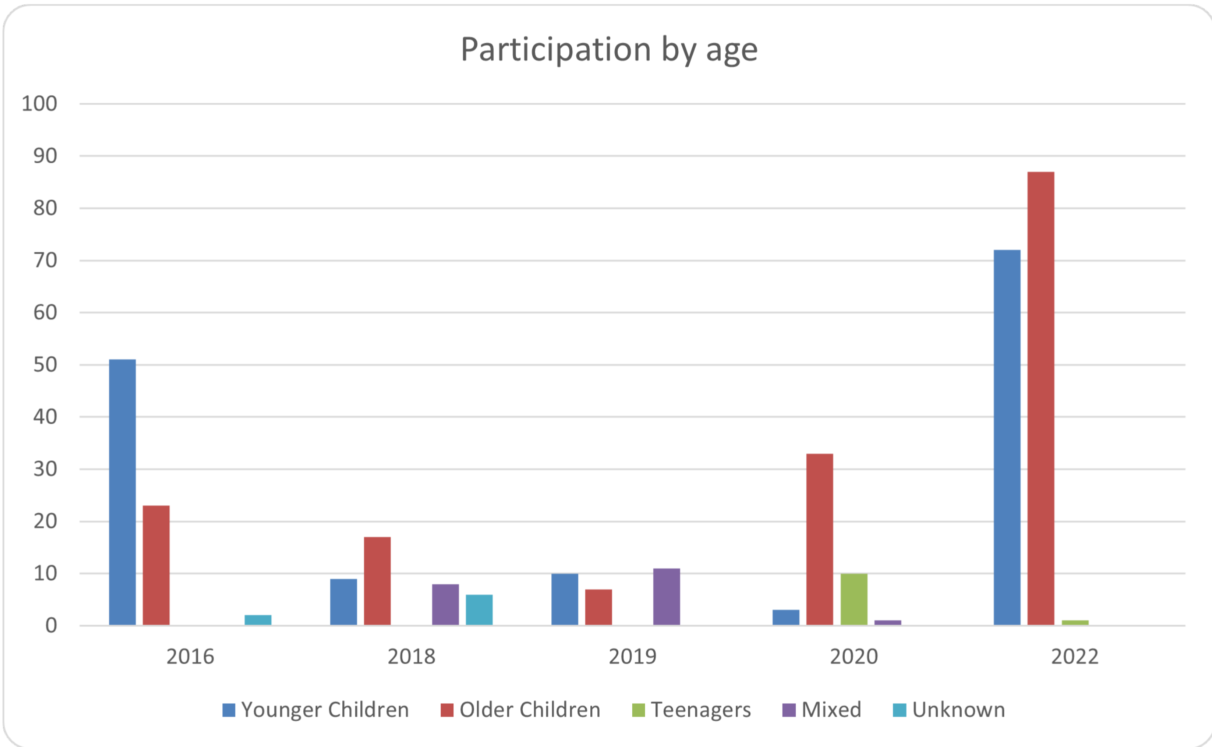

Figure 4.1. Age distributions of the participating children throughout the years

4.4.2 Coding

Following the data collection we started the coding process. For each drawing, we annotated the year it was submitted, the age of the child (or children), and the name as submitted by the child. We furtherly grouped the drawings into age ranges: "younger children", 8 and younger; "older children", 9 to 12; "teenagers", 13 and older; "mixed age groups", when children in a group belonged to two or more age ranges, and "unknown" (see Figure 4.1).

We inferred the country from the name of the school, combined with the information given by the chairs about the schools that had participated in a given year. We inferred the gender from the name of the child, putting "Unknown" when the name was gender-neutral or a drawing was anonymous. As shown in Figure 4.2, the participation by gender is generally balanced, with the exception of 2018 in which the number of female participants was significantly higher than male participants. Mixed groups also had a significant presence in 2018 and 2019, and to a lesser extent in 2020 and 2022.

We also annotated whether each drawing was drawn manually with pen and paper, digitally or a 3D representation, and whether it was in colour or black and

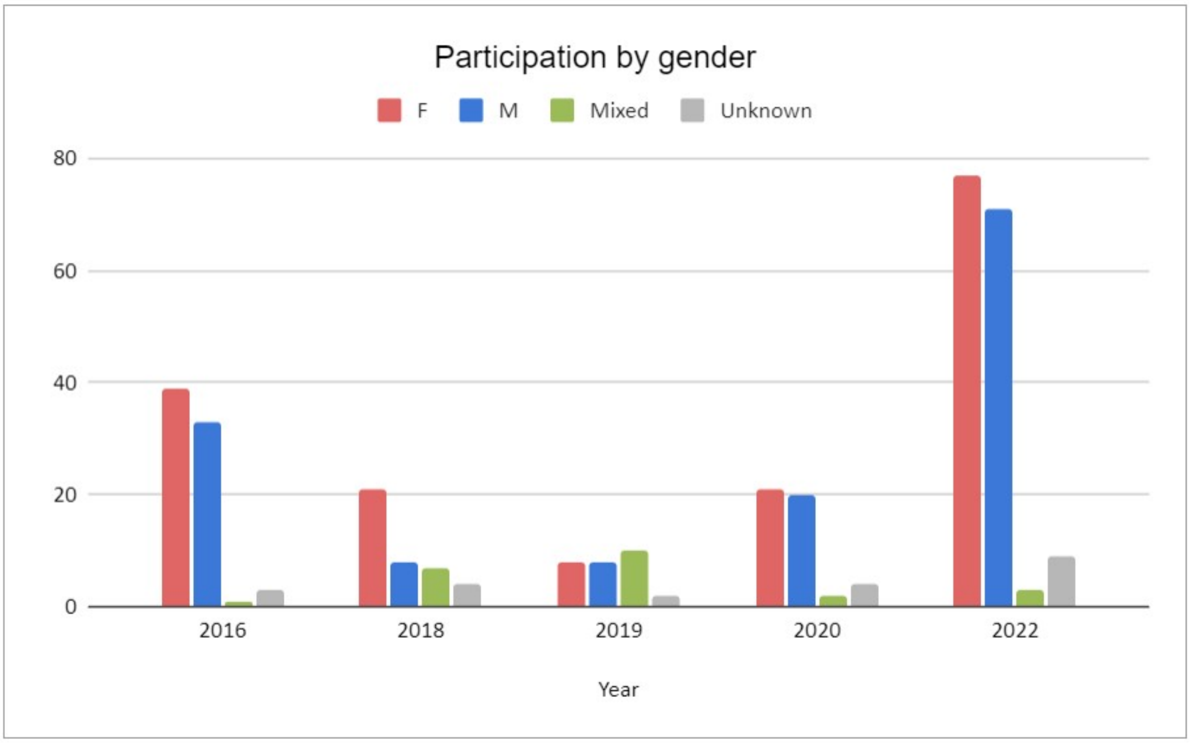

Figure 4.2. Gender distributions of the participating children throughout the years

white (for this purpose, drawings that were drawn using only a specific colour - for example with a blue or green pen - were annotated as black and white).

Then, we started our coding from the categories identified by Valguarnera et al. [325] within a subset of this same database, which were: magic, grounded in reality, communication, translation, time travel, teleportation, mind reading, transportation, digital devices, holograms, wearable, robots, school, video games, human, animals, food, money and space.

To these, we added the following categories, some of which described the previous years' challenges, and some described different themes in the envisaged tools: apps, novel technology, no technology, VR, sensors, emotions, friendship, multiculturality, disability, health, environment and flying.

Having defined the categories, each drawing was then coded by three researchers separately; when two or more researchers agreed on a specific code, it was entered for the final analysis. We also added the category "not understandable", for drawings whose meaning we could not ascertain. This was used mainly for 2016's drawings, as the textual descriptions were handwritten by young chil-

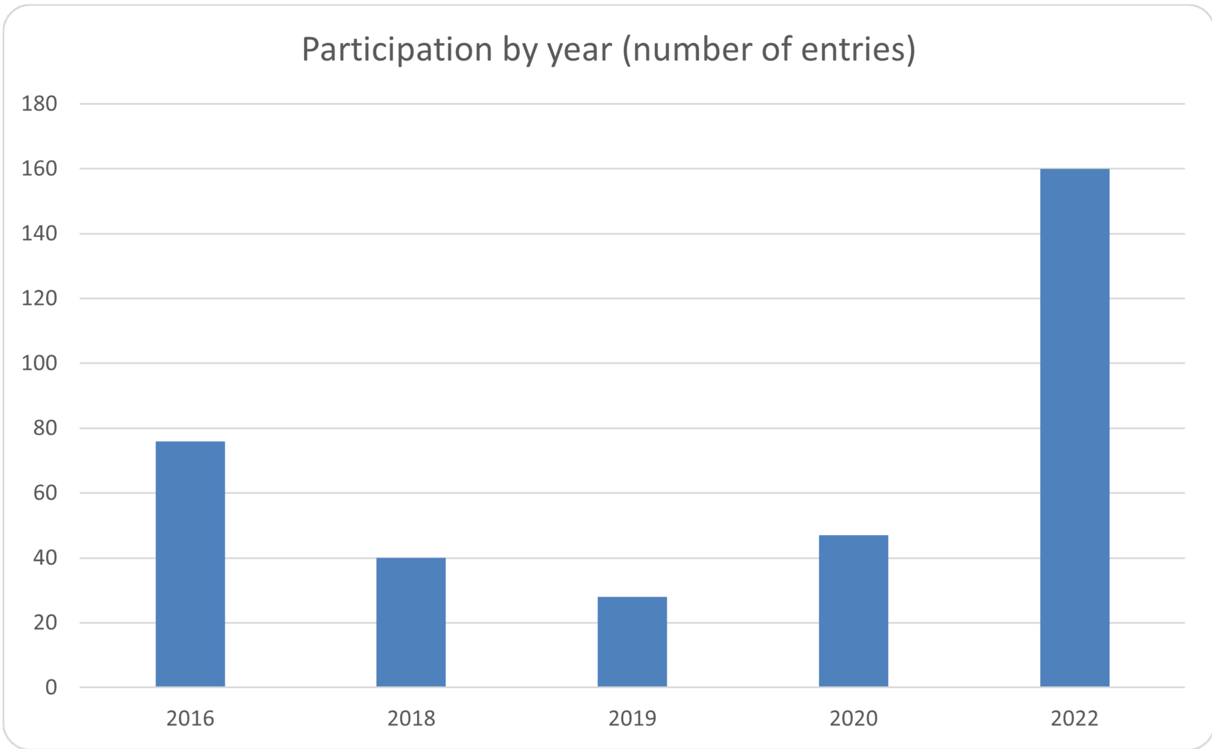

Figure 4.3. Number of participants to the challenge for each year

dren and they often did not help understand unclear drawings.

Most of the categories were self-explanatory, but some of them were more subject to interpretation; for example, the category “digital device” was used when the idea depicted a piece of hardware already existing in the real world (a tablet, a computer, a smartphone), while the category “novel technology” was used when the idea depicted some kind of hardware that does not exist in the real world (for example, a helmet that translates languages).

Overall, the categories that we used can be clustered in three groups: categories related to the characteristics of the drawings, such as whether it was digital or pen and paper, categories related to "how" the idea was represented, such as holograms, wearables, robots and so on, and categories related to "what" the idea was about, such as communication, transportation, animals, health etc.

While the theme of the challenge in 2016 was very generic (“My smart thing of 2030”), some categories can be directly mapped to the themes of the R&D Challenge from 2018 onwards:

- **IDC 2018 - “Diversity”** - multiculturalism, disability, translation, communication.

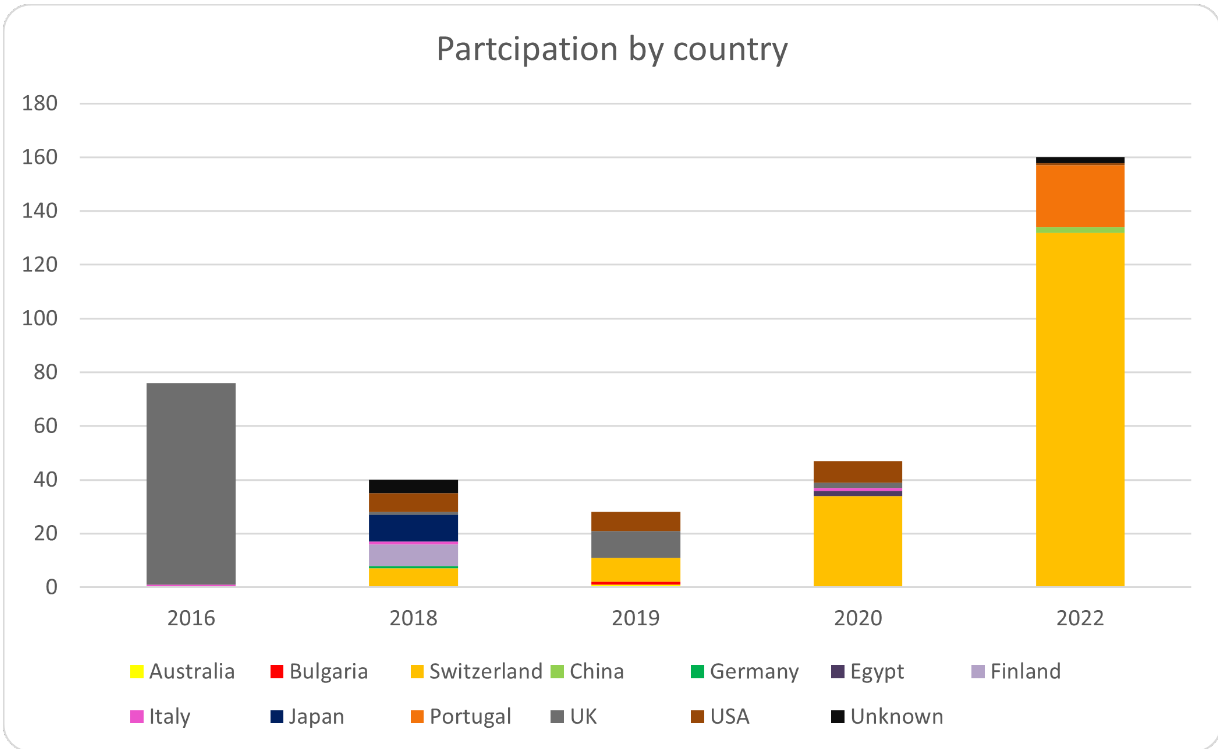

Figure 4.4. Number of participants to the challenge for each year, divided by country

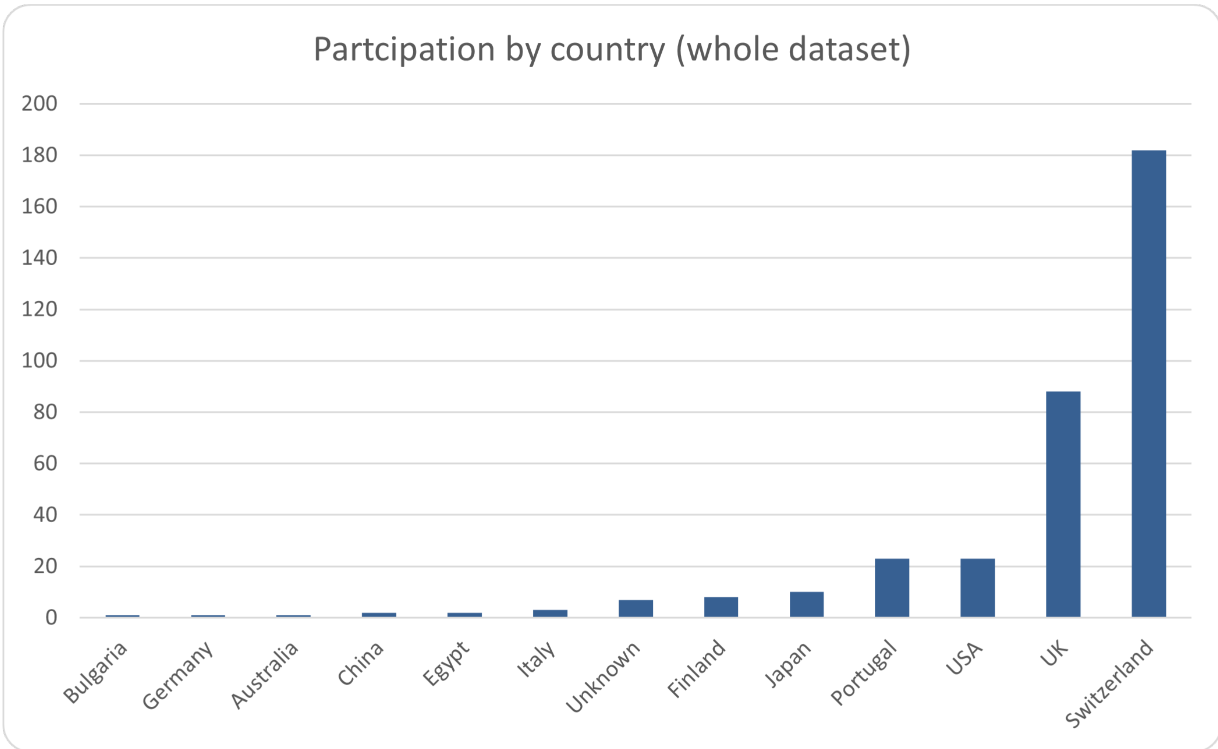

Figure 4.5. Number of participants to the challenge for each country, in the whole dataset

- **IDC 2019 - "Health"** - health, food.
- **IDC 2020 - "Climate change, inequality"** - environment, disability.
- **IDC 2022 - "Connectedness"** - communication, translation, transportation, teleportation.

4.4.3 Analysis

An analysis of the metadata associated with children's submissions provided the number of participants and countries for each year, as represented in Figure 4.3 and 4.4 and show that both the participation in terms of absolute number of participants, and in terms of number of participants by country has been very unbalanced throughout the years. The highest number of participants was in 2022, with 160 entries, which makes up almost half of the dataset, while 2018, 2019 and 2020 are all below 50 entries. We can also see that the number of participating countries for each year is small, with one country often making up the majority of the entries: UK for 2016, and Switzerland for 2020 and 2022. Switzerland alone makes up more than half the dataset, with 182 entries (see Figure 4.5).

The amount of entries by country, considering the whole dataset, is also very unbalanced, with Switzerland and the UK making up the vast majority of the dataset. Regarding age and gender the data is more balanced, although teenagers are scarcely represented, except for 2020 (see Figure 4.1).

Given the inconsistency of the data set, it was not possible to proceed with a statistical analysis. Instead, we focused on the most common categories represented each year, and how they relate to each year's theme.

In 2016, the most depicted categories related to the "how" were digital devices (61%) and wearables (49%), while the most depicted category related to the "what" was humans. In 2018, when the theme of the challenge was Diversity, digital devices were also widely represented (35%) in the categories related to the "how", while the categories related to the challenge were represented respectively in the 23% of drawings for multiculturalism, 3% for disability, 18% for translation, 73% for communication. Another two widely depicted themes were humans (78%) and friendship (50%). In 2019, the theme of the challenge was Health. The most commonly depicted technologies related to the "how" were apps (46%) and wearables (21%), while the categories related to the challenge were represented in 50% of the drawings for health, and 39% for food. Other widely represented categories include emotions (32%) and games (25%). In 2020, the theme was "Climate change, inequality"; regarding the categories related to the "how", 30% of the drawings depicted novel technology, and 26% depict robots; as for the categories related to the challenge, the environment category was present in 79% of the drawings, while disability only in 4% of the drawings. Other widely represented categories include humans, health, games and communication, all between 11% and 15% of the dataset. In 2022, the theme was "Connectedness". Regarding the "how", 30% of the drawings depicted novel technology, 28% depicted digital devices and 31% depicted wearables; the categories related to the challenge were depicted respectively in 36% of the drawings for communication, 18% for translation, 14% for transportation, and 18% for teleportation.

By looking at the most common themes depicted in the drawings we can see how giving children a specific theme - as it has been done from 2018 onwards - they produce more varied drawings, that span all the possible categories associated with the theme, while in 2016 children concentrated on the "how" - with a significant number of drawings featuring wearables and digital devices - without really addressing the "what", with many drawings describing devices that "did everything".

In the following years, the challenge tackled different themes that were related to real life problems, such as diversity, health and climate change. While specific depictions of technology varied - from wearables to novel technologies - children managed to produce rich and creative drawings while remaining on the specific topic of the challenge. However, the variety that we see might also be influenced by other factors, such as children being younger in 2016 - when the challenge only involved children in primary school - or the fact that the activity took place in a limited number of classes, with children influencing their classmates as they drew together.

4.5 Discussion, Emerging Issues and Limitations

Based on the analysis presented above, we aim to answer the following research question: ***RQ1.2*** *How can the CCI community empower children to participate in research and inspire researchers through design challenges and other initiatives?*

When coding the drawings, the first aspect that captured our attention was the fact that, despite the competition being open to children from all over the world, only a few countries are actually represented in the challenge, and the majority of the data set is composed of drawings from just two countries, UK and Switzerland, that were also the most represented countries respectively in 2016 for UK and in 2020 and 2022 for Switzerland (see Figures 4 and 5). Besides, the number of participants also varied significantly between editions.

The main issue that emerges from the data set is the strong imbalance concerning the number of participants among years and countries; this points us towards the need for a **wider participation**, both in terms of schools and countries involved. It is also worth noting that other challenges also actively involved libraries, coding clubs and other non-school entities, which we believe played an important role in expanding participation in all age groups. While the R&D challenge has mentioned “clubs” since 2021, all submissions so far have come from schools, and 2023 is the first edition in which after-school programs, clubs and maker spaces are explicitly mentioned.

One of the possible reasons for the sparse participation to the challenge could be the **issue of language**. Originally, the challenge has only been available in English; however, in 2021 children were invited to submit videos in their own native language, and since 2022 each challenge’s prompt has been translated in several languages. However, the translations have not been consistent. For example, the call for 2022 was translated in Italian and Portuguese, while the call for 2023 has been also translated in Chinese, Persian and French - as well as being available in English. The translations that are available each year most likely stem from the contribution of passionate researchers who translated the call in their native language, who also personally contact schools to involve them in the challenge, and this is also reflected in the amount of drawings submitted by each country; for example, in 2022 the vast majority of drawings were submitted by Portuguese and Italian-speaking Swiss children, who speak the language in which the call was translated. However, the translation alone does not seem to attract submissions without the presence of researchers who personally work with schools; as an example of this, in 2022 there were no Brazilian or Italian children who submitted drawings.

The availability of the call in different languages allowed children to submit drawings in their native language, however this created a burden on young researchers and collaborators, who translate the submissions without having prior knowledge of the children, and without being privy to the context of the activity.

We also have n**o information about how the drawing activity was run** at each site, whether it was part of a class in technology or any other subject, e.g. art, how much children were already aware of and used to technology in the classroom and at home, what were the precise prompts given to them beyond the official description. We do not know how much time and effort was devoted to the drawing activity, what were the motivations behind children's participation and what role the adults played in the challenge. While each challenge's theme is presented every year on the IDC conference website, there are no established guidelines on how to run it, or what materials teachers should give to children.

Another issue pertains to the submission form: while the challenge call encourages children to participate in teams, teachers who wish to submit their pupils' work must submit a separate form for each group member, which takes a significant time as the form is composed of several fields. When teachers agree to run the activity, but have little time to submit the fall, the burden falls once again on researchers and collaborators who have to step in and prepare the drawings for submission.

Even though many schools and teachers are happy to participate just for the sake of participating, it is also worth noting that in its present form teachers and children do not gain any benefit from participating in the challenge: no recognition, no innovation, no involvement besides setting up the activity and providing data to researchers; this is also an aspect that merits a reflection. As referred to by Kinnula et al. [169] children must feel motivated to participate and sense that their participation is relevant and generates value.

As for the second part of our research question, unfortunately there is no available data about how many submissions were made over time by adult researchers, members of the CCI community, thus we have no evidence of how popular the calls have been and how many researchers have been inspired by the R&D challenge. A different indicator we can use to provide an answer here is the number of ideas sent by children as an indirect measure of the effort put by the IDC community in soliciting contributions. In this case, we can see the distribution and number of ideas submitted over time as in Figures 1 and 3 and observe how contributions mainly come from few countries. This could possibly suggest that only a few researchers actively contributed to the challenge by engaging with schools, soliciting, and gathering submissions.

We can speculate, based on the lessons learned from analyzing similar initiatives, that the reasons behind this lack of involvement could be the little familiarity with and popularity of the initiative, perhaps linked to low awareness of its previous editions and a difficulty in understanding how it could have a direct impact and relevance on own research path. Thus, it is important to be able to keep and **pass down the knowledge** from participants of past editions.

These issues all lead to involved parties not having clear benefits from participation, with an overall unbalance between cost and benefits when considering the difficulty in **engaging teachers** already busy with curriculum, These issues all lead to involved parties not having clear benefits from participation, with an overall unbalance between cost and benefits when considering the difficulty in **engaging teachers** already busy with curriculum, for instance in translating material describing the challenge and do the same for children's submissions too, and the distraction it could pose to children.

However, the same is true for researchers as well. While chairing the R&D competition is a significant undertaking in terms of time and responsibilities, the recognition is limited, and the number of submissions by adult researchers - that are based on children's ideas - is scarce, with some years only having 2 finalists whose papers are included in the proceedings: we look at a total of 12 papers produced by the R&D challenge finalist researchers from 2017 to 2022 – a total of 5 years excluding 2021 in which only the junior challenge was run. We can also find a WIP referring explicitly to the R&D challenge [325], that was presented as a poster in the 2022 edition of the IDC conference.

We could on turn interpret the fact that few countries, possibly research groups, keep appearing and contributing over different edition as a signal that **continuity and routine** are important for schools, children, and teachers. Once children and teachers had a rewarding experience with the challenge it is likely they would want to repeat it. The same could also be valid for researchers, that could see this opportunity as a way to reward the children and teachers they are collaborating with in other projects and give them a space to meet the rest of the IDC community while being recognised as an essential part of it.

Our research question served as a guide for our investigation and gave us the opportunity to keep a critical eye on the challenge's past, present, and future. As a result, we can offer a list of guidelines and best practices.

4.6 Proposed Guidelines and Best Practices

Starting from the issues and limitations that we uncovered in the previous section and grounded on the review of similar initiatives (see section on Other Challenges and Competitions), here we propose some guidelines and best practices to address them.

Promoting a wider participation and encouraging continuity

To achieve this goal, we propose reaching out directly to schools and other organisations, building a relationship and encouraging participation throughout the years. Researchers in the community who are interested in this topic should work together in a permanent committee to encourage participation from different countries and at all school levels - from elementary to high school. We recommend reaching out to schools who have participated in the past, and expanding the challenge to other countries as well. We also propose the development of a permanent website for the R&D challenge, where teachers and children can find previous years' challenges and submissions, making the challenge a year-round activity and making it easy to find all the relevant information in the same place, while also promoting the challenge through social media and newsletters, keeping teachers engaged and informed throughout the year.

Engaging teachers

As said before, when doing research at school with children and teachers the focus should be on giving something back to all the involved parties, and that is especially true in a case such as he R&D challenge, in which we expect teachers to perform significant work from which they do not benefit at this time. While we should try to make it as easy as possible for teachers to take part in the challenge, the level of involvement should be up to each teacher: while many of them are overworked and do not wish to add additional responsibilities to their plate, teachers who wish to be more involved in the challenge should be able to do so, and be recognized as true partners by the researchers. Teachers' involvement could include reaching out to other schools in their area, creating activity guides to help other teachers run the activity, as well as actually participate in the second part of the challenge together with adult researchers to build on children's ideas.

Running the activity and submitting drawings

To reduce the burden on teachers and ensure that the challenge is run in the same way all over the world, we propose writing a set of activity guides, tailored for different grades or age groups. This would have multiple benefits, as it would ensure consistency throughout the years and also make it easier for teachers to fit the activity during the school day.

Another current barrier to participation is the submission process, which is too time-intensive for many teachers: we recommend implementing a registration system in the already mentioned permanent website, to allow teachers to submit drawings in batches. Another advantage of such a system would also be the possibility to recall data from previous submissions, to make it easier for teachers who submit drawings by the same children over the years, or by children from the same schools, thus ensuring continuity.

Motivation for children

Children should also be more engaged in the challenge, and able to benefit from it as well. While, in the spirit of involving children in the design of initiatives meant for them, children can and should be directly involved in the betterment of the challenge, the first step in this direction would be making the challenge into a real competition, in which children of all ages can participate for the chance to win a prize, as that is an aspect that all competition and challenges have in common. While both in 2022 and in 2023 children's submissions were divided in two categories - up to 12 years old, and 12 to 17 years old - there is no clear difference in expectations and guidelines between the two categories, and the 2022 junior challenge required additional work to create a design concept based on one of the submitted drawings. While the split into two age categories is a good starting point, we propose a competition in which all submitted drawings will be judged by a jury of researchers and teachers, with winners being awarded recognition, prizes and trophies, so that children might be more motivated and engaged in the challenge.

While turning the challenge in a competition provide extrinsic motivation in children, other changes might also be useful in intrinsically motivate them: the analysis of the drawings revealed that children produced a richer variety of drawings when the theme of the challenge was more specific. Therefore, another avenue would also be to provide more specific challenge themes, in the form of real-life problems to tackle. Recognition is also another way to intrinsically motivate children, which could be achieved by the publication of previous years' submission in a permanent website, as mentioned before.

Passing down knowledge

As of now, previous years' challenges are not saved anywhere, and information about the number of submissions and finalists is also not available online; moreover, previous years' chairs are not always involved in subsequent editions of the challenge, and that makes it difficult to spot issues or problems, or just to pass down knowledge and best practices from one chair to another. While a permanent website would already be a step in the right direction, we also propose that each year the chair or chairs of the challenge should write a paper detailing their experience with the challenge, from how they chose a theme to the lessons learned during the challenge. By doing so, there would also be a tangible reward for chairs, who would get to publish a paper about their experience. We also propose to create a database of all previous submissions, available to all researchers.

Issue of language

While having a wide network of schools and institutions participating from many different countries would be an asset for the competition, this would also raise the issue of language. Although the competition is held in English and the results are presented in an English-speaking conference, in many countries it is not the primary language and many teachers - especially those who teach other subjects - do not speak English well.

We maintain that submitting entries to the challenge with a title and a description in English should still be a requirement, and we argue that this has successfully been done by many challenges and competitions throughout the world, even with the awareness that this would mean that many children's ideas would have to be translated. While not being the native language of many children, English is widely taught in schools, and we argue that involving ESL (English as a Second Language) teachers - both to translate younger children's ideas, and to assist older children and teenagers in translating their ideas themselves - would allow for a greater understandability in the drawings' descriptions, and also make the participation to the challenge a multidisciplinary activity for the class.

However, this would not solve the issue for libraries, coding clubs and other entities that do not necessarily have an English-speaking adult facilitator, therefore different accommodations should be made for those entities if and when needed, with the overall goal of reducing the burden on researchers and collaborators.

4.7 Conclusions

In this chapter we shared our analysis of and reflections on the past R&D challenges with the view of how it could turn into a true asset for the IDC community.

We aimed to show the enormous potential of such an initiative and argued that the R&D challenge is a chance that researchers, teachers, and children should not pass up. We believe it is our duty as researchers to make this opportunity as available and beneficial to all parties involved as we reasonably can. And because it embodies the values and principles of the IDC community, it should be treasured to develop into a reliable presence by possibly considering the guidelines and good practices highlighted above. We are aware of how much this will all cost in terms of time and effort, as we will need to strengthen and expand the current R&D challenge as well as plan for continued support to its future editions. Not to mention having to create, curate and keep a growing data set of drawings collected over time, complete with the metadata necessary to monitor changes in the perception children have of technology. Nonetheless, we are confident this is a worthwhile investment and the right direction to go for the IDC community. In keeping with the statement made in the IDC2016 Chairs' Welcome: "Children's voices will be a feature of the conference with a new Research and Design competition" [2], we want children's voices to continue being a feature and grow stronger by promoting inclusion, louder with more to say as children play different roles, and speak a variety of languages to embrace diversity.

In the next chapter, we will continue on the subject of children's inclusion in design, by performing a literature review on their involvement in the design process of technology, in terms of diversity and inclusion.

Chapter 5

Children's involvement in the design of technology throughout the years

5.1 Introduction

This chapter is based on our work, "*Children's involvement in the design of technology: a literature review*", which has been submitted to the International Journal of Child-Computer Interaction and is currently under review.

Participatory design was developed in Scandinavia in the 1970s to give workers the opportunity to develop systems together with researchers while retaining control over their work. [291]. As a type of research, it examines the tacit knowledge of people working with technology, i.e. the implicit, unwritten knowledge, what people know without being able to say it explicitly, with the aim of preserving it and creating technologies that fit into existing tacit knowledge and work processes [291].

Since its beginning, research on participatory design has grown significantly, going from "democracy at work" to "democratizing innovation" [38] as technology progresses and design activities reorient themselves from the workplace towards everyday life.

As technology became commonplace both at school and at home, children began to use it, but initially they were not involved in its design: Whenever a new product was developed, it was the parents and teachers who were asked what the children might need, like or want [83]. This began to change at the turn of the century, when children were involved in the design process in various roles, e.g. as users, testers, informants and design partners [83].

This also aligns with the principles expressed by the United Nations' Convention on the rights of the Child, according to which "*States Parties shall assure to* *the child who is capable of forming his or her own views the right to express those views freely in all matters affecting the child, the views of the child being given due weight in accordance with the age and maturity of the child*".

Since then, involving children in the design of technology meant for them has become commonplace. Many studies have not only advanced the state of the art - with new methods, reflections on ethical issues, experiences and theoretical contributions - but have also applied existing co-design techniques to investigate children's likes, dislikes and preferences in different areas.

In the late 1990s, when co-design with children was gaining popularity in research, it was believed that children aged 7 to 10 were the most effective design partners [83] as they could discuss their ideas verbally and were capable of abstract thinking while not having too many preconceived ideas about technology. However, times have changed a lot since then. Technology is becoming more widespread and children are starting to use it earlier and earlier: in 2010, a Dutch study reported that the majority of pre-school children (4 years old) were already able to start and play a game on a computer on their own or with the help of an adult [207], while a 2014 Turkish study reported that although pre-school children did not own smartphones, they regularly used their parents' devices, with some children using them to play games for up to 3-4 hours a day [110]. In 2020, the situation had changed drastically: according to an English study, 35% of children aged 3 to 5 already owned their own device (smartphone or tablet) and used it for an average of almost 2 hours a day [250].

On the other hand, the COVID-19 pandemic showed the other side of the coin: the worldwide school closures prompted educators to take measures to avoid disruption in children's education by using technological platforms and internet-based tools to enable students to learn remotely. However, not all children had the same opportunities to access remote learning platforms and tools. There was a significant digital divide not only in majority world countries such as Nigeria, Brazil, Pakistan, Kenya, South Africa and Turkey [21, 182], but also in developed countries such as the UK and the US [62, 187].

Just as children's use of technology has changed over time, co-design has had to change and evolve to keep up with the times. Research is now more careful in involving not only children of all ages, but also children with different special needs and from different socio-economic backgrounds. The aim of this chapter is therefore to analyse the current state of research on co-design with children, both in terms of the inclusion of children and methods, techniques and practical applications, in order to identify gaps and opportunities for future research. It aims to answer **RQ 1.3** What is the extent of published research focused on collaborative design with children, in terms of methods, diversity and inclusion? To answer this question, we performed a review of the literature on this topic, as furtherly detailed in the next section.

5.2 Methodology

We performed a survey of the literature on the topic of collaborative design and children; to do so, we searched the two main relevant libraries - the ACM (Association for Computing Machinery) library and the Science Direct library with the keywords *("participatory design" OR "co-design" OR "collaborative design" OR "design") AND "children"*, searching in the author keywords, the article title and abstract. Subsequently, we screened the retrieved manuscripts according to the eligibility criteria detailed below, and analysed - both quantitatively and qualitatively - the papers included in the review.

5.2.1 Eligibility Criteria

The following inclusion and exclusion criteria were applied to the papers identified in the search:

Inclusion criteria:

- Peer-reviewed
- Full papers or short papers
- Papers relevant to the topic of involving children in the design of technology, either reporting on a study whose methodology was collaborative design with children as participants, methods and techniques for co-designing, theoretical contributions, reflections, guidelines and lessons learned, or literature reviews about co-designing with children

Exclusion criteria:

- Papers written in languages other than English
- Doctoral consortium papers, work in progress papers, posters, theses and workshop papers
- Grey literature (not peer-reviewed, such as newspaper articles, government reports etc.)

5.2.2 Information sources

We searched the ACM (Association for Computing Machinery) library and the Science Direct library. The former allowed us to retrieve results from the proceedings of the most relevant conferences in the field of Child-Computer Interaction and Human-Computer interaction, such as IDC (Interaction Design and Children), CHI (Conference on Human Factors in Computing Systems), while the latter allowed us to retrieve results from the most relevant journals in the field, such as International Journal of Child-Computer Interaction, Computers & Education, International Journal of Human-Computer Studies, Computers in Human Behavior, Interacting with Computers.

The search was conducted in March 2024.

5.2.3 Search strategies

To retrieve papers about collaborative design and children, we searched for *("participatory design" OR "co-design" OR "collaborative design" OR "design") AND "children"* as keywords for the article title and abstract. We knew that, by adding "design" as a keyword by itself, we would also retrieve papers about designing technology *for* children, without the involvement of children, and also that this set of keywords would retrieve papers about co-designing technology for children with adult stakeholders (parents, teachers, caretakers) as design partners. We decided to cast a wider net at this stage, and screen non-relevant papers at a later stage.

We retrieved 264 results from the ACM library, and 67 results from the Science Direct database, for a total of 331 manuscripts identified in this first phase.

5.2.4 Selection Process

The retrieved results were imported into Rayyan - a web-based tool for systematic literature reviews - together with their full texts for further screening and analysis. Next, we excluded papers in a foreign language (n=4), publications of the wrong type (n=38), irrelevant papers (n=61), for a total of 227 included manuscripts; the literature search process and outcomes are shown in Figure 5.1. The complete list of included papers is available in Appendix A.

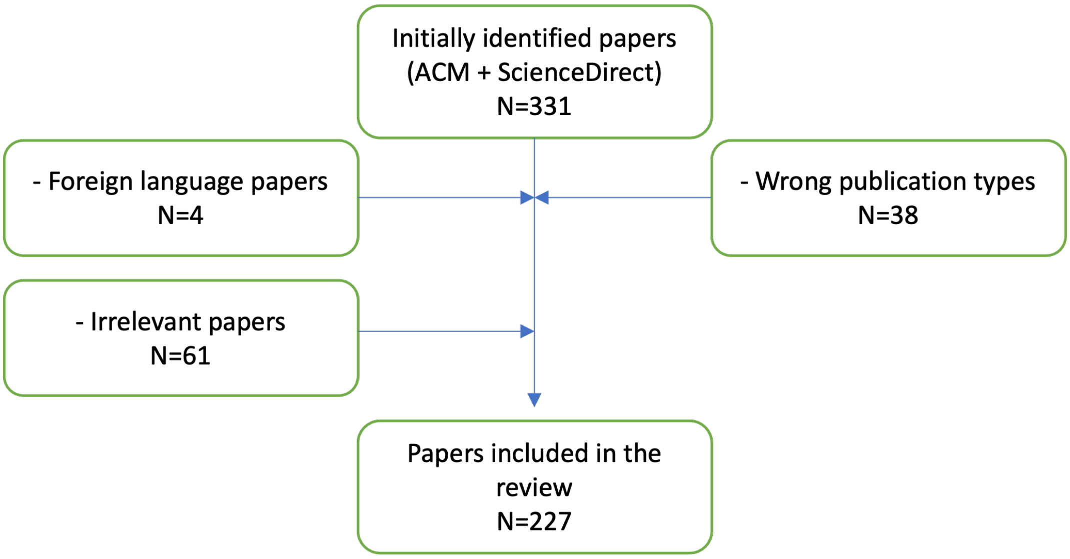

Figure 5.1. Literature search process and outcomes

5.2.5 Data collection process

The 227 studies included in the review were exported from Rayyan in a csv format, which was used to populate an Excel spreadsheet, to which we appended additional columns to the spreadsheet in order to collect additional data about the papers. Data was extracted by a single author by reading the full text of the paper. We did not seek any additional information from paper authors, as all the relevant information was available in the published texts.

5.2.6 Data items

The data exported from Rayyan were used to populate the columns Authors, Title, Keywords and Year of publication. Then, for each paper, we analysed the section that reported the research goals or research questions. Using this information as a guideline, we categorised the papers according to the research goal. To do so, we followed a thematic analysis approach, by coding each section and then consolidating the codes in categories.

We obtained the following categories:

- **Theoretical contributions**: papers whose contribution consisted in frameworks, insights, lessons learned, recommendation, reflections or challenges.
- **Methodological contributions**: papers whose contribution consisted in

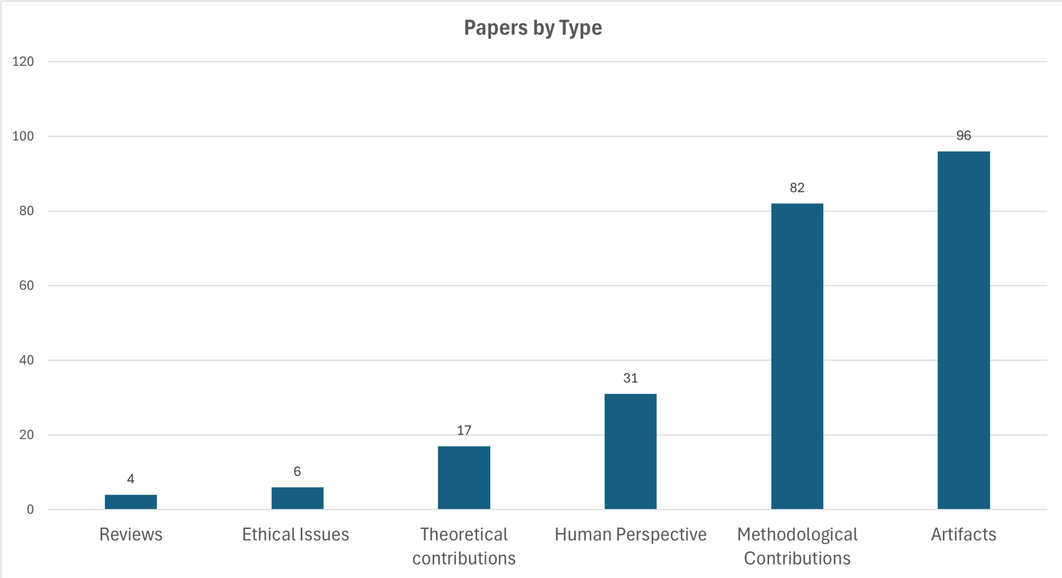

Figure 5.2. N. of published papers by type

new methods, tools, approaches to involve children in the design of technology, or in the application of existing methods to new demographics.

- **Human Dimension**: papers whose contribution regarded the participants' role or identity in design, group dynamics, user gains, learning opportunities and goals, engagement and participation.
- **Ethical issues**: papers whose contribution consisted in the exploration of ethical issues regarding the involvement of children in design.
- **Review**: literature reviews on the topic of designing with children.
- **Artifacts**: papers whose contribution was the outcome of the design process.

Some papers were classified as belonging to two or more categories, for example if the contributions were both the outcome of the design process and the exploration of a new method. Figure 5.2 shows the outcome of this classification.

Subsequently, for each paper we analysed the section that reported the role children had in the design, either explicitly discussed or by reporting on the activities conducted with the children. We started by considering Druin's categorisation of children's role in the design process as users, testers, informants and design partners [81]; however, some papers explicitly defined other roles for

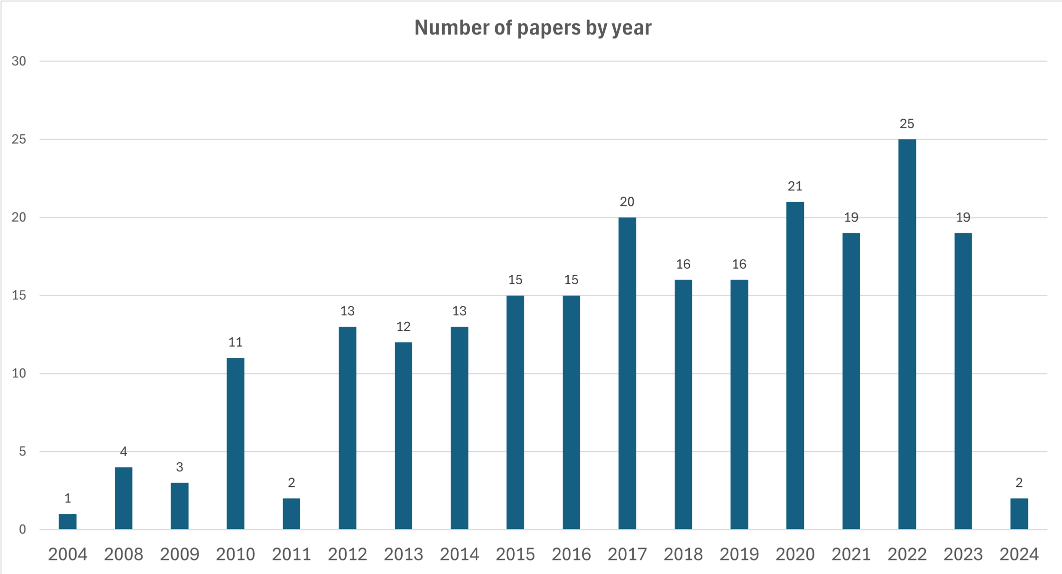

Figure 5.3. N. of published papers by year

the children, such as "enhanced informant" or "process designer", and meta-roles such "protagonist" ; we coded those as "other", and will discuss them later on; in other cases, the children's role was not explicitly delineated, and could not be determined by the activities performed with the children, in which case we categorised it as "unclear".

Finally, for each paper we annotated:

- The number of children involved in the study
- The age range of the children involved in the study
- Whether children with special needs had been involved in the study, and the specific nature of those special needs.

After collecting all these data, we began our analysis.

5.3 Analysis

5.3.1 Publication trends

The earliest retrieved article was published in 2004 [149], and it was the only article retrieved for that year. The extend of published research remained low

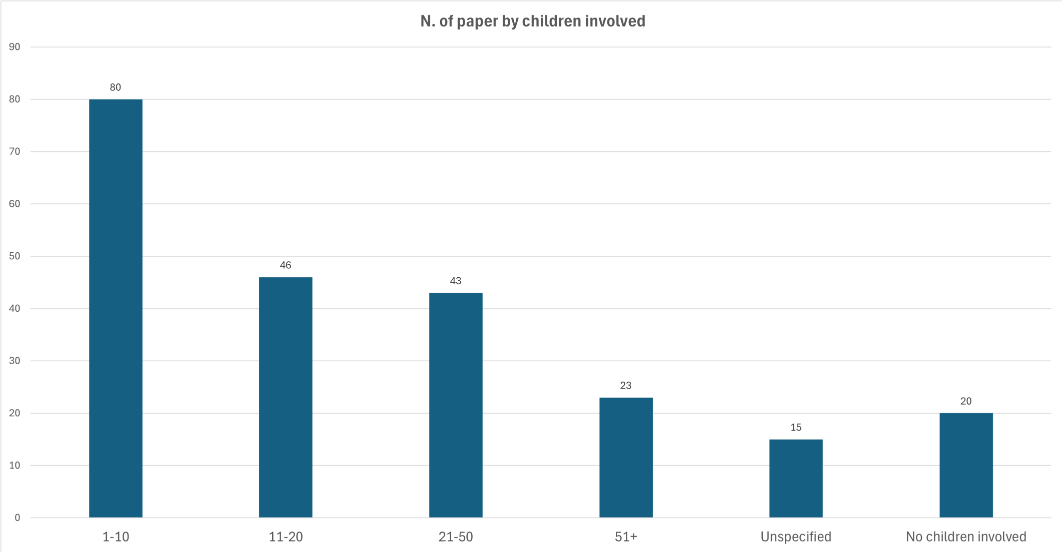

Figure 5.4. N. of published papers by number of children involved

until 2009, with less than 5 papers per year, and started growing in 2010, as shown in Figure 5.3. This shows that interest in involving children in the design of technology grew from the late 90s to this day.

Figure 5.2 shows that, *for almost half the papers in the dataset - 96 out of 227 - the research goal lies in the artifact produced by the design process*; we will not further analyse these papers as they do not contribute to advancing the field of collaborative design with children, however their presence - and their prevalence - shows that involving children in the design of technology is a frequent occurrence in Human-Computer Interaction. Four papers consist in literature reviews related to the topic of collaborative design with children, analysing different facets of the subject such as the involvement of children with special needs [34, 40], methods and techniques [313] and design for families [148]; those will also not be furtherly analysed, but accounted for in terms of previous efforts in a similar direction than the one we follow here.

As shown in Figure 5.4, almost half of the retrieved papers (126 out of 227) describe studies involving 20 children or less, with only 23 papers involving more than 50 children (although usually not all at the same time). In 20 papers children were not involved at all, while 15 papers do not specify the exact number of children involved.

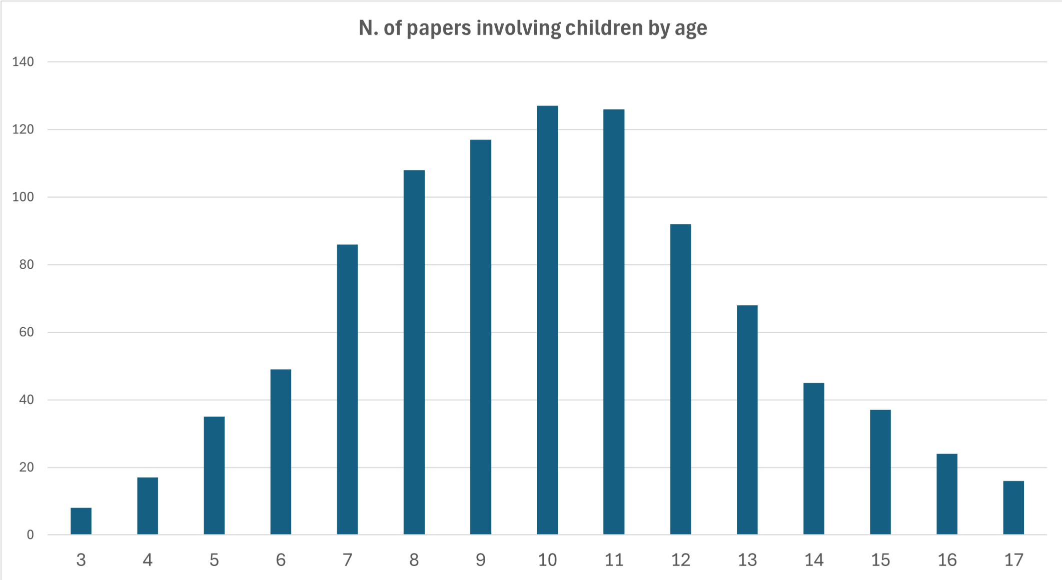

Figure 5.5. N. of published papers involving children of different ages

5.3.2 Children's inclusion by age

The most studied population group is school-age children (7-12 years), who were involved in 167 papers, which is consistent with Druin's findings that this age group is the most suitable for co-designing activities [83]. Teenagers are involved in 75 studies, while preschoolers are involved in 56 studies; however, 44 of those papers also involved school-aged children, meaning that they did not focus on preschoolers as a specific age group, and 15 involved teenagers as well, casting an even wider net.

Figures 5.5 and 5.6 shows the number of published papers by demographics of the children involved, both for each age and for each age range (preschoolers, school-aged children and teenagers).

These data show not only that *preschool children are underrepresented in research, but also that their inclusion as co-designers has only recently begun, with 8 out of 12 papers that include them as a distinct population group were published between 2015 and today.*

Teenagers are also underrepresented and have only been included in recent years, with 12 out of 16 articles that include them as a distinct population group were published in 2015 or later.

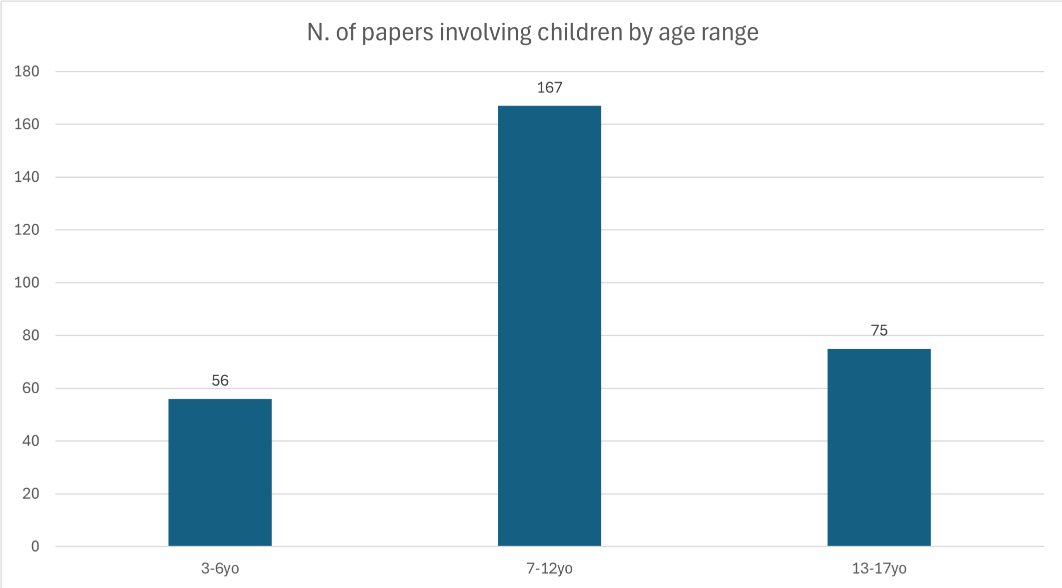

Figure 5.6. N. of published papers involving children of different age ranges

5.3.3 Inclusion of children with special needs

While most of the articles (N=167) concern children without special needs, children with special needs are also represented in the articles found. The most represented special need is autism (N=34), with all other forms of disabilities represented in less than 10 papers each; some papers include children with different special needs, such as Autism and ADHD, and as such they are counted in both categories.

However, the percentage of articles that include children with disabilities in the data set (see Table 1 and Figure 7) does not correlate with the actual prevalence of specific disabilities and developmental disorders in children: For children, the most common disability at the global level is hearing loss, followed by intellectual developmental disabilities, ADHD, visual impairment, and ASD; even when considering only high-income countries, ADHD, hearing loss and vision loss are all more prevalent than ASD [235]. In our dataset, only 7 papers involve children with ADHD, 4 papers involve Deaf and Hard-of-Hearing children and 8 papers involve children with Intellectual Disability. *Thus, there is not an equal representation of various disabilities and special needs*.

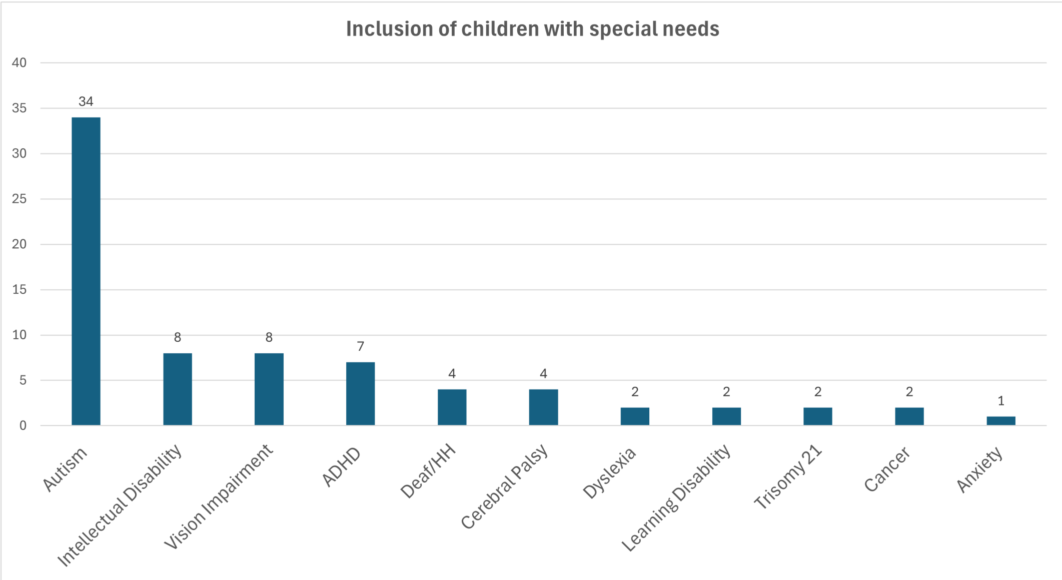

Figure 5.7. N. of published papers involving children with special needs

Special Needs	**N. papers**
No special needs	167
Autistic Children	34
Intellectual Disabilities	8
Vision Impairment	8
ADHD	7
Deaf/Hard of Hearing	4
Cerebral Palsy	4
Dyslexia	2
Learning Disabilities	2
Trisomy 21	2
Cancer	2
Antiety	1

Table 5.1. N. of papers involving children with and without special needs.

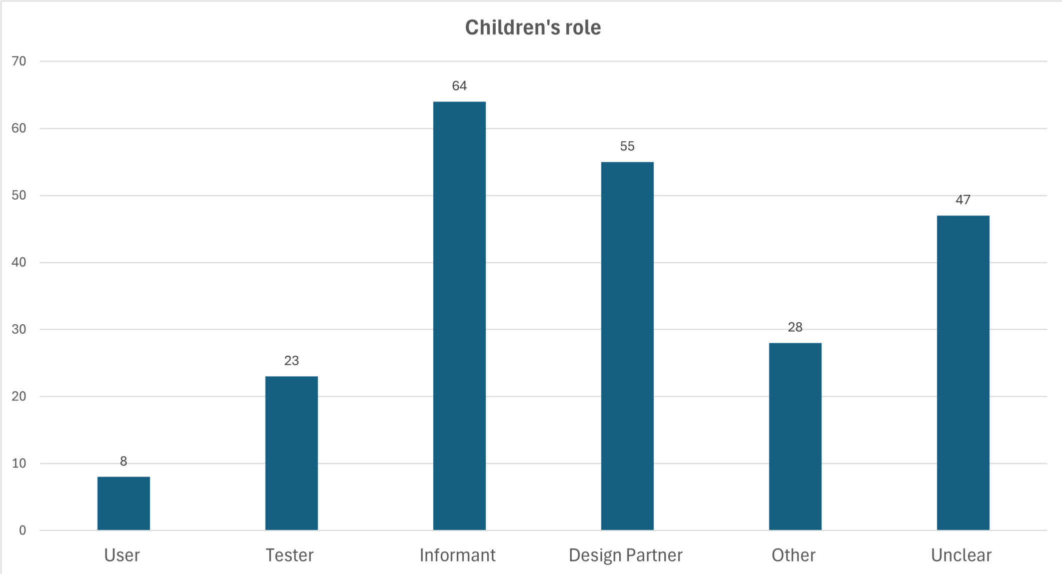

Figure 5.8. N. of published papers involving children in a specific role

5.3.4 Children's role in the design process

The majority of papers (150 out of 227) described - either explicitly or implicitly - children as having one or more of the roles identified by Druin [81], such as user, tester, informant or design partner; however, 28 papers explicitly identified children as having other roles - such as protagonist or process designer - and in 47 papers the children's role was unclear - meaning that, based on the information provided in the paper, we did not feel confident in classifying the children as having a specific role. Figure 5.8 shows the distribution of children's roles among the papers.

While the number of papers involving children as users (N=8) or testers (N=23) is low, the role of informant is the most frequent (N=64); some papers explain this choice by mentioning the high level of effort and long-term commitment that being a design partner would require from a child [149], the short amount of time in which the researchers could interact with the children [243], the large number of requirements which made it unfeasible to involve children from the beginning [341], or the need not to overexert a vulnerable user group [268]. In many cases, however, the role of informant was not explicitly mentioned, and we made the determination based on whether the process was described as adult-led, and on the activities in which the children participated.

Moreover, the distinction between informant and design partner is not always clear; while Druin lists specific methods - such as Cooperative Inquiry - as being used to involve children as design partners, the main distinction consists in the child being an equal stakeholder in the design of technology, part of the research and design team throughout the whole process. However, some of the papers that explicitly mentioned children as design partners only reported their participation in a very limited number of sessions, or were unclear about the number of sessions in which children had participated [8, 72, 109, 114, 123, 159, 165, 181, 204, 225, 231, 244, 327, 360]. In all, 55 papers identified the children as design partners; *it is interesting to note that only 13 of those papers involved more than 20 children, while roughly half of them - 27 out of 55 - involved 10 children or less, suggesting that children can have a more impactful role in the design process when in small groups. Moreover, children with special needs and very young children are rarely involved as design partners, with children with special needs being involved only in 7 of 55 papers, and preschoolers never being involved as a specific population group*.

Children can sometimes also take a role between informant and design partner, as is the case in [171], in which they are described as "enhanced informants".

Some papers described the children's involvement in the design process in a different way, such as "co-designers", "designers", "researchers" or "co-researchers" [11, 23, 55, 74, 119, 128, 154, 166, 167, 213, 216, 283, 294, 314, 329, 377], "protagonist" [59, 146, 156, 199], ore more generically describe the design process as child-led [122, 201, 290]. Some other roles are defined as "inventor" [352] or "process designer" [275, 277], as well as "match-maker" [277] or "group work manager [180]. While each paper gives their own definition of these role, they are still very infrequently used in the literature.

5.3.5 The Human Dimension in designing with children: empowerment, motivation, roles, goals, user gains and group dynamics

Papers focusing on the human dimension in collaborative design make up this category, which can be further subdivided in several subcategories: paper focusing on children's participation in design, on children' and adults' roles in design, on group and power dynamics between participants, and on stakeholders' gains from the design process. In this section, we will provide an overview of the contributions of the papers in these categories.

Users' participation in design has always been a political topic, born out of the idea of democracy. The papers in this category discuss this very issue: Iversen and Dindler propose an Utopian agenda to explicitly manifest these values in CCI research [153], while Schepers et al. [277] discuss participation in the context of long-term, sustained participatory design, advocating for this approach over the more typical short-term participatory design studies.

Going more in depth, some papers seek to promote participation of vulnerable children, such as teenagers with ASD [377] or disadvantaged children [55], as well as discussing specific situations such as after school centres [314] or the impact of the COVID-19 pandemic that led to online participatory design [65].

While not explicitly declared as a research goal, the issue of children's participation in design is central to the topic of participatory design, and many papers that do not fall in this category do, nevertheless, touch on it, asking questions such as "How can we involve this specific population in design?". Some example of this are [101, 341], focusing respectively on children with vision impairment and autistic children.

Some papers aim to specifically describe children's role in design, for example suggesting [156] and then expanding on the protagonist role [146, 199], with a focus on children's empowerment and the political dimension of participatory design; the aim for more genuine forms of participation also leads to defining the role of the process designer [275] as well as other roles such as group-work manager [180], match-maker or mediator [277].

While the paper that first suggest the definition of child as a protagonist is one of the most cited in the dataset, with 296 citations as of May 2024, papers describing other roles have not had the same success, and these new roles have not been widely adopted in the literature.

However, four papers also focus on the adults involved in co-design with children, with a significant overlap with the theme of power dynamics: Yip et al. [369] discuss the adult-child partnership in design as adults and children having complementary roles, such as user-observer, tester-test facilitator, informant-interpreter, and adult-child design partner, and describe four dimensions - facilitation, relationship building, design-by-doing, and elaboration - that are dynamic and exist in a spectrum from unbalanced to balanced. Dreessen and Schepers focus on the back-stage activities of adults involved in co-design [78]. Barendregt et al. [28] also focus on back-stage work and on the balance of designers and teaching staff. Cumbo, Eriksson and Iversen propose the "least-adult" role in participatory design [70], as an approach to engage children in a child-led context.

In general, the idea that researchers should share power with participants is at the core of participatory design [333]; this is particularly difficult when working with children, as there is an inherent power differential with adults. While children can, and often do find ways to exercise power during design session - such as subtly or forcefully shifting conversations and activities - exercising power is not the same as being empowered, and that can be especially true for developmentally diverse children [333]. At the same time, children respond better to power-sharing choices such as not asking them to raise their hands to speak, or avoid controlling how they interact with the materials [223].

However, researchers are not necessarily the only adults involved in designing with children; when children are involved in design together with their parents, there is an additional layer of power and group dynamics that need to be taken into consideration, as parents often need more time to adapt to the role of design partner; at the same time, involving parents and children in co-design together can reveal interesting insights into the relationships and tensions in the family [368].

Other papers analyse the group dynamics among children involved in the design process, such as Mechelen, Laenen and Abeele [331], that propose the use of Social Interdependence Theory to anticipate on challenges in the group dynamics among children, and Vaajakallio, Lee and Mattelmäki [318] that reflect on the challenge children face when collaborating creatively with one another.

Finally, as researchers there is another important dimension to consider when designing with children: what do children gain from the co-design experience? Schepers, Dreessen and Zaman [276] identify three benefits for child participants, namely developing self-esteem, learning-by-doing, and broadening their horizons; these correspond broadly to the perceived gains identified by former participants in co-design teams - collaboration, communication, design process knowledge, and confidence [210]. Introducing learning goals in participatory design activities can also be an important factor in making sure children obtain a benefit from their participation, even if they are not explicitly communicated to the children, who still learn several skills by participating in co-design activities [41]. Learning outcomes are not only a gain for participants, but can also help them contribute more valuable insights to the design [32]. However, defining good learning goals is hard, and requires researchers to carefully craft activities in order to meet such goals [27].

Overall, the human dimension in participatory design with children is a rich, diverse dimension that aim to put participants at the center of the design process.

5.3.6 An overview of methods, tools and techniques

Throughout the years, many methods and tools for collaborative design with children have been proposed in the literature; some of these have had a significant impact on the field of Child-Computer Interaction, with a high citation count that reflects their influence on the community. While this category is the second largest in our dataset, with 81 papers, we will concentrate on the most influential methods. The first of these is Cooperative Inquiry [121], which has been widely adopted throughout the world since its creation, and has also been expanded and refined several times, and has also been adapted to be used with children with and without subject and design knowledge [366], and extended with the introduction of Ecological Inquiry [285]. Another widely adopted technique is Layered Elaboration [343], which allows for asynchronous co-design.

A technique has been proposed to support the co-design of serious games [167], while MakerWear, a wearable construction kit, has been used to engage children in the design of wearables [165].

It is interesting to note that many of the most cited papers in this category discuss methods and approaches to involve children with special needs in design - such as children with ASD [35, 104, 105, 202, 203, 240] or other neurodivergences [36], showing that these methods can also be useful when dealing with typically developing children. This can be seen as an extension of the concept of inclusive design, according to which focusing on designing for people with disabilities brings benefits to everyone [130].

Following with the theme of inclusion, the TRAck method has been developed to ensure that researchers consider all children's contributions equally [258].

It is worth noting that a significant number of papers in this categories only have a small citation count, with 30 papers out of 82 having 20 citations or less; *this shows that there is a vast number of underused methods and approaches of which the CCI community could, and should make full use*.

5.3.7 Ethics in co-design with children

When working with users in general and more so with children, ethics must be at the forefront; because of this, papers concerning ethical issues represent a very important, even if small part of this dataset. McNally et al [209] discuss the ethical implications of co-designing with children by asking former child participants for their perspectives, identifying four main areas for researchers to consider when conducting research with children: anonimity, consent and dissent, power structures and use of ideas. Lee et al. [184] delve into the exploration of co-design activities in an online space, as this shift was made necessary by the COVID-19 pandemic, and identify three other ethical considerations that specifically pertain to the situation: the issue of screen time, and how to organise the activities while ensuring the children's well-being; privacy, which needs to be navigated collaboratively with families; and finally the issue of participation, with children with less access to technology and bandwidth struggling with online activities.

When children - or even researchers - come from diverse background, gender and ethnicity can also become an important issues, and researchers have to actively work to construct rules of engagement to prioritise children's well-being, as well as increase intercultural sensibility among children [315]. Other vulnerable user groups such as children with disabilities [290] or with cancer [192] also merit additional ethical considerations, as researchers have to negotiate multiple agendas - especially when children's caregivers or health care workers are present. The principle of "do no harm" might sometimes lead to include children that are not part of the vulnerable group, such as including healthy children when designing for children with cancer.

The ethical issues related to co-design are manifold and deserve more space, as some population groups - such as very young children - are still underrepresented.

5.3.8 Theoretical contributions

This category includes frameworks, reflections and insights. One of the most significant contributions in this category is the FACIT PD framework [345], created to aid researchers in choosing existing techniques for co-design, or developing new ones according to eight dimensions that relate to the design partners, goals and techniques. Other contributions in this category focus on motivating children [332], understanding how children conceptualise intelligent interfaces [359] and discussing how children imitate one another during participatory design workshops [179], as well as discussing phenomenology as a framework for participatory design [100]. The issue of including children with disabilities is also represented in this category, with Holone and Herstad [139] discussing the challenges of implementing Participatory Design with children with severe disabilities.

5.4 Biases and Limitations

As we searched the ACM (Association for Computing Machinery) library and the Science Direct library and only included English language papers in this review, we can say that we have an Anglo-centric perspective, which can certainly lead to bias.

Furthermore, due to the large size of our initial dataset - as well as the inherent difficulties in obtaining the full text of articles from different libraries - we have refrained from searching for forward and backward references that might have enabled the inclusion of further important literature.

However, we believe that this review will fill a gap in the literature as, as far as we know, there has been no other systematic literature review on the broad topic of collaborative design with children.

5.5 Conclusions

In this paper we have reviewed the literature on participatory design with children. Although this field has grown considerably in recent decades, there are still gaps that need to be filled, especially in terms of the representation of children of different ages and with special needs. In particular, young children and adolescents are still underrepresented, while Deaf and Hard-of-Hearing children and children with visual impairments having been given little attention when compared to the global prevalence of such conditions.

Although Druin has been advocating for the inclusion of children as equal stakeholders in the development of technology for more than 20 years [81], the full participation of children as design partners is still not as widely accepted as we could expect. In many works, children are only involved as informants or testers or are only engaged in the design process for a limited time. In addition, pre-school children and children with special needs are rarely included as design partners. This suggests that the inclusion of these underrepresented user groups as design partners could be an important future direction for PD and CCI research at large.

At the same time, our review of methods and tools showed that many methods, once developed, are rarely used in further research; reasons for that should be further investigated in a separate study. This suggests that there is a wealth of knowledge in this area that researchers could draw on to further advance the field of PD with children.

However, the centrality of theoretical contributions and ethical discourse pertaining to the research area of participatory design involving children cannot be overstated. Though their quantity may be limited, research addressing these aspects ought to serve as the fundamental underpinning guiding researchers in the formulation of novel methodologies and approaches, ensuring their validation from both theoretical and ethical standpoints.

This concludes the theoretical part of this dissertation. The next four chapters will consist of the applied part of my work, the participatory design and evaluation of an interactive storytelling tool for emergent readers.

Part II

Co-designing a storytelling tool for emergent readers

Chapter 6

Children's preferences and wishes for storytelling tools

6.1 Introduction

In this chapter, we describe the exploratory study that created the basis for the later design of ROBIN, a storytelling tool for emergent readers. It is based on our work presented at the Nordic Human-Computer Interaction Conference (NordiCHI) conference in 2022, "*This book is magical!*"*: exploring emergent readers' preferences and wishes for storytelling tools.* [322].

As already mentioned, this doctoral dissertation focuses on younger children, aged 4 to 6 years old, who are becoming users of technology in their own right, both for educational and entertaining purposes. While parents often have a good attitude towards the use of technology for learning purposes [49, 237], digital play is not as popular and it was in fact shown to be the least preferred option among different type of play [147]. Therefore, technology designed for children should be not only entertaining but also educational, to respect parents' wishes and preferences for their children and so favour the dissemination of and growth of innovative solutions.

The aim of the exploratory study is to gain a sense of how children interact with different kinds of books and storytelling tools, while later chapters will discuss the extraction of user requirements and the design and evaluation of a prototype.

After recruiting a small group of children aged 4 to 6 years old, we met with them weekly for two months, engaging them in specific activities, both with and without technology, such as reading traditional books, reading game-books, and playing with various toys designed to tell them stories or help them create stories.

As we built a relationship with the children, we relied on direct observations and on the analysis of the drawings produced by the children during the activities. The analysis of our data allowed us not only to extract requirements for the future design of prototypes, but also to gain a deeper insight on how to conduct co-design sessions with children in this age range, and to answer the following research question: **RQ 2.1** What kind of storytelling activities can engage emergent readers and meet their needs and wishes, and what design insight can we learn from that?

6.2 Methodology

6.2.1 Recruitment

A local children's library supplied us with a space to conduct our sessions and circulated an announcement to recruit children using their own mailing list, composed of all the parents that had previously registered at the library. The announcement consisted in a brief presentation of our project, and a consent form, approved by the ethics committee of our university, to be signed by parents, asking for the child's age and the school they attended, and to consent to the audio-video registration of the sessions. We did not operate any sort of selection among the participants; the first 12 children who registered were the ones involved in the project. While we were originally planning for a smaller group, around 6-8 children, we decided to accept a higher number of requests to account for unplanned absences (due to illness or other reasons). We also included two slightly younger children (around 3y 6m old) to accommodate sibling groups attending together. There were also two children who joined our project after the first session, upping the total number of participants to 14. As we had imagined, not all children participated to all sessions; however, we managed to establish a core of children who attended regularly. Table 6.1 shows the ages and gender of the children, and the sessions in which they participated. Some of the children only participated in one session, and one did not come to any session, so we did not include them in our analysis.

6.2.2 Setting

We conducted 6 sessions, all taking place in a separate room that was offered to us by the library. The room was comfortable, large and quiet, offering the possibility to project content on a spacious white wall, however it had very big glass

Id	Gender	Age	S1	S2	S3	S4	S5	S6
C1	F	4y 6m	Yes	Yes	No	Yes	No	No
C2	M	5y 8m	Yes	Yes	No	No	No	No
C3	M	4y 3m	Yes	Yes	No	No	No	No
C4	M	4y 8m	Yes	Yes	Yes	Yes	No	Yes
C5	M	6y	Yes	Yes	Yes	Yes	No	No
C6	F	3y 7m	No	No	Yes	Yes	Yes	Yes
C7	F	5y 4m	No	No	Yes	Yes	Yes	Yes
C8	F	4y 7m	Yes	Yes	Yes	Yes	No	Yes
C9	F	5y 11m	Yes	Yes	Yes	Yes	No	No
C10	F	4y 9m	No	No	No	No	No	No
C11	F	3y 6m	No	No	Yes	No	Yes	Yes
C12	F	5y 4m	No	No	No	Yes	No	No
C13	F	4y 9m	No	Yes	No	Yes	Yes	Yes
C14	F	5y 7m	No	No	No	No	No	Yes

Table 6.1. Id, gender and age of the children at the beginning of the study, and participation in each of the sessions

windows that proved to be a distraction, as people – both adults and children – were often passing by the windows, capturing the attention of the children. The sessions took place in the afternoon, around an hour after the end of the school day, to allow time for children to have a snack and relax after school. This was suggested by the library volunteers, as it was near the usual time when children usually came to the library with their parents. We started the first session by introducing ourselves and then asking each child to introduce themselves; each of the following sessions started with a recap of the previous sessions, in which we asked the children what they remembered from the previous week. After that, we usually performed two activities per session, alternating different types of reading, and options with and without screens. At any given time, one researcher participated in the activity with the children, acting as the facilitator/adult reader, while at least one other researcher observed the activity and took notes. We kept to the established routine along the full length of the study. While most of the activities were performed by the whole group at the same time, for some of them we divided the children into smaller groups. When dividing the children in smaller groups, we tried to respect children's preferences - some of the children were already friends or classmates before the study - while at the same time creating groups with a certain degree of diversity in terms of ages and r

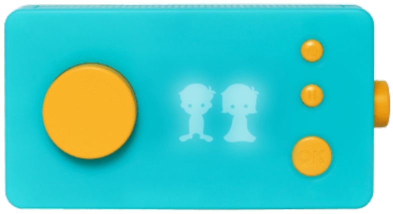

Figure 6.1. Lunii

gender, as compatible with the distribution of participating children. So, for example, a group might be composed by two couples of friends - one composed of two older children and one of two younger children - or when we had two boys participating in a session, we assigned each boy to a different group. All the sessions were recorded, with the consent of the children's parents or guardians.

6.2.3 Activities

A range of different activities was devised to engage children and help us better understand their needs when designing for enjoyable and educational reading experiences. From existing literature and interviews we conducted with experts in education and literature for children as well as storytellers, we extracted few heuristic rules for having engaging reading aloud sessions. These being: making sure the room is quiet, each child has a comfortable seat, possibly at the same level of the reader, that the story being read was suitable for their age. We also took inspiration from some techniques that were relayed to us by these professionals, such as using puppets, impersonating characters, acting out the scenes, asking questions and adding fun moments.

We offered the following activities:

Traditional books: we proposed two traditional books, chosen among the most popular for this age group.

Traditional Game-books: game-books are a form of interactive fiction in which the reader can choose different alternatives during the narration. These particular game-books were specifically marketed for the 4-6 age range.

Digital Game-Book (Prototype): This is a prototype mobile version of one of the game-books used during the session; it has hyperlinks that allowed to follow the chosen path just by touching the screen.

Lunii: Lunii [198] (Figure 6.1) is a radio-like toy that allows the children to choose some elements in a story (for example the protagonist, the setting and an item in the story) and then tells the story while children listen.

Silent Book: silent, or wordless books, are books with just pictures, without any text. Children and adults read them together to create narratives, by describing what happens in the pictures.

Storycubes: Storycubes [20] are a set of 9 dice representing various items and characters, that are rolled and then used to create a story.

Digital Storycubes: a digital version of the Storycubes.

Tellie: Tellie[60] (Figure 6.2) is a small robot with a white, soft body and different lights, that allows children to choose among different stories and songs. Tellie has two storytelling modes: one without questions, and another that asks children two questions for each story. After each story, Tellie plays a short song related to the story.

Augmented Book: A paper book that has QR codes in the pages, that led to videos and songs, with the different chapters being recited in the videos.

Session 1

During the first session, 7 children were present; the first activity involved a traditional book, which was read aloud by one adult reader to the children. The children sat on pillows on the ground, in a circle, with the adult also sat on the ground at the same level of the children. The reader frequently stopped to ask questions, such as "*What does this word mean?*", prompting the children to interact during the reading.

The second activity consisted in reading aloud a traditional game-book. Again, children sat in a circle while the adult read the book, asking them questions when it was time to choose, and also other questions such as "*What would you have done?*". The book was read twice, as the children wanted to see what other different stories they might have created, with the second reading slightly shorter than the first one as children were already familiar with the story. None of the children had read a game-book before, and all of them were fascinated and curious about how they worked. One children commented: "*This book is magical!*"

r

Figure 6.2. Tellie

Session 2

During this session, 11 children were present. The first activity in this session consisted in reading aloud a traditional book, also marketed for the specific age range of the children; seating arrangements were the same as the previous sessions, and again the adult reader engaged the children with questions and prompts. However, the book contained several "made-up words" which significantly limited the ability of the adult reader to ask the children about vocabulary. The second activity consisted in using Lunii. While children's activity while using Lunii, alone or with a parent or peer, has previously been analysed [14], it was unclear whether children would respond positively by listening to Lunii in a group. This activity was still led by an adult facilitator, who frequently stopped the recording to ask questions to the children, helping them relate the story to their everyday experiences. For example, when glasses were mentioned, the facilitator asked "*Do you know anyone who wears glasses?*".

Session 3

During this session, 7 children were present. The first activity consisted in "reading" a silent book, which was projected on a wall. The children sat on pillows in front of the wall where the story was projected, while the adult facilitator flipped through the pages, asking questions such as "*What do you think is hap-*

pening here?". During this activity, we noticed that the children who had already read the book at home were the most enthusiastic and eager to answer our question. This is in accordance with Trivette and al.'s findings [311], according tho whom repeated reading of the same book is associated with positive outcomes regarding both story comprehension and story-related vocabulary. At one point, the facilitator asked the children to get up and count how many items of a kind were there in the page, by pointing at them on the wall where the book was projected. All children participated in this activity, even the younger or more reserved ones, and they seemed very engaged by it. For the second activity, children were split in two group, respectively made of three and four children; each group played, in random order, with the Storycubes and the Storycubes mobile app. Each group had an adult facilitator, and children switched from one activity to the other after around 10 minutes. While children understood how the dice worked, and were curious both about the physical dice and the tablet, they did not want to tell a story themselves; however, they would answer questions if prompted, to build on stories started by the adult facilitators.

Session 4

During this session, 9 children were present. The first activity consisted in playing with Tellie. We started with the "no questions" mode, then with the "ask questions" mode. For this activity, children sat at a large table. The first mode did not elicit many comments or prompts by the children; however, they were very attentive and even the youngest ones kept the focus for the whole activity. After the activity, children were asked what the best part of using Tellie was. Almost all the children answered that the part that they had liked best was the song. The second mode - storytelling with questions - elicited more comments as children promptly answered the questions. Children reported liking this mode more than the first one. After the activity, we invited children to draw how they would like to change Tellie and make it better, to furtherly explore the potential of the Drawing Intervention Method used by Barendregt and Bekker to engage young children (4-7) in co-design and evaluation activities [26]. However, even if we followed the same procedure, the children struggled to understand what they were supposed to draw, resulting in many unrelated drawings, such as rainbows (the subject of the last story to which they had listened).

Only the older children produced drawings that were related to the task; one boy drew a robot, while a group of three girls drew ideas from one another, resulting in a set of three almost identical drawings, which were relevant to the task - they drew tablets - but did not show any real collaboration. Overall, we did not find the drawings to be sufficiently informative and agree with [26] who reckoned this method to be "probably more suitable for children from 6 years and up". However, as Xu, Read and Sheenan note [363], some elements in drawings are difficult to interpret, and extra annotations - either added by the children, or annotated by the researchers in response to clarification questions asked to the children - would go a long way in helping researchers interpret children's drawings.

Session 5

During this session, 4 children were present, and we only had one activity, in which we read the augmented book. The small size of the group allowed even the youngest children, who had struggled to pay attention and keep up with the group in the previous sessions, to speak and interact more. After the activity, we had some unstructured play time in which the children could choose a toy and play with it in autonomy.

Session 6

During this session, 7 children were present. We split them into two groups, respectively made of 4 and 3 children. Each group read, in random order, the paper version and an e-book version of the same game-book. The e-book version had been designed by us as an hypertext in which the pages, that had been scanned from the paper book and were as such identical in both versions, were dynamically linked in such a way as to follow the order in which they would be read in the paper version. So, instead of, for example, "going to the page with the seashell", the children could just touch the seashell on the screen and go to the correct page. The small group size allowed even the younger and shy children to interact a lot. Children were very curious about the paper book, wanting to touch it and flip the pages. The facilitator read the book, asking questions when there was a choice, and and also general questions. Both versions of the book - the paper and the digital - were read one page at a time, after which there was a choice that led to another page. A child, who had not attended Session 1 and therefore was not familiar with how game-books work, exclaimed that "*This page was not here before!*".

6.3 Analysis

6.3.1 Coding

First, we clustered the activities that we offered according to two different dimensions: their level of technology and their level of interactivity.

According to their level of technology, we had three categories:

- **Traditional storytelling (TS)**: books, either regular or game-books, read in their paper form by an adult to a group of children. This category also includes the physical StoryCubes.
- **Digitally assisted storytelling (DAS)**: books either projected on a screen or shown on a tablet, but still read by an adult to a group of children. This category also includes the StoryCubes app.
- **Digital storytelling (DS)**: the stories are read aloud by a specific toy, with or without interaction from the children.

According to their interactivity, we had also three categories:

- **Not interactive (N)**: there is no expected interaction between the facilitator/the toy and the children; any possible interaction depends on the skill of the facilitator. This category includes regular books - with or without the app, as it only showed videos, Lunii, and Tellie in the "no questions" mode.
- **Interactive (I)**: interaction is expected between the facilitator/the toy and the children, however the interaction is not guided in any way and depends on the skills of the facilitator. This category includes the silent book and the Storycubes - both regular and digital.
- **Guided Interaction (G)**: interaction is expected between the facilitator/the toy and the children; it is clear when and what the interaction should be, as it is explicitly written or presented. This category includes Tellie in the "ask questions" mode, and the game-books - both regular and digital.

For each activity, we recorded the categories, the number of children involved **(C)** and the length in minutes **(L)**.

To quantify children's engagement during an activity, we decided to analyse the recordings of our sessions and counting the utterances spoken by the children during the activity, either spontaneously or in response to the facilitator's prompts, using the following criteria:

- Each utterance spoken by each children was counted separately, even if different children repeated the same utterance.

- To be considered for further analysis, an utterance had to be different than a simple "Yes" or "No", but "yes" or "no" followed by other words were considered valid.

- To be considered for further analysis, an utterance had to be related either to the story content, or to the activity itself - for example, mentioning that they had previously read the story.

To account for the number of children and the length of the activities, we divided the number of utterances **(U)** by these two factors. These data are shown in Table 6.2.

6.3.2 Analysis

We performed both a quantitative and a qualitative analysis of the data that we obtained.

Quantitative analysis

First, we performed a series of one-tailed, unequal variance t-tests to examine the significance of the association between each category - both for the level of technology and interactivity dimension - and the number of utterances spoken by the children, normalised for the length of the activity and number of participants.

We found that traditional storytelling significantly outperformed non-traditional storytelling *(p=0,0125)* while digital storytelling elicited fewer utterances compared to the other levels of technology, digitally assisted and traditional *(p=0,009)*.

When analysing the activities by their level of interactivity, we found that, taken together, both kinds of interactive activities significantly outperformed non-interactive activities *(p=0,005)*. However, there was not any significant difference between interactive activities and activities with guided interaction.

Finally, we discovered a statistically significant association between the number of children involved in an activity and the amount of utterances spoken, with smaller groups (4 children or fewer) eliciting significantly more utterances than bigger groups *(p=0,048)*.

Sess.	Activity	Tech.	Inter.	C	L	U	U/C/L
1	Standard Book 1	TS	N	7	11,5	38	0,47
1	Standard Game-Book 1, story 1	TS	G	7	9	43	0,68
1	Standard Game-Book 1, story 2	TS	G	7	6	36	0,86
2	Standard Book 2	TS	N	11	9	29	0,29
2	Lunii	DS	N	11	12	48	0,36
3	Silent Book, projected on wall	DAS	I	7	26	110	0,6
3	Storycubes (regular) group 1, story 1	TS	I	4	4	14	0,88
3	Storycubes (regular) group 1, story 2	TS	I	4	3,5	10	0,71
3	Storycubes (regular) group 2, story 1	TS	I	3	3,5	7	0,67
3	Storycubes (regular) group 2, story 2	TS	I	3	3	5	0,56
3	Storycubes (app) group 1, story 1	DAS	I	4	5	11	0,55
3	Storycubes (app) group 1, story 2	DAS	I	4	4,5	10	0,56
3	Storycubes (app) group 2	DAS	I	3	7	6	0,29
4	Tellie, story 1 - no questions mode	DS	N	9	6	6	0,11
4	Tellie, story 2 - ask questions mode	DS	G	9	4	12	0,33
5	Augmented book with app	DAS	N	4	13	28	0,54
6	Standard Game-Book 2, group 1	TS	G	4	10	45	1,13
6	Digital Game-Book 2, group 1	DAS	G	4	10	34	0,85
6	Standard Game-Book 2, group 2	TS	G	3	9	20	0,74
6	Digital Game-Book 2, group 2	DAS	G	3	10	12	0,4

Table 6.2. Data captured from children's activities

Qualitative analysis

Our qualitative analysis is based on the direct observation of the children's behaviour during the sessions.

At least two researchers were involved during each session; after each session, each researcher went through the recording separately and took notes regarding the children's behaviour during the different activities. We then compared notes in brainstorming sessions, clustered the notes and identified common themes. In the end, three main themes appeared: children's preferences for specific toys, curiosity and frustrations, age and personality.

Children's preference for specific toys

The children with whom we worked went to the library with their parents on a regular basis; therefore, the fact that they had a strong interest in books was not surprising. While not yet being able to read independently, children were eager to explore the books with their hands, turning the pages and making sense of the content by looking at the pictures. However, they also took a keen interest to the tangible toys that we brought with us during the sessions, and specifically Tellie. While Tellie on its own did not elicit many utterances, when listening to it children remained focused on the activity. Also, when able to play independently with Tellie children used it to play songs, which they deemed "*the best part*". They also danced to Tellie's songs, and in general experienced the freedom of moving it around and taking it with them.

Curiosity and frustration

Children expressed a lot of curiosity towards books and tools they did not know; this was true both for the gamebooks and for Tellie. However, in several cases the curiosity led to frustration. In the case of the gamebooks, for example, there was only one possible path to get to the "happy" ending, and all other paths led back to the beginning of the book. After two or three tries, children began to express their frustration: for example, they said "*We have been here before!*" and "*Isn't there any new page? I want to see a new page*".

Tellie also caused frustration, although for different reasons. The model that we used during the sessions had both voice recognition and buttons, located on the robot's hands. Children, however, had trouble with the voice recognition, and often accidentally activated the button by playing with Tellie's hands, as they tended to touch it and explore it while it was narrating or playing music. This led to frustration, with the children complaining that Tellie "*was broken*".

Age and personality

While age is undoubtedly an important factor when involving young children, we found that, by working in small groups and taking the time to build a relationship with them, even younger children can successfully and enthusiastically participate in the activities. This was also true for older children who might be particularly shy; at one point, one child said "*I am glad that [Other child's name] is not here today, because he always says everything*". This made us aware of how we must be mindful of giving each child space to express themselves, without silencing the voices of the most extroverted children, but at the same time allowing also the more reserved ones to shine.

6.4 Discussion

We explored different activities and settings over a period of time as a means to allow children to adjust and get acquainted with us researchers, the tasks and activities as well as with the other children. The activities that attracted more interaction while also holding children's attention for longer were those involving game-books mediated by the adult readers, as they allowed for a constant back and forth between the adult reader and the children, within the fixed times in which interaction was expected.

We also noted that, during activities that were not designed for interaction such as standard book or silent book reading, the skill of the adult reader - whether it was a senior researchers with decades of experience, or a PhD student just starting out - also made a difference in children's engagement, as expert readers know how and when to ask questions, even when the activity is not designed for them. This consideration is of particular importance to us: as we explore the parent-child or child-child shared reading scenario, our goal is not to replace humans as storytellers but to help parents and caregivers who do not have the skill or time to choose stories and perform the role of narrator when reading with their children [336].

On a different note, it is worth pointing out how Tellie was a great favourite, and anytime children were left free to choose they would fight for it and showed to appreciate its cute appearance as well as the singing and colorful lights used to complement storytelling. Even if aesthetics played a role in the choice of the favourite toy, it did not seem to influence the level of engagement it generated during the reading experience. If anything, the cute aesthetics made it more likeable and approachable for children, a trait that is also supported by literature

[98, 137].

On a more general note, it emerged that activities conducted in smaller groups lead to more interaction, and also allowed younger and shy children to participate more fully. We also found that, as we got to know the children better and built a relationship with them, they started to become more forthcoming in expressing their opinions and engaging with us. Because of this, we feel that when working with younger children it is important to keep a good ratio of children to researchers, to allow for smaller groups and more one-to-one interaction, and to plan longer studies with more than one session.

While structured activities such as shared reading of a game-book engaged the children and were effective in getting them to express their opinions, they gave us limited insight in terms of children's actual wishes and preferences: these activities are still performed in a group and led by an adult, and as such did not empower children to fully be protagonists of the activity. They are, however, a good starting point that can inform the future design of interactive tools that can enhance the experience of parents and children, or siblings group reading together.

Unstructured activities, such as the free exploration of new tools in which we only participated as observers, allowed us to gain a deeper insight in how children play and tell stories. By allowing the children unstructured time to play and get to know the tools, we freed them from any expectation that might have come from our instructions, and this allowed us to gather honest and spontaneous feedback in the form of observations. They also allowed us to observe how young children collaborate spontaneously, so that we can also include that in the design of new tools. This lines up with [205]'s findings, according to which less structured sessions tend to elicit more reliable and valuable data.

Finally, we also explored the use of drawings to empower children to create design ideas. While children greatly enjoyed the activity, the younger children had difficulty producing drawings related to the topic - which was "*How would you make Tellie better? Can you draw a better Tellie?*". Children's drawings were related to the story to which they had just listened; as the story featured a rainbow, almost all children drew rainbows. Also, while children discussed what they were about to draw and took inspiration from one another, they did not work together on any drawing.

In spite of these challenges, we believe that even younger children can produce more informative drawings when given more structure, in the forms of outlines or shapes to be completed; this is also supported by research, as more adult facilitation is one of the ways in which design methods can be adapted to be used with younger children [97, 134]. It is also worth noting that one of the forms of self-expression that children enjoyed the most was the use of stickers, which they also used in their drawings, and that can furtherly be explored as a mean for children to express their creativity.

6.5 Limitations and challenges

The size of our sample, although ideal for collaborative design, is small and does not allow us to generalise our findings, even if very definite trends emerge. Moreover, the fact that we worked with a children's library to recruit the participants meant that we worked with children who regularly visited the library, and whose parents already have an interest in children's literature and storytelling. This is a very difficult limitation to overcome, as we need to involve parents in order to have access to the children, and parents who are not interested in children's books are unlikely to be interested in letting their children participate in such a study.

However, we plan to address this issue in the future by collaborating with local preschools, which would give us access to a more diverse community of children. The length of the study is also a limiting factor: with only six sessions, we spent a lot of time building a rapport with the children and getting to know them, but by the time we had done that, we already had to wrap up the study. We also propose to tackle this issue by continuing to host regular collaborative design sessions at the local library, with the hope that the same group of children will continue to attend.

Having a stable group of children attending our sessions could also help us address another limitation: due to the group setting of our activities, and the high level of variability in children's willingness to speak out during them, there is the possibility that our results could have been influenced not only by the content of the activity, but also by the different children that were participating in each session. While a certain level of variability is to be expected when offering free activities in a public setting such a library, we did manage to attract six children who attended regularly, meaning, four or more sessions out of six. In the future, we can take further steps to address this issue by working in a school setting, which will allow us to involve all the children in a class in our studies.

The biggest challenge that we encountered in our work was finding activities that could keep a group of children, all of different ages and personalities, engaged and in a state of flow, and so avoiding frustration and boredom. We believe that each child should be able to participate in design activities as a protagonist, and be empowered to create and share ideas; this means that we need to find activities that can allow younger or more reserved children to express themselves, while at the same time giving space to older, extroverted children to do the same without dominating the conversation.

6.6 Conclusions

The sessions that we conducted have provided us with some interesting insights to guide the design of our prototype. We also have a better appreciation of which design activities and methods work for eliciting children's feedback; specifically, while we plan to keep giving a big role to the researchers' direct observations, we will still look for novel methods to gather direct feedback from young children. One avenue that we will explore in the following chapters is the analysis of embodied actions during children's interaction with evaluation tools, an approach already broached by Sylla et al. [306], who studied *The Five Degrees of Happiness* and the *Sticky ladder* rating scales with preschoolers.

The next chapter will focus on the first iteration of the design of ROBIN.

Chapter 7

Designing ROBIN

7.1 Introduction

In this chapter, we will explore user requirements for a storytelling tool for emergent readers. It is based on our work presented at the N6th FabLearn Europe / MakeEd Conference 2022, *ROBIN - Designing a ROBot for Interactive Narratives to engage preschool children.* [323].

While some of the user requirements come from the co-design sessions detailed in the previous chapter, we also interviewed adult stakeholders to include their point of view in the design. To do so, in the spring of 2020 we conducted a series of contextual interviews with three parents and two preschool teachers (one of whom also had a child in preschool). Basing our findings both in the interviews and the co-design sessions, we built on the children's preferences for tangible, interactive tools and came to the design of a humanoid, interactive storytelling robot that we named ROBIN. This chapter aims to answer RQ 2.2 How can we co-design a storytelling toy for emergent readers, to use in an informal context at home?

7.2 Eliciting requirements

7.2.1 Interviewing parents and teachers

In the spring of 2020, after the first Covid-19 lockdown which had led to widespread school closures and the adoption of distance learning even in preschools, we had to adapt our methodology to the new situation; while our original goal was to conduct a full contextual inquiry, observing children during shared reading activities in school before interviewing teachers, due to the pandemic we were unable to conduct field studies and so we conducted interviews with three parents and two teachers, one of whom was also parent to a child in preschool, both Swiss and Italian. While our interviews were geared towards getting a sense of how schools had handled the distance learning, and what could have been done better, we obtained several interesting insights on how the parents and teachers looked at the use of technology by young children, which have provided the foundation for the design of ROBIN. Specifically:

- The heavy involvement of parents in their children's educational activities, such as printing activity worksheets, sending them back and having their children watch videos, was hard for many parents, as they were working from home and had to juggle both family and work responsibilities.

- Teachers reported that many parents wanted to limit their children's screen time; one parent confirmed that, since children were already using media much more than usual, they would prefer screen-free educational activities for their children.

- The pandemic widened the already present digital divide: we interviewed very involved parents, who had time, devices and Internet connection for their children to use; that is, however, not the reality for many families - as the teachers confirmed. To become widespread, innovations should be affordable, and rely as little as possible on parents' time and effort or on Internet connections.

These insights led us to consider three main user requirements for ROBIN:

- **Screen-free**: we designed ROBIN to be a tangible, screen free robot, with which children can interact by either touch or voice.

- **Ease of use**: in our vision, children should be able to interact with ROBIN independently, but also with a peer or adult if available.

- **Usable offline**: ROBIN should not be dependent on an Internet connection; while a connection might be used to download updates or new stories, it should not be needed for everyday use.

7.2.2 Co-designing with children

Collaborative design with younger children is no longer a novelty, and it has in fact been around for 20 years [97], with many co-design techniques both adapted for use with younger children [134] [26] and specifically designed for them [**?**] [29]. Cultural probes and contextual interviews have also been used to capture shared parent-child reading experiences in their homes [336].

Here, we discuss the co-design sessions detailed in the previous chapter, but from the perspective of eliciting user requirements.

During the first session, we conducted a direct observation of children's behaviour when involved in shared group activities with an adult. From the second session onward, we started each session by asking children what they remembered about the previous week's activities; after each session, we asked children which activity they had liked best, and why, and captured spontaneous comments and reflections in our field notes.

We also asked children to draw their ideas and wishes for a storytelling technology, following Barendregt's [26] results that showed how the Drawing Intervention method can be used to generate design ideas in younger children.

Combining our observations with the analysis of the recordings and the drawings, we got several insights; some of them are in agreement with previously reported findings, such as the fact that tools and books that are explicitly designed for interaction between adult reader and children - such as gamebooks - elicit more interactions than traditional books. This finding relates to Hiniker et al.'s [135] study about play between preschoolers and parents, who reported that, in the absence of an explicit design for shared participation in a playful activity, the experience tends to be solitary. Other findings are, however, unique to this study:

1. Some game-books caused frustration in cases where there was only one "right" path, that led to the correct ending of the story. In this case, children had to go back to the start of the book, twice or sometimes more, before getting to the ending. They started expressing frustration and asking to see "new" pages, or commenting that they had seen a specific page before. This effect was more marked with older children, as expected. Therefore, we believe that game-books with multiple "happy" endings are to be preferred.

2. In bigger groups, shy or younger children tend to speak less, as more extroverted or older children interact more. However, we succeeded in engaging younger children by working in smaller groups (2-4 children).

3. When allowed to choose, children were drawn to tangible toys, even more than they were to a tablet. During free play activities, children spontaneously chose either tangible toys or books, while seldom reaching for the tablet.

4.They were especially drawn to Tellie, a humanoid robot that told stories and played music. Whenever possible, they took Tellie around, hugging it and touching its ears and limbs. When using Tellie, children reported that music was their favourite part of the experience.

5. While designed and marketed for children in that age range, many tools were not easy to use, and children were often confused on how to use them if they did not have any prior instructions, often asking for our help.

6. Many children were especially attracted to the stickers with emojis, stars or hearts that we used to allow them to express their preferences and thoughts. They even used them when drawing, and often asked to bring some home.

This led us to extract the following user requirements:

Interactivity: ROBIN should interact with children, asking them questions and reacting appropriately to their answers; however, ROBIN should support both voice and touch interaction as shy children are less likely to want to speak to a robot, or even an adult reader.

Attention keeping: ROBIN should support short stories, up to 10 minutes, offering frequent breaks with questions, sounds and light to keep the child's attention. After 10 minutes, the child should be offered a break and asked if they want to continue the activity.

Ease of use: Building on the "ease of use" requirement that we had elicited from the interviews with parents and teachers, ROBIN should be as easy to use as possible, so that children can play independently without always having to involve adults. ROBIN should also be robust against user errors, always asking for confirmation before shutting down or exiting a story.

Responsiveness: ROBIN should give children a clear feedback when they press a button or they say a sentence; the child should always know what to do to advance the story.

Support for multiple users: ROBIN should be usable by more than one child at the same time; specifically, we envision three reading modes: reading alone, reading with a peer, reading with an adult, reading with an adult and peers (siblings/classmates).

Tangibility: ROBIN should be tangible, small enough to be easily picked up or held by a child.

Aesthetic: ROBIN should not present as belonging to a specific gender, to appeal to both boys and girls, and it should be soft to the touch, easy to cuddle.

Music and lights: ROBIN should be able to play songs, as many of the patterns used in songs - such as rhymes, or sound repetitions - help children develop phonological awareness. It should also be able to display different coloured lights, as those are good clues to attract children's attention and memory retention.

Visual symbolic interaction: ROBIN should support a form of visual interaction made up of symbols such as stars and hearts, to reflect the children's predilection for stickers and emojis.

Emotional Support: Making children feel supported and helping them deal with emotions has a positive impact on learning - this can happen by asking questions about how they and characters in the story feel and showing them expressions of emotional states, moods and feelings, like in emoijs in response to situations and elements found in reading.

7.3 Designing ROBIN

Unlike other storytelling robots that have been researched so far, ROBIN is not an alternative to adult-child or child-child shared reading, but a complement to it: while it is possible for children to read with ROBIN alone, its main functionality will be to support different kinds of pairs and groups as they read stories together. Moreover, we strive to deeply analyse the impact of personalisation on children's engagement with ROBIN.

7.3.1 Physical attributes

Our first iteration of ROBIN is around 30 cm tall, so it can be easily carried around by children. It is soft to the touch, with a vinyl exterior. The color is neutral, avoiding strongly gendered colors. While it has a generally humanoid shape, it does not have any specific facial features (see Figure 1); instead, it features a pixel matrix on the "face", allowing it to assume different facial expressions such as a smile (Figure 1); the body contains a speaker, while all four extremities feature LED lights and sensors that allow them to be used as buttons. These are also marked in Figure 1.

In our vision, children can interact with ROBIN both by touching the extremities and by talking, to accommodate different children's personalities. The symmetry of the design allows for ROBIN to be used by two children at the same time - for example, a child controlling the right hand and foot, and another controlling the left ones.

On the back (Figure 1), ROBIN features a USB-C port, allowing both for recharging - while many children's toys still use batteries, a rechargeable lithium battery is preferable both in terms of safety and environmental sustainability - and connecting to another device, for example to download new stories and songs. There is also a jack to connect a pair of headphones, allowing children to also use ROBIN in environments such as planes or cars. This feature is also present in Lunii, a radio-like toy for storytelling.

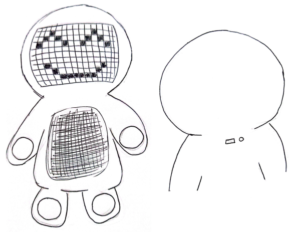

Figure 7.1. Front view of ROBIN, featuring the pixel matrix, the speaker and the buttons, and back view featuring the USB-C port and headphones jack

7.3.2 Functionality

ROBIN allows the child to either select a story by their name, or to listen to a random story chosen by the robot. We envision two possible modes of interaction: **dialogic reading**, which employs the PEER sequence, or "**choose your own adventure**", each with four sub-modes: alone reading, reading with a peer, reading with an adult, reading with peers and an adult.

In each case, ROBIN starts telling the story; the storytelling is accompanied by different coloured lights, and by symbols that appear on the pixel matrix. The storytelling stops at regular intervals, and ROBIN asks the child a question.

The types of questions that are asked in the two different modes are different; in the dialogic reading, the questions prompt the child to say something about the story; in the "choose your own adventure" mode, questions allow the child to choose different paths in the story, and as such, there are not "right" or "wrong" answers.

The child can answer the questions either by speaking or by using the buttons on ROBIN's extremities; in the dialogic reading mode, if the answer is wrong, ROBIN repeats the question once more, if it is right, compliments the child and then expands the child's response by rephrasing and adding information to it, in accordance to the PEER sequence. In the "Choose your own adventure" more, the different answers lead to different paths in the story.

ROBIN can also play songs, both at the end of a story, and as a separate activity. The child will be encouraged to sing along, to encourage learning new words and rhymes through song. The songs will also be accompanied by coloured lights and images on the pixel matrix.

We understand that designing a prototype that would address all these different requirements and interaction models would be quite an ambitious endeavour. Therefore, we aim to start designing our prototype by focusing on a subset of the requirements, that will allow us to fill the broader gaps in the design and conduct a Wizard-of-Oz study. Specifically, our goal is to start designing for the voice-activated mode of interaction.

7.4 Conclusions

While we were able to extract many user requirements from our previous work, leading us to a first sketch of ROBIN, there are many gaps in the design that still needs to be filled. The aspects that we need to refine can be grouped into four broad categories:

Personalisation: What is the impact of personalisation on children's engagement with ROBIN?

Appearance and personality: What are the ideal characteristics of ROBIN, in terms of personality, perceived gender and voice?

Story content: What kinds of content work better for engaging children? How do children and adults transform them in personalised narratives?

Role of parents: What should the role of the parents be when using ROBIN with their children?

In the next chapter, we will delve more deeply into the first ROBIN prototype, that we designed and evaluated as a Wizard of Oz prototype, and we will discuss the results of the evaluation.

Chapter 8

Evaluating ROBIN

8.1 Introduction

In this chapter, we report on the evaluation of ROBIN, a tangible interactive storytelling prototype in the form of a plush toy to captivate emergent readers in a choose-your-own-adventure storytelling experience. This chapter discusses the iterative evaluation process that we conducted with a total of 36 children aged 3 to 6 years old, attending preschool in two different countries. It is based on our work, "*Can you help me tell you a story?*" - *Exploring children's interactions with a storytelling toy.*, which has been submitted to the Nordic Human-Computer Interaction Conference (NordiCHI) conference in 2024 and is currently under review.

The schools where the studies took place share a similar curriculum and pedagogical approach, which enabled us to test the portability of the design concept involved in the prototype, and also mitigate inherent biases, paving the path for possible replication studies in the future.

The storytelling toy is the result of the collaborative design process that we detailed in the two previous chapters, combining the direct involvement of children and the input from adult stakeholders: teachers, parents and experts in education. Its aim is to foster the development of pre-reading skills in young children and understand how to better support storytelling activities for this user group.

The contributions we make with this chapter are twofold; first, we report on the evaluation of a prototype storytelling toy with young children, discussing challenges and issues in evaluating technology with users in this peculiar age range. Secondly, we discuss design guidelines for storytelling toys for children, as they emerged from our evaluation. This chapter aims to answer **RQ 2.3** What are the main design dimension of a storytelling toy for emergent readers?

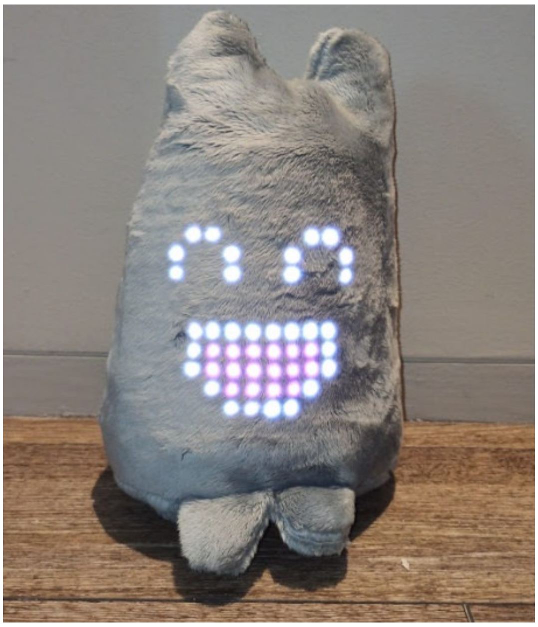

Figure 8.1. ROBIN

sectionThe prototype

ROBIN (see Figure 8.1) is the second iteration of our prototype, and the first one that we physically built to evaluate it. While it includes all the main user requirements that we elicited and discussed in the previous chapters, it only includes a subset of the planned functionalities, as we wished to concentrate on the user experience of the prototype. The main change that we made compared to the first iteration was going from a soft, vinyl body to a plush toy, as this made it possible to rapidly develop the prototype and make changes as needed.

Its main characteristics are:

- Soft body in a neutral color, with no recognisable gender or animal shape.
- Roughly 30 cm tall.
- No screen; a LED matrix under the fabric displays emoticons to show a range of emotions such as happy, sad, confused, angry. When audio is being played, the matrix displays a speaking animation.
- It can be customised by each child, with a variety of hats, scarves and bandanas that are presented to the child before starting the activity.
- A speaker to reproduce sound.

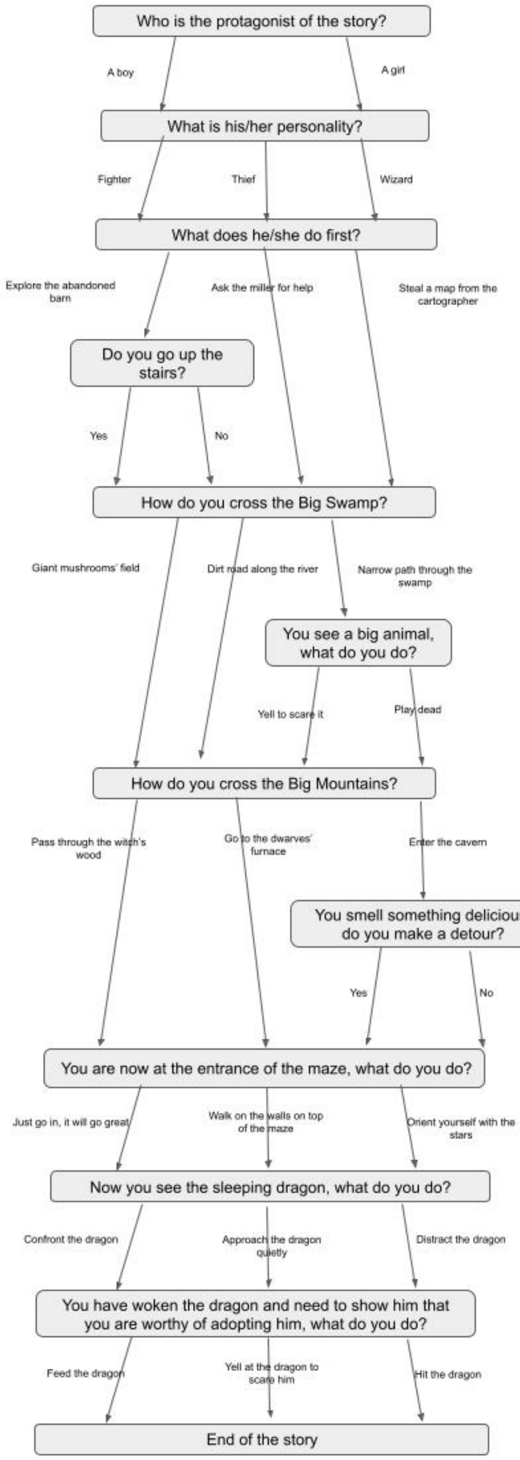

Figure 8.2. Flow chart of the possible paths in the story

As it is a Wizard of Oz prototype, it does not have any speech recognition capabilities, and it is instead controlled through a smartphone app, used by the researcher during the user evaluation. This was a deliberate choice as we wanted to focus on the design and the user interaction, instead of the implementation.

The story told by the prototype is based on *Finding the dragon* [129], a "choose-your-own-adventure" book for children aged around 6 years old, in which the reader can make choices that change the story line, telling a different story each time. This specific story was chosen as it featured both male and female protagonists, and it presents a classic fantasy story that could appeal to all children.

As mentioned before, this kind of storytelling, which is explicitly designed for interaction, has been shown to foster engagement in children [322] in its paper form. Moreover, choose-your-own-adventure books have a greater impact on children's learning of new narrative skills compared with traditional books [168]. The impact of story line choices is also positive when looking at educational cartoons, where being able to make choices about the story results in children learning more about the content of the story itself [372].

The story begins with ROBIN asking the child their name, whether they like story and whether they would like to help it telling a story; this feature was added following the pilot study detailed below. Then, the story begins, and the prototype asks the child who is the protagonist of the story, with two options: a boy or a girl. Subsequently, it asks what are the protagonist's abilities, with three options which will have an impact in the story: a wizard, a thief or a fighter.

As the story proceeds, the user chooses what the protagonist of the story does next, with the tool displaying a series of emotions appropriate to the story, such as an angry face, an happy face and so on.

The story was recorded in Italian and Portuguese by expert women storytellers who were native speakers of their respective languages, speaking in an expressive voice which included a wide range of intonation and emotion. This choice made the recording activity extremely time-consuming, only allowing us to record a single story for our prototype; however, research suggests that children benefit more from digital storytelling when the story is read with an expressive voice, compared to a flat voice such as the one that can be easily obtained using a text-to-speech engine [173].

We conducted a series of user evaluations of the prototype with children in the target age for its use, between 3 and 6 years old, building on the results - and challenges - of each evaluation to inform the following ones.

We started with a pilot study involving one preschooler in Portugal; using the insight gained from the pilot study, we made some changes to the prototype and evaluated it with a group of preschoolers in the same country. Then, we performed another user study in Switzerland, with another group of preschoolers.

8.2 Recruitment and selection of participants

First, we obtained approval from the Ethics Committees of our institutions, that was satisfied with the description of our study protocol. All children's data was fully anonymised and stored on secure servers, and the video and audio recordings were cancelled at the end of the study.

We prepared a description of our study and a consent form, which was translated in Italian and Portuguese.

Then, we contacted two private preschools with which we already had a long standing collaboration, and spoke to the teachers to present our study, answering any questions they had. In turn, they circulated the descriptions of the study and the consent form among the parents; the information sheet also contained contact information for the researchers involved in the study, so that parents could ask questions or clarification.

All the children whose parents signed the consent form were given the possibility to participate. There was no further selection of children.

Children who participated in the study did so willingly, and they were informed that they could stop anytime.

We conducted the study with 18 children aged 5 years old from the school in Portugal, all aged 5 years old, and 18 children from the school in Switzerland, all aged between 3 and 6 years old. While a larger number of parents had signed the consent form, not all children wanted to participate, and we also had to account for absences from school. The list of participants from Portugal and Switzerland is presented in Tables 8.1 and 8.2.

8.3 Study design

8.3.1 Pilot

Before proceeding with the full-scale evaluation, we performed a preliminary pilot testing with the goal of uncovering usability problems, evaluate the expected duration of the evaluation activity with the child, and improve upon our study design.

We conducted the pilot study with one child, a girl aged 5 years old, which we later involved in the full-scale study and is identified as A1 in Table 8.1.

ID	Gender	Age
A1	F	5
A2	F	5
A3	F	5
A4	M	5
A5	M	5
A6	F	5
A7	F	5
A8	M	5
A9	F	5
A10	F	5
A11	F	5
A12	M	5
A13	F	5
A14	M	5
A15	M	5
A16	M	5
A17	F	5
A18	M	5

Table 8.1. List of children who participated in the evaluation in Portugal

ID	Gender	Age
B1	M	5
B2	F	5
B3	M	4
B4	M	5
B5	F	6
B6	F	4
B7	F	4
B8	F	4
B9	F	4
B10	F	5
B11	M	3
B12	F	5
B13	F	3
B14	F	4
B15	M	4
B16	F	3
B17	F	4
B18	M	3

Table 8.2. List of children who participated in the evaluation in Switzerland

Figure 8.3. Child interacting with ROBIN in the Book condition

During the pilot testing, we let the child explore the prototype at their own pace. A teacher also sat in during the activity and also offered their feedback and perspective. We started by introducing our prototype to the child; however, at the beginning she did not know what to do, and during the activity she was very shy (which was her normal personality according to the teacher) and she seemed distracted and confused. She mentioned that she did not like the color gray.

As the tool spoke, the sentences were very long, and the facilitator often had to repeat them to allow the child to make a choice. Moreover, the teacher noticed that some of the words used in the story were too uncommon for children in that age range (such as "miller" or "cartographer").

While the child was eventually able to successfully complete the activity, we identified several usability problems that led to changes in the design of the prototype, to make it more accessible to children independent of their age and language level. The usability problems and the solutions are detailed below.

We also decided to create props that the children could use to customise the tool, such as hats and scarves, to furtherly engage with the children and help them personalise and shape their experience.

Usability Problem

1. At the beginning, the child did not know what do do.
2. Some words in the story were too uncommon for children.
3. The sentences were too long and the facilitator had to repeat the different options to the child.

Solution

1. A new audio section was added, in which the prototype introduces itself, asks the child for their name and asks for their help in telling a story. (addresses #1)
2. The text of the story was simplified and shortened. (addresses #2 and #3)
3. A play-pause-replay button was added to allow the child to listen more than once to each section of the story. (addresses #2)

8.3.2 Portugal

After the changes to ROBIN, we proceeded with the user study in Portugal, which involved 18 children as detailed in Table 1. The child who participated in the

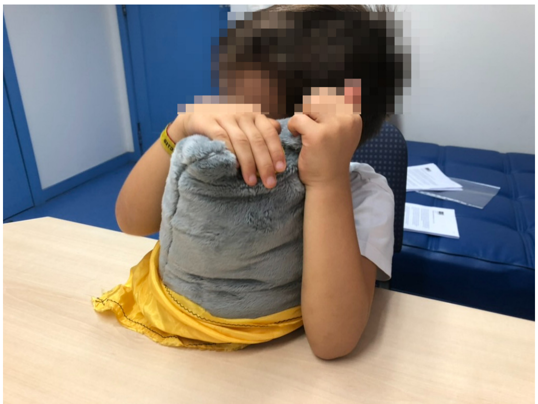

Figure 8.4. Child hugging ROBIN

pilot study (A1) also participated in this user study. During this study, our focus was not only on uncovering usability issues, but also on understanding children's preferences and enjoyment of ROBIN.

The evaluation took place in the school, in a separate, quiet room. Each child performed the activity on their own, accompanied by a teacher with which they were familiar. At least two researchers were present: one acted as a facilitator and operated the smartphone app, the other took notes and recorded the session. When a third researcher was present, they also took notes. The teacher sat in the background, not intervening unless asked by the child.

We structured the activity with three distinct phases:

1. **Customising ROBIN**: during this phase, the child was presented with a series of accessories that they could put on the prototype, such as hats, scarves and bandanas. We introduced ROBIN to the child, and asked them whether they would like to put on a hat or a scarf. If the child did not show interest, we proceeded to the next phase.

2. **Activity**: during this phase, the child interacted with the prototype by listening to the story and answering questions, making choices that influence the story line. If the child hesitated to speak or seemed confused, the facilitator would prompt her to answer by repeating the possible choices, or play again the story section.

3. **Assessment**: in this phase, children are invited to rate three aspects of the activity on a scale from 1 to 5: how they liked the story, how they liked the prototype and how much fun they had.

Figure 8.5. Child assessing ROBIN using the Sticky Ladder

The assessment was conducted using a version of the Sticky Ladder [10], as shown in Figure 4, that was made out of wood, with five Velcro rungs and three cardboard tokens with Velcro on the back, each representing one of the three aspects that was to be assessed. This method was chosen because, compared to others such as the Five Degrees of Happiness, does not need any level of dexterity or skills with the pencil, which can be an issue for younger users, and also because it seems to foster a higher level of focus and reflection in children [306].

8.3.3 Switzerland

For this study, we kept the same structure for the activity, but we decided to investigate how children would interact with ROBIN in different conditions: by following along the story with picture book (see Table 8.4 - Book or No book) and in pairs, to account for the fact that children in this cohort were, on average, younger than the children in Portugal.

When children interacted in the "Book" condition, a researcher followed along with them in the book, showing them a page at the time. While the book also had some text, none of the children in our study had already learned how to read, so they only relied on the pictures. When children interacted in pairs, we did not enforce turn-taking, but encouraged them to repeat the activity a second time if they wished to do so.

The evaluation took place with one child at a time, in a separate room, in the presence of three researchers: one acted as a facilitator and helped the children follow along with the book in the "Book" condition, another operated the smartphone app and recorded the experience, while the third took notes.

The children were randomly allocated to the Book or No Book condition, and they were asked whether they wanted to perform the activity with someone else; in this case, the children were paired by the teacher, who was familiar with the children and their personalities. This accounts for the differences in the number of children for each condition.

8.4 Data collection and analysis

For each child, we recorded (both audio and video) the whole evaluation process, from the time they started interacting with the prototype, to the assessment using the Sticky Ladder method.

At least one researcher also took notes during the sessions, detailing the following aspects of the activity:

- **Customisation**: whether they customised the prototype or not, and with what accessories.
- **Touching**: whether they touched the device, either during the customisation phase or during the activity itself, and what kind of touch interactions they had.
- **Speaking**: whether they spontaneously and without prompting, if they were shy or whispered, if they said anything other than answering the questions.
- **Engagement**: whether the child looked at the device during the activity or looked away, whether they seemed bored or attentive, if they looked at the adult facilitator, if they smiled.
- **Story line**: we annotated the sequence of the story created by each child.
- **Assessment**: how the child interacted with the Sticky Ladder, whether they seemed to understand how it worked, and the rating given to each aspect of the activity.

ID	Gender	Age	Fun	Story	Prototype
A1	F	5	4	5	3
A2	F	5	5	4	5
A3	F	5	4	5	5
A4	M	5	5	5	5
A5	M	5	5	5	5
A6	F	5	4	5	1
A7	F	5	5	5	5
A8	M	5	5	5	5
A9	F	5	4	5	5
A10	F	5	4	5	3
A11	F	5	5	5	5
A12	M	5	5	5	5
A13	F	5	4	3	5
A14	M	5	5	5	5
A15	M	5	5	5	5
A16	M	5	5	5	5
A17	F	5	4	5	5
A18	M	5	4	5	5

Table 8.3. Results of the Sticky Ladder assessment with children in Portugal

ID	Book	Pairing	Gender	Age	Fun	Story	Prototype
B1	No book	Alone	M	5	5	4	5
B2	No book	Alone	F	5	5	5	5
B3	No book	Alone	M	4	4	2	4
B4	No book	Alone	M	5	5	5	5
B5	No book	Alone	F	6	5	4	5
B6	No book	Alone	F	4	5	1	5
B7	Book	Alone	F	4	5	3	5
B8	Book	Alone	F	4	2	2	1
B9	Book	Alone	F	4	5	5	5
B10	Book	Pair	F	5	2	3	4
B11	Book	Pair	M	3	2	5	3
B12	Book	Pair	F	5	5	5	2
B13	Book	Pair	F	3	2	1	3
B14	Book	Alone	F	4	3	2	1
B15	Book	Alone	M	4	1	2	5
B16	No book	Alone	F	3	5	5	5
B17	No book	Pair	F	4	5	5	5
B18	No book	Pair	M	3	5	5	5

Table 8.4. Results of the Sticky Ladder assessment with children in Switzerland

We performed both a quantitative and qualitative analysis of the data: the quantitative analysis focused on the scores assigned by the children during the assessment of the prototype, which we analysed to find differences related to the age or gender of the child, as well as the condition of the activity (alone or in pairs, with or without the book). The data were analysed both separately for each country, and together, to explore differences among the different countries.

8.4.1 Quantitative analysis

All the children, both in Portugal and Switzerland, were able to complete the activity successfully; as reported in literature, they were able to understand how the ladder worked, and had no issues when positioning the tokens. However, even if our ladder was wide enough to place two token on the same rung, at first some children did not understand that they could place more than one token on the same rung.

The results of the assessment are presented in Table 8.3 and 8.4, respectively for Portugal and Switzerland. The average enjoyment of the robot was high, with an average of 4.30 out of 5 across the whole dataset, as were the average enjoyment of the story (M=4.19) and the average reported fun (M=4.25).

We conducted independent samples one-tailed tests to investigate the effect of gender on reported fun, enjoyment of the story and enjoyment of the prototype. Considering only the data from Portugal, **boys reported having significantly more fun than girls**, *t(16)=-2.81121, p=.006274)*, while there was no significant effect for gender regarding the enjoyment of the story *t(16)=-1.24939, p=.114746)* and the prototype *t(16)=1.60806, p=.063687)*, despite girls giving worse scores than boys to the prototype. In Switzerland, there were no significant differences in reported fun, enjoyment of the story and of the prototype between the genders, and also between younger (3-4 years old) and older (5-6 years old) preschoolers. There were also no significant differences between the "Alone" and "In Pairs" condition.

Compared to children in Portugal, **children in Switzerland reported enjoying the story significantly less** *(t=-3.3341, p=.001038)*.

However, since all children in Portugal were older (5 years old) and most of the children in Switzerland were younger (12 out of 18 children were 3-4 years old), we also conducted independent samples one-tailed tests on the whole dataset, comprising both children from Portugal and Switzerland.

We found that, overall, **younger children reported having significantly less fun** *(t=-2.32198, p=.013179)* and that **they reported liking the story less than older children** *(t=-3.98913, p=.000167)*. Considering the whole dataset, **girls also reported enjoying the prototype less** *(t=-1.852, p=.036363)*.

8.4.2 Qualitative analysis

All of the children were able to complete the activity successfully; three children needed some **prompting by the adult facilitator** to answer, and **four children (one in Portugal, three in Switzerland) did not answer verbally at all**; in this case, we positioned the hats that had been left over from the customisation phase on the table, and let the child point at the hats to select their answer.

Five children frequently **looked at the adult facilitator before answering**; four children frequently **whispered their answers**, and one child stuttered.

While most children **looked at the prototype and seemed enthralled** in the activity, some children also **looked away** during the storytelling. Children who started out as shy often **gained confidence** at the activity progressed.

Moreover, five children in the "Book" condition **pointed at the book to choose**, at least in some instances. One of the children who did not speak at all and was supported using the hats was also in the "Book" condition.

In Switzerland, Children who did the activity in pairs tended to be **distracted by each other**, which happened in two pairs (four children). However, they also spontaneously **took turns in choosing**, and **discussed the story** among themselves. When younger children were paired with older children, the younger and shyer ones were able to interact with the prototype. A child who had previously refused to participate, B11, was subsequently paired with her older sibling B10, and showed enthusiasm and engagement during the activity, even asking to do it again after the first story.

Children who did the activity in the "Book" condition **showed considerable interest** in the book, wanting to turn the pages and look ahead, and they frequently **pointed at the book** not only to answer questions but also to make comments related to the story.

Most children (27 out of 36) chose to **customise the prototype**, with children also putting hats on themselves. While three of the girls used exclusively pink accessories (B5, B6, B9), there were no distinct preferences in the accessories used by the children.

Around a third the children (13 out of 36) **touched the prototype** during the activity, with six children hugging it and petting it repeatedly during the activity.

8.5 Discussion

All children who participated in the study were able to successfully complete the activity and the evaluation, with some requiring help from the adult facilitators. While children understood the role of the prototype in the storytelling activity, many of them also interacted with the facilitator, either looking at them before answering or requiring some prompting before doing so. Children also whispered their answers, and they frequently hesitated before answering, with some children completely refusing to speak during the activity.

From this, we can infer two possible design guidelines. Firstly, storytelling toys should support **different types of interaction apart from speaking**, for example through touch. The children showed almost no interest in the emotions expressed by the prototype, as they never paused to ask why the prototype was sad, happy or angry, nor did they comment on the emotions at all. Therefore, it might be better to sew the eyes directly onto the fabric, display the speech animation through a flashing light and use the LED matrix on the surface of the prototype to project images related to the story.

Secondly, the **role of the adult facilitator** should be expanded, making space for storytelling as a shared experience, as that is the kind of experience that children spontaneously tend to gravitate to. However, how child-adult dyads interact with technological tools for shared storytelling is still an open area of research [267]; when interacting with digital storytelling tools, parents are often more comfortable acting as a go-between between the child and the technology [190].

While younger children reported having less fun and liking the story less than older children, the enjoyment of the prototype did not change significantly between age groups; therefore, it is possible that by choosing a different story, more suitable for a younger audience, this might change.

Children who followed along the story with the paper book reported less fun and less enjoyment of the prototype; they showed more interest in the book than in the prototype, trying to look ahead at the pages and looking at the pictures while listening. This result is unexpected, especially as robot reading companions for children usually involve children following along on paper books [51, 191, 376]. As a third guideline, we therefore recommend that **storytelling toys should be able to function both with and without a paper book**.

Although most of the children reported enjoying the prototype, only about a third of the children in the whole dataset touched it during the activity, with only a small minority - six in total - touching it, cuddling it and playing with it repeatedly during the activity. Although the prototype was soft and made of the same fabric as plush toys, children did not perceive it as such, and most of them did not touch it after the initial phase of customisation. However, many children smiled at it during the activity, and a child even waved to say goodbye.

This leads to a fourth design guideline related to the **affordances of a storytelling toy**. As suggested by [348], both physical affordances - such as those related to size and shape - and digital features such as audio and visual feedback can be used to engage young children in pretend play and facilitate motor activities, both gross and fine. In the specific case of a storytelling toy, we suggest emphasising physical components related to fine motor activities, such as buttons, while audio and visual feedback should not only be related to the story but also as a response to children's interactions with the toy.

8.6 Biases and limitations

We recognise that, as our dataset is small, it is not possible to reach any definitive conclusions, however our data reveal some trends that could be explored in the future. Also, we tested the prototype with only one story, which children might also have disliked.

Due to circumstances such as absences from school and children's willingness to participate in the activity, our dataset also skewed female; in addition, children in Portugal were all 5 years old, while 12 out of 18 children in Country2 were 3 or 4 years old. At this age, even an age gap of months could significantly change children's abilities and preferences, so this makes it possible that any difference that we found between Portugal and Switzerland might also be due to the age gap between the children.

Moreover, as we worked with private preschools, we also had a bias in terms of socio-economic status, since all families involved with the study were financially comfortable enough to afford private school. However, by conducting the study in two different countries with different cultures, we hoped to mitigate any inherent biases.

8.7 Conclusions

Our user study has revealed some interesting insights into how children interact with a tangible storytelling tool, but it also opens up the possibility of exploring new research directions.

While the smartphone app to control the prototype was originally intended as a way to conduct the Wizard of Oz user evaluation, it could be offered to parents as a platform for a shared reading experience with their children.

It would also be interesting to explore in more depth the role of the paper book during the shared reading experience and the user gains of parents and children during this experience. While research often focuses on educational goals and children's engagement, fun as a user gain is an underrepresented yet important metric.

In the next chapter, we will discuss another possible use case for ROBIN: refugee children who are learning Italian as a second language, and how they engage with ROBIN and other forms of storytelling.

Chapter 9

Engaging Ukrainian child refugees with ROBIN

9.1 Introduction

This chapter is based on our work submitted and accepted at the IDC Conference 2024, *Exploring the use of an interactive storytelling toy to engage Ukranian child refugees in learning Italian.*

In recent years, several humanitarian crises have led millions of people to leave their homes and take refuge in surrounding countries; according to the Swiss State Secretariat for migrations, over 75.000 refugees from Ukraine applied for asylum in Switzerland in 2022, many of them children [99].

Ukrainian children in Switzerland are enrolled in school and expected to learn both the local language - Italian in the case of Ticino - and another national language, usually French, while being supported by local associations such as the Red Cross, that runs an after-school activity to help the children integrate in Swiss society and learn the local language, as well as helping them socialise and share their experience of being away from their home country. We collaborated with the Lugano chapter of the Red Cross and held three workshops with Ukrainian child refugees aged 6 to 10 years old, to explore how different storytelling activities - both traditional and digital - encouraged them to speak Italian. In particular, we will focus on the use of ROBIN, and present a new iteration of its design, based on the feedback gathered during the activities.

This chapter aims to answer **RQ 2.4** How can a storytelling toy engage child refugees who are learning a new language?

Session	Participants	Activities
1	12 children (9M, 3F)	Interactive story with prototype
2	11 children (8M, 3F)	Interactive story with paper book; wordless book
3	8 children (5M, 3F)	Traditional story with prototype

Table 9.1. Overview of participants and activities

9.2 Study design

Our study took place in the context of an after-school activity organised by the Lugano Red Cross on Wednesdays afternoons; we worked with the children, whose age and number are reported in Table 9.1, during three afternoons over the course of two months. The sessions were held in a quiet room, equipped with tables, chairs and a rug in which children could sit during the activity.

After an ice-breaking activity, such as introducing ourselves or drawings, we had one or two storytelling activity per session. During the first session, we introduced the children to our first prototype, ROBIN, whose co-design process has been detailed in the previous chapters. During the second session, we conducted two storytelling activities with paper books: an interactive gamebook and a wordless book. In both activities, a researcher acted as the adult reader. During the third session, we presented a redesigned digital prototype which addressed some of the problems encountered in the first session, and was used to read a story to children together with an adult reader. In the following section, we will go into more detail about each activity. Activities and participants are recapped in Table 1.

All the stories selected for the workshops were chosen among commercially available children's books. Specifically, both gamebooks and the wordless book were marketed as being suitable for children aged 4 and older, while the stories used during the third workshop were popular children's stories by Italian author Gianni Rodari [261].

While children were not compensated for participating in this study, as all activities took place during their regular after-school activities, we donated the books used in the study to the Red Cross to use during their after school activities in the future.

9.2.1 Child Participants

There were 12 children (9 boys and 3 girls) who participated in the first workshop, 11 children (8 boys and 3 girls) in the second workshop, and 8 children (5 boys and 3 girls) in the third workshop; all children were between 6 and 10 years old, and enrolled in a local primary school; as participation to the after school activity was voluntary, the same children did not participate in all the sessions.

9.2.2 Adult participants

Two researchers and at least two Red Cross volunteers, who acted as facilitators, and a Ukrainian interpreter attended each session. One researcher took notes while the other acted as the adult reader during the activities.

9.2.3 Data collection

We recorded each workshop - both audio and video; a researcher also took notes during the activities. We then analysed the data qualitatively, looking at children's reactions and behaviour to gauge their engagement.

9.3 Session 1

During the first workshop, we used the same version of ROBIN whose evaluation has been detailed in Chapter 8. The prototype verbally told an interactive story about a dragon, in which the children decide how the story proceeded by verbally answering questions, in the style of a gamebook. It was a plush toy around 30 cm tall, with a speaker and a LED matrix used to represent emotions related to the story (see Figure 1) such as happiness or sadness, commanded through a smartphone app.

Children sat in a circle together with the adult storyteller, who held the paper game book with the same story as the prototype, so that the children could look at the pictures during the activity.

At the beginning, the prototype asks the children their name, and whether they like to read stories. Children introduced themselves with their name without hesitation, and the researcher who acted as adult reader introduced themselves as well. Then, the prototype asks the children whether they would like to help them tell a story, and they answer positively as well.

By requiring each child to respond in turn, the Red Cross facilitator imposed turn-taking and allowed each child to have an impact on the story; while the story was originally meant for children 4 years old and older, we noticed that the vocabulary used in the story was often difficult for the children, and the interpreter had to support them several times.

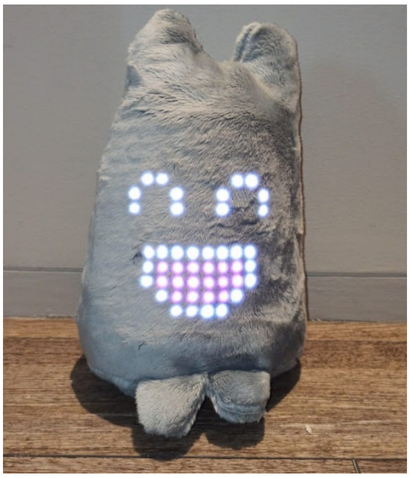

Figure 9.1. ROBIN

During the activity, children showed significant interest in the expressions shown by the prototype, to the point that sometimes they had to be reminded that the toy had also asked them a question; children who sat closer to the prototype also touched it often. We also observed several instances of pointing behaviour, children often looked at the pictures in the book to better understand new words, and then repeated them in Ukrainian. Children spoke a lot during the activity, both in Italian and Ukrainian, with many of them laughing and touching the prototype, petting it and squeezing it.

Overall, all children seemed to enjoy the prototype's expressions, and asked about them, laughing when the expression was a cheerful one - such as smiling or having heart-shaped eyes. After the activity ended, they asked to see all the emotions that the prototype could display. When asked what they liked about the activity, they all had different answers, ranging from "the dragon", "the expressions" and "everything".

However, as ROBIN had originally been designed for one to one interactions, it was equipped with a small speaker, which was not loud enough for a group; in addition, children seemed to enjoy the touch aspect of the toy, but as it has no recognisable limbs, they seemed unsure while doing so and did not know if and where they could touch it. We decided to address these issues and designed a new prototype, which we presented to the children in Session 3.

9.4 Session 2

The aim of the second session was to better understand children's needs and inform the redesign of the prototype. To do so, we held two reading activities with the children: the first was a paper gamebook, with a different story than the one they had listened to in Session 1, to understand the impact of the story on children's reaction. The second was a wordless picture book, to gauge the level of engagement that such an activity could generate. During this session, the children sat on chairs, in a circle around the adult reader.

9.4.1 Activity 1 - Paper Gamebook

The first activity consisted in reading a paper gamebook with a story about a spaceship. In this book, children begin by choosing a main character, and then they turn pages according to their choices in the story. We began the activity by asking children questions about space and spaceships, such as "How do astronauts float in space?". While sitting in the chairs, children seem quieter and more attentive than in the previous session; then, the adult reader started reading the book, while showing the book to the children. With the help of the facilitators, they took turns answering the questions to advance the story, while the adult reader turned the pages of the book. They also needed help with some terms with which they were not familiar with.

Halfway through the exercise, the Red Cross facilitators explicitly told the children that they could get up and get closer to the book to see better; the majority of the children did so, while a small minority remained in their chairs and seemed disinterested in the activity.

When asked whether they had preferred the gamebook read by the human reader, or the prototype who had read them a gamebook in Session 1, all children answered that they liked the prototype better, thus confirming the need for a digital prototype in our redesign.

9.4.2 Activity 2 - Wordless book

The second activity consisted in "reading" a wordless book called "Trip to the Moon". Wordless book do not have any written words, and they rely only on pictures to tell a story. The adult reader turns the pages, asking the children what they see in the pictures, and what they think is happening.

Since the children had to describe the pictures in their own words, they could use the vocabulary they had already mastered, while only needing little help

Figure 9.2. Second Prototype, Octopus

from the interpreter when there was something in the pictures that they did not know how to describe. During this activity, children spoke a lot more than both in the previous activity and in Session 1, and even previously uninterested children began to show interest in the activity. When asked which activity they had preferred, almost all children answered that they preferred the picture book. The combination of the feedback provided in Session 2 confirmed the children's preference for a story in simpler language, divided in smaller chunks and read at a slow pace, which we implemented in our redesign of the prototype.

9.5 Session 3

During the third session, we presented the children with a revised prototype, in the shape of an octopus (see Figure 2), whose design was informed by the technical issues emerged in Session 1 and by the preferences expressed by the children in Session 2, such as their inclination towards simpler and shorter stories and interactive storytelling. The second prototype was equipped with a bigger speaker who could play sounds at a higher volume, and had LED strips mounted in the four frontal tentacles, that lighted up with different color palettes to attract children's attention and let them touch it during the reading activity.

As the previous prototype, it has a LED matrix used to display emotions, however instead of telling an interactive story, the prototype told two regular stories chosen from an anthology by a famous children's author named Gianni Rodari.

This was also a Wizard of Oz prototype, controlled through a smartphone app used by a hidden researcher; to adapt it to the needs of children learning a second language, the story was read at a slower pace and was split into chunks which could be played again or back and forth, with the adult reader asking the prototype if they could repeat or go back or continue telling the story. Between chunks of the story, the adult reader asked children questions about the story, according to the dialogic reading process [267], which the children answered promptly.

While at first the children were shy about the new prototype, they soon began familiarising with it, petting it and playing with the tentacles. They laughed and pointed at the different expression, linking them to the story - for example, noting that the prototype showed an angry face because one character in the story was angry. They also commented on the different colors that the LED strips showed on the tentacles. Overall, younger children seemed to be more captivated with the prototype, staying at the front and touching it more than the others.

When asked, all the children except one reported that they liked the second prototype better than the first.

9.6 Discussion

In our sessions, we explored the use of both digital and traditional forms of storytelling with child refugees who are learning the language of the country in which they settled, at least temporarily. As we only conducted three sessions with a small number of children, gathering only qualitative data, we obtained only preliminary insights, that could be a starting point for the design of technology specifically tailored for the needs this vulnerable user group.

- **Fun as a dimension**: We observed that, while children engaged in both digital and traditional storytelling, they showed more curiosity and interest for the digital prototypes, which they regarded as "more fun". Moreover, children enjoyed the the digital storytelling activity regardless of the difficulty in understanding a new language; even when the story was hard for them to understand, they still described the experience as "fun" and, when asked, could remember both elements of the story and of the prototype. Fun has been shown to have a positive effect on children's learning [310] and motivation [150]. We argue that this should be an important dimension in the design of technology for refugee children who - unlike their peers - are not learning a foreign language at school but are trying to learn the language of the country they live in, showing that it is necessary for them to engage in language learning activities in an out-of-school context.

- **Non-auditory cues in storytelling**: Children also showed interest in the expressions shown by the prototype, pointing at them and commenting them during both Session 1 and Session 3, and they were fascinated by the different colours of the tentacles in the second prototype, grabbing and squeezing them. While this aspect could be due to the novelty effect of interacting with a prototype, we hypothesise that it could also be due to the fact that, as the children were not Italian native speakers, they concentrated on the visual elements of the storytelling activities, such as the expressions and the lights in the prototypes, in accordance with [195]. This suggests the need for multi sensory storytelling tools, with features such as representations of emotions and facial expressions, lights and music.

- **The role of the adult reader**: The presence of an adult reader was critical for the success of all the activities: both in the case of the digital and traditional storytelling, children often needed additional help or explanations that a book or a toy could not provide. In our case, we also worked with an interpreter that could help children when they knew a word in Ukrainian but not in Italian. This is consistent with the idea that, during adult-child storytelling activities mediated by technology such as virtual agents, parent-driven interactions still make up the majority of the conversations [190]. We believe that technology designed for refugees children should still put people at the centre, as an aid for volunteers and caregivers and not as a tool to be used on its own.

However, our study has significant limitations, starting with the small number of participants and the short duration of the study, that do not allow us to generalise our findings. Moreover, we did not measure the effectiveness of our prototype on vocabulary size or fluency, but only gathered qualitative insights on children's engagement and usability of the prototype.

Nevertheless, as the global refugee crisis continues unabated and the number of displaced children increases every year, the need to facilitate their acquisition of the language spoken in the host country increasingly important. We argue that designing customised technologies and evaluating the effectiveness of existing ones are both essential aspects in addressing this challenge, as these children face very different circumstances compared to native speakers or students learning a second language in school.

9.7 Conclusions

This chapter highlights important insights into the exploration of digital and traditional storytelling with child refugees learning the language of their host country. Our observation underscored the important of fun as a dimension in the design of technology, with children showing heightened engagement in digital prototypes, as they perceived them as more enjoyable. This emphasis on fun aligns with the literature discussing its positive impact on learning, and shows the necessity of engaging refugees children in language learning activities beyond the classroom setting. Furthermore, the specific context of learning a second language emphasised the importance of non-auditory cues in storytelling, suggesting the need to incorporate visual elements such as facial expressions and colourful features to enhance language comprehension and engagement.

The role of adult facilitators who share the same language and cultural background as the children is also a critical factor in supporting children's participation and comprehension.

These dimensions, as well as further studies aimed ad assessing the effectiveness of storytelling tools to improve vocabulary and fluency in refugees children, represent a starting point and an interesting direction for new research.

Part III

Discussion

Chapter 10

Discussion

10.1 Children's involvement and contributions to the design of technology

This section discusses RQ 1: "How can children children contribute to shape the design of new technology?" by addressing RQ 1.1, RQ 1.2 and RQ 1.3. In this section I will also consider the research question as a whole, and report on lessons learned and considerations.

10.1.1 Children's perception, understanding and expectations about technology

Children's perception, understanding and expectations about technology constitute a crucial area of research in the field of CCI. Chapter 3 aimed to explore how drawings could aid in understanding how children conceptualise technology, and to shed light on the factors that shape their perspective.

Our analysis shows that children's drawings frequently depict technology through a lens of wonder, often imbuing it with qualities akin to magic. This phenomenon is particularly pronounced among younger children, who struggle to see the difference between magic and technology. Even with older children, elements of magical thinking still persist, and influence their perception of technology.

However, that should not be seen as a negative. Magical thinking is an important and necessary component of children's cognitive development; by fostering imagination and creativity, it contributes to their sense of empowerment and agency in engaging with the world - two themes that are particularly important in CCI research.

As children mature, the evolving nature of their representation of technology mirrors their cognitive development, and their depiction of technology becomes more aligned with reality, reflecting a heightened awareness of how technology works. In addition, children who were exposed to video games, and explicitly referenced them in the texts accompanying their drawings, exhibited more grounded and realistic expectations about technology. This suggests that playful exposure to technology during childhood can facilitate a foundational understanding of its functionalities, tempering magical expectations with a more realistic outlook.

Conversely, anthropomorphic depictions of technology - wherein children attribute human-like qualities to devices, such as "being my best friend" - have significant implications for their expectations, fostering higher expectations of intelligent response from technology. This is a factor that is also true for adult users, who tend to expect more from tech that they perceive as human-like, such as virtual assistants.

When designing for children, these insights underscore the importance of balancing playfulness with developmental appropriateness. On one hand, designing technology that incorporate elements of playfulness and fun can enhance children's engagement and learning outcomes, and help them foster a sense of curiosity and agency, which will in turn help them understand technology better, and have more realistic expectations. On the other hand, both existing literature and our research strongly suggest that technology should be aligned with children's cognitive developmental stage, to ensure that children can use it effectively.

Ultimately, designers should not discount the role of magical thinking in children's perception of technology. As the CCI community endeavours to empower children by actively involving them in the design of new technology, children's imagination should not be constrained by adults' ideas of what technology should look like. When co-designing with children, designers should strive to provide opportunities for imaginative exploration, balancing magic and reality by both exposing children to real-world technology and encouraging them to imagine technology through a lens of wonder.

The next section will cover RQ 1.2 in depth, and discuss the role of the CCI community in empowering children to participate in research.

10.1.2 The role of the CCI community in empowering children and inspiring researchers

Current initiatives within the CCI community, such as the IDC Research and Design Challenge, have the immense potential of both allowing researchers to empower children to participate in the future of technology, and creating a dataset of children's drawings and ideas about technology, that could allow researchers to understand how children's perception of technology change over time.

However, the R&D challenge fail to attract a diverse representation of children from all over the world, with only a few countries represented each year. This suggests a pressing need to broaden participation by engaging not only schools, but also coding clubs, libraries and other non-school entities. By diversifying the participant pool, the R&D challenge could harness a wider range of perspectives and experiences, enriching the field. However, our research in Chapter 4 showed that there are significant barriers that prevents this from happening.

First, the lack of accessibility of the challenge prompt in different languages presents a barrier to participation for the children and teachers involved; however, while translation efforts are necessary, they pose a burden on young researchers and collaborators, and they are insufficient without active engagement from researchers involved within local communities.

Furthermore, a significant deterrent to participation - for both teachers and researchers - is the time-intensive nature of the design challenges. Streamlining the submission process and providing resources for researchers could help alleviate this burden, making participation more attractive. By optimising the logistical aspect, researchers and teachers alike could focus on maximising the impact of children's contributions to the challenges.

Likewise, ensuring that both adults - researchers and teachers - and children derive tangible benefits from participation is essential to sustain engagement in the R&D challenge. Recognition and acknowledgement are valuable incentives that, as today, are still lacking for all the parts involved, and that would help foster a mutually beneficial relationship between schools and researchers, incentivising the former to continue their involvement with the CCI community.

As the previous section as shown, children's drawings can be a rich source of inspiration and understanding for researchers, and as such, the retention and expansion of a dataset comprising children's ideas throughout the years could hold immense promise for advancing the field of CCI. As a matter of fact, investing in a long-term data collection effort could yield valuable insights into evolving trends, preferences and attitudes of children, and help designers inform the design of new technology.

In conclusion, empowering children to participate in research through design challenges such as the R&D challenge represents a cornerstone of the CCI community's values.

Our research suggests guidelines to address barriers to participation, optimise processes and foster a culture of inclusivity and collaboration, with the ultimate goal of harnessing the collective creativity and imagination of children and drive meaningful advances in research.

The next section will discuss RQ 1.3 in depth, and discuss the results of our literature review on children's involvement in design.

10.1.3 Children's involvement in design throughout the years

While the previous two sections dealt with research questions related to children's participation in research by gathering feedback through the analysis of their drawings, Chapter 5 analyses children's participation in research as active participants in the design process.

Participatory design is rooted in democratic principles and collaborative decision-making processes, and holds profound political and social significance in shaping innovation. At its core, participatory design advocates for the inclusion of users in the design and development of technology, and challenges traditional power dynamics by elevating the voices of those who were not traditionally involved in the design process.

In the context of designing technology for children, participatory design assumes particular importance as it affords young users a platform to actively engage in shaping the technology that directly impact their lives.

By inviting children to participate in the design process, with their perspective, preferences and needs, participatory design reinforces their sense of agency and ownership over technology, affirming their status as experts in being children.

Through participation in design, children gain not only valuable skills such as design process knowledge, collaboration and communication, but they can also develop their self-esteem and broaden their horizons.

However, our review of the literature shows that some population of children are still underrepresented, such as young children and teenagers, as well as Deaf children and children with visual impairments, who have been given little attention in literature.

Furthermore, while many methods, tools and approaches have been developed over the years, many of them are rarely used in subsequent research; while the specific reasons for this lack of adoption is an possible future avenue of researchers, this finding still suggests that there is a plethora of methods on which designers could draw to advance their research.

Finally, while researchers have been advocating for the inclusion of children as equal stakeholders for more than 20 years, children do not often participate as full design partners, but are involved as informants or testers, and that is especially true for preschoolers.

As the next section will show, this dissertation is not immune to this underlying problem, as in my work preschoolers have also been involved as informants and testers, instead of full design partners; while the next section will delve into the specific reasons for this choice, aiming to include preschoolers as design partners is also an important future direction for CCI research.

10.2 Co-designing technology for emergent readers

This section will aim to answer RQ 2. "How can technology foster young children's literacy skills?", by addressing RQ 2.1, 2.2, 2.3 and 2.4. Here, I will discuss my journey, starting from a series of collaborative design session to understand children's preferences and wishes for storytelling tools, discussing the design and evaluation of ROBIN, a plush toy prototype for interactive storytelling, and finally discussing ROBIN's evolution as a tool to help child refugees learn a new language.

10.2.1 Children's preferences and wishes for storytelling tools

In Chapter 7, I describe how I explored different activities and settings as a means to elicit feedback from young children, and understand their preferences and wishes for storytelling tools.

As we worked with very young children, between the ages of 3 and 6 years old, we were not able to involve them as full design partners. While we introduced ourselves as researchers and explained the aim of our research, we found it exceedingly hard to generate design ideas with the majority of children with whom we were working. Our difficulty was supported both by literature on collaborative design and on children's cognitive development; while older preschoolers (5-6 years old) can successfully generate design ideas by using appropriate techniques and an adequate amount of scaffolding, this was not possible in our case as many children were on the younger side.

However, by observing children and introducing them to different activities, we were able to gather genuine feedback which we used not only to design and evaluate our prototype, but also to investigate children's experiences with different kind of technology, and to understand which techniques worked better to gather feedback from children.

From our failure to involve children as full design partners, we still learned how to involve very young children by letting them show us the thing that they did best: being a child.

Our research shows that younger children, as well as shy ones, participate more fully when activities are conducted in small groups, and they also become more forthcoming once they start building a relationship with the researchers. This suggest the need, already advocated by research, for a long-term commitment on the part of researchers, planning - whenever possible - longer co-design studies.

We also found that unstructured activities, such as letting children explore toys freely, allowed us to gain a deeper insight in how they played and told stories. By allowing time for unstructured play, we freed children from any expectations that they might have from our presence, and we were able to gather genuine feedback by observing them.

By mixing unstructured play time and structured activities in which children interacted with existing storytelling tools together with an adult, we were able to understand what factors influenced children's engagement: elements such as explicitly designing for interaction, as well as the preference for tangible tools, formed the foundation for the design of ROBIN, which we will discuss in depth in the following section.

10.2.2 Designing ROBIN

Chapter 7 marks the first instance in this dissertation in which we involved adult stakeholders, such as parents and teachers.

While research advocates for the inclusion of children as full partners in the design of technology, they are not the only stakeholders whose view we should consider: children are not yet independent in their use of technology, and parents and teachers have the right - as well as the responsibility and the duty - of choosing technology that aligns with their values, needs and expectations.

Our research came at a very peculiar time for children, at the height of the COVID-19 pandemic, which certainly coloured parents and teachers' opinions about the use of technology by young children. While the idea of limiting children's screen time is certainly not new, the preference for screen-free entertainment for children was also rooted in the fact that, as a result of the pandemic, parents had no choice but to subject their children to hours of screen time for allow for distance education.

The heightened concern for the already present digital divide was also a result of the pandemic, which widened the gap between families who could afford multiple devices and a reliable internet connection, and families who could not, leading teachers to resort to creative ways to involve all their students in distance learning.

Combining insights obtained through interviews with parents and teachers with the elements obtained through the co-design sessions described in Chapter 6, we were able to elicit a series of users requirements which became the foundation for ROBIN, a RObot for Interactive Narratives.

While some of these requirements evolved over time, the core characteristics of ROBIN stayed consistent throughout its different iterations: tangible, designed for interaction, easy to use and supporting children's emotions.

The next section will explore how we evaluated ROBIN, validating and evolving our design by testing it with children from two different countries.

10.2.3 Evaluating ROBIN

Chapter 8 reports on the evaluation of ROBIN in two different countries - Portugal and Switzerland - with the aim of providing design guidelines for further design of storytelling tools for young children, as well as gaining insight on how to perform user evaluation with young children.

By involving children in the 3-6 years old range from two different countries, we sought to mitigate any bias due to cultural and linguistic factors; however, the small number of children involved in the evaluation does not allow us to discount the possibility of any biases.

While the initial pilot study performed with one child in Portugal showed some usability problems, we were able to quickly address them and perform the evaluation in both countries.

One of the problems that we encountered, and we had not anticipated, was the issue of language: teachers in Portugal objected to the children playing with a prototype designed to speak in Brazilian Portuguese, as parents prefer that their children learn and speak Portuguese from Portugal. As the distinction mirror the one between American and British English, with the former more widely represented in a variety of media and technology, exploring parental expectations about technology for children's literacy could be an interesting avenue for future research.

Overall, some of the design guidelines obtained through the evaluation confirm findings from our previous study, and in particular that is true for the role of the adult facilitator. Chapter 6 showed how having an adult speaker with significant experience could help children engage even when a book or a tool was not explicitly designed for interaction, setting the adult-child dyad at the center of the interaction, and our evaluation of ROBIN supports the same finding: children wish to involve adults when interacting with ROBIN, often looking at them before answering and actively looking to share their experience with them.

Other design guidelines regard the modalities of interaction and the physical affordances of a storytelling toy, as well as the option to function both with and without a paper book.

In conclusion, the evaluation of ROBIN contributes valuable insight on the topic of designing technology-enhanced learning experiences for young children, by providing guidelines and highlighting areas for further exploration and research. One such area will be the topic of the next section, in which we will discuss RQ. 2.4, the adaptation of ROBIN to the next context of supporting second language acquisition for child refugees.

10.2.4 ROBIN's evolution as a tool for language acquisition by Ukrainian child refugees

While ROBIN was originally co-designed as a tool to support young children in learning pre-reading skills, the global refugee crisis led us to explore its possible use to support refugee children in learning a second language.

Chapter 9 discussed how we adapted ROBIN to this new context, and how we explored the use of different digital and traditional storytelling activities in the same context, leading us to the design of a new iteration of ROBIN, with a renewed focus on physical affordances - one of the design guidelines discussed in Chapter 8. This was highlighted in the second prototype, whose octopus-like shape provided children with the opportunity to touch and squeeze the tentacles during the interaction.

Our observations underscored the importance of fun as a dimension, with children showing heightened engagement and interest in digital prototypes, which they perceived as more enjoyable, and the importance of non-auditory cues to support children in better understanding the story.

Once again, the role of the adult facilitator emerged as a critical factor: in contrast with the examples of the previous chapter, in this case the role of the adult is also that of an interpreter and cultural mediator, important not only to offer children additional help and explanation but also as a bridge between two cultures.

10.3 Contributions

This section highlights the contributions of this doctoral dissertation within the CCI field, which are summarised Table 10.1 with the summary of findings and implications for Participatory Design with children. In particular, the content of this dissertation is structured across two parts.

Part I, Children's Involvement and contributions to the design of technology, provides theoretical contributions to the field of CCI, emphasising the different ways in which children have been included and can be included in the design of new technology.

It starts from an analysis, in Chapter 3, of children's drawings to understand their perception of technology, showing how drawings can be a valuable way of obtaining insights into children's expectations and understanding of technology. This chapter answers RQ 1.1 and provides a preliminary exploration of how children's magical thinking influences their view of technology.

Chapter 4, answering RQ 1.2, looks at the wider picture, and goes on to highlight the importance of involving the CCI community to empower children and give them agency, providing a set of guidelines to widen participation to the Research and Design challenge and create and maintain a rich dataset of children's drawings.

Chapter 5, answering RQ 1.3, consists of a literature review on the topic of collaborative design with children, aiming at summarising the most important findings on the topic, as well as highlighting underrepresented populations and discussing children's actual roles in the design of technology.

As such, the first part of this dissertation provides a strong theoretical foundation on the topic of children's contribution to the design of technology; the insights obtained in this first part inform my subsequent work in Part II.

Part II consists of a practical application of the participatory design approach, with allowed me not only to design and evaluate several iterations of the ROBIN prototype, but also to delve into the topic of participatory design, running a proof of concept with the direct involvement of children and providing answers to RQ 2.1 to 2.4.

The contributions of this part are mainly methodological - specifically in Chapter 6 and 8, that discuss respectively the co-design sessions that informed the design of our storytelling tools and the user evaluation that we conducted after-

Table 10.1. Summary of Findings and Implications for Participatory Design

Research Question	**Key Findings**	**Implications for PD**
RQ 1.1	Children depict technology as magical and anthropomorphic, leading to higher expectations. Playful exposure to technology mitigates this phenomenon, allowing for more realistic expectations.	Designers should balance magic and reality, making space for children's creativity while also exposing them to realistic technology.
RQ 1.2	Investing in a long-term collection of children's drawings through widened participation to design challenges could be a rich source of inspiration and foster inclusivity and collaboration in research.	Guidelines to address barriers to participation in design challenges.
RQ 1.3	Young children and teenagers, as well as children with special needs, are underrepresented in PD, and children do not often get to fulfill the role of design partners.	Overview of underrepresented populations and roles in PD with children.
RQ 2.1	Children engage more with tools explicitly design for interaction, and young children engage more in small groups and when building relationships with researchers.	Insights on effective co-design with young children.
RQ 2.2	User Requirements for ROBIN: tangible, designed for interaction, easy to use and supporting children's emotions	User requirements for a prototype
RQ 2.3	Design guidelines for ROBIN: multiple modes of interaction, role of the adult facilitator, physical affordances, functioning with and without a paper book	Insights on user evaluation with young children, design guidelines
RQ 2.4	Design guidelines for storytelling tools for child refugees: fun as a dimension, non-auditory cues, role of the adult facilitator	Design guidelines

wards. In these chapter, we discuss the specific challenges and the methods that we adapted to conduct research with very young children, as well as providing practical design guidelines for a storytelling tools.

Since preschoolers are one of the underrepresented population in co-design, as identified in Chapter 5, our approach to conduct co-design with this population advances the field of CCI by providing a series of adapted methodological approaches to elicit feedback and design ideas from very young children.

Moreover, Chapter 7 and 10 specifically discuss design guidelines for storytelling tools for the two population with whom we worked: young children learning to read, and child refugees learning the languages of their host country.

There are some common themes that recur throughout all these chapter: the role of the adult facilitator, whose importance is highlighted in all our studies, as well as the importance of providing different types of interactions and cues to aid young listeners and enhance comprehension.

The importance of the adult-child dyad in the design of storytelling tools shows how technology does not aim to replace human interaction, but to complement it.

The next section will examine the challenges, limitations and constraints that I encountered over the course of this dissertation.

10.4 Limitations and challenges

While each chapter of this dissertation presents valuable insights and contributions to the field of CCI, it is essential to acknowledge the limitations and challenges encountered during the research.

As I started my doctoral studies in September 2019, my research was significantly affected by the COVID-19 pandemic.

The school closures affected our ability to collaborate with the public schools, and even after the schools reopened, COVID-19 policies and the heavy workload of teachers made it impossible for us to collaborate with the public schools, which led us to shift our focus from the school context to the situation of the individual child outside of school.

During the study described in Chapter 6, we were able to work with a local children's library to recruit children and conduct co-design sessions. The library's efforts to publicise the announcement of our study on their mailing list enabled us to recruit a good number of participants, and the children who took part in our co-design sessions had parents who were interested in reading and literacy and were therefore already familiar with many of the books and toys we used during our sessions.

In addition, the schools we were able to work with in the study presented in Chapter 8, both in Switzerland and Portugal, were all private schools, which led to a lack of diversity in terms of socio-economic status. However, the high proportion of skilled labour migrants in Switzerland meant that the children in the private schools had different cultural and linguistic backgrounds, adding an extra layer of diversity.

The study described in Chapter 9, which took place with Ukrainian child refugees in the context of an after-school activity organised by the Red Cross, uncovered a new challenge: as the adult facilitators had their own goals and aims, we found that we had to reach a compromise with them regarding children's agency and participation to the activities: in the context of an after-school centre to promote literacy, children were often encouraged to participate even when they were uncertain, in situation in which we would have accepted their refusal to engage in the activities.

Overall, the lack of diversity in our participants is the main limitation of this dissertation, as well as the small number of children involved in each study, which does not allow me to generalise my findings. It is however interesting to note that some themes - such as the importance of the adult during shared reading activities - recur even across studies and countries. This, as well as the other limitations and challenges, provide a valuable direction for future research, emphasising the need for continued innovation in the field of CCI. The next section will discuss more specifically the possible directions for future research that come from this dissertation.

10.5 Future Directions

The research presented in this dissertation has laid the foundation to understand children's involvement in the design of technology, and more specifically to understand how to involve young children in the design of technology for literacy.

While this dissertation offers valuable insights on the provided research questions, there is still considerable potential to build upon its findings and address the limitations and challenges identified in the previous section.

Concerning the role of drawings in children's perception and understanding of technology, the R&D challenge provides researchers with a rich collection of drawings every year; by incorporating new drawings from the latest years, it would be possible to gain a better understanding of how children's perception changed over time.

Likewise, the guidelines provided in Chapter 4 for the Research and Design challenge represent only a starting point; once implemented, future research could assess their effectiveness in widening participation and inspiring young researchers, while at the same time reducing the time-intensiveness of the challenge for the participating researchers.

The literature review in Chapter 5 uncovered the fact that many methods and approaches presented in research are rarely re-used in subsequent works; the reasons for this lack of adoption of existing approach could also be an interesting avenue for future research.

The research presented in Part II is well suited to being expanded and built upon; on one hand, all our studies involve a small number of children and mostly provide qualitative data, suggesting the possibility to explore how different storytelling tools and approaches impact vocabulary size, language comprehension and other pre-reading skills, both in native speakers who are learning to read and in second language learners such as refugee children.

On the other hand, the lack of diversity identified as the main limitation of this doctoral thesis suggests that both the co-design studies and the evaluation of the prototype could be expanded to include children from different social, cultural and linguistic background.

Another important issue is children's role in the design of technology: as a result of working with very young children, we were not able to fully involve them as design partners, while obtaining valuable feedback from them in the role of informants. Involving preschoolers as full design partners is still an open area of research, with some research suggesting it possible only for older preschoolers. However, as children are exposed to technology at increasingly younger ages, their involvement in the design of technology should be at the forefront of future research.

Overall, the possible future directions outlined in this section represent ambitious and innovative advances to the field of PD with children and technology for literacy. By building on the foundations laid by this dissertations, future research can significantly contribute to enhance the diversity, inclusion and educational value of PD with children and storytelling toys.

Chapter 11

Conclusions

This doctoral dissertation has explored the intersection of participatory design with children and language learning, with a focus on empowering children to fully participate in the design of technology.

Through a series of theoretical contributions and methodological studies, I have uncovered valuable insights that contribute to both theory and practice in the field of Child-Computer Interaction.

My investigation into the involvement of children in the design of technology has uncovered several key findings. First, we identified the role of drawings as a means to uncover children's expectations and preferences about technology, with children often depicting technology as magical. This underscore the importance of fostering children's imagination, while at the same time exposing them to real-world technology to temper their expectations.

Furthermore, my exploration of the role of the CCI community in empowering children led me to define guidelines for the Research and Design challenge, with the aim of widening participation and harnessing the creativity of young children to drive meaningful advantages in research.

Moreover, my review on the topic of participatory design with children uncovered gaps in the literature, as well as the actual extent of children's participation in design as partners.

The second part of my dissertation focused on the practical application of co-design with young children, allowing me to both explore methodological approaches to involve this underrepresented demographic, and provide guidelines for the design of a storytelling tool.

While I was not able to involve children as full design partners, their involvement allowed me gauge the effectiveness of several ways of obtaining feedback from them; one of the most promising approach was a mix of structured and unstructured play activities, allowing me to observe children as they interacted freely with technology.

On the topic of designing for literacy, my research underscored the critical role of adult facilitators in supporting children's participation and comprehension during storytelling activities. This emphasises the importance of human-centred design approaches that prioritise the needs and preferences of both children and their caregivers, as also expressed by parents and teachers in a series of interviews.

In conclusion, this thesis represent a valuable contribution to the field of CCI, by offering theoretical contributions, methodological insights and practical applications for involving children in the design of technology.

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Appendix A

.1 Papers included in the review in Chapter 5

	Title	Year	Authors
[358]	Pushing political, cultural, and geographical boundaries: Distributed co-design with children from Namibia, Malaysia and Finland	2022	Winschiers-Theophilus, Heike and Goagoses, Naska and Rötkönen, Erkki and Zaman, Tariq
[95]	Pushing boundaries of co-design by going online: Lessons learned and reflections from three perspectives	2022	Fails, Jerry Alan and kumar Ratakonda, Dhanush and Koren, Nitzan and Elsayed-Ali, Salma and Bonsignore, Elizabeth and Yip, Jason
[351]	A codesign study exploring needs, strategies, and opportunities for digital health platforms to address pandemic-related impacts on children and families	2023	Warren, Jillian L. and Antle, Alissa N. and Kitson, Alex and ra and Davoodi, Alireza
[340]	Towards a participative approach for adapting multimodal digital books for deaf and hard of hearing people	2017	Vàliz, Soledad and Espinoza, Victoria and Sauvalle, Ignacia and Arroyo, Rodrigo and Pizarro, Marcelo and Garolera, Marion
[122]	Situating computational empowerment in formal education: A multi-perspective view	2023	Göbl, Barbara and Guenther, Elisabeth Anna and Kayali, Fares and Frauenberger, Christopher

[268]	Participatory design with children in the development of a support system for patient-centered care in pediatric oncology	2008	Rul and , Cornelia M. and Starren, Justin and Vatne, Torun M.
[238]	Shimpai Muyou: Confronting Child Suicides in Japan through a Serious Game & School-based Intervention	2023	Paracha, Samiullah and Hall, Lynne and Watson, Derek and Khuram, Ayesha and Shah, Naqeeb
[50]	FroggyBobby: An exergame to support children with motor problems practicing motor coordination exercises during therapeutic interventions	2017	Caro, Karina and Tentori, Mònica and Martinez-Garcia, Ana I. and Zavala-Ibarra, Ivan
[277]	Going beyond short-term,"reduced" PD: Towards an encompassing typology for children's participation in infrastructuring processes	2022	Schepers, Selina and Schoffelen, Jessica and Zaman, Bieke and Dreessen, Katrien
[164]	Sparking interest: A design framework for mobile technologies to promote children's interest in nature	2019	Kawas, Saba and Chase, Sarah K. and Yip, Jason and Lawler, Joshua J. and Davis, Katie
[121]	Cooperative Inquiry revisited: Reflections of the past and guidelines for the future of intergenerational co-design	2013	Guha, Mona Leigh and Druin, Allison and Fails, Jerry Alan
[245]	Learning maths with a tangible user interface: Lessons learned through participatory design with children with visual impairments and their educators	2022	Pires, Ana Cristina and Bakala, Ewelina and Gonzàlez-Perilli, Fernando and Sansone, Gustavo and Fleischer, Bruno and Marichal, Sebastian and Guerreiro, Tiago
[171]	YoungDeafDesign: Participatory design with young Deaf children	2022	Korte, Jessica
[167]	Bridging serious games and participatory design	2014	Khaled, Rilla and Vasalou, Asimina

[11]	Co-designing with children a collaborative augmented reality book based on a primary school textbook	2018	Alhumaidan, Haifa and Lo, Kathy Pui Ying and Selby, Andrew
[180]	A comparative study into how pupils can play different roles in co-design activities	2018	L and oni, Monica and Rubegni, Elisa and Nicol, Emma
[378]	Co-design and qualitative validation of animated assessment item content for a child-reported digital distress screener	2021	Zieschank, Kirsty and Day, Jamin and Irel and , Michael J. and March, Sonja
[333]	On power and participation: Reflections from design with developmentally diverse children	2021	Vasalou, Asimina and Ibrahim, Seray and Clarke, Michael and Griffiths, Yvonne
[103]	Conversing through and about technologies: Design critique as an opportunity to engage children with autism and broaden research(er) perspectives	2013	Frauenberger, Christopher and Good, Judith and Alcorn, Alyssa and Pain, Helen
[65]	Distributing participation in design: Addressing challenges of a global pandemic	2021	Constantin, Aurora and Alex and ru, Cristina and Korte, Jessica and Wilson, Cara and Fails, Jerry Alan and Sim, Gavin and Read, Janet C. and Eriksson, Eva
[317]	New co-design techniques for digital game narrative design with children	2022	Uğraş, Tuba and Rızvanoğlu, Kerem and Gülseçen, Sevinç
[225]	Designing a Virtual Reality Empathy Game framework to create empathic experiences for children	2023	Muravevskaia, Ekaterina and Gardner-McCune, Christina
[312]	Designing an educational interactive eBook for newly diagnosed children with type 1 diabetes: Mapping a new design space	2019	Tsvyatkova, Damyanka and Storni, Cristiano

[138]	Aligning technological and pedagogical considerations: Harnessing touch-technology to enhance opportunities for collaborative gameplay and reciprocal teaching in NZ early education	2014	Hoda, Rashina and Henderson, Annette and Lee, Shiree and Beh, Bridget and Greenwood, Jason
[174]	Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece	2015	Kostakis, Vasilis and Niaros, Vasilis and Giotitsas, Christos
[278]	To Empower or Provoke? Exploring approaches for participatory design at schools for neurodiverse individuals in India	2022	Sharma, Sumita and Achary, Krishnaveni and Kinnula, Marianne and Norouzi, Behnaz and Kinnula, Henrietta and Iivari, Netta and VentÃ¤-Olkkonen, Leena and Holappa, Jenni
[17]	Characterizing children's conceptual knowledge and computational practices in a critical machine learning educational program	2022	Arastoopour Irgens, Golnaz and Vega, Hazel and Adisa, Ibrahim and Bailey, Cinamon
[249]	Adaptation of the trauma group intervention"Teaching Recovery Techniques' for online delivery: A participatory design and usability study	2022	Pérez-Aronsson, Anna and Thell, Maria and Lampa, Elin and Löfving, Sandra Gupta and Tökés, Antonia and Torakai, Naqib and Ibrahim, Kalid and Aljeshy, Reem and Warner, Georgina
[236]	Using the blended spaces framework to design heritage stories with schoolchildren	2015	O'Keefe, Brian and Benyon, David
[294]	The child's perspective as a guiding principle: Young children as co-designers in the design of an interactive application meant to facilitate participation in healthcare situations	2016	Stålberg, Anna and Sandberg, Anette and Söderbäck, Maja and Larsson, Thomas

[275]	Rethinking children's roles in Participatory Design: The child as a process designer	2018	Schepers, Selina and Dreessen, Katrien and Zaman, Bieke
[232]	Designing an educational music game: What if children were calling the tune?	2016	Nouwen, Marije and Schepers, Selina and Mouws, Karen and Slegers, Karin and Kosten, Niek and Duysburgh, Pieter
[203]	An inclusive design approach for developing video games for children with Autism Spectrum Disorder	2017	Malinverni, Laura and Mora-Guiard, Joan and Padillo, Vanesa and Valero, Lilia and HervÃ¡s, Amaia and Pares, Narcis
[269]	Examining children's design processes, perspective-taking, and collaboration when using VR head-mounted displays	2022	Ryokai, Kimiko and Jacobo, S and ra and Rivero, Edward and Park, Julia
[76]	KidSpell: Making a difference in spellchecking for children	2022	Downs, Brody and Pera, Maria Soledad and Wright, Katherine L and au and Kennington, Casey and Fails, Jerry Alan
[240]	Learning to work together: Designing a multi-user virtual reality game for social collaboration and perspective-taking for children with autism	2015	Parsons, Sarah
[227]	Co-designing a social robot for child health care	2023	Neerincx, Anouk and Veldhuis, Daan and Masthoff, Judith M.F. and de Graaf, Maartje M.A.
[155]	Understanding teenagers' motivation in participatory design	2013	Iversen, Ole Sejer and Dindler, Christian and Hansen, Elin Irene Krogh
[149]	Capturing tacit knowledge from young girls	2004	Isomursu, Minna and Isomursu, Pekka and Still, Kaisa
[116]	Students' achievement goals: Goal approximation, engagement, and emotions in co-design activities and product	2023	Goagoses, Naska and Winschiers-Theophilus, Heike and RÃ¶tkÃ¶nen, Erkki

[153]	A Utopian agenda in child-computer interaction	2013	Iversen, Ole Sejer and Dindler, Christian
[178]	"Pictures are easier to remember than spellings!": Designing and evaluating KidsPic - A graphical image-based authentication mechanism	2022	kumar Ratakonda, Dhanush and Mehrpouyan, Hoda and Fails, Jerry Alan
[34]	Widening participation in technology design: A review of the involvement of children with special educational needs and disabilities	2015	Benton, Laura and Johnson, Hilary
[287]	CyberPLAYce-A tangible, interactive learning tool fostering children's computational thinking through storytelling	2019	Soleimani, Arash and Herro, Danielle and Green, Keith Evan
[313]	A review of selected methods, techniques and tools in Child-Computer Interaction (CCI) developed/adapted to support children's involvement in technology development	2019	Tsvyatkova, Damyanka and Storni, Cristiano
[55]	TitanTutor: An educational technology solution co-designed by children from different age groups and socio-economic backgrounds	2018	Chimbo, Bester and Gelderblom, Helene
[64]	Designing computer-based rewards with and for children with Autism Spectrum Disorder and/or Intellectual Disability	2017	Constantin, Aurora and Johnson, Hilary and Smith, Elizabeth and Lengyel, Denise and Brosnan, Mark
[251]	Stimulating children's engagement with an educational serious videogame using Lean UX co-design	2021	Ramos-Vega, Maria C. and Palma-Morales, Victor M. and Pérez-Maran, Diana and M. Moguerza, Javier

[161]	Children's conceptions of mental well-being and ideas for its promotion through digital environments	2021	Kankaanranta, Marja and MehtÃ¤lÃ¤, Saana and Hankala, Mari and Merjovaara, Olli and Rousi, Rebekah
[369]	Examining Adult-Child Interactions in Intergenerational Participatory Design	2017	Yip, Jason C. and Sobel, Kiley and Pitt, Caroline and Lee, Kung Jin and Chen, Sijin and Nasu, Kari and Pina, Laura R.
[331]	Challenging group dynamics in participatory design with children: lessons from social interdependence theory	2015	Van Mechelen, Maarten and Zaman, Bieke and Laenen, Ann and Abeele, Vero V and en
[73]	Participatory design at the museum: inquiring into children's everyday engagement in cultural heritage	2010	Dindler, Christian and Iversen, Ole Sejer and Smith, Rachel and Veerasawmy, Rune
[276]	Exploring user gains in participatory design processes with vulnerable children	2018	Schepers, Selina and Dreessen, Katrien and Zaman, Bieke
[209]	Children's Perspectives on Ethical Issues Surrounding Their Past Involvement on a Participatory Design Team	2016	McNally, Brenna and Guha, Mona Leigh and Mauriello, Matthew Louis and Druin, Allison
[210]	Gains from Participatory Design Team Membership as Perceived by Child Alumni and their Parents	2017	McNally, Brenna and Mauriello, Matthew Louis and Guha, Mona Leigh and Druin, Allison
[166]	Children as Designers - Recognising divergent creative modes in Participatory Design	2020	Kender, Kay and Frauenberger, Christopher and Pichlbauer, Johanna and Werner, Katharina
[223]	Robot Co-design Can Help Us Engage Child Stakeholders in Ethical Reflection	2022	Mott, Terran and Bejarano, Alex and ra and Williams, Tom
[355]	Co-Design Beyond Words: 'Moments of Interaction' with Minimally-Verbal Children on the Autism Spectrum	2019	Wilson, Cara and Brereton, Margot and Ploderer, Bernd and Sitbon, Laurianne

[368]	The Evolution of Engagements and Social Bonds During Child-Parent Co-design	2016	Yip, Jason C. and Clegg, Tamara and Ahn, June and Uchidiuno, Judith Odili and Bonsignore, Elizabeth and Beck, Austin and Pauw, Daniel and Mills, Kelly
[124]	Using Participatory Design with Proxies with Children with Limited Communication	2017	Hamidi, Foad and Baljko, Melanie and Gomez, Isabel
[359]	Using Co-Design to Examine How Children Conceptualize Intelligent Interfaces	2018	Woodward, Julia and McFadden, Zari and Shiver, Nicole and Ben-hayon, Amir and Yip, Jason C. and Anthony, Lisa
[70]	The "Least-Adult" Role in Participatory Design with Children	2020	Cumbo, Bronwyn J. and Eriksson, Eva and Iversen, Ole Sejer
[202]	Participatory design strategies to enhance the creative contribution of children with special needs	2014	Malinverni, Laura and Mora-Guiard, Joan and Padillo, Vanesa and Mairena, MariaAngeles and Hervas, Amaia and Pares, Narcis
[290]	Micro-ethics for participatory design with marginalised children	2018	Spiel, Katta and Brulé, Emeline and Frauenberger, Christopher and Bailly, Gilles and Fitzpatrick, Geraldine
[144]	Designing Together, Miles Apart: A Longitudinal Tabletop Telepresence Adventure in Online Co-Design with Children	2023	Hunt, Casey Lee and Sun, Kaiwen and Dhuliawala, Zahra and Tsukiyama, Fumi and Matkovic, Iva and Schwemler, Zachary and Wolf, Anastasia and Zhang, Zihao and Druin, Allison and Huynh, Am and a and Leithinger, Daniel and Yip, Jason
[109]	Conversational Technologies for In-home Learning: Using Co-Design to Understand Children's and Parents' Perspectives	2020	Garg, Radhika and Sengupta, Subhasree

[78]	The roles of adult-participants in the back- and frontstage work of participatory design processes involving children	2018	Dreessen, Katrien and Schepers, Selina
[360]	"It Would Be Cool to Get Stampeded by Dinosaurs": Analyzing Children's Conceptual Model of AR Headsets Through Co-Design	2022	Woodward, Julia and Alemu, Feben and E. Lopez Adames, Natalia and Anthony, Lisa and C. Yip, Jason and Ruiz, Jaime
[273]	Co-design Techniques for and with Children based on Physical Theatre Practice to promote Embodied Awareness	2021	Schaper, Marie-Monique and Pares, Narcis
[319]	"It became Elvis" - Co-design lessons with children	2010	Vaajakallio, Kirsikka and Mattelmaki, Tuuli and Lee, Jung-Joo
[371]	"Money shouldn't be money!": An Examination of Financial Literacy and Technology for Children Through Co-Design	2023	Yip, Jason C. and Ello, Frances Marie Tabio and Tsukiyama, Fumi and Wairagade, Atharv and Ahn, June
[272]	Robots, Bullies and Stories: A Remote Co-design Study with Children	2021	Sanoubari, Elaheh and Munoz Cardona, John Edison and Mahdi, Hamza and Young, James E. and Houston, Andrew and Dautenhahn, Kerstin
[105]	Blending Methods: Developing Participatory Design Sessions for Autistic Children	2017	Frauenberger, Christopher and Makhaeva, Julia and Spiel, Katta
[334]	Fostering Children's Stewardship of Local Nature Through Game Co-design	2022	Vella, Kellie and Dema, Tshering and Soro, Aless and ro and Brereton, Margot
[28]	Modelling the roles of designers and teaching staff when doing participatory design with children in special education	2018	Barendregt, Wolmet and Borjesson, Peter and Eriksson, Eva and Torgersson, Olof and Bekker, Tilde and Skovbjerg, Helle Marie

[87]	Enhancing the vocabulary learning skills of autistic children using augmented reality: a participatory design perspective	2023	El Shemy, Ibrahim and Urrea Echeverria, Ana Lucìa and Erena-Guardia, Gema and Saldana, David and Vulchanova, Mila and Giannakos, Michail
[184]	The Show Must Go On: A Conceptual Model of Conducting Synchronous Participatory Design With Children Online	2021	Lee, Kung Jin and Roldan, Wendy and Zhu, Tian Qi and Kaur Saluja, Harkiran and Na, Sungmin and Chin, Britnie and Zeng, Yilin and Lee, Jin Ha and Yip, Jason
[344]	DisCo: a co-design online tool for asynchronous distributed child and adult design partners	2012	Walsh, Greg and Druin, Allison and Guha, Mona Leigh and Bonsignore, Elizabeth and Foss, Elizabeth and Yip, Jason C. and Golub, Evan and Clegg, Tamara and Brown, Quincy and Brewer, Robin and Joshi, Asmi and Brown, Richelle
[350]	Lessons Learned and Future Considerations for Designing Remotely Facilitated Co-Design Studies with Children Focused on Socio-Emotional Experiences	2022	Warren, Jillian L. and Antle, Alissa N. and Kitson, Alex and ra and Davoodi, Alireza
[56]	P for Politics D for Dialogue: Reflections on Participatory Design with Children and Animals	2020	Chisik, Yoram and Mancini, Clara
[234]	Collective co-design activities with children for designing classroom robots	2024	Obaid, Mohammad and Baykal, Gokcce Elif and Kirlangic, Guncel and Goksun, Tilbe and Yantacc, Asim Evren
[156]	Child as Protagonist: Expanding the Role of Children in Participatory Design	2017	Iversen, Ole Sejer and Smith, Rachel Charlotte and Dindler, Christian

[258]	Giving ideas an equal chance: inclusion and representation in participatory design with children	2014	Read, Janet C. and Fitton, Daniel and Horton, Matthew
[318]	"It has to be a group work!": co-design with children	2009	Vaajakallio, Kirsikka and Lee, Jung-Joo and Mattelmaki, Tuuli
[343]	Layered elaboration: a new technique for co-design with children	2010	Walsh, Greg and Druin, Alison and Guha, Mona Leigh and Foss, Elizabeth and Golub, Evan and Hatley, Leshell and Bonsignore, Elizabeth and Franckel, Sonia
[179]	Children imitate! appreciating recycling in participatory design with children	2010	Kuure, Leena and Halkola, Eija and Iivari, Netta and Kinnula, Marianne and Molin-Juustila, Tonja
[352]	"This is a flying shopping trolley": a case study of participatory design with children in a shopping context	2008	Weiss, Astrid and Wurhofer, Daniela and Bernhaupt, Regina and Beck, Elke and Tscheligi, Manfred
[35]	Developing IDEAS: supporting children with autism within a participatory design team	2012	Benton, Laura and Johnson, Hilary and Ashwin, Emma and Brosnan, Mark and Grawemeyer, Beate
[322]	"This book is magical!": exploring emergent readers' preferences and wishes for storytelling tools	2022	Valguarnera, Sveva and L and oni, Monica
[342]	A case for intergenerational distributed co-design: the online kidsteam example	2015	Walsh, Greg and Foss, Elizabeth
[366]	Brownies or bags-of-stuff? domain expertise in cooperative inquiry with children	2013	Yip, Jason and Clegg, Tamara and Bonsignore, Elizabeth and Gelderblom, Helene and Rhodes, Emily and Druin, Allison

[293]	Children with ADHD and their Care Ecosystem: Designing Beyond Symptoms	2023	Stefanidi, Evropi and Schoning, Johannes and Rogers, Yvonne and Niess, Jasmin
[346]	Inclusive Co-Design within a Three-Dimensional Game Environment	2016	Walsh, Greg and Donahue, Craig and Pease, Zachary
[264]	Playing on the Globe: Facilitating virtual communications between Namibian and Finnish learners to co-design an interactive map game	2021	Rotkonen, Erkki and Winschiers-Theophilus, Heike and Goagoses, Naska and Itenge, Helvi and Shinedima, Gabriel and Sutinen, Erkki
[214]	Digitally augmenting the flannel board	2012	Medeiros, Maria Ana and Branco, Pedro and Coutinho, Clara
[288]	When Empathy Is Not Enough: Assessing the Experiences of Autistic Children with Technologies	2017	Spiel, Katta and Frauenberger, Christopher and Hornecker, Eva and Fitzpatrick, Geraldine
[101]	Supporting the design contributions of children with autism spectrum conditions	2012	Frauenberger, Christopher and Good, Judith and Alcorn, Alyssa and Pain, Helen
[36]	Diversity for design: a framework for involving neurodiverse children in the technology design process	2014	Benton, Laura and Vasalou, Asimina and Khaled, Rilla and Johnson, Hilary and Gooch, Daniel
[106]	Nurturing Constructive Disagreement - Agonistic Design with Neurodiverse Children	2019	Frauenberger, Christopher and Spiel, Katta and Scheepmaker, Laura and Posch, Irene
[89]	"The concept of learning goals will always be in my head"	2021	Eriksson, Eva and Torgersson, Olof
[152]	Co-creating an enabling reading environment for and with Namibian children	2016	Itenge-Wheeler, Helvi and Kuure, Essi and Brereton, Margot and Winschiers-Theophilus, Heike

[107]	Desiging Social Play Things	2020	Frauenberger, Christopher and Kender, Kay and Scheepmaker, Laura and Werner, Katharina and Spiel, Katta
[283]	Engaging Children to Co-create Outdoor Play Activities for Place-making -	2020	Slingerl and , Geertje and Lukosch, Stephan and Brazier, Frances
[74]	Towards tangible gamified co-design at school: two studies in primary schools	2014	Dodero, Gabriella and Gennari, Rosella and Melonio, Aless and ra and Torello, Santina
[102]	Interpreting input from children: a designerly approach	2012	Frauenberger, Christopher and Good, Judith and Keay-Bright, Wendy and Pain, Helen
[41]	Teachers' Expected and Perceived Gains of Participation in Classroom Based Design Activities	2019	Borjesson, Peter and Barendregt, Wolmet and Eriksson, Eva and Torgersson, Olof and Bekker, Tilde
[204]	Children's Creativity Lab: Creating a 'Pen of the Future'	2014	Mann, Anne-Marie and Hinrichs, Uta and Quigley, Aaron
[27]	Legitimate Participation in the Classroom Context: Adding Learning Goals to Participatory Design	2016	Barendregt, Wolmet and Bekker, Tilde M. and Borjesson, Peter and Eriksson, Eva and Torgersson, Olof
[309]	Child-centered interaction in the design of a game for social skills intervention	2011	Tan, Jean Lee and Goh, Dion Hoe-Lian and Ang, Rebecca P. and Huan, Vivien S.
[243]	Chatbots to Support Children in Coping with Online Threats: Socio-technical Requirements	2021	Piccolo, Lara Schibelsky Godoy and Troullinou, Pinelopi and Alani, Harith
[94]	Query Formulation Assistance for Kids: What is Available, When to Help	2019	Jerry Alan Fails, Maria Soledad Pera, Oghenemaro Anuyah, Casey Kennington, Katherine Landau Wright, and William Bigirimana
[104]	Designing Smart Objects with Autistic Children: Four Design Exposés	2016	Frauenberger, Christopher and Makhaeva, Julia and Spiel, Katta

[113]	Embodied narratives: a performative co-design technique - Proceedings of the Designing Interactive Systems Conference	2012	Giaccardi, Elisa and Paredes, Pedro and Dìaz, Paloma and Alvarado, Diego
[67]	Co-designing Inclusive Multisensory Story Mapping with Children with Mixed Visual Abilities	2019	Cullen, Clare and Metatla, Oussama
[222]	Children's participation in the design of digital artifacts in rural schools	2022	Morais, Dyego and Falcao, Taciana Pontual and Tedesco, Patrìcia
[212]	Co-designing Mobile Online Safety Applications with Children	2018	McNally, Brenna and Kumar, Priya and Hordatt, Chelsea and Mauriello, Matthew Louis and Naik, Shalmali and Norooz, Leyla and Shorter, Alaz and ra and Golub, Evan and Druin, Allison
[23]	Stranger Danger! Social Media App Features Co-designed with Children to Keep Them Safe Online	2019	Badillo-Urquiola, Karla and Smriti, Diva and McNally, Brenna and Golub, Evan and Bonsignore, Elizabeth and Wisniewski, Pamela J.
[118]	Towards A Design For Life: Redesigning For Reminiscence With Looked After Children	2020	Gray, Stuart and Hahn, Rachel and Cater, Kirsten and Watson, Debbie and Williams, Keir and Metcalfe, Tom and Meineck, Chloe
[192]	Ethics in health promoting PD: designing digital peer support with children cured from cancer	2014	Lindberg, Susanne and Thomsen, Michel and Åkesson, Maria
[335]	Embedded assumptions in design and Making projects with children	2021	Venta-Olkkonen, Leena and Kinnula, Marianne and Hartikainen, Heidi and Iivari, Netta

[270]	How Should a Social Robot Deliver Negative Feedback Without Creating Distance Between the Robot and Child Users?	2023	Sakamoto, Yumiko and Herath, Anuradha and Vuradi, Tanvi and Sallam, Samar and Gomez, Randy and Irani, Pourang
[215]	"Bursting the Assistance Bubble": Designing Inclusive Technology with Children with Mixed Visual Abilities	2018	Metatla, Oussama and Cullen, Clare
[315]	"What's Your Name Again?": How Race and Gender Dynamics Impact Codesign Processes and Output	2023	Uchidiuno, Judith Odili and Solyst, Jaemarie and Kemper, Jonaya and Harpstead, Erik and Higashi, Ross and Hammer, Jessica
[347]	"Treat me as your friend, not a number in your database": Co-designing with Children to Cope with Datafication Online	2023	Wang, Ge and Zhao, Jun and Van Kleek, Max and Shadbolt, Nigel
[151]	Virtually Escaping Lock Down - co-designing a mixed reality escape room narrative with Namibian learners-	2021	Itenge, Helvi and Sedano, Carolina Islas and Winschiers-Theophilus, Heike
[370]	Laughing is Scary, but Farting is Cute: A Conceptual Model of Children's Perspectives of Creepy Technologies	2019	Yip, Jason C. and Sobel, Kiley and Gao, Xin and Hishikawa, Allison Marie and Lim, Alexis and Meng, Laura and Ofiana, Romaine Flor and Park, Justin and Hiniker, Alexis
[177]	Co-designing online privacy-related games and stories with children	2018	Kumar, Priya and Vitak, Jessica and Chetty, Marshini and Clegg, Tamara L. and Yang, Jonathan and McNally, Brenna and Bonsignore, Elizabeth
[183]	The Unboxing Experience: Exploration and Design of Initial Interactions Between Children and Social Robots	2022	Lee, Christine P and Cagiltay, Bengisu and Mutlu, Bilge

[59]	Pre-schoolers' Stewardship - Embracing Higgledy-piggledy Behaviours through Participatory Plaything	2022	Clasina Sodergren, Antonia and Suero Montero, Calkin
[199]	Brave and Kind Superheroes - Children's Reflections on the Design Protagonist Role	2022	Mahboob Kanafi, Matin and Iivari, Netta and Kinnula, Marianne
[314]	"I'm a little less inclined to do it": How Afterschool Programs' Culture Impact Co-Design Processes and Outcomes	2023	Uchidiuno, Judith Odili and Solyst, Jaemarie and Harpstead, Erik and Higashi, Ross
[31]	"It's just too much": exploring children's views of boredom and strategies to manage feelings of boredom	2020	Begnaud, Danielle and Coenraad, Merijke and Jain, Naishi and Patel, Dhruvi and Bonsignore, Elizabeth
[201]	Creating creative spaces for co-designing with autistic children: the concept of a "Handlungsspielraum"	2016	Makhaeva, Julia and Frauenberger, Christopher and Spiel, Katta
[218]	Design strategies for youth-focused pervasive social health games	2013	Miller, Andrew D. and Pater, Jessica and Mynatt, Elizabeth D.
[8]	A digital storytelling tool for Arab children	2012	Zahra Al-Mousawi, Asmaa Alsumait
[274]	Leaving the Field: Designing a Socio-Material Toolkit for Teachers to Continue to Design Technology with Children	2021	Scheepmaker, Laura and Kender, Kay and Frauenberger, Christopher and Fitzpatrick, Geraldine
[117]	Life as a Robot (at CHI): Challenges, Benefits, and Prospects for Attending Conferences via Telepresence	2017	Golub, Evan and McNally, Brenna and Lewittes, Becky and Shorter, Alaz and ra and Kidsteam, The Kids of
[68]	CCI in the wild: designing for environmental stewardship through children's nature-play	2020	Cumbo, Bronwyn J. and Iversen, Ole Sejer

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[247]	Designing interspecies playful interactions: studying children perceptions of games with animals	2017	Pons, Patricia and Jaen, Javier
[206]	Considering context, content, management, and engagement in design activities with children	2010	Mazzone, Emanuela and Iivari, Netta and Tikkanen, Ruut and Read, Janet C. and Beale, Russell
[253]	Capturing and Considering Idea Development in School Pupils' Design Activities	2021	Read, Janet and Fitton, Dan and Horton, Matthew
[108]	A systematic mapping study on participatory game design with children	2024	Galvao, Ludmilla and Garcìa, Laura Sanchez and Felipe, Tanya Amara
[211]	Toward Understanding Children's Perspectives on Using 3D Printing Technologies in their Everyday Lives	2017	McNally, Brenna and Norooz, Leyla and Shorter, Alaz and ra and Golub, Evan
[40]	Designing technology for and with developmentally diverse children: a systematic literature review	2015	Brorjesson, Peter and Barendregt, Wolmet and Eriksson, Eva and Torgersson, Olof
[44]	Negotiating Gender and Disability Identities in Participatory Design	2019	Brulé, Emeline and Spiel, Katta
[39]	Sharing Stories "in the Wild": A Mobile Storytelling Case Study Using StoryKit	2013	Bonsignore, Elizabeth and Quinn, Alex and er J. and Druin, Allison and Bederson, Benjamin B.
[75]	"There Is No Rose Without A Thorn": An Assessment of a Game Design Experience for Children	2015	Dodero, Gabriella and Gennari, Rosella and Melonio, Aless and ra and Torello, Santina

[63]	Understanding reading experience to inform the design of ebooks for children	2012	Colombo, Luca and L and oni, Monica and Rubegni, Elisa
[213]	Behind the Scenes: Design, Collaboration, and Video Creation with Youth	2019	McRoberts, Sarah and Yuan, Ye and Watson, Kathleen and Yarosh, Svetlana
[327]	SpiroPlay, a Suite of Breathing Games for Spirometry by Kids	2020	van Delden, Robby and Plass-Oude Bos, Danny and de With, Antje Jacoba Vivian (Vivianne) and Vogel, Koen and Klaassen, Randy and Zwart, Nynke and Faber, Joyce and Thio, Boony and van der Kamp, Mattienne
[12]	Children as Robot Designers	2021	Alves-Oliveira, Patricia and Arriaga, Patrìcia and Paiva, Ana and Hoffman, Guy
[119]	Characters as agents for the co-design process	2012	Grundy, Cathy and Pemberton, Lyn and Morris, Richard
[100]	Phenomenology, a framework for participatory design	2010	Frauenberger, Christopher and Good, Judith and Keay-Bright, Wendy
[111]	Design of IoT Tangibles for Primary Schools: A Case Study	2017	Gennari, Rosella and Melonio, Aless and ra and Rizvi, Mehdi and Bonani, Andrea
[24]	Children's Rights in Your Pocket - Lessons Learned from a Three-Year Case Study on Participatory App Design with Children	2023	Baldauf, Matthias and Ingold, Selina and Thoma, Andrea and Dickenmann, Corinne and Ziegler, Michael and Falkenreck, M and y and Cicia, Letizia and Kirchschlager, Thomas and Flisch, Regula
[127]	Children's use of government information systems: design and usability	2009	Harrison, Teresa M. and Zappen, James P. and Watson, David

[112]	Designing a Platform for Child Rehabilitation Exergames Based on Interactive Sonification of Motor Behavior	2018	Ghisio, Simone and Kolykhalova, Ksenia and Volpe, Gualtiero and Amadeo, Beatrice and Coletta, Paolo and Ferrari, Nicola and Tacchino, Chiara and Fiscon, Sofia and Primavera, Ludovica and Moretti, Paolo and Camurri, Antonio
[84]	Fantasies in narration: narrating the requirements of children in mobile gaming design	2010	Duh, Henry Been-Lirn and Chen, Vivian Hsueh-Hua
[57]	Co-Designing with Early Adolescents: Understanding Perceptions of and Design Considerations for Tech-Based Mediation Strategies that Promote Technology Disengagement	2023	Chowdhury, Ananta and Bunt, Andrea
[58]	Supporting Self-Regulation of Children with ADHD Using Wearables: Tensions and Design Challenges	2020	Cibrian, Franceli L. and Lakes, Kimberley D. and Tavakoulnia, Arya and Guzman, Kayla and Schuck, Sabrina and Hayes, Gillian R.
[349]	Co-constructing child personas for health-promoting services with vulnerable children	2014	Wärnestål, Pontus and Svedberg, Petra and Nygren, Jens
[139]	Three tensions in participatory design for inclusion	2013	Holone, Harald and Herstad, Jo
[332]	Expressions of ownership: motivating users in a co-design process	2008	van Rijn, Helma and Stappers, Pieter Jan
[114]	Designing affective animations with children as design partners using role-playing	2011	Girard, Sylvie and Johnson, Hilary
[246]	Designing and evaluating interfaces for domestic eco-feedback: a blended educational experience	2015	Pittarello, Fabio and Pellegrini, Tommaso

[9]	Science Everywhere: Designing Public, Tangible Displays to Connect Youth Learning Across Settings	2018	Ahn, June and Clegg, Tamara and Yip, Jason and Bonsignore, Elizabeth and Pauw, Daniel and Cabrera, Lautaro and Hernly, Kenna and Pitt, Caroline and Mills, Kelly and Salazar, Arturo and Griffing, Diana and Rick, Jeff and Marr, Rachael
[165]	MakerWear: A Tangible Approach to Interactive Wearable Creation for Children	2017	Kazemitabaar, Majeed and McPeak, Jason and Jiao, Alex and er and He, Liang and Outing, Thomas and Froehlich, Jon E.
[148]	Family and design in the IDC and CHI communities	2012	Isola, Sara and Fails, Jerry Alan
[377]	Co-designing with Adolescents with Autism Spectrum Disorder: From Ideation to Implementation	2020	Zhu, Randy and Hardy, Dianna and Myers, Trina
[266]	Design for Change With and for Children: How to Design Digital StoryTelling Tool to Raise Stereotypes Awareness	2020	Rubegni, Elisa and L and oni, Monica and Jaccheri, Letizia
[159]	PrototypAR: Prototyping and Simulating Complex Systems with Paper Craft and Augmented Reality	2019	Kang, Seokbin and Norooz, Leyla and Bonsignore, Elizabeth and Byrne, Virginia and Clegg, Tamara and Froehlich, Jon E.
[244]	From Personal Informatics to Family Informatics: Understanding Family Practices around Health Monitoring	2017	Pina, Laura R. and Sien, Sang-Wha and Ward, Teresa and Yip, Jason C. and Munson, Sean A. and Fogarty, James and Kientz, Julie A.
[285]	Towards an ecological inquiry in child-computer interaction	2013	Smith, Rachel C. and Iversen, Ole S. and Hjermitslev, Thomas and Lynggaard, Aviaja B.
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[46]	Investigating family perceptions and design preferences for an inhome robo	2020	Cagiltay, Bengisu and Ho, Hui-Ru and Michaelis, Joseph E and Mutlu, Bilge
[91]	an emotion regulation app for school inclusion of children with ASD: design principles and preliminary results for its evaluation	2015	Fage, Charles
[160]	ARMath: Augmenting Everyday Life with Math Learning	2020	Kang, Seokbin and Shokeen, Ekta and Byrne, Virginia L. and Norooz, Leyla and Bonsignore, Elizabeth and Williams-Pierce, Caro and Froehlich, Jon E.
[193]	A Universe Inside the MRI Scanner: An In-Bore Virtual Reality Game for Children to Reduce Anxiety and Stress	2020	Liszio, Stefan and Basu, Oliver and Masuch, Maic
[231]	BodyVis: A New Approach to Body Learning Through Wearable Sensing and Visualization	2015	Norooz, Leyla and Mauriello, Matthew Louis and Jorgensen, Anita and McNally, Brenna and Froehlich, Jon E.
[136]	vSked: evaluation of a system to support classroom activities for children with autism	2010	Hirano, Sen H. and Yeganyan, Michael T. and Marcu, Gabriela and Nguyen, David H. and Boyd, Lou Anne and Hayes, Gillian R.
[263]	Disrupting Computing Education: Teen-Led Participatory Design in Libraries	2022	Roldan, Wendy and Lee, Kung Jin and Nguyen, Kevin and Berhe, Lia and Yip, Jason
[93]	Tablet-based activity schedule for children with autism in mainstream environment	2016	Charles Fage, Léonard Pommereau, Charles Consel, Emilie Balland, and Hélène Sauzéon

[146]	Empowering children through design and making: towards protagonist role adoption	2018	Iivari, Netta and Kinnula, Marianne
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[115]	Making chocolate-covered broccoli: designing a mobile learning game about food for young people with diabetes	2010	Glasemann, Marie and Kanstrup, Anne Marie and Ryberg, Thomas
[262]	Opportunities and Challenges in Involving Users in Project-Based HCI Education	2020	Roldan, Wendy and Gao, Xin and Hishikawa, Allison Marie and Ku, Tiffany and Li, Ziyue and Zhang, Echo and Froehlich, Jon E. and Yip, Jason
[131]	Design of an exergaming station for children with cerebral palsy	2012	Hern and ez, Hamilton A. and Graham, T.C. Nicholas and Fehlings, Darcy and Switzer, Lauren and Ye, Zi and Bellay, Quentin and Hamza, Md Ameer and Savery, Cheryl and Stach, Tadeusz
[219]	Developing a Mobile System for Children and Teenagers with Scoliosis to Improve Therapy Adherence	2018	Minge, Michael and Lorenz, Katharina and Dannehl, Susanne and Jankowski, Natalie and Klausner, Martina
[216]	Robots for Inclusive Play: Co-designing an Educational Game With Visually Impaired and sighted Children	2020	Metatla, Oussama and Bardot, S and ra and Cullen, Clare and Serrano, Marcos and Jouffrais, Christophe
[47]	"My Unconditional Homework Buddy:" Exploring Children's Preferences for a Homework Companion Robot	2023	Cagiltay, Bengisu and Mutlu, Bilge and Michaelis, Joseph E

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[303]	Designing Manipulative Tools for Creative Multi and Cross-Cultural Storytelling	2019	Sylla, Cristina and Pires Pereira, Iris Susana and Sa, Gabriela
[228]	Community Based Robot Design for Classrooms with Mixed Visual Abilities Children	2021	Neto, Isabel and Nicolau, Hugo and Paiva, Ana
[289]	Participatory Evaluation with Autistic Children	2017	Spiel, Katta and Malinverni, Laura and Good, Judith and Frauenberger, Christopher
[181]	Ideation and ability: when actions speak louder than words	2012	Larsen, Henrik Svarrer and Hedvall, Per-Olof
[226]	Understanding the challenges and opportunities for richer descriptions of stereotypical behaviors of children with asd: a concept exploration and validation	2010	Nazneen, Fnu and Boujarwah, Fatima A. and Sadler, Shone and Mogus, Amha and Abowd, Gregory D. and Arriaga, Rosa I.
[96]	Three Design Directions for a Diversity Computing Design Space	2023	Falk, Jeanette and Kubesch, Moritz and Blumenkranz, Anna and Frauenberger, Christopher
[32]	Learning through Participatory Design: Designing Digital Badges for and with Teens	2016	Bell, Adam and Davis, Katie
[345]	FACIT PD: a framework for analysis and creation of intergenerational techniques for participatory design	2013	Walsh, Greg and Foss, Elizabeth and Yip, Jason and Druin, Allison
[132]	Designing action-based exergames for children with cerebral palsy	2013	Hern and ez, Hamilton A. and Ye, Zi and Graham, T.C. Nicholas and Fehlings, Darcy and Switzer, Lauren

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[341]	Participatory Design of Therapeutic Video Games for Young People with Neurological Vision Impairment	2015	Waddington, Jonathan and Linehan, Conor and Gerling, Kathrin and Hicks, Kieran and Hodgson, Timothy L.
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[134]	Co-Designing with Preschoolers Using Fictional Inquiry and Comicboarding	2017	Hiniker, Alexis and Sobel, Kiley and Lee, Bongshin
[7]	MyCalendar: Fostering Communication for Children with Autism Spectrum Disorder through Photos and Videos	2015	Abdullah, Muhammad Haziq Lim and Brereton, Margot
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[79]	Family as a Third Space for AI Literacies: How do children and parents learn about AI together?	2022	Druga, Stefania and Christoph, Fee Lia and Ko, Amy J
[85]	Designing a story-based platform for HIV and AIDS counseling with Tanzanian children	2009	Duveskog, Marcus and Kemppainen, Kati and Bednarik, Roman and Sutinen, Erkki
[19]	Autonomous Vehicles for Children with Mild Intellectual Disability: Perplexity, Curiosity, Surprise, and Confusion	2023	Arvola, Mattias and Forsblad, Mattias and Wiberg, Mikael and Danielsson, Henrik

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[367]	"It helped me do my science.": a case of designing social media technologies for children in science learning	2014	Yip, Jason and Ahn, June and Clegg, Tamara and Bonsignore, Elizabeth and Pauw, Daniel and Gubbels, Michael
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[172]	The impacts of deaf culture on designing with deaf children	2017	Korte, Jessica and Potter, Leigh Ellen and Nielsen, Sue
[92]	Tablet-Based Activity Schedule in Mainstream Environment for Children with Autism and Children with ID	2016	Fage, Charles and Pommereau, Léonard and Consel, Charles and Ball and , Emilie and Sauzéon, Héléne
[90]	Using Gameplay Design Patterns with Children in the Redesign of a Collaborative Co-located Game	2019	Eriksson, Eva and Baykal, Gokcce Elif and Bjork, Staffan and Torgersson, Olof
[143]	Narrative support for young game designers' writing	2015	Howl and , Kate and Good, Judith and du Boulay, Benedict
[282]	Would You Rather: A Focus Group Method for Eliciting and Discussing Formative Design Insights with Children	2021	Simko, Lucy and Chin, Britnie and Na, Sungmin and Saluja, Harkiran Kaur and Zhu, Tian Qi and Kohno, Tadayoshi and Hiniker, Alexis and Yip, Jason and Cobb, Camille
[72]	Giggle gauge: a self-report instrument for evaluating children's engagement with technology	2020	Dietz, Griffin and Pease, Zachary and McNally, Brenna and Foss, Elizabeth

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[197]	ExposAR: Bringing Augmented Reality to the Computational Thinking Agenda through a Collaborative Authoring Tool	2022	Lunding, Mille Skovhus and Gronbaek, Jens Emil Sloth and Bilstrup, Karl-Emil Kjaer and Sorensen, Marie-Louise Stisen Kjerstein and Petersen, Marianne Graves
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