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PLAY-BASED DESIGN:
PARTICIPATORY DESIGN METHOD FOR DEVELOPING
TECHNOLOGIES WITH 3 AND 4 YEAR-OLD CHILDREN

by
Luiza Superti Pantoja

A thesis submitted in partial fulfillment
of the requirements for the Doctor of Philosophy
degree in Informatics in the
Graduate College of
The University of Iowa

August 2019

Thesis Supervisor:  Associate Professor Juan Pablo Hourcade
To my dear husband, Cris, who supported me throughout this Ph.D. in many ways including taking care of our son and proofreading my texts. To my beloved Ph.D. baby, Leo, who kept me grounded and focused on my goals while also surprising me at every new milestone. To my mom and dad, Denise and José Luiz, for their continuing love and support. To my dear brother, Pedro, who inspires me constantly. To my dear old and new friends who kept me connected to my roots and always made their shoulders available.
ACKNOWLEDGEMENTS

This work had the support and participation of many people. I thank all my committee for their time, comments, and effort in supporting this dissertation.

I thank my research colleagues who made our group a collaborative, fun, and rich environment to explore innovative research with the little ones. I also thank our growing HCI group for their feedback and support.

I thank the preschool director, the teachers, and all the children who participated in our design sessions throughout the years, contributing with their time, space, and their great ideas for our projects.

I also thank my scholarship sponsor, CAPES, for making it possible for me to study in the U.S., and I thank my academic department for the fellowship I received during my last year.

Finally, I thank my advisor and mentor, Dr. Juan Pablo Hourcade for all his support and guidance throughout these years. I am immensely grateful for sharing this Ph.D. journey with him and I cannot thank Juan Pablo enough for choosing to work with me, introducing me to the world of Child-Computer Interaction, and being there throughout this whole experience encouraging me to become a better researcher and designer.
ABSTRACT

Young children in the United States are widely using technology at ages 3 and 4, but to date there are no well documented participatory design methods for including this age group in the development of technologies. A few attempts at using methods designed for older children were unsuccessful. To address this gap in methods, this research developed Play-based Design, a novel participatory design method inspired by make-believe play in the style of *Tools of the Mind*, an evidence-based preschool curriculum.

Play-based Design first sets the context for play and design through stories. It then enables children to plan play by selecting roles and contribute their ideas as they act and speak during make-believe play activities in which they interact with other children, voice agents, adult facilitators, and generic props. This research includes four sets of design sessions with 3-4 year old children. The first provided the design of *StoryCarnival* a web-based app to set up *Tools of the Mind* style play. The second set of design sessions led my research team through the development of voice agents to support *Tools of the Mind* style play as it happens. These two sets of sessions provided inspiration and insight for using *StoryCarnival* combined with voice agents to support design activities for technologies with physical and social components. The last two sets of sessions gave me an opportunity to understand whether Play-based Design could be applied to obtain design requirements from children for technology unrelated to make-believe play by focusing on obtaining ideas for Internet-of-Things applications in the home.

The research presented in this dissertation required an interdisciplinary journey through child development theories, storytelling for children, graphic design, qualitative methods, software development, and related approaches from the literature. Participant observations, group discussions, and video analysis were used to collect and analyze data. Results from the last two
sets of design sessions focused on obtaining ideas for Internet-of-Things technologies to provide evidence that Play-based Design can enable 3-4 year old children to contribute their ideas to the design of technologies. More specifically, in this dissertation, I provide supporting evidence for my thesis statement: “When applied to participatory design sessions with young children, Play-based Design can: (1) allow young children to express their ideas through make-believe play, which is a developmentally appropriate activity; (2) enable children to act out design ideas or verbally express them by conversing with researchers or voice agents; (3) support fluid communication between adult researchers and children; and (4) inform the design of technologies that facilitate activities that have social and physical components (e.g. tangible user interfaces, voice agents, IoT).”
Young children in the United States are using computers that were not necessarily designed for them. Currently, some of the results of this premature access to computers is a great variety of apps targeting preschoolers as well as interactions with voice agents at families’ homes. What could be different if young children participated in the design of technologies they are using? Can young children’s ideas influence the design of technologies they currently have access to?

A few attempts at using methods designed for older children were unsuccessful, so this research developed Play-based Design, a new participatory design method inspired by make-believe play in the style of Tools of the Mind, an evidence-based preschool curriculum. My research explores make-believe play for 3-4 year-old children to express their creative ideas while working with adult designers to develop new technologies. Make-believe play is a natural activity for young children and it improves communication with adults during the design process.

Play-based Design sets the context for play and design through stories. It then allows children to plan play by selecting roles and contribute their ideas as they act and speak during make-believe play activities while interacting with other children, voice agents, adult facilitators, and physical props. I conducted four sets of design sessions with 3-4 year old children. The first resulted in the design of StoryCarnival a web-based app to set up play. The second resulted in the design of voice agents to support play as it happens. These two sets of sessions provided inspiration for using StoryCarnival and voice agents to support design activities for technologies with physical and social components. The last two sets of sessions helped to understand whether Play-based Design can incite design ideas from children for complex technologies by focusing on Internet-of-Things applications in the home.
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In high-income countries, current generations of children are using computing devices at very young ages (Common Sense Media 2013, Hourcade et al. 2015, Yarosh et al. 2018). It is common to find preschool children who already have some experience interacting with different devices, such as smartphones, tablets and voice agents like Amazon Alexa or Google Home (Common Sense Media 2013, Hourcade et al. 2015, Yarosh et al. 2018). However, these changes happened fast and there are gaps in the literature related to identifying how educational technologies can help preschool children learn critical cognitive skills, identifying developmentally appropriate technologies other than mobile devices, and developing design methods for working with children under the age of five.

Initially, my research investigated cognitive skills that can be supported by technology. My motivation was to identify skills that are critical and could be developed with help of technology, yet are not the focus of most technology design for 3-4 year old children. The skills I identify with my research group were executive functions such as self-regulation, attention, and selective memory. This line of inquiry pointed to the Tools of the Mind (ToM) preschool curriculum that integrated Vygotsky’s theories of sociocultural development in its educational practices (Blair and Raver 2014, Bodrova and Leong 2007). Studies involving hundreds of children provide evidence of the positive impact of ToM on self-regulation and academic performance when compared to standard curricula (Blair and Raver 2014, Diamond et al. 2007). However, typical training to implement the ToM curriculum requires teachers to attend a two-week workshop in addition to receiving 12 days of in-classroom follow up (Diamond and Lee 2011). These barriers can make it difficult for preschools to adopt the practices of ToM, so in our initial field work with preschool
children my research group and I explored developing technology that could lower the barriers for teachers to support make-believe play in the style of ToM classrooms.

The make-believe play promoted in ToM involves groups of children engaged in pretend play that includes common goals, planning, role-play, interactive social dialogue and negotiation, improvisation, and the use of generic physical props as opposed to realistic toys (Bodrova and Leong 2007). The result of the first set of design sessions was StoryCarnival, a web-based app that helps set up ToM style play through interactive stories and a play planning module. As we explored supporting this style of make-believe play, we realized it was also an ideal participatory design activity for this age group. As we did so, we realized we were getting ideas from children who would act them out or tell them to us. These ideas came about in a favorable context that was: a) developmentally appropriate, b) based on an activity for which there is evidence of long-term benefits to children. A second set of design sessions where we explore the design of voice agents to support make-believe play activities enabled us to obtain design ideas from children.

These experiences gave us the insight that the technologies we developed to support ToM style play could be repurposed to enable 3-4 year old children to have a voice in the design of technologies for this age group. The result is Play-based Design, a participatory design method. Participatory design involves an active cooperation between researchers and users to design technology (Bødker 1996, Druin 1999, B.-N. Sanders and Stappers 2008). Currently, there are many participatory design methods intended to empower children in the design of the technologies they will use (Druin 2002, Fails 2012, Walsh et al. 2013), but these methods were designed to involve children aged 7-12 (Guha et al. 2013). These methods typically foster creative collaboration between adults and children throughout the design process, often prompting children to propose ideas using drawings, construction of low-fidelity prototypes, and evaluating existing
prototypes with sticky notes (Walsh et al. 2013). Participatory design techniques have proven successful for eliciting innovative ideas with children aged 7-12 years-old (Guha et al. 2013), but during preschool years children have different developmental milestones. For example, their motor and cognitive skills are still developing, which makes it hard for them to sketch informative drawings for technologies (CDC 2017). In addition, preschoolers have different communication abilities, social skills, and a less developed ability to think abstractly (Guha et al. 2004). Therefore, if researchers want to empower children under the age of five to elicit innovative ideas for new technologies, it is important to use a design method that is appropriate for their needs, abilities, and interests.

1.1. Motivation

As a group of computer users, 3-4 year old’s involvement during the technology design process is still lacking. In order to design better technological tools for preschool children, it is important to understand their needs, abilities, and interests by empowering them to express themselves. It is also important to make sure adult designers can communicate and listen to young children’s ideas to ensure a fluid and successful design process. More importantly, there are currently no design methods for use with this age group for which there is empirical evidence of success in enabling children to contribute their design ideas.

Considering this context, I developed Play-based Design, a participatory design method aimed at supporting groups of 3 to 4 year old children to express their voices during the technology design process. The inspiration for Play-based Design came from work with two different groups of children. I then applied the method with two other groups of children to investigate ideas for home-based Internet-of-Things (IoT) technologies.
Play-based Design first sets the context for design through interactive stories presented through StoryCarnival. The stories support children to gain a common understanding of the context where the technology will be used, and it also motivates them to participate in the activity by portraying engaging characters with different skillsets. Then, we use the StoryCarnival planner to plan role play with children taking on specific roles based on the characters from the stories. Finally, children play pretending to be in the context presented to them, using generic physical props to stand for objects, including technology. During make-believe play, children act out the experiences they want within the context that was previously set up sometimes switching their roles and creating new meanings for the props. As they play, they interact with other children, adult facilitators, and a voice agent controlled by adult facilitators that scaffolds play.

Through the use of qualitative methods, I provide evidence that the method worked well with two different groups of children for developing design ideas for a relevant, complex technology in IoT. Play-based Design worked for developing a wide range of ideas for IoT applications, suggesting flexibility for exploring a broad design topic. In addition, I analyzed the sessions to learn how many design requirements can be captured while using Play-based Design, and in what ways young children communicated their ideas. My goal is to offer guidelines for other researchers to implement Play-based Design to support fluid communication between adults and young preschoolers, while empowering young children during the design of the technologies they will use.

1.2. Thesis Statement

My thesis claims are summarized by the following statement. Table 1.1 summarizes the activities I studied in each project, which are directly related to the claims.

When applied to participatory design sessions with young children, Play-based Design can:
1. Allow young children to express their ideas through make-believe play, which is a developmentally appropriate activity for this age group

2. Enable children to act out design ideas or verbally express them by conversing with researchers or voice agents

3. Support fluid communication between adult researchers and children

4. Inform the design of technologies that facilitate activities that have social and physical components (e.g. tangible user interfaces, voice agents, IoT)

To develop, implement, and evaluate Play-based Design, these are the activities I have conducted:

1. Understand the steps necessary to support make-believe play

2. Implement the technical infrastructure to support Play-based Design

3. Investigate how to support adults to prompt children and keep them engaged in the activity

4. Evaluate the effectiveness of Play-based Design for generating ideas for a technology that does not support make-believe play

5. Validate that Play-based Design works with younger children

Table 1. List of activities that I studied to develop Play-based Design and support my claims.

<table>
<thead>
<tr>
<th>Goal for Developing Play-based Design</th>
<th>StoryCarnival</th>
<th>Voice Agents</th>
<th>IoT technologies with 4 year-olds</th>
<th>IoT technologies with 3 year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand the steps to support make-believe play</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Implement technical infrastructure</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Investigate how to support adults to prompt children</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
1.3. Research Questions and Approaches

This research was of exploratory and qualitative nature, and the initial question guiding my work was the following:

**RQ1:** How can technology lower the barriers to support make-believe play in the style of Tools of the Mind?

To address **RQ1**, I conducted participatory design sessions with a group of 3 to 4 year-old children in a classroom setting. These sessions informed the design of StoryCarnival, a prototype that supports the practice of make-believe play in Tools of the Mind style. The data analysis of these sessions provided evidence of the effectiveness of make-believe play to involve young children during the technology process and generating design requirements.

These findings redirected my research to focus on the following question: *How can designers successfully collaborate with children under the age of five during the technology design process to contribute with their ideas for technologies?* In order to further define the scope of the research, I focused on the partnership and communication that occurs between children and adults during the design sessions:

**RQ2:** Can young children really provide ideas beyond researcher’s observations?

**RQ3:** How can we better support adults to prompt children in order to keep them engaged in *Tools of the Mind (ToM)* style play?
To address **RQ2** and **RQ3**, I conducted participatory design sessions with a new group of 3 to 4 year-old children in a classroom setting. These sessions informed the design of a Tangible Voice Agent prototype that supports young children’s engagement during *ToM* style play. The data analysis of these sessions provided further evidence of the effectiveness of collaborating with young children to gather design requirements for another kind of technology. However, both prototypes developed at this point focused on supporting play and it was not clear if there were differences between 3 year-old children and 4 year-old children. Therefore, I also investigated the following questions:

**RQ4**: Is Play-based Design effective for getting ideas for complex technologies that do not support play?

**RQ5**: Are there practical adjustments needed in our participatory design method when working with 3-year-old children?

To address **RQ4** and **RQ5**, I conducted another round of participatory design sessions with one group of 4 year-old children and one group of 3 year-old children. These sessions focused on prompting children for providing their ideas for Internet of Things technologies.

1.3.1. *StoryCarnival*

The goal of this qualitative research was to understand the opportunities and challenges for designing a technology to support make-believe play in the style of Tools of the Mind preschool curriculum. This research consisted of an interdisciplinary literature review that identified important child development theories, cognitive skills, developmental milestones, and existing technologies for children under the age of five. It also identified evidence-based educational practices in Tools of the Mind, which inspired the design of *StoryCarnival*. There was a field research involving of four technology immersion sessions and 11 participatory design sessions.
conducted at a local preschool with 5 participants aged 3 to 4 year-old. The goal was to explore make-believe play activities in the *Tools of the Mind* style. From this qualitative work, my research group developed a web-based technology, *StoryCarnival*, that supports make-believe play in the style of ToM through interactive stories that set a common theme for play and a play planner that guides children through selecting which character they will play. The positive experiences in obtaining design ideas from children during the process of designing and developing *StoryCarnival* led me to conduct another literature review surveying and categorizing current participatory design experiences involving children under the age of five during the technology design process. This work provides an overview of existing experiences and opportunities for involving young children in the design process, as well as a technology, *StoryCarnival*, that we later used to support the implementation of a new participatory design method.

1.3.2. Tangible Voice Agents

The goal of this qualitative research was to explore using voice agents to support adults in keeping young children engaged in ToM style make-believe play. In conducting this research we also sought to confirm that the make-believe activities we were supporting again enabled children to contribute design ideas. With my research group, I conducted 24 design sessions with 8 participants in their preschool, exploring different prototypes, developing new stories, and iteratively implementing children’s requests throughout the sessions. We found that researchers could communicate with children through the voice agent to make suggestions, compliments, and promote collaboration with their peers. Children preferred a tangible voice agent they could pick up and incorporate in their creative endeavors with physical props. The make-believe play activities were effective for learning design requirements for voice agents, and during these sessions we experimented working with a large group of children and changing the order of the
activities (e.g. choosing characters first and watching the story later), which proved to be disruptive.

1.3.3. Internet of Things Technologies

The goal of this qualitative research was to explore using Play-based Design to obtain design ideas from young children for home-based Internet of Things technologies. With my research group, I conducted 12 Play-Based Design sessions with 7 participants aged 4 years-old and 7 Play-Based Design sessions with 6 participants aged 3 years-old. All the sessions were conducted in their preschool. We found that both age groups could contribute with a total of 32 ideas for IoT technologies. While comparing Play-based Design sessions between 3 and 4 year-old children, we found that older children tended to be off-task or disengaged in play more often than the young ones.

1.4. Contributions

In this dissertation, I present a novel participatory design method, the design of technologies to support ToM style make-believe play, and empirical contributions related to the effectiveness of the method. My research resulted in the following outputs:

1. Play-Based Design
   a. Design method for working with children under 5 that is based on a developmentally appropriate activity with evidence of long-term benefits for children

2. StoryCarnival
   a. Technology that supports make-believe play in the style of ToM
   b. Used for supporting Play-Based Design

3. Voice Agents
a. Explored a variety of designs through different prototyping techniques
b. Design guidelines for developing voice agents for young children
c. Helps facilitate both make-believe play in the style of ToM and Play-Based Design

4. Internet of Things

a. Evidence that Play-based Design enable children to provide ideas for a broad and complex domain: Internet of Things
b. Exploration of Play-based Design with two different age groups
c. Design opportunities for Internet of Things technologies for young children

1.5. Dissertation Overview

This dissertation is divided into 8 chapters, described below:

- In Chapter 2, Background and Related Work, I summarize and discuss relevant child-development theories and developmental milestones that informed my approach to designing technologies for young children. I also examine the benefits of developing self-regulation skills during preschool years, followed by a discussion of the evidence-based school curricula, Tools of the Mind, which inspired Play-based Design. Additionally, I discuss existing arguments related to preschool children and technology use, followed by an overview of existing technologies for this age group.

- In Chapter 3, Participatory Design Methods for Preschool Children, I present an analysis of the literature painting a picture of the landscape of design methods used when developing technologies for young children. I aimed to understand existing approaches used while designing technologies with children under the age of 5. I report on findings
indicating a gap when it comes to working in partnership with young children during the technology design process.

- In Chapter 4, StoryCarnival, I describe the first set of sessions exploring make-believe play in the style of *Tools of the Mind* that contributed to a better understanding of the steps necessary to support this activity using technology. These sessions provided evidence for the potential of developing a participatory method to allow young children to express their ideas through make-believe play.

- In Chapter 5, Tangible Voice Agents, I describe the design and exploration of tangible voice agents with a group of 8 children under the age of five. This set of sessions investigated how to better support adults to prompt children in order to keep them engaged in *ToM* style play. We explored using a voice agent to support fluid communication between adult researchers and children. The voice agents could redirect children’s behaviors and promote social interactions.

- In Chapter 6, Internet of Things Technologies, I describe the exploration of using Play-based Design to gather design ideas with two different groups of children for Internet of Things technologies. I conducted 12 design sessions with 7 four-year-old children and 7 design sessions with 6 three-year-old children. I conclude the chapter with guidelines for implementing the method based on the findings of this qualitative analysis conducted with two age groups.

- In Chapter 7, Discussion, I discuss the involvement of young children during the technology design process within the bigger context and philosophy of participatory design. I also discuss the limitations of my research, the themes that emerged, opportunities for future work and conclusion of my thesis.
In this chapter, I discuss relevant child-development theories and developmental milestones that informed my approach and motivation to design technologies that stimulate creativity, social connection, and communication (3Cs) for young children. Next, I examine the importance of practicing self-regulation skills during the preschool years, followed by a discussion of the Tools of the Mind, the evidence-based school curricula that inspired the initial steps to develop Play-based Design. After that, I discuss existing arguments related to preschool children and technology use, followed by an overview of existing technologies that could be appropriate for this age group.

2.1. Child Development Theories

As children grow, they experience many challenges and variability throughout distinct developmental stages. Hourcade (2015) highlights the importance of understanding how children develop in order to design appropriate technology that is supportive of their needs, abilities, and interests. Preschool children are the focus of my research, therefore the initial steps of my review investigated relevant child-development theories that discuss the cognitive changes children experience when they are growing up. The goal of this section is to reflect on developmental processes and approaches to understand how they can inform an appropriate design method for 3 to 4 year old children.

Piaget was one of the pioneer scholars to investigate children’s early intellectual development. He had a background in evolutionary biology, and he established an innovative model for cognitive development proposing different stages of childhood according to the development of intelligence (Piaget and Inhelder 2008, Shaffer and Kipp 2013). The Preoperational period roughly includes children aged from 2 to 7 years-old and it marks the appearance of the symbolic function and pretend play (Shaffer and Kipp 2013).
He described four general factors that affect mental development: maturation, acquired experience, social interaction, and finality (Piaget and Inhelder 2008). Maturation occurs gradually as the nervous system develops, creating new possibilities every time children exercise their new abilities. He believed children understand new objects and events by interacting with them, therefore constructing their knowledge from acquired experiences (Hourcade 2015, Piaget and Cook 1952). According to Piaget and Inhelder (2008), social interaction is a two-way exchange where an individual give as much as he receives from the interaction with others. Finality is about the process of achieving a cognitive equilibrium, where children construct their knowledge through a series of compensations that occur in response to external signals (Piaget and Inhelder 2008).

According to Piaget, play is an essential aspect in children’s lives. Play requires them to constantly adapt to the social and physical world of adults who have different interests and rules (Piaget and Inhelder 2008). Symbolic play corresponds to the peak of children’s play and it is crucial to their affective and intellectual equilibrium, because it offers an avenue for self-expression. Through symbolic play children transform reality according to their signifiers and wishes (Piaget and Inhelder 2008). Piaget’s views on the importance of play are compatible with Play-based Design, which promotes symbolic play and social interactions as activities for generating ideas.

Similarly, our project is motivated by Vygotsky’s insights on child development. Some of the main differences in the way Piaget and Vygotsky perceived child development have to do with the social aspects that surround children. For Piaget, children are actors who construct knowledge through their actions on the environment. Vygotsky, on the other hand, placed a greater emphasis in the social processes, in particular the role of culture and the tools children interact with. For Vygotsky, human cognition is inherently affected by the beliefs, values, and tools passed to
individuals by their culture (Shaffer and Kipp 2013). He proposed that infants are born with a few elementary mental functions that are eventually transformed by their culture into new and more sophisticated higher mental functions (Shaffer and Kipp 2013).

From Vygotsky’s perspective, children’s active engagement in learning and the social historical context are crucial for their mental development processes. He proposes a process of learning where children encounter cultural artifacts and procedures associated with them, which they use with the support of more experienced people. These tools help children develop higher mental functions such as focused attention, self-regulation, deliberate memory, and logical thought (Bodrova and Leong 2007, Vygotsky 1980). Moreover, Vygotsky defined the concept of the zone of proximal development, which is defined as the difference between the tasks a child can accomplish independently and the tasks a child can accomplish with assistance from a more skilled partner (Bodrova and Leong 2007, Shaffer and Kipp 2013). Once the child learns and internalise the tasks, they become part of the child’s independent developmental achievement (Bodrova and Leong 2007, Vygotsky 1980).

Vygotsky also connected memory to association, proposing that repetition in a fun and engaging activity is key for enhancing children’s motivation (Bodrova and Leong 2007, Vygotsky 1980). Vygotsky’s insights on the nature of play saw it as a fruitful setting for development that creates the zone of proximal development while motivating children in a fun activity (Bodrova et al. 2013). In regard to preschoolers, he observed that during play children are constantly faced with a conflict between the rule of the game and what they would do if they could act freely (Bodrova et al. 2013). One of his students, Daniel Elkonin, expanded his ideas about the role of play in supporting the development of self-regulation, further observing the details of the play
scenario, use of props, and planning before playing (Bodrova et al. 2013). All these ideas about play and motivation inspired the activities explored in Play-base Design.

Another relevant scholar is Maria Montessori, who developed an educational method also known to improve executive functions (Diamond and Lee 2011). The Montessori method is characterized by having a set of specific educational materials that help children to learn in blocks of thematic activities such as mathematics, arts, and science into the classroom setting. There is also a focus on sharing the tools between multi-age peers, and it emphasizes experimentation and focus on motivating activities. For instance, if a child gets highly engaged in an activity, the teacher is not supposed to interfere because it means the child is learning something by experimenting and focusing his or her attention (Diamond and Lee 2011, Lillard and Else-Quest 2006). Play-based Design applies some of these concepts regarding the use of physical props, engaging activities between multi-age peers, and minimal interference from facilitators.

Most influential child development researchers agree that the experiences children go through have a major impact on how they learn and develop. There are also connections between the social aspects, the tools used in the learning process, and the importance of play and motivation as being important factors for cognitive development. Our design method was initially inspired by Vygotsky’s ideas, but it is also compatible with Piaget’s views, in the sense that we focus on symbolic play, social experiences that use developmentally appropriate materials. Our method is also compatible to Montessori’s views because we observe children to learn their needs, and our technique fosters experimentation while also promoting the use of physical materials.

The next section will discuss the developmental milestones for 3 and 4 year old children according to the United States Centers for Disease Control (CDC 2017).
2.2. Developmental Milestones

The United States Centers for Disease Control (CDC) is one of many agencies throughout the world to publish developmental milestones for young children. These milestones group typical behaviors by age intended for parents to identify any developmental delays. In order to better understand 3 and 4 year old children and how they may use computers it is useful to refer to relevant developmental milestones for both age groups. The CDC milestones include four developmental categories: Social and Emotional, Language/Communication, Cognitive (learning, thinking, problem-solving), and Movement/Physical development (CDC Milestones Moments).

By 3 years old, children can play make-believe with dolls, animals, and people. They can also build towers, copy adults and friends, take turns in games, manipulate toys with buttons, levers, and moving parts, and they can show a wide range of emotions including affection and concern for friends (CDC Milestones Moments). In terms of communication skills, 3 year old children can follow instructions with 2 or 3 steps, they can name most familiar things including friends, and they can carry on a conversation using 2 to 3 sentences. Children at this age are still developing their motor skills but they can climb well, run easily, pedal a tricycle, and walk up and down stairs (CDC Milestones Moments).

By 4 years old, children are expanding their creativity with make-believe play, but they often confuse what is real and what is make-believe. They enjoy playing and cooperating with other children, doing new things and talking about what they are interested in. Children at this age have more advanced cognitive skills and they can name colors and numbers, understand the idea of counting, remember parts of a story, understand the idea of “same” and “different”, play board or card games, and they can tell what they think will happen next in a book. In terms of communication, children at this age know basic rules of grammar, sing a song or say a poem from memory, and tell stories (CDC Milestones Moments). At 4 years old, children’s motor skills are
more developed, and they can hop and stand on one foot, catch a bounced ball, pour, and cut with supervision (CDC Milestones Moments).

The developmental milestones show that both 3 and 4 year old children can play make-believe. However, there are also developmental differences, which may indicate a need for adapting Play-based Design sessions when working with only 3 year old children.

The next section will discuss the approach we conceptualized to frame the design of developmentally appropriate technologies for young children.

2.3. 3Cs Technologies

We elaborated an approach to design technologies for children under the age of five that focus on the 3Cs: creating, connecting, and communicating (Hourcade et al. 2017, Hourcade et al. 2018). More specifically, technologies that follow the 3Cs approach are supportive of creative activities that connect children with their social and physical environment while emphasizing communication. This approach has been previously published at IHC (Pantoja et al. 2017), Interactions magazine (Hourcade et al. 2017) and IJCCI (Hourcade et al. 2018), and the texts presented here were extracted and adapted from these articles.

Besides the child development theories previously mentioned, Seymour Papert’s ideas also influenced and informed our approach to technology design. Papert was a pioneer researcher who began exploring the design of computer systems for children in the early 1980s (Hourcade 2015). During that time, he shared his vision of constructionism as the PC revolution brought computers to homes and schools (Papert and Harel 1991). Constructionism builds on Piaget’s constructivism idea of knowledge structures, but it introduces the thought that learning happens in a context where the learner is consciously engaged in constructing a public entity, “whether it’s a sand castle in the beach or a theory of the universe” (Hourcade et al. 2018, Papert and Harel 1991). Papert wanted
children to be active, empowered learners who create items of interest in social settings (Hourcade et al. 2018). He thought such creative projects could leverage children’s strong interests to allow them to arrive at powerful ideas (Papert 1980). In his support for these social, creative activities, Papert set the tone for our conceptualization of the 3Cs.

The research and practice that arose out of his vision in the following decade focused primarily on children older than age five and tended to have a focus on the development of mathematical thinking (Papert and Harel 1991). According to Wyeth (2008), Papert’s innovative work Mindstorms, recognized that computer programming has great potential for the acquisition of problem solving and reflective thinking (Hourcade et al. 2018, Wyeth 2008). However, Papert’s empowering, child-centered vision was wider than programming and encompassed an educational approach that involved children learning and arriving at powerful ideas by working on projects arising out of their strong interests, with the guidance of adults, and access to computers as powerful and flexible tools to develop these projects (Kestenbaum 2005, Papert and Harel 1991).

In his vision, Papert sought a balance between information access and creation, both in computer use, and more generally in learning (Kestenbaum 2005). However, the current status of computer device use by preschool children often involves socially isolating activities structured by apps, with a primary focus on the device, experiencing media, and engagement through instant gratification (Miranda et al. 2017, Media and Young Minds 2016). In fact, some are alarmed by mobile devices socially isolating children, and disconnecting them from their physical and social space (Turkle 2017).

Individually experiencing a small amount of engaging, gratifying media is unlikely to harm children. However, we should look toward bringing balance in the direction of a more constructionist approach to technology use by preschool children, as technologies occupy more
and more of young children’s time (Common Sense Media 2013), at ages critical to brain development (Media and Young Minds 2016). There are examples of research projects bringing constructionist approaches to preschool children, primarily in the form of tangible user interfaces used for programming (e.g., Elkin et al. 2016, Horn et al. 2013, Wyeth 2008, Zuckerman et al. 2005).

Our approach has been to design and lower barriers to learning ecologies that strive to provide preschool children with greater support for the 3Cs: creating, connecting, and communicating. It is inspired in part by Papert’s example of escolas de samba, which have a highly creative focus across many areas. For instance, the plot is the central point of the parade’s production and is translated into songs, choreographies, costumes, ornaments, floats, and technology (Tureta and Araujo 2013). This process brings together powerful ideas from engineering, mathematics, the arts, and local culture. We look to enable similar creative endeavors for preschool children that involve planning and a continuation of creative activities that link to their interests over an extended period of time, just like escolas de samba do. Technologies could enable children to be authors and creators, with the least amount of constraints possible so they can more easily link their strong interests with powerful ideas.

Escolas de samba are also about connections between people, their cities, and their culture. Participating in an escola de samba is an intrinsically social and physical activity. In Rio de Janeiro in particular, each escola de samba requires the collaboration of thousands of people creating and learning together. There are many elements connecting with the physical environment as well, including making the items necessary for the parade performance, connecting with the city and its neighborhoods, and the physical nature of the Carnival parade itself. In other words, participating in escolas de samba is very far from an isolating experience. In fact, all the connections amplify
individual creativity, and make it relevant to participants’ strong interests. We need to do the same when designing learning ecologies for preschool children to learn together. Connecting with the social, cultural, and physical environment means children get to use their whole bodies in activities, interact with non-electronic physical items, and feel connected with their strong interests and with people around them. Therefore, when we design a learning environment that involves technology, we do not have to stop at designing the technology, but instead also design the physical and socio-cultural environment (Smith et al. 2013).

The end product of escolas de samba is mainly about communication and expression through song, dance, fashion, and physical artifacts. The process requires a tremendous amount of communication in order to coordinate such a complex enterprise involving people in a wide variety of roles. Communicating is also crucial for the social aspects in Papert’s vision of constructing public entities. There can be no exchange of ideas, no feedback loop from others without communication and technology can actually be used to improve communication. While the most common way this happens is to help with remote communication, technologies can also help children communicate more richly with those in physical proximity by giving them additional channels (e.g., Hourcade et al. 2012, Machalicek et al. 2010). We propose to design learning ecologies for preschool children that encourage and enhance communication because the preschool years are critical for language development (Bloom 2000), and children cannot afford to be in environments that discourage communication.

The 3Cs approach is compatible with Papert’s views and stimulates developmentally appropriate skills for preschoolers. In addition, it is consistent with approaches used in high-quality preschool curricula, such as Tools of the Mind (Bodrova and Leong, 2007), and those proposed by other child–computer interaction researchers (e.g., Wyeth and Purchase 2003) and implemented
in some research projects (e.g., Baranauskas and Posada 2017, Marco et al. 2010, Montemayor et al. 2004). This approach also informed the development of Play-based Design, which combines social and physical activities.

In the next section I will discuss preschool children’s developmental challenges, the importance of learning self-regulation skills during these years, and the impacts these skills might have on child development.

2.4. Self-Regulation Skills

Self-regulation is the ability to react or ignore a person or event. For instance, if an adult prompts a toddler to pick up a toy and put it away, the child can either listen to the adult and put the toy away or she might ignore the prompt because she is too engaged in the activity and does not want to let go of the toy. With enough practice, children learn to control their impulses and desires in order to follow important directions. Thus, self-regulation relates to the capacity of planning, persistence, and delay of gratification (Dawson and Guare 2010). Blair and Raver (2015) associate self-regulation to features such as focusing and maintaining attention, regulating emotion, reflecting on information and experience, and engaging in sustained positive interactions (Blair and Raver 2015). Diamond et al. (2007) remarks that researchers focusing on self-regulation generally emphasize social situations and motivational components (Diamond et al. 2007). Therefore, self-regulation includes encouraging helpful and healthy emotions and control over disruptive ones. Jahromi and Stifter (2008) define self-regulation as the active suppression process employed for pursuing a goal, which includes emotion regulation, behavioral control, and executive function (Jahromi and Stifter 2008).

Many studies support a correlation between executive functions development and school readiness (Dawson and Guare 2010, Lillard and Else-Quest 2006, Ponitz et al. 2009, Rimm-
Executive functions are important for early regulation of behavior and the development of social and cognitive skills, such as keeping information in working memory, inhibiting impulsive reactions, and shifting and sustaining attention for goal-directed actions (Blair et al. 2005, Dawson and Guare 2010, Hourcade 2015). The main brain areas involved in executive function are the frontal lobes, in particular the prefrontal cortex (Zelazo and Miller 2002). There are several cognitive processes involved in executive functions and the mechanisms behind it are still a subject of divergences among researchers concerned with the study of the brain. The definitions and terminology of these cognitive processes might vary in the literature. However, my research focused on self-regulation, which have strong evidence supporting its connection with school readiness improvement.

In the literature, there’s often a distinction between inhibitory control and self-regulation that indicates a separation between the cognitive and the social emotional aspects typically associated to self-regulation. This is important to notice because most of the theoretical foundation of Play-based Design is grounded on Vygotsky’s ideas, who perceives self-regulation as a skill that integrates both aspects (Bodrova and Leong 2007).

In school, young children must learn to internalize and follow rules, listen to directions, share toys, and wait for their turn, suppressing their instinctive impulses (Denham et al. 2012). All of these abilities are associated to self-regulatory skills and there is considerable evidence in the literature supporting the impact of these particular skills in school success (Blair and Raver 2015, Diamond et al. 2007, McClelland et al. 2007, Kaufman et al. 2000). Preschool children might have challenges related to their self-regulation skills while entering the school setting, because their brains are not fully developed to control and process their emotions (Zelazo and Miller 2002).
When children move from preschool to kindergarten, they face a wide range of new experiences, demands, and goals. Children’s abilities to participate and learn from academic experiences may vary and some children might have difficulty to adjust to kindergarten (Diamond and Lee 2011, Hourcade 2015, Ponitz et al. 2009). The difficulties children face at this stage may have long-term effects and cause them to stay behind throughout their schooling (Kaufman et al. 2000). Therefore, the improvement of literacy and numeracy skills alone may not be enough for all children to succeed in school.

For instance, a large study conducted with a national sample of 3,595 teachers revealed that a substantial portion of children arrive at kindergarten without the appropriate skills (Kaufman et al. 2000). Among the problems discovered, 46% of teachers reported difficulty to follow directions, which was the most common problem found at approximately half kindergarten classes or more. Another usual concern was difficulty working independently, reported at the same study by 34% of the teachers.

An earlier survey asked kindergarten teachers to rank the skills and abilities most relevant to children’s readiness to learn (Hair et al. 2006). Their findings resonate with the study mentioned previously and includes aspects such as being physically healthy, being able to communicate needs, wants, and thoughts; being enthusiastic and curious in approaching new activities, paying attention and following directions, not being disruptive, and being sensitive to other children’s feelings (Hair et al. 2006). Overall, teachers seem to support the idea that skills associated with self-regulation facilitate teaching and learning activities inside the classroom (Blair and Raver 2015).

Additionally, self-regulation is significantly associated with the development of mathematical skills in school-aged children (Bull and Scerif 2001, Clark et al. 2010, Epsy et al.
function tests on 66 preschool children (Epsy et al. 2004). The results demonstrated that self-regulation greatly contributes to early mathematical skills in that age range, even after controlling for intelligence and maternal education level. Blair and Razza (2007) evaluated the role of self-regulation in emerging academic ability with 141 children at ages 3 to 5 from low-income homes that attended Head Start programs (Blair and Razza 2007). Their findings indicated that aspects of self-regulation accounted for unique variance in their academic outcomes independent of general intelligence. In particular, self-regulation was a strong correlate of both early math and reading ability.

A more recent study examined the development of executive function abilities on 104 children at age 4 and followed up on their mathematical achievements at age 6 (Clark et al. 2010). The results substantiate previous studies, indicating a relationship between children’s performance on set shifting, self-regulation, and general executive behavior measures and their early mathematical success at school (Clark et al. 2010). In addition, there is evidence that self-regulation can also affect early reading abilities (Blair and Razza 2007, McClelland et al. 2007). Thus, the lack of inhibition and poor working memory could be some of the difficulties for children with lower mathematical ability. Moreover, deficits in executive functions can also affect language and literacy learning (Clark et al. 2010). Some of the complications usually associated with poor self-regulation are attention deficit disorder, teacher burnout, student dropout, drug use, and crime (Diamond et al. 2007). Young lower-income children are more likely to have poor executive functions and consequently fall progressively behind in school.

On the positive side, several studies indicate that early interventions can make an impact on children’s learning abilities (Blair and Raver 2015, Clark et al. 2010, Diamond and Lee 2011).
In fact, the preschool years are a period of great improvements and maturation in children’s executive functions. As children’s prefrontal cortex develop, they experience rapid changes that heavily influence their abilities to regulate responses with marked improvements in inhibitory control (Jahromi and Stifter 2008, Zelazo and Miller 2002). Therefore, the preschool years are a crucial time for shaping children’s individual learning experiences (Clark et al. 2010). At this age, the right interventions on their self-regulation development have the potential to cause long-term effects and contribute to their academic success (Diamond et al. 2007).

The literature reveals the importance of fostering the practice of self-regulation skills during the preschool years, possibly even more than promoting the practice of literacy and mathematics skills. Play-based Design considers the importance of these skills and incorporates activities that support the practice of self-regulation, such as planning and make-believe play. The rationale of the design activities supported by Play-based Design will be further explained in the next section by discussing the Tools of the Mind curriculum, which inspired the style of play promoted in the method.

2.5. Tools of the Mind

Tools of the Mind (ToM) is an evidence-based curriculum that combines theories and practical insights to teach literacy and mathematics skills while promoting the development of self-regulation in children from ages 3 to 7 (Barnett et al. 2008, Bodrova and Leong 2007, Diamond and Lee 2011). The curriculum program was developed over the course of 18 years with extensive research conducted in preschool and kindergarten classrooms across the United States and other countries such as Chile and Canada (Blair and Raver 2014). There are a variety of techniques and activities designed to support and train executive functions, that help children improve their self-regulation skills. Some of the classroom regular practices are structured role-play, regulatory
private speech, scaffolding, and shared cooperative activities. There is a great emphasis on self-regulation, play, and social interactions through which children make academic progress.

The ToM curriculum is strongly based on Vygotsky’s insights on child development (Bodrova and Leong 2007). According to Vygotsky (1980), executive function skills develop as children engage in specific social interactions. From his perspective, there is no separation between cognitive and social emotional self-regulation. Children’s active engagement in learning is crucial for their mental development processes and so are the tools they use with the support of more experienced people (Bodrova and Leong 2007, Vygotsky 1980).

These tools are part of children’s culture and help them develop attention, self-regulation, memory, and logical thought. In contemporary times, computers with developmentally appropriate software are part of the physical and cultural tools that can support learning. A significant part of Vygostky’s theory applied in the ToM program is the make-believe play, which is an integral part of children’s lives and it can foster self-regulatory skills (Bodrova and Leong 2007). The emphasis on play in school curricula may be controversial, because most people think of play as an unstructured activity made for fun. According to Miller and Almon (2009), there is research indicating a shift in kindergarten priorities where children in all-day classrooms spend more time in literacy and math instruction, taking or preparing for tests than they do playing (Miller and Almon 2009). This is not ideal because play is a major stress reliever and it can be an effective way to help regulate children’s behaviors.

For instance, Vygotsky’s definition of play involves three major components: (1) children create an imaginary situation, (2) they take on and act out roles and (3) follow a set of rules determined by these specific roles (Bodrova and Leong 2007, Bodrova et al. 2013, Vygotsky 1980). When children incorporate the idea of a role in a make-believe situation, they have to
control themselves to stay in role and act accordingly. This motivates them to train and improve their self-regulation skills. The ideal play activity has many rules and it matures as children become better at self-regulating themselves. The same play can last for several days and this is actually a positive scenario that indicates a progression in their skill levels (Bodrova and Leong 2007, Bodrova et al. 2013).

Moreover, ToM style make-believe play is planned in advance, includes the performance of roles with implicit rules, role speech, and the use of symbolic props. There are also distinctions in kindergarten and preschool classrooms. In kindergarten, the play is tied to stories and literature rather than grounded in children’s everyday experiences (Blair and Raver 2014). Therefore, make-believe play can evolve into a high-level dramatization, where themes and roles can be mixed together and also be based on fairy tales. This high-level pretend play can be a powerful instrument to develop language, text comprehension, vocabulary skills, and creativity (Blair and Raver 2014, Bodrova and Leong 2007).

Different studies analyzed the effectiveness of the ToM curriculum on self-regulation. Diamond et al. (2007) compared the ToM curriculum with a District’s version of Balanced Literacy curriculum with 147 preschoolers (Diamond et al. 2007). Their findings indicate that Tools successfully improved self-regulation on children who had poor skills. In addition, the children in the ToM classrooms had significantly faster mean reaction time than the children in the control classrooms. Moreover, ToM impacted children’s stress response that was specific to high-poverty schools and it was positive to children’s academic progress (Diamond et al. 2007).

Barnett et al. (2008) conducted a randomized trial to investigate the effectiveness of the ToM curricula. The study compared social behavior, language, and literacy growth in 3 and 4-year-old children. The treatment group had 88 children engaged in the ToM curriculum methods and the
control group had 122 children experiencing a district model focused on literacy (Barnett et al. 2008). In this study, the ToM curriculum exhibited improvement of both children’s executive function and classroom quality, with smaller statistical effects indicating language development (Barnett et al. 2008). The findings suggest that a developmentally appropriate curriculum with a strong emphasis on play can enhance self-regulation and improve both social and academic success of young children.

A more recent study completed a large-scale controlled trial of the kindergarten version of the ToM curriculum with 79 classrooms and total analysis sample of 759 participants (Blair and Raver 2014). The findings from this study also indicated significant outcomes of the curriculum on vocabulary, reasoning, and attention among children in high-poverty schools. Like previous studies, their analysis verified the ToM curriculum improved children’s academic progress relative to children in the control schools. The effects of the curriculum in mathematics were significantly higher as well, which supports the relevance of an educational approach that builds on self-regulation development (Blair and Raver 2014).

Our design method is grounded on the theories and practices supporting the ToM curriculum and it explores lowering barriers to make-believe play using technology. By role playing, young children can express their creativity, connect with their peers, and communicate their interests while engaging in the technology design process.

The next section will discuss potential impacts of technology on preschool children’s development. It will also investigate relevant and inspiring applications of educational technologies designed for children.
2.6. Preschool Children and Technology

There is evidence that parents are providing mobile devices to their kids at very young ages (Common Sense Media 2013, Hourcade et al. 2015). Technological development decreased the prices of such devices, which facilitated children’s access. Another reason for their popularity is that touchscreen technology matches the motor abilities of younger children (Hourcade et al. 2015). In fact, the market of commercial apps is following this trend by offering varied quality apps targeted at preschoolers or even younger children (Hernandez 2014, Hourcade et al. 2015). According to Hernandez (2014), 9 of the top 10 paid education apps are designed for young children, ages four and up.

On the other hand, researchers do not have a general agreement about the impacts of touchscreen devices on young children’s development because this is a fairly new topic of investigation. Some of the main criticisms include: (1) the possibility that computers could lead to social isolation, (2) computers could be used only for entertainment and provide access to inappropriate content, (3) computers could affect the development of perceptual and motor skills, (4) computers could lead to physical injury (e.g., if a computer falls), or (5) obesity due to lack of physical activity (Hourcade et al. 2015). These are all valid concerns, but we can trace a parallel between computer and television in order to better understand screen impacts on young children.

There is evidence that the wrong TV show can have bad effects on children while the right kind can have positive outcomes, such as improving their vocabulary. For instance, fast-paced television cartoons and great exposure to programs designed for adults can impact executive functions on 4-year-olds (Lillard and Peterson 2011). On the other hand, Linebarger and Walker (2005) identified certain characteristics present in quality educational television programs that help young children learn. Features such as including child-directed speech, elicitation of responses, object labeling, and a coherent storybook-like framework are positive for learning (Linebarger and
Successful educational media strategies like these can offer inspiration and be adopted in the design of interactive technologies for young children.

Nonetheless, just like television, there is evidence that technology can be beneficial if used properly (Bavelier et al. 2010, Hourcade et al. 2015, McCarrick and Li 2007). A recent study concluded that the impact of technology on children depends on what technology is used and how it is used. The effects on children can be positive, neutral, or negative (Bavelier et al. 2010).

Likewise, a group of researchers from Wayne State University conducted correlational and controlled investigations of how computers impact young children’s learning and cognition (Hourcade et al. 2015). The participants were children enrolled in Head Start, a school program focused on low-income children aged three to five. The researchers found that children with access to a computer performed better on measures of school readiness and cognitive development (Li and Atkins 2004, Li et al. 2006). In their correlational study, the researchers found that children whose parents reported active involvement in their computer use scored higher on cognitive measures than children whose parents reported non-active involvement (Hourcade et al. 2015, McCarrick and Li 2007). The researchers reflected the reasons why computers benefit children could be the variety of learning experiences they provide, their interactive nature, and their contribution to problem solving and learning. In addition, they argued that computers could motivate children, and often involve interactions with others (Hourcade et al. 2015, McCarrick and Li 2007).

Castles et al. (2013) conducted a similar study based on a survey and testing of 1,539 four-year-old children. They found a positive correlation between computer use and letter knowledge, which is considered a strong predictor of reading ability (Castles et al. 2013). Moreover, educational media efforts have been successful when it comes to literacy and numeracy (Bavelier...
et al. 2010, Castles et al. 2013, McCarrick and Li 2007). A recent study analyzed YouTube videos of very young children, aged around 12 to 29 months, interacting with tablet devices. Their findings suggest that a significant portion of the videos involved social use of the devices (Hourcade et al. 2015). In terms of content, educational apps were similarly popular to games and many of the apps appeared to enable children to practice perceptual and motor skills (Hourcade et al. 2015). These are encouraging findings that reinforce the idea that technology can have positive impacts on children.

According to McManis and Gunnewig (2012), software programs can strongly impact children’s learning experiences with their educational value, ability to engage in learning, child-friendliness, interactivity, and ability to monitor progress. Alper and Herr-Stephenson (2013) emphasizes that children need to acquire appropriate media literacy levels in order to easily navigate between different devices. This must be reached with the help of parents and teachers that can add depth to children’s understanding. Additionally, selecting the appropriate set of educational tools is vital for the development of executive skills. Every device has affordances and characteristics that make it well suited to certain kinds of learning exercises.

Particular kinds of technology that tend to focus on younger demographics are tangibles. Tangible technologies have the advantage of using friendly shaped devices that children can easily manipulate. A good example is Electronic Blocks, a programming environment shaped like stackable blocks designed for children aged between 3 and 8 years old. Children can connect the blocks and program different structures that interact with one another (Wyeth 2008). Like Electronic Blocks, many of the existing tangible technologies focus on simplifying computer programming for children. Interesting applications of tangibles can be seen in science museums, attempting to provide memorable learning experiences in those specific environments (Horn et al.
For instance, Horn et al. (2008) developed a tangible exhibition for elementary and middle school children that consisted of a robot, a programming console made of wooden blocks and a platform on which the robot can move around. The wooden blocks were shaped like a jigsaw puzzle and the users could connect them to program the robot’s actions (Horn et al. 2008). In addition, the system used a web camera and computer vision to convert physical programs into digital robot instructions.

Other examples focus on promoting interactive storytelling and embed technology into stuffed toys. For instance, StoryMat is a soft cloth quilt with figures divided into 126 areas by software. The system has a stuffed animal embedded with a transmitter that can listen, record, and replay children stories. This toy aims at supporting fantasy play, peer collaboration, and language learning for children aged 5 to 8 years old (Cassel and Ryokai 2001). Another similar technology is StoryToy, which makes use of motor sensors embedded in stuffed farm animals to track their location in a farm setting (Fontjin and Mendels 2005). The sensors communicate to a PC where a program translates the events into audio responses that are played from a speaker inside the farm. Children aged 2-5 years old can explore three types of play according to their age and cognitive abilities (Fontjin and Mendels 2005).

Tangible technology is a very interesting idea that explores a social and physical approach, usually focusing on one type of activity. Also, there’s an undeniable appeal for young children to make sense of the world around them by manipulating objects. However, some of its disadvantages are the cost and the practicality, which promote barriers to accessibility. Moreover, it’s important to look for flexible approaches and activities children can do with technology they already have access to. Fortunately, mobile devices can have many functions and lower the barriers to good educational practices and applications.
Relevant examples of existing technology that facilitate educational practices are software developed for scientific inquiry. Interactive technologies that support this process usually act as facilitators that scaffold the scientific procedures by walking children through the different stages (Hourcade 2015). This idea is similar to our approach, in the sense that an activity is made easier through the use of technology. However, it’s usually developed for older children and the devices play a big part on the process. For instance, Shimoda et al. (2013) designed an online learning environment that supported scientific inquiry in the classroom. The system was developed for children aged 10-13 and it offered them tools to brainstorm ideas, conduct discussions, enter data, report on work and track progress in a scientific inquiry process (Shimoda et al. 2013, Hourcade 2015).

Another example is Zydeco, a system that integrates mobile devices with a networked web server to support and integrate scientific inquiry in different places such as classrooms and museums (Cahill et al. 2011). The system was designed to scaffold data collection, analysis, synthesis and evaluative work for middle school students. An additional example is ScienceKit, a mobile social media application designed to allow learners to document and share their everyday experiences in science (Yip et al. 2014). The system was designed for 8-11 year old children and it integrates drawings, audio and video to facilitate scientific practices (Yip et al. 2014).

Those examples can offer some inspiration for our research practices. However, the technologies we explored in our Play-based Design sessions focused on collaborative social activities that are developmentally appropriate for young children. We investigated ways in which child-centered technology can foster play and the use of physical props other than mobile devices. Our approach used devices people already own to increase accessibility and eliminate the need to buy new gadgets to have access to our content. The design of our technologies was inspired by the
best television practices, technology for young children to be educational, convenient, and user-friendly. In addition, we strived to respect children’s privacy and avoided collecting their data in all of our projects. The web-based app we developed during our first sessions, functioned merely as a facilitator for the Play-based Design activity to function at an optimal level.

In the next chapter I will present an analysis of the current design methods for working with young children.

CHAPTER 3: PARTICIPATORY DESIGN METHODS FOR PRESCHOOL CHILDREN

In this chapter I present an analysis of the literature regarding participatory design methods for working with children under the age of five. Little is known about the design process used to develop most commercial apps for children under the age of five, and the documented occurrences of children in this age group contributing beyond a testing role are few, and even more limited for children under four years old (Borum et al. 2015, Farber et al. 2002, Norooz and Froehlich 2013, Petersen et al. 2015).

In order to better understand the current landscape of design methods for children under the age of five, I conducted an extensive literature review in five key venues relevant to the field of child-computer interaction. These venues were the Interaction Design and Children (IDC) conference (started in 2002), the Human Factors in Computing Systems (CHI) conference, the International Journal of Child-Computer Interaction (IJCCI), the International Conference of the Learning Sciences (ICLS), and the International Conference on Computer-Supported Collaborative Learning (CSCL). We searched for the terms “young children”, “very young children”, and “preschool children” in publications that appeared between the years 2000 and 2017, because the widespread use of touchscreen devices started about halfway through this
period. My goal was to better understand the possibility of elevating the voices of children under the age of five when designing technologies for them.

The challenge with children under five, is that some of the methods that worked with older children are unlikely to work the same way. Young children have different communication abilities, social skills, a less developed ability to think abstractly, and they are still developing their motor skills. This may explain the small number of experiences shared about designing with this age group. Despite the challenges, we believe that deeply engaging with young children throughout the design process could generate positive outcomes if we use age appropriate methods to give voice to young children. I believe that exploring new design methods with young children can lead to more opportunities for researchers to work with preschoolers.

The analysis generated a previously unavailable picture of the landscape of design methods used when developing technologies for young children. It also presents a gap when it comes to working in partnership with young children during the technology design process. I identified five papers that involved only children under the age of five as informants. These papers explored a variety of approaches such as sketching, prototype construction, fictional inquiry, comicboarding, peer tutoring, observations, and interviews. However, none of the reported experiences included sustained efforts that worked well enough to produce interpretable or actionable ideas for designers to implement in their technologies.

3.1. Criteria for Selection

The criteria I used for selecting publications followed two major guidelines. First, the publication had to report on children under the age of five either using technology or participating in some level of the design process to develop a technology. Second, the publication had to provide clear information on how the researchers designed, evaluated, or established requirements for the
technology. Therefore, I excluded publications where the details provided would be insufficient for the analysis, such as Work in Progress or Demo papers.

I also excluded publications that did not include children under five years-old or did not specify the age of participants or target users. I noticed that there are publications using the word “preschool” in their title or abstracts without involving children under the age of five. This can be confusing and make it harder to identify publications that involve children under five. However, this is probably due to distinctive meanings and age ranges associated with the word “preschool” in different countries.

Likewise, I excluded publications that were not distributed in the five venues specified (CHI, IDC, ICLS, CSCL and IJCCI) and that were published outside the period of 2000 to 2017. Additionally, I decided to exclude publications that included only adult proxies (e.g., interviews with parents, experts, or other adults) to learn about the children, because my goal is to learn from existing experiences directly involving young children in the technology design process. The search terms yielded a total of 877 results, from which I selected 99 articles according to the inclusion criteria.

3.2. Criteria for Classification

Over years of experience working to design technologies with children, Druin identified three dimensions for the roles of children in the design process: (1) the goals of the research, (2) children’s relationships to technology, and (3) their relationship to developers (Guha et al. 2013). According to these dimensions, she proposed four levels for children’s involvement in the design process: user, tester, informant, and partner (Druin 2002, Guha et al. 2013, Hourcade 2015). At the user level, children are usually observed using technology or conducting activities in different settings, during different stages of the design process (Hourcade 2015). They might also participate as users if the purpose of the technology is to help children develop a particular skill (Hourcade 2015). The testing level is perhaps the most common, where children are asked to use a system to
complete predefined tasks in order to evaluate the technology. Children’s participation in the
design process as testers generally happens in later stages of technology development when there
are high-fidelity prototypes, but it can also happen at the beginning with low-fidelity prototypes
(Hourcade 2015). Beyond testing, Druin identifies the roles of informant and partner that usually
enable a deeper understanding of children’s needs, abilities, and interests (Druin 2002, Guha et al.
2013). Informants share their ideas and opinions with the design team at key points in the design
process. Partners go a step further and are a constant presence in the design team, participating in
all major decisions (Druin 2002, Guha et al. 2013). Methods that involve informants or partners
have been broadly adopted with children aged five and older (Fails 2012, Guha et al. 2013, Walsh
et al. 2013), but that is not the case with children under the age of five. Researchers who have
attempted to include preschoolers as informants have had to address challenges due to young
children’s developmental characteristics such as their social and communication skills, their ability
to understand abstract concepts, and to sketch their ideas (Borum et al. 2015, Guha et al. 2004,
Hiniker et al. 2017).

I chose to use Druin’s framework because it is flexible enough to consider the dimensions
of children’s participation to be part of a continuum of possibilities that may change during the
design process (Druin 2002, Guha et al. 2013). Similar to the work of Isola and Fails, we surveyed
the literature and classified 99 selected publications using Druin’s taxonomy for the four design
roles assumed by children in the technology design process, with a focus on identifying the ones
that involved children under five at some level of the process. We categorized children's
participation as described in the publications as “users”, “testers” or “informants”. We could not
identify any publication that included children under five as partners, which would require
meetings on a regular basis and a higher level of involvement from the beginning of the design
process through the end. In case a publication self-identified children’s role in the design process (e.g., informants), we classified the publication according to the role identified by the authors. In case a publication involved children in multiple roles throughout the design process, we considered the most advanced role in the spectrum in our classification.

The other codes we used in our analysis were developed through iterative discussions with my research group and later clustered by similarity. We collected information about the methods used in the research, the settings where the study was conducted, the year and type of publication, the type of technology developed in the project, the purpose of the technology, the number of participants, and the number and length of the sessions when the information was available. One researcher was responsible for selecting and classifying the publications and any ambiguity that emerged throughout the analysis was discussed among other members of our group until a consensus was reached.

In our classification of the role of “users”, we considered publications featuring research where children generally did not perform any specific set of tasks to evaluate a technology, they either used technology freely while researchers observed or videotaped their interactions, or they were tested for particular skills (Druin 2002, Hourcade 2015). In some cases, researchers used ethnographic exploration to understand interactions that occurred in specific settings over a period of time (Wyeth 2006). In other cases, researchers analyzed freely available YouTube videos, with no direct interaction with children, to understand how children use specific kinds of technology such as mobile devices, voice user interfaces, and assistive technologies (Anthony et al. 2013). There were also instances where young children attended public events and interacted with technologies in particular venues, such as fairs, museums, or art exhibitions (Petersen et al. 2015). In these instances, there were usually minimal interactions with the researchers, and in many of
these cases young children were not the actual target demographic of the technology. There were also cases that aimed to understand or evaluate the learning potential of certain technologies, with use of standardized tests to assess children’s skills before and after interacting with specific technologies (McCarthy et al. 2013).

In the role of “testers”, we considered publications featuring research that conducted a planned user study with predefined tasks for children to perform during their interactions with technology with the goal of improving the technology (Mansor 2012). The researchers usually did not have any expectations of getting design ideas from the children, except assessing particular features or usability issues with their prototypes (Bai et al. 2015). In most cases like these, we observed a general occurrence of few sessions with children where they usually did not participate more than once. In some cases, the researchers conducted interviews with the children or their adult proxies during some part of the process (Zaman and Abeele 2010).

In the role of “informants”, we included publications featuring approaches where researchers expected children to provide design ideas for a technology (Hiniker et al. 2017). The cases we observed seemed to either involve children more than once or use a variety of techniques to get ideas, opinions, and preferences during critical parts of the technology design process (Hiniker et al. 2017). Since there were few publications in this category and the focus of our inquiry was to learn more about experiences that attempted to gather design ideas from young children, we gathered more details about the techniques used in each project and the lessons learned from publications involving young children as “informants”. These details are presented in the discussion section of the literature review results, followed by other experiences from the literature that did not match our survey criteria.
We classified the types of technology developed in the selected publications according to 14 categories, grouping similar technologies when appropriate. For example, in the category of tangible technologies, we included publications that presented research on developing digital manipulatives of different kinds, such as toolkits, sensors, educational toys, RFID, and other kinds of interactive objects (Raffle et al. 2007). In the category of mobile devices, we clustered publications presenting research on designing systems, digital media and applications developed for tablets and smartphones (Berggren and Hedler 2014), separating these from technologies developed for desktops and laptops because of the difference in manipulating each of these devices, which is relevant to our age group (Aram and Bar-Am 2016). The category of interactive environments includes technologies such as interactive playgrounds, experimental theaters, or physical gaming that involve an external setting that goes beyond the computer and the digital manipulatives (Montemayor et al. 2002). We included evaluation methods designed for children, such as Smileyometer and This and That (Zaman et al. 2013), as types of technology even though they might not require a device to be used. We considered important to include these tools that attempt to provide a way for young children to express their preferences because we are investigating methods for this particular age group.

We classified the purpose of the technology according to 10 categories, grouping similar ones when appropriate. For instance, self-expression refers to promoting communication, creative expression through art or storytelling, and expression of children’s preferences and abilities (Hiniker et al. 2017). Social emotional development refers to encouraging and teaching social behaviors or supporting exploration of children’s emotions (Bai et al. 2015). STEM groups different purposes such as development of math skills, computational thinking, problem solving, and science learning (McCarthy et al. 2013). Interaction behaviors refers to specific technology
interactions, such as how young children use the mouse or interact with voice input systems (Hourcade et al. 2004). Accessibility includes technologies that attempted to support children with disabilities and neurodiverse children, including children with low vision, autistic children, or children with hearing impairments (Anthony et al. 2013). General cognitive development refers to promoting the practice of skills such as memory, attention, learning processes, and planning (Ching and Wang 2006). Physical development refers to publications that focused on physical activities or physical exploration (Soler-Adillon et al. 2009).

3.3. Results of the Literature Review

In this section I present the results of my comprehensive review. I selected 99 publications out of 877 results based on the criteria previously discussed. Most of the publications (49 of 99) involved young children as testers of some kind of technology, followed by 45 publications that involved them as users, and only 5 publications that involved them as informants (see Table 2). The majority of the selected publications (n=61) were from IDC, and in this venue, there was a preponderance of short papers (n=33) (see Table 3). This was followed by papers published at CHI (n=24), where there was a majority of full papers (n=20).

Table 1. Crosstabulation of Publishers and Young children’s roles participating in the design process.

<table>
<thead>
<tr>
<th>Publisher</th>
<th>Informants</th>
<th>Testers</th>
<th>Users</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHI</td>
<td>1</td>
<td>8</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>CSCL</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ICLS</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>IDC</td>
<td>4</td>
<td>34</td>
<td>23</td>
<td>61</td>
</tr>
<tr>
<td>IJCCI</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>TOCHI</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>49</td>
<td>45</td>
<td>99</td>
</tr>
</tbody>
</table>
Table 2. Crosstabulation of Publishers and Type of publication for each venue.

<table>
<thead>
<tr>
<th>Publisher</th>
<th>Full</th>
<th>Journal</th>
<th>Note</th>
<th>Short</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHI</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>CSCL</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ICLS</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>IDC</td>
<td>27</td>
<td>0</td>
<td>1</td>
<td>33</td>
<td>61</td>
</tr>
<tr>
<td>IJCCI</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>TOCHI</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>10</td>
<td>1</td>
<td>39</td>
<td>99</td>
</tr>
</tbody>
</table>

The first selected publication where children under the age of five were involved in the role of informants was published in 2007 and the other four were published in 2010, 2013, 2014 and 2017, respectively (see Table 4). The highest amount of publications happened in 2013 (n=14), when there was more involvement of young children as users (64.3%), and in 2015 (n=13) when there was more involvement of children as testers (61.5%). In 2017, there was nearly an even split between young children’s roles (6 testers, 5 users, and 1 informant).

Table 3. Crosstabulation of Young children participation and Year of publication.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Informants</td>
<td>Count</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>1</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>% within Year</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>20.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>14.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>7.1%</td>
<td>11.1%</td>
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<tr>
<td>Testers</td>
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<td>0</td>
<td>4</td>
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<td>3</td>
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<td>5</td>
<td>2</td>
<td>4</td>
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<td>8</td>
<td>4</td>
</tr>
<tr>
<td>% within Year</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
<td>33.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>80.0%</td>
<td>66.7%</td>
<td>50.0%</td>
<td>42.9%</td>
<td>62.5%</td>
<td>40.0%</td>
<td>28.6%</td>
<td>66.7%</td>
<td>61.5%</td>
<td>66.7%</td>
<td>50.0%</td>
</tr>
<tr>
<td>Users</td>
<td>Count</td>
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<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
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<td>3</td>
<td>9</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>% within Year</td>
<td>100.0%</td>
<td>100.0%</td>
<td>0.0%</td>
<td>66.7%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>0.0%</td>
<td>33.3%</td>
<td>50.0%</td>
<td>42.9%</td>
<td>37.5%</td>
<td>60.0%</td>
<td>64.3%</td>
<td>22.2%</td>
<td>38.5%</td>
<td>33.3%</td>
<td>41.7%</td>
</tr>
<tr>
<td>Total</td>
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<td>3</td>
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<td>5</td>
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<td>6</td>
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<tr>
<td>% within Year</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
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<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Even though our focus was selecting publications that included children under five years-old in the design process, there were some publications that also included older children. The age range of the participants varied from 0 to 17 years-old (see Fig. 1). In total, there were 38
publications that included only children under the age of six, and 15 publications that included solely children under five.

Figure 1. Graph visualization of the age ranges included in the selected publications.

We coded the types of methods used in the publications by grouping them as qualitative (n=60), mixed (n=20), or quantitative (n=19). To gain a better understanding of the methods, we analyzed relevant categories (e.g. settings) using crosstabulation. Overall, there was a predominance of qualitative methods among the selected publications, as seen in Fig. 2.

Figure 2. Count of the methods used in the selected publications.
We categorized the settings where the research was conducted according to the descriptions presented on the publications, whenever the information was available (see Fig. 3). In instances where we were not able to clearly identify the setting of the study, we classified it as “unclear” (n=15). In other instances, publications featured research conducted in more than one setting, which we classified as “multiple” for crosstabulation purposes (see Table 4).

The most common method/setting combination was the use of qualitative methods at schools (n=23) (see Table 5). The second most common method/setting combination was the use of qualitative methods at young children’s homes (n=8). Another common method/setting combination was the use of quantitative methods at research laboratories (n=7).

<table>
<thead>
<tr>
<th>Methods</th>
<th>Car</th>
<th>Home</th>
<th>Hospital</th>
<th>Laboratory</th>
<th>Multiple</th>
<th>Public event</th>
<th>Rural villages</th>
<th>School</th>
<th>Unclear</th>
<th>YouTube</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>20</td>
</tr>
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<td>5</td>
<td>8</td>
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<td>1</td>
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<tr>
<td>Quantitative</td>
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<td>7</td>
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<td>0</td>
<td>6</td>
<td>3</td>
<td>0</td>
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</tr>
<tr>
<td>Total</td>
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<td>14</td>
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<td>1</td>
<td>34</td>
<td>15</td>
<td>3</td>
<td>99</td>
</tr>
</tbody>
</table>

When analyzing the count of the settings discriminating the cases with multiple research sites (see Fig.3), there was a total of 41 occurrences of research conducted at schools, 20 occurrences of research conducted at laboratories, 17 occurrences of research conducted at participant’s homes, and 9 occurrences of research conducted in public events. There were 3 cases featuring documental research analyzing existing videos from YouTube, 2 cases that conducted research at hospitals, and 1 case each of research conducted at a car, at a clinical site, and in a rural village.
The crosstabulation between methods and young children participation, indicate that the most popular combination among the publications were qualitative methods involving children as “users” (n=31). The combination between qualitative methods and children as “testers” was also popular (n=24), followed by the quantitative/“testers” combination (n=17). Mixed methods were fairly distributed among the roles of “users” (n=12) and the roles of “testers” (n=8).

Table 5. Crosstabulation of Young children participation and Methods.

<table>
<thead>
<tr>
<th>Informants</th>
<th>Mixed</th>
<th>Qualitative</th>
<th>Quantitative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>% within Methods</td>
<td>0.0%</td>
<td>8.3%</td>
<td>0.0%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Testers</td>
<td>Count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>24</td>
<td>17</td>
<td>49</td>
</tr>
<tr>
<td>% within Methods</td>
<td>40.0%</td>
<td>40.0%</td>
<td>89.5%</td>
<td>49.5%</td>
</tr>
<tr>
<td>Users</td>
<td>Count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>31</td>
<td>2</td>
<td>45</td>
</tr>
<tr>
<td>% within Methods</td>
<td>60.0%</td>
<td>51.7%</td>
<td>10.5%</td>
<td>45.5%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>60</td>
<td>19</td>
<td>99</td>
</tr>
<tr>
<td>% within Methods</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Figure 3. Count of research settings.
In addition, we analyzed the number of children participating on the studies (there were 7 cases excluded where the information could not be found on the publication) and the number of sessions conducted, even though in many cases this information was not clearly stated (there were 48 cases excluded). The minimum number of participants was 2 and the maximum was 840. The number of sessions varied between 0, which includes publications that conducted documental analysis of YouTube videos, and 16 (see table 7).

Table 6. Report of number of sessions and participants.

<table>
<thead>
<tr>
<th></th>
<th>Nº sessions</th>
<th>Nº of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.56</td>
<td>43.44</td>
</tr>
<tr>
<td>Median</td>
<td>2.00</td>
<td>17.00</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>2.338</td>
<td>100.971</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Maximum</td>
<td>16</td>
<td>840</td>
</tr>
</tbody>
</table>

The combination between qualitative methods and tangible technologies was the most common (n=24), followed by qualitative methods and mobile devices (n=13). Among publications using quantitative methods, there was a variety of technology types, with the most common combination was quantitative/input devices (n=4). The crosstabulation between methods and technology type indicate that the majority of publications using mixed methods focused on developing technologies for mobile devices (see Table 8). There were 9 publications working with more than one technology type, which we classified as “multiple” (see Table 8).

Table 7. Crosstabulation of Methods and Technology type.
When analyzing the count of technology types, the majority of publications featured the development of tangible technologies \((n=30)\), followed by publications developing technologies for mobile devices \((n=27)\) (see Fig. 4). Laptop and desktop technologies came in third with 11 occurrences, followed by robotics \((n=10)\).

![Figure 4. Count of technology types developed in the selected publications.](image)

When combining technology types with young children’s participation in the design process, the cases featuring tangible technologies mostly involved children as “users” \((n=14)\), followed by “testers” \((n=9)\), and “informants” \((n=2)\) (see Table 8). Technologies developed for mobile devices frequently involved children in the role of “users” \((n=13)\), followed by “testers” \((n=8)\) and “informants” \((n=2)\). In one case, children were involved as “informants” to develop multiple technologies. The combination between robotics/“testers” and “robotics”/“users” had an equal number of occurrences \((n=5\text{ each})\). The combination between laptop/desktop technologies and “testers” \((n=5)\) was more common than laptop/desktop and “users” \((n=3)\). Moreover, the combination of input device/“testers” and evaluation tool/ “testers” had the same number of occurrences \((n=4)\).
Table 8. Crosstabulation of Technology type and Young children participation.

<table>
<thead>
<tr>
<th>Technology Type</th>
<th>Informants</th>
<th>Testers</th>
<th>Users</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented reality</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Evaluation tool</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Eye tracking</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Haptics</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Input device</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Interactive</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Laptop/desktop</td>
<td>0</td>
<td>5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Mobile devices</td>
<td>2</td>
<td>8</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>Multiple</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Robotics</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Tabletop</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Tangibles</td>
<td>2</td>
<td>9</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>Virtual agent</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Voice input systems</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>49</td>
<td>45</td>
<td>99</td>
</tr>
</tbody>
</table>

There were 35 publications featuring technologies that promoted “self-expression”, 16 publications focused on developing technologies to promote “social emotional development”, and 13 publications featured technologies that promoted STEM (see Fig. 5). Subsequently, there are 12 publications featuring analysis of “interaction behaviors”, followed by technologies that promoted “literacy” (n=9), and “physical development” (n=8). Publications featuring technology that promoted “general cognitive development” and “accessibility” had an equal number of occurrences (n=6). It is important to note that 9 publications had more than one goal with their technology design and these cases were classified as “multiple” for crosstabulation purposes (see Table 9).
The combination of technology purpose and young children’s participation reveals that among the cases promoting “self-expression”, 17 publications involved children in the role of “testers”, 9 publications with children as “users”, and 3 publications with children as “informants”. In addition, publications promoting “social emotional development” mostly involved children as “testers” (n=8), contrasting with technologies promoting “STEM” that typically involved children as “users” (n=8). Moreover, publications investigating “interaction behaviors” frequently involved children as “testers” (n=7), with 4 cases involving children as “users”, and 1 case involving children as “informants” (see Table 10).

Table 9. Crosstabulation of Technology purpose and Young children participation.

<table>
<thead>
<tr>
<th>Purpose of Technology</th>
<th>Informants</th>
<th>Testers</th>
<th>Users</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>General cognitive development</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Healthcare</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Interaction behaviors</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Literacy</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Multiple</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>
3.4. Discussion of Review Findings

Overall, the results suggest that there were few attempts to include only young children in the development of technologies, even though young children’s exposure to technology is increasing over the years. The results are aligned with other research findings that highlight a common trend of targeting older children (around 10-years-old), particularly in IDC (Yarosh et al. 2011). This may be due to the developmental and methodological challenges of working with children under five. It may also be due to previous recommendation from the American Academy of Pediatrics’ for limiting screen time for young children that may have dissuaded researchers from focusing on this age group (Miller et al. 2017). The gap in the literature is even more pronounced if we consider only experiences involving young children in the roles of design informants. We present a discussion of the findings of our analysis for each role of children’s involvement in the technology design process: users, testers and informants. However, we will provide greater attention on the existing experiences involving young children in the role of informants because that is the focus of our inquiry and object of our study described on the next part of this thesis.

3.4.1. Children Under Five as Users

Our findings demonstrate that 45 publications involved young children in the role of “users” during the technology design process. Since the year 2000, these experiences have been frequently

<table>
<thead>
<tr>
<th>Physical development</th>
<th>0</th>
<th>3</th>
<th>3</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-expression</td>
<td>3</td>
<td>17</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>Social emotional development</td>
<td>0</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>STEM</td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Sustainability</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>49</td>
<td>45</td>
<td>99</td>
</tr>
</tbody>
</table>
published throughout the years, with an average of approximately 2.6 publications per year over a period of 17 years, reaching a peak of 9 publications in 2013. In this category, the age ranges were usually broad, varying from 0 to 17 years-old. This can be explained by the number of occurrences of public events (n=9), where it can be difficult to control the age of the participants, or by studies conducted with families in their homes (n=7) where there might be siblings of different age groups.

In general, when young children participated as “users”, the research approaches included observations (n=30), usually combined with surveys or interviews with adult proxies (n=17), and ethnographic techniques (n=8). There were few attempts to perform some kind of interview with young children (n=6) during the studies. Moreover, there were few publications using controlled experiments (n=4) to evaluate the learning gains from technologies and these cases typically used pre and post-test assessments (n=4).

These experiences happened in a variety of settings such as schools, hospitals, children’s homes, and public events held in museums, art galleries, and schools (see Fig. 6). However, we only identified 3 studies that occurred in a research laboratory. In the first one, researchers observed live video feeds of families’ interactions during storytelling sessions (Saksono and Parker 2017). In the second study, researchers included only children aged 5 and older to test an interactive playground after observations in public events with multiple age groups (van Delden et al. 2017). In the third, the researchers assessed communication learning gains among parent-child interactions using e-books versus wordless picture books (Rees et al. 2017). In this category, we also encountered analyses of YouTube videos (n=3) of young children using specific types of technologies, such as touchscreen mobile devices and voice interfaces, with the goal of understanding interaction behaviors.
The goal of inquiry in this category was typically free exploration of new technologies either to understand how children would interact with certain types of technologies (n=16), to understand or evaluate the learning potential of specific technologies (n=13), or to observe how interactions occur on specific environments (n=10), as shown in Fig. 6. In some cases, the involvement of children as users occurred in the early stages of the design process with the goal of formulating requirements for designing a technology (n=7).

The count of types of technology and their purposes can indicate the current trends and opportunities for inquiry involving young children. The majority of publications involving young children as “users”, developed “tangibles” (n=14) and technologies for “mobile devices” (n=13). This finding makes sense for this age group, because the tactile characteristics of tangible technologies can be appropriate for young children. Mobile devices are also more accessible to young children and there are not many motor barriers when interacting with this type of technology. In terms of purpose of technology, the majority of publications focused on promoting “self-expression” (n=9) and “STEM (n=8). With the exception of “self-expression”, this finding is aligned with the popularity of math skills, literacy, and entertainment available in commercial educational technologies (PBS Learning Media).

![Figure 6. Overview of the findings about experiences involving young children as users.](image)
3.4.2. Children Under Five as Testers

Our findings demonstrate that there was almost an equal number of publications involving young children as “users” (n=45) and “testers” (n=49) in the technology design process. Starting in 2003, experiences involving children as “testers” were frequently published throughout the years, with an average of approximately 2.8 publications per year over a period of 17 years, reaching a peak of 8 publications in 2015. This may indicate a growing number of technologies that target young children, following the increase of use of this demographic. In this category, the age ranges were also broad, varying from 1 to 15 years-old. There were no public events on this category, so the broad range can be explained by studies that were conducted with families that had multiple children and by the design decision of addressing and comparing interactions between different age groups with cross-sectional designs.

In general, when young children participated as “testers”, the research approaches included usability tests (n=22) with emerging technologies, iterative design including testing (n=16) with prototypes in different stages of the process, controlled experiments (n=10) to evaluate certain modes of interaction (e.g. prompts, social agents, input devices), surveys or interviews with adult proxies (n=17) and children (n=17), wizard-of-Oz techniques (n=7), and a few technology walkthroughs (n=2).

The majority of publications in this category conducted research in schools (n=22), followed by publications conducting at least a part of their studies in a research laboratory (n=18), which is probably due to the fact that some user studies might need enhanced controlled conditions. There were 10 publications that conducted studies in participant’s homes, and 1 publication that tested a technology in a car. Moreover, there were 7 cases where we were not able to clearly identify the setting.
The goal of inquiry was mostly to investigate interactions with specific technologies (n=30), followed by cases where the goal was to evaluate a particular mode of interaction (n=15). In addition, some publications had the goal to formulate design requirements (n=9) for improving their technologies. There were also publications with the goal of evaluating methods (n=5) for learning about young children’s preferences, such as “Laddering Interview”, “This or That”, “Smileyometer”, and “Fun Semantic Differential Scales” (Yusoff et al. 2011, Zaman and Abeele 2010, Zaman et al. 2013). While attempting to use “Laddering Interviews” with young children, the researchers found that only children aged five and older were able to construct meaningful ladders (Zaman and Abeele 2010). On the other hand, the “This or That” approach seemed to yield reliable and valid responses for children aged four and older, while “Smileyometer” produced inconsistent results about preschoolers’ preferences (Zaman et al. 2013). The “Fun Semantic Differential Scales” appeared to work with young children but there are no reports about children’s age distribution and whether the tool produced reliable results across the intended age range (3 to 5 years-old) (Yusoff et al. 2011). Finally, there were only 2 publications with the goal of comparing different technologies.

The majority of publications involving young children as “testers” developed “tangibles” (n=9) and technologies for “mobile devices” (n=8). This is very similar to publications involving children as “users”, but overall there was more variety of types of technologies being tested with children. This can indicate that testing technologies with young children is a feasible way to explore a variety of interactions. In terms of purpose of technology, the majority of publications focused on promoting “self-expression” (n=17), “social emotional development” (n=8), and “interaction behaviors” (n=7). This finding contrasts with the popularity of math skills, literacy and entertainment available in commercial educational technologies (PBS Learning Media).
3.4.3. Children Under Five as Informants

There are currently limited experiences in the literature that focused on involving young children in the spectrum of informants or partners of technology. Our literature review further corroborates this gap, with only 5 selected publications catalogued in this category. Considering this sample of five publications, the majority were short publications, with three short and one full publication from IDC, and one short publication from CHI. Since the majority of the publications in this category were short papers, in many cases the authors did not elaborate much on the details of their design experiences with young children and there were, on average, 2.3 sessions conducted with young children.

In this category, Wyeth (2007) was the single publication that included only children aged four years-old, while the other publications ranged from either four to five or four to six years-old. In addition, all publications conducted their studies in school settings with the exception of one that did not clarify where the study took place (see Fig. 8).

In general, the goals of inquiry in this category were to explore the learning potential of technologies (n=2), in particular tangibles for teaching children about colors and mobile devices for teaching children about geometry (see Fig. 8). The other 3 publications each had goals of
inquiry that were specific to the types of technologies they were developing, such as generating design insights for an app, developing design guidelines for tabletop technologies, or exploring different types of tangible technologies (see Fig. 8).

The types of technologies developed were tangibles, tabletop, or mobile devices. This is also aligned with the findings from the other two roles involving young children, which may indicate a trend of technologies directed at young children. The technologies we observed had different purposes with three publications focusing on “self-expression”, one focusing on “STEM”, and one focusing on “interaction behaviors” of children while using tabletop technologies. This finding highlights the variety of purposes that can be explored with young children while involving them in the design process to learn about their skills, abilities, and preferences.

Figure 8. Overview of the findings about experiences involving young children as informants.

Even though some of the publications did not offer many details about the methods used with young children, we compiled the researchers' reports on the approaches they used and the lessons they learned from children’s contributions as informants (see Table 11).
Table 10. Techniques and lessons learned while involving young children as informants.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Approaches</th>
<th>Lessons Learned</th>
<th>Length of sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyeth, P. (2007, June).</td>
<td>(1) <strong>Brainstorming:</strong> Children participated in brainstorming activities aimed at drawing out ideas, impressions and feelings related to six tangible computing prototypes (e.g. speech bubbles – plays a sound when it senses movement). The researcher described the functionality of the prototypes and children were asked to complete an activity with the prototype. For example, with the speech bubble prototype, children selected a resource in the room that would be better if it could speak or make noise.</td>
<td>The researchers gained insights from their sessions with 4-year-old children, and they did not report any issues. Children provided ideas for both direct and indirect interaction with the prototypes. They also recognized that the prototypes could be added into existing objects of their classroom to create new events based on their actions. According to the authors, participants described what the prototypes did “(e.g. the plank will move, the baby will say ‘mama’)” but they rarely considered what produced the behavior.</td>
<td>3 sessions of 20 minutes</td>
</tr>
<tr>
<td>Marco, J., Baldassarri, S., &amp; Cerezo, E. (2010, June).</td>
<td>(1) <strong>Wizard-of-Oz session:</strong> The sessions were conducted in a school, with 4-5-year-old children. It is unclear how many sessions occurred in total, and how many participants were involved. Children performed tasks while playing in pairs with a prototype. Their gestures with the toys were observed by an adult who played the role of “Wizard of Oz”, triggering the game events using a keyboard beside the tabletop. (2) <strong>Peer tutoring session:</strong> Children worked in groups of three but one of them learned how to play before the other two. The child who learned the game later helped the other children to play while using a farmer’s hat. (3) <strong>Usability session:</strong> Children played minigames in pairs and all tests were video recorded and logged.</td>
<td>The authors report frequent test sessions where children played with tabletop games and took on different roles that evolved from informants to testers to users. They used different evaluation methods that were adapted to children’s skills, focusing on what they did or intended to do. Initially, the designers observed how children manipulated the toys to perform the game tasks. The children made unexpected gestures for each task and some were incorporated in the final design. They also discovered many problems in their technology based on a detailed analysis of videos from the sessions. The authors recommend increasing the number of participants and minimizing adult intervention during sessions when moving forward in the design process. The authors also advise to keep in mind that “children are always right” and it’s important to make appropriate changes in the design concepts. Finally, they report an age difference in motor skills between 3 and 4- and 5-year-old children while performing certain movements in a minigame.</td>
<td>unclear</td>
</tr>
<tr>
<td>Shen, Y., Qin, Y., Li, K., &amp; Liu, Y. (2013, June).</td>
<td>(1) <strong>Observation:</strong> The researchers observed a class about color conducted by two educators. Based on their observations, they developed a prototype and took it to the classroom to get feedback. (2) <strong>Interview:</strong> After the first prototype test, the researchers gathered the children, and asked them simple questions like “what you think about this new companion”. (3) <strong>Sketching:</strong> Lastly, children draw their ideas on paper.</td>
<td>The authors report that young children prefer to discover colors in the physical environment, and they like to share their knowledge with others. According to their observations of how children used the prototype and to children’s ideas, the researchers added more interactive modes into their prototype. The researchers do not report any details about how they used children’s drawings, so it is unclear how useful this technique was.</td>
<td>3 sessions of 40 minutes</td>
</tr>
<tr>
<td>Berggren, J., &amp; Heller, C. (2014, June).</td>
<td>(1) <strong>Observation:</strong> The researchers observed children as testers of a low-tech prototype. Children worked in pairs while sharing one iPad. Before and after each session the children gathered for instructions and reflective discussions. During observation, the researchers focused on aspects such as children’s handling of tablet, need of guidance, and level of collaboration. (2) <strong>Sketch workshop:</strong> Children participated as co-designers in a sketch workshop, where they used a template to make drawings of cameras, buttons and possible quests. (3) <strong>Test and interview:</strong> The researchers developed a digital prototype and tested it with the children in the last session. After the test, the researchers conducted short interviews with the kids. (4) <strong>Teacher interview:</strong> The teacher was involved throughout the planning and execution of the activities. After each visit the researchers interviewed the teacher to gain insights and feedback.</td>
<td>During observations of children playing, the researchers noticed the importance of the shutter sound because of children’s actions when taking imaginary pictures. During the sketch workshop, children colored the template and they mostly drew conventional cameras or cameras similar to tablets. The activity provided insights about children’s perceptions of cameras and their preferences for the application interface. Children also provided ideas for what they would like to search in the future. According to the authors, co-designing with young children made them feel secure and confident in the presence of the designers, which was positive to promote natural and unaffected behaviors. However, there were not many direct design decisions based on the co-workshop results. In the last session, the prototype handling was improved but some children felt uncomfortable letting go of their two-handed grip when using the digital prototype. The authors concluded that naturalistic observation of children and behavioral analysis are more useful than conducting interviews with them. The authors report that asking young children to reflect on their own behavior often yielded responses that contradicted adult’s observations.</td>
<td>3 sessions of 1 hour</td>
</tr>
</tbody>
</table>
Hiniker, A., Sobel, K., & Lee, B. (2017, May). (1) Fictional Inquiry: The researchers divided participants into two groups (one with 4-year-olds, and one 5- and 6-year-olds). Each group had 2 adult facilitators who read the story aloud and asked children to sketch the screens of a technology. Children sat with their group to sketch but they worked individually, while the researchers asked open-ended questions during the activity.

(2) Comicboarding: There were 3 exercises with comicboards that had panel-style scaffolding, where the comic was complete except for one missing panel for children to fill in. The facilitator read the comicboard out loud with the child, along with a prompt explaining the missing panel.

(3) Prototype construction: The facilitator asked children to think of something they would like to make and presented a variety of construction materials. The facilitator supported children to identify an end goal and to articulate a plan for achieving it. Then, children used an iPad to record a video of themselves describing their plans.

(4) Usability test: Finally, each child engaged in a series of user tests with a prototype iPad application.

The researchers report that all of the 5- and 6-year-old participants were able to create design solutions to the fictional inquiry prompt. On the other hand, the authors found that none of the 4-year-old participants created artifacts or solutions that designers could interpret with fictional inquiry, comicboarding, or construction methods. Even though facilitators used the same prompts and scaffolding, the younger participants were unable to articulate on-topic ideas with none of the techniques. According to their results, 4-year-olds generated less cohesive ideas and often shifted to another topic. Based on their results, the authors recommend designers to anticipate that children might get ideas from all aspects of their environment. They also report that children were easily influenced by their ideas and materials. Therefore, the authors suggest using more open-ended materials and interpreting children’s solutions with this limitation in mind.

The authors report that they were able to extract useful findings from participants of all ages with traditional usability tests. According to their report, children from both age groups engaged with the interface in a meaningful way “that revealed insights into their mental models of time, order, symbolism and magnitude”.

Considering other venues, years and types of publications that were not included in our criteria, we found a few other examples in the literature that attempted to foster involvement of young children during the design process. Seitinger et al. (2006) report a work in progress that conducted design activities with 20 three to five-year-old children at a preschool in the process of developing an interactive pathway to be incorporated into the preschool’s playground. The activities included observing the children, asking them to draw their playground, testing a prototype, and designing spinners that were later incorporated into a prototype that was also used by the children (Seitinger et al. 2006). The children seemed to enjoy having their art incorporated into the technology, which was their only participation in the design process beyond testing. In all, the children participated directly in four sessions (excluding those in which they were solely being observed).

Borum et al. (2015) adapted the Bags of Stuff method from Guha et al. (2013) to explore designing with 55 children aged three to five years-old (no information is provided on age distribution). The project included children and teachers as testers, informants, and design partners throughout different stages of the development process, but no details are provided in terms of the
number of sessions involved (Borum et al. 2015). Borum et al. (2015) noted difficulties while adapting the *Bags of Stuff* method. In addition, the researchers also had challenges using the *Mixing Ideas* approach because it was difficult for young children to draw ideas for user interfaces. Moreover, children’s drawings did not tend to provide useful information from which designers could elicit ideas.

Mansor (2012) reported an experience of a user study conducted with ten children aged three and four years-old, published at OzChi. The researcher initially developed the design concept of his prototype by observing three to five-year-old children in their school environment. After this initial session, the author conducted an informal discussion and play session using a paper prototype, to gather design ideas with the children (Mansor 2012). In this study children were involved in the role of informants at the beginning of the process offering design ideas to improve the paper prototype, and they later participated in the role of testers in a series of pilot studies that preceded an evaluation of a tabletop technology.

The examples above made useful contributions toward understanding how to work with children under five in the role of informants in the technology design process. Researchers who wish to include children under the age of five as informants or partners, must address the challenges with children’s social and communication skills, their limited ability to understand abstract concepts, and to sketch their ideas (Borum et al. 2015, Guha et al. 2004, Hiniker et al. 2017). The review suggests there is currently a gap and a need to develop new design methods for this age group that consider the particularities of young children’s needs, abilities, and interests.

### 3.4.4. Lessons Learned from Literature Review

The results reveal few examples of research conducted exclusively with children under five years-old. In the experiences I identified, children’s participation in the technology design process is
overwhelmingly as either “users” or “testers”. According to the findings, the most popular methods involving children under five in the roles of users and testers are observations, interviews, or surveys with adult proxies, usability tests, and iterative design including testing. There are reports indicating that both observations and usability tests can be helpful to elicit useful findings from preschoolers (Berggren and Hedler 2014, Hiniker et al. 2017).

On the other hand, there were limited experiences involving children under five years-old as “informants” in the technology design process. I identified a variety of approaches explored with preschool aged children such as sketching, prototype construction, fictional inquiry, comicboarding, peer tutoring, observations, and interviews. However, few of these methods worked well enough to generate design requirements for developing technologies. For example, sketching, comicboarding, fictional inquiry, and prototype constructing do not seem to have produced interpretable or actionable ideas for designers to implement in their technologies (Berggren and Hedler 2014, Hiniker et al. 2017). Instead, I identified some promising attempts such as brainstorming sessions with young children using tangible technologies (Wyeth 2007), using a Wizard-of-Oz approach to get insights for a design concept (Marco et al. 2010), or paying attention to children’s actions while they explore a prototype (Berggren and Hedler 2014). Unfortunately, there were few details about the methods used in these experiences and few sessions conducted by the researchers. This indicates a need to further explore promising approaches that elicit design ideas while working together with children under five during the technology design process. Considering that methods involving children in the design process beyond testing have been widely adopted when designing technologies for children aged five and older (Hourcade 2015), there is an opportunity to develop more options for researchers to create similar experiences involving preschoolers.
In the next chapter I will present the first exploration of implementing Tools of the mind style play with a group of five 3-4 year-old children.

CHAPTER 4: STORYCARNIVAL

This chapter discusses the first set of research activities exploring make-believe play in the style of *Tools of the Mind*, which contributed to a better understanding of the steps necessary to support this activity using technology. The research activities provided evidence of the potential of collaboration between adults and young children. Children provided design requirements by expressing their ideas through make-believe play, and their ideas were iteratively incorporated into the development of StoryCarnival. StoryCarnival supports adults to facilitate make-believe play by providing a common context for play and helping children to plan their play. During these research activities, a new participatory design method started to take shape.

4.1. Technology Components

*StoryCarnival* is a web-based technology that facilitates the setup and planning of make-believe play in the style of *ToM*. Make-believe play in *ToM* style is pretend play in a social context, where pretend play is defined as play that includes the use of fantasy and make-believe, and symbolical representations (Hoffmann and Russ 2012). The play activities support children's creativity, their connection with their social and physical environment, and face-to-face communication (Bodrova and Leong 2007). These activities involve children planning play by selecting themes and taking on roles with implicit rules. Play includes the use of generic physical props that may stand for a variety of imagined objects (Bodrova and Leong 2007). The goal is for children's play to eventually incorporate symbolic representations and actions, planning, complex themes, rich roles, and an extended timeframe. All of these behaviors can be beneficial to the practice of self-regulation skills
and children get more proficient in the activity over time (Blair and Raver 2014, Bodrova and Leong 2007).

*StoryCarnival* supports play in two different ways. First, it sets a common foundation for children to understand the theme of play by introducing it with a storytelling component (see Fig. 9). This feature was developed because we found children did not have many stories in common and the popular stories tended to have a main character they all wanted to be. Therefore, the stories we created included characters of the same importance collaborating creatively in different contexts to solve problems. After learning about a story setting and its characters, *StoryCarnival* supports children's play planning by enabling them to select and negotiate the roles they will interpret during play (see Fig. 10). Children take turns selecting their roles and can be reminded of the specific role a character plays in the story as *StoryCarnival* provides reinforcement on the role of each character.

![Figure 9. StoryCarnival’s storytelling component, highlighting the characters.](image)
4.2. Research Goals

The main goal of our research was to understand how technology can lower the barriers to support make-believe play in the style of *Tools of the Mind*. We were also interested in gaining insights on the participation of three to four-year-old children in design activities. More specifically, we initially adapted the existing method of technology immersion (Druin 1999) to understand how this generation of children are using current mobile devices. Subsequently, we explored supporting ToM style play and iteratively incorporated technology in our design sessions to facilitate the play. We were interested in learning how communication occurred between children and adults during our sessions, and what types of events led to actionable design requirements for our web-app.

4.3. Participants

We conducted sessions with five children, three boys and two girls, from the same class in a small preschool (one classroom per age level) in a city with a population of about 100,000 people in the United States. The children were three to four years old, and all had access to smartphones or tablets at home. We obtained permission to conduct our research from our institution’s Human Subjects Office and obtained consent from all parents. In addition, children only participated in activities on a given day if they wanted to. If they were not sure, we gave them the option of observing the activities and joining in if interested. We use fictitious names to refer to the children in the quotes.
4.4. Research Activities

We conducted all research activities in rooms at the children’s small preschool and we video recorded every session. During our design sessions, two to four research team members and one teacher were always present in the room in addition to the children. Two of the research team members had parenting experience with children of a similar age, and another had extensive experience working at schools. After completing each session, the adult members of the design team met, wrote a summary of the session, and noted any design requirements that arose out of the session. We conducted two types of sessions with the children. The first four sessions used an adaptation of the technology immersion method (Druin 1999, Guha et al. 2013). In the remaining eleven sessions, we iteratively developed and improved *StoryCarnival*.

4.4.1. Technology Immersion Sessions

The original intent of technology immersion sessions as developed by Druin (1999) was to introduce children to a novel technology (Guha et al. 2013). In our case, that was not necessary, but instead we needed to get a better sense for how this generation of children interacted with devices already familiar to them. During these sessions, children used educational software from organizations with a long track record on educational media: PBS Kids and CBeebies. We selected web-based apps recommended for their age group that ran on a full screen. The children used the apps on four different devices: Samsung Galaxy Tab 4, Kindle Fire 7” 4th generation, Microsoft Surface Pro 4, and Apple iPad 4th generation. These activities met our desired criteria in not only providing us with useful design requirements, but also in that children enjoyed participating and were more likely than not to benefit from them.
4.4.2. Participatory Design Sessions

After four technology immersion sessions, we started to experiment conducting design sessions based on our ideal guidelines and considering the difficulty three and four-year-old children have sketching interfaces and verbally expressing how a technology should be designed. We were inspired by the activity we were aiming to support with our technology: make-believe play.

Given the make-believe play activities we aimed to support with technology (Bodrova and Leong 2007, Stanton-Chapman 2015), the design sessions we conducted typically included the introduction of a story theme involving a setting and characters (see Fig. 9), planning play (see Fig. 10), and supporting the children during play, which included the use of generic physical props (e.g. basic shapes, see Fig. 11) and role-play, giving children the freedom to act out the experiences they wanted.

![Figure 11](image1.jpg)

Figure 11. Examples of physical props used during our Play-based design sessions.

In our design sessions, the adults in the research team steered children toward the beneficial activities we wanted to support, while children steered us toward the experiences that were fun and meaningful for them. This was enabled by the structured, yet open-ended nature of the sessions. As the sessions went by, we replaced some of the facilitating by adults with support through interactive technology while integrating children’s preferences. These activities also met our criteria of being attractive to children and were more likely than not to have a positive impact on them.
4.5. Coding Design Sessions

We coded the design sessions in order to understand patterns of communication and learn how to better conduct sessions in the future. Initially, we transcribed the videos of our sessions and looked for the behaviors and activities that stood out for both adults and children. We then used the line-by-line technique outlined by Charmaz in her approach to Grounded Theory, categorizing segments of data with a short name that summarizes the actions observed (Charmaz 2006). We used this technique with the transcripts from three design sessions to find categories through comparative analysis of the themes in the data. Then, we grouped similar events using an affinity diagram to define the categories that were later applied to code the videos using the software Morae Manager™. After we coded nine videos, we adjusted the categories to better reflect the events we observed by comparing the number of markers using a broad category versus two specific ones. For example, after a preliminary analysis of the codes, we decided to break down “Communicating”, referring to children’s communication, into two distinctive types we identified: Verbal and Non-verbal Communication.

Our final codes consist of a total of nine categories. In order to capture how children behaved, we used the four categories listed below:

1. **Communicating Verbally**: This category was used to mark events where children communicated with adults verbally by saying what their choices were or by giving us ideas and suggestions.

   *Vincent says: “Can we do the farm next time?” Vincent suggests the theme for the next session play, and he points out that his intention is for the next time, not now.*
2. *Communicating Non-verbally*: This category marked events where children communicated with adults with gestures such as shrugging shoulders, nodding their heads, or pointing to a choice.

   *Researcher prompts Vincent to choose which device he prefers, between the iPad and the Surface. He points to the iPad.*

3. *Behavioral/Emotional Expression*: This category marked events where children expressed emotions through laughter, screaming, or confused looks. Also, this category marked behavioral expression of likes, and dislikes.

   *Jill seems a little bored with peers interacting among them but not with her. All of a sudden, she starts to make loud noises (possibly imitating a horse-neigh) to call for attention. She makes three loud noises and a softer one, until a peer starts to interact with her again.*

4. *Technology Interaction*: This category marked children’s interaction with computer devices, such as touching or dragging objects on the screen.

   *Vincent tried to press the correct choice twice even though the app would not provide feedback.*

In order to capture the way that adults interacted, we used the four categories defined below:

1. *Verbal prompting*: This category refers to prompts for action or preference, yes or no questions, and prompting children to take turns. Below is an example from a participatory design session:
Researcher: “Ok, Hector will be the cashier. Who wants to be the baker?”

Vincent raises his hand.

Researcher prompts Jill: “Maybe you want to be the grocer and sell oranges?” Jill: “No I want to sell this stuff here.”

2. Using visual aid: This category was applied when researchers used a visual aid while interacting with children (including prompting), such as paper, physical props or computers. An example of this kind of interaction is illustrated below:

   Researcher picks up a round Styrofoam prop and asks the children: “What do you think this could be at the supermarket?”

3. Co-participation in the experience: This code was used to reflect the instances where the researchers co-participated in the participatory design sessions by playing a role, by giving ideas for the play or by actively commenting on a playful situation.

   Vincent chooses the props he will use and wonders: “What could be a tree?”

   Researcher jumps in and says: “I can be a tree.” Researcher pretends to be a tree by holding the apples while the child jumps to pick them up.

4. Teacher participation: In addition, we always had one teacher present during our sessions. In some instances, the teachers participated by making a comment, clarifying what a child said when we could not understand or by stopping unhealthy behaviors.

   Teacher: “He said French bread.”

We also included a separate category for technology prompting children to do something.
1. *Prompt from technology:* This code was used to mark the times when certain apps gave a verbal prompt to the children, which happened only during the technology immersion sessions. 

*The app screen shows four different characters and verbally prompts the user:*

*“Pick someone to lead the band.”*

One member of the research team coded all 15 sessions based on the above categories. A second member of the research team received training from the first coder on the categories by reviewing two sessions; one for each type of design activity we conducted. Then, the second member of the research team coded one randomly selected technology immersion session, and one randomly selected participatory design session. We used Cohen’s Kappa to calculate inter-rater reliability, with a substantial agreement of .710.

After the coding was complete, one member of the research team compiled a list of design requirements from the notes we took after each session debrief discussion and identified the session events associated with these requirements.

### 4.6. Findings

After each session, the design team discussed and recorded notes, including design requirements. These notes helped us to identify the events that led to each requirement and to distinguish between two ways in which children helped us during the design process. In some cases, we concluded that we could have arrived at the same requirements by asking the children to conduct a specific task, as if they were participating only as testers. In situations like this, we observed children’s behaviors we wanted to avoid or encourage with our technology and identified what triggered those behaviors. For the remaining requirements, the children went beyond what would have typically been expected of testers by explicitly providing ideas or suggestions through verbal
communication or through actions, often as part of exchanges with adult members of the design team.

Table 12 displays a list with seventeen design requirements we identified throughout our design sessions. The second column refers to the sessions where we identified each requirement, and the third column indicates if we learned the requirement based on observation, suggestion, or action from children, or a combination of observation and suggestion.

Table 11. Design requirements, sessions that led to them, and how we learned the requirements.

<table>
<thead>
<tr>
<th>Design Requirements</th>
<th>Example from Technology Immersion (T) or Design Session (S)</th>
<th>Observing Behaviors (OB) Suggestions/Actions (SA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep important information on the center of the screen</td>
<td>T2, T3</td>
<td>OB</td>
</tr>
<tr>
<td>Make pictures interactive</td>
<td>T1</td>
<td>OB</td>
</tr>
<tr>
<td>Preference for smoother screens</td>
<td>T1</td>
<td>OB</td>
</tr>
<tr>
<td>Use audio for the verbal prompts</td>
<td>T1</td>
<td>OB</td>
</tr>
<tr>
<td>Select screen size based on social aspects of activity</td>
<td>T3</td>
<td>OB</td>
</tr>
<tr>
<td>Encourage social use of apps</td>
<td>T2,T3</td>
<td>OB</td>
</tr>
<tr>
<td>Incorporate choices of roles and themes, where children choose their preference and confirm/change their minds</td>
<td>S1,S3,S4,S6,S7</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Prompt children in random order</td>
<td>S3</td>
<td>OB</td>
</tr>
<tr>
<td>Gray out roles that have already been picked (option)</td>
<td>S1,S7</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Use engaging characters and/or cartoons to represent the roles children will play</td>
<td>T4,S2,S3</td>
<td>OB/SA</td>
</tr>
<tr>
<td>App interactions during make-believe play should be designed not to interfere with play and social interactions</td>
<td>S7,S8,S9,S10</td>
<td>OB</td>
</tr>
<tr>
<td>Incorporate storytelling as a foundation for the play</td>
<td>T1,S11</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Offer physical props that are better suited for the activity and promote creativity</td>
<td>S1,S4,S5,S6,S7,S8,S10,S11</td>
<td>SA</td>
</tr>
<tr>
<td>Support merging of themes</td>
<td>S8</td>
<td>SA</td>
</tr>
<tr>
<td>Support continuing play</td>
<td>S1,S9,S10</td>
<td>SA</td>
</tr>
<tr>
<td>Support planning the use of the physical environment</td>
<td>S4,S5,S9,S11</td>
<td>SA</td>
</tr>
<tr>
<td>Supporting collaborative and individual play when needed</td>
<td>S5,S7,S8,S9,S10, S11</td>
<td>SA</td>
</tr>
</tbody>
</table>
Next, we provide specific examples of the events leading to design requirements, including cases where observation of children’s behavior led to design insights and cases where children explicitly suggested or acted out their preferences.

4.6.1. Examples of Design Requirements based on Observations

During our design sessions, children informed design requirements for StoryCarnival through their behaviors and here we present two examples of our observations.

4.6.1.1. App interactions during make-believe play

We learned that app interactions during make-believe play should be designed not to interfere with play and social interactions. We arrived at this requirement after using our app during play-based design sessions to help children remember their roles. This experimentation led to the observation that children became distracted by the app. They stopped socializing with their peers to interact with the device, as in the example below:

A researcher pulls the app for one child to check his role's tasks. All children approach the device and start touching the screen to select their roles without taking turns. It becomes distracting because every time a role is touched, it starts playing the sounds, on top of each other before the previous one finishes.

Based on these observations, we restructured how the app helped facilitate play to avoid these distracting interactions by constraining when the sounds would play once they were touched and by avoiding using the app during role-play unless necessary.

4.6.1.2. Incorporate storytelling as a foundation for the play

We also learned that storytelling is helpful to establish a common foundation for children to engage in make-believe play. For example, in our first design session, we observed that children were not
aware of the different roles that could be portrayed in a supermarket theme. Due to this limitation, they all chose to be the shopper, as shown in the following excerpt:

A researcher explains the different roles children can play in the supermarket theme while showing them pictures and modeling every possibility. Then, he prompts each child to determine their preferred part. However, all four participants choose the same role (the shopper). The researcher confirms their choices and then proposes for them to take turns acting out different roles on the next play activity.

This behavior got in the way of make-believe play in the style we wanted to promote. As we advanced with our prototype iterations, we decided to incorporate a storytelling component in our requirements to promote a common understanding of story themes prior to children starting play. Storytelling also increased children’s interest in joining the activity, as in the following example from design session 11:

Markus is shy and unsure of whether he wants to join the activity. After watching the story from our app, Vincent, Jill and Hector choose the characters that they will play. All of a sudden, Markus jumps in and chooses the character he wants to be, indicating that he decided to join.

4.6.2. Examples of Design Requirements based on Suggestions or Actions

Children in our target age group became more verbal over time and offer suggestions while also acting out the experiences they wanted, similar to what older children can do through sketching. Here are two examples of requirements provided through their actions.
4.6.2.1. Support merging of themes

A requirement we learned from children acting out their preferred experience is that we should support children merging themes in their make-believe play. For example, we witnessed children using props the way they used them in another thematic story setting, as illustrated below:

While playing the “space” theme, Vincent picks a round prop and pretends to eat it. He moves around the space and says: "Oranges." Then, he picks a cylindrical prop, pretends to eat it and says: "French bread." Later, he asks the researchers: "When can we play store again?" The researcher then asks him: "What's your favorite theme so far?" He replies: "Store."

While observing this behavior, one of the researchers suggested that the oranges could be “space oranges”. This exchange led us to identify theme flexibility and merging as a design requirement for our technology.

4.6.2.2. Support continuing play

An additional design requirement we identified is to support the continuation of play over several sessions. As we advanced in the design sessions, we noticed some children would go back to and improve upon a role they had played, continuing a story they had started on a previous session.

For example, Jill liked a horse character that was part of two of the themes we introduced. She not only enjoyed role-playing as this character, but she would expand upon what the character did, and would also bring back things the character did in previous sessions. In our last session, Jill chose to play the horse character, which was incorporated into a new story theme. At first, she played along to continue the storyline, but then she decided to begin using props to recreate the horse’s stable, something she had put together during a previous session. In this case, Jill’s actions expressed the type of experience she wanted to have, and that we should support. Her constant
reinterpretation of the role was only made possible through the continuation of story arcs across multiple sessions. We realized that it was important for our technology to support her ongoing creative process.

4.6.3. Patterns by Session Type

The coding of the videos enabled us to better understand how we communicated with children and how they communicated with us during sessions. This enabled us to identify different communication patterns between the two types of sessions we conducted.

There were clear differences in children’s behavior between technology immersion and design sessions (see Fig. 12). During technology immersion sessions, children primarily used nonverbal communication and interacted with technology. Verbal communication occurred at lower frequencies. The fourth session was a bit of an anomaly as only one child was present when the others were out sick.

Figure 12. Children’s coded interactions, per minute, per child. Sessions are on the horizontal axis. The sessions after the technology immersion sessions are all design sessions.
On the other hand, during all but one design session, children used verbal communication more frequently than non-verbal communication. In addition, during several design sessions children showed a high frequency of behavioral/emotional expression.

Fig. 13 shows communication patterns by adults. The main pattern we noticed is that there was more adult participation during design sessions than during technology immersion sessions. In addition, there were more adult prompts and co-participation whenever we introduced something new, as in design sessions 1 and 4.

Figure 13. Adult's coded interactions, per minute. Sessions are on the horizontal axis. The sessions after the technology immersion sessions are all design sessions.

There was also a significant amount of variation across sessions, even within a particular session type, that we identified while analyzing detailed charts (see Figs. 14 and 15). We believe this is due to the differences in how we introduced and facilitated activities, better communication among all parties in later sessions, the children getting a better sense of what they wanted to get out of the activities, and the increased role of technology in later design sessions. In addition, given the age of the children and their attention spans, none of the sessions went past 20 minutes.
During the technology immersion sessions, both adults and technology prompted children in different instances. The visual aids used in these sessions refer to the different mobile devices presented to the children (see Fig.14). Some of the apps they interacted with had more verbal prompts than others, but children were usually responsive to the prompts, performing the interactions with minor difficulties.

In technology immersion sessions, the teacher only intervened in the first one, during an attempt to get the children to further explain their choices. Moreover, there were few instances where researchers co-participated with children during these sessions. Researchers’ co-participation happened in occasions when children needed support using the app either to move the activity forward, or to understand what kind of interaction was requested (e.g. drag an object). There were also instances when the researchers had to prompt children to take turns moving the activity forward (e.g. touching a character to answer a question), in particular during the social use of an app (e.g. TI 3).

![Figure 14. Children’s coded interactions over time during Technology Immersion sessions.](image)
During the design sessions, there were more teacher interventions (see Fig.15) such as occasions when children would not share the props with their peers (e.g. S6). During these sessions, we usually used visual aids at the beginning with our storytelling component (see Fig.9) and also throughout the sessions with the physical props (see Fig.11). Overall, there were fewer interactions with technology during design sessions, because the stories we developed were not interactive and did not require children to touch the device. There were a few exceptions where we tested our play planning component (see Fig.10) to remind children of their roles during play.

In design sessions, researchers co-participated significantly more in the activities, usually by taking roles as part of make-believe play. This kind of co-participation was more frequent in the first sessions and became more sparse over time, as children gained experience in make-believe play. As the sessions progressed, researchers co-participated in particular occasions to introduce new activities or to suggest ideas for the play (see Fig.15).

Another noticeable trend that happened as we progressed with our sessions, was an increase on children’s “behavioral and emotional expression”, which refer to instances where children acted out the experiences they wanted during play and also to instances where we attempted to use technology during the play (e.g. S8, S9, S10 and S11). On the other hand, there was a decrease of children’s “non-verbal communication” overtime (see Fig.15.), indicating that children felt more comfortable to express themselves by communicating verbally or through their behaviors.
Figure 15. Children’s coded interactions during participatory design sessions.

4.7. Conclusions

Our experience involving 3-4 year-old children in the technology design process helped us develop StoryCarnival and shape our ideas for developing Play-Based Design. For instance, the pretend play structure we used in our participatory design sessions combines motivation strategies, planning, and a structured, yet open-ended play activity that benefits children in many ways. The stories are used as tools to create a common language and motivate children to play. The planning that takes place before the actual play is meant to solidify children’s motivation by giving them ownership and agency over the activity, and exercising their creativity while they make their own decisions. The combination of these activities creates a playful structure where children can be social, creative, and act out their preferences, abilities, and needs in different contexts. Eventually,
children became more experienced in the activity and their actions can inform innovative design requirements.

During our implementation of make-believe play in ToM style, we saw some of the advantages of having young children participate in roles that go beyond testing such as allowing them to express their unique ideas through play. Our coding of the design sessions provides evidence of high levels of activity and participation from children over time. Both types of design methods we used proved valuable. Adapting the technology immersion method to help adults in the design team understand how young children interact with and relate to technologies in their lives yielded valuable information on basic design principles for apps designed for our target age group. The design sessions enabled us to understand how to best use technology to support children participating in the activities in which we wanted them to participate while incorporating their interests, needs, and abilities.

The design sessions gave us insight that children in our target age group were capable of acting out the experiences they wanted, which was a good fit for designing interactive technologies, like *StoryCarnival*, that aim to support healthy and social activities exploring the physical space as opposed to only screen interactions. Next, I discuss the practical lessons we learned while conducting design activities exploring ToM style play that generated the insights for developing Play-based Design.

4.7.1. Lessons for Design Activities with 3 to 4-Year-Old Children

As we reflected on our analysis of the design sessions, we learned some high-level lessons that may prove useful for other design teams contemplating conducting participatory design sessions with the same age group.
4.7.1.1. Physical props can be used to generate ideas and pursue imaginary situations

The use of art materials has a long tradition in participatory design methods used with children, as in the *Bags of Stuff* method (Guha et al. 2013). Most uses of art materials in the literature have been to enable children and adults to prototype technologies (Fails 2012, Guha et al. 2004, Norooz and Froehlich 2013, Walsh et al. 2013) or to make items that become part of the technologies (Seitinger et al. 2006). In our case, we encouraged children to make use of generic props to represent any kind of item.

As early as in our first participatory design session, children demonstrated they had no difficulty imagining physical props representing other things in an imaginary situation. Early on, we scaffolded the generation of ideas by showing one object at a time and verbally prompting children to imagine what that object could be in a certain context. This kind of generation of ideas became integrated in the activity as children learned and became comfortable participating in our design sessions, often not requiring any prompting to make use of generic props. The excerpt below shows an example from a session where a child verbalizes her thinking process with respect to props:

*Jill organizes the new props according to their color: "Yellow is butter and blue is the water." Later in the session, she connects the role she decided to play with the props she was organizing: "I'm the florist. So, all the blocks could be the flowers!" She moves on to choose a hat to further characterize her role: "and I need a hat to be the florist."

The flexibility that generic props bring is apparent in the excerpt above. Once children become comfortable using them, they can represent just about any object.
4.7.1.2. Make-believe play may promote healthy emergent behaviors

Setting up part of our participatory design sessions as make-believe play appeared to promote healthy emergent behaviors through collaboration or simply set a context for children to be creative. For example, we observed that children acted out their creative ideas inspired by our prompts. In the excerpt below a broken prop became an opportunity for collaboration in an imaginary situation:

*Vincent and Hector engage in putting the pieces of the broken prop together, as suggested by a researcher. They pretend to "fix the spaceship" together. When they finish, Vincent says: "I'm driving away. Bye-bye. Astronaut, come in." Hector plays along and 'comes inside' the spaceship.*

This exchange not only shows an example of how the design activities could promote healthy behaviors among children, but also gave us ideas for the use of ‘broken’ items that have to be fixed as part of our technology-supported activities.

4.7.1.3. Children communicate verbally and through action to have the experience they want

After learning to use generic physical props creatively, children learned to switch what props represented and to imagine objects being present without the need for anything physical representing them. They gradually became more active in exploring different uses for the props and different ideas for their roles. Additionally, children developed more agency in steering the activities during design sessions toward their preferred experience. The excerpt below illustrates an example where children verbally communicated their preferences for a theme and roles to play:

*Researchers prompt children to see if they have a theme of their preference to play during the session and remembered previous themes we played before.*
Jill suggests: "Hey, we can play on the castle!" Researchers confirm the suggestion and prompt the other two kids to learn if they also like the theme.

Vincent says: "if we are playing castle, I’m going to be the guard." Jill then says: "I will be the princess." Then, Hector jumps in: "I’m going to be king."

The castle theme was the only theme that the children developed themselves, without the adult team members suggesting it or creating a story to introduce it.

The following excerpt provides an example of when a child made a specific request that affected how we ran our design sessions:

Vincent throws a prop in the air and when it falls on the floor it breaks. He looks surprised and moves to pick up the pieces to try to put it together.

Vincent then says: "Maybe you should get new toys."

This request, in conjunction with similar verbal requests, led us to purchase new generic physical props, many of which worked better in helping children develop ideas than the ones we were previously using.

4.7.1.4. Meaningful interactions with peers are important for a good experience

Social interactions among children can be a great source of information. Children can help their peers have a more enjoyable experience, but they can also promote frustration if they are not on the same page. These interactions during design sessions can help design teams understand how to better support the development of social skills and social aspects of technology use. In the excerpt below, one child verbally communicates his frustration with a peer who does not engage in playing with him:
Hector looks for his peer and decides to interact with him in a disruptive way. However, Vincent is focused on his role and wants to play, so he does not engage with Hector. Hector tries to mess with the props, disorganizing Vincent’s "baker station". Vincent complains: "He's messing it all up." The researchers intervene to interact with Hector first. Vincent then complains that he does not have a customer: "No one wants any bread." So, another researcher comes in and pretends to be a customer.

The example above led us to double our efforts in ensuring that the technology we were designing supported activities that would enable each child to find a fulfilling role leading to positive interactions with other children. Consequently, we developed a new story theme to introduce several collaborative roles of equal importance.

In a positive scenario that took place in our first design session, one participant got positively inspired by a peer and made a creative decision for her role as a grocer:

Researcher asks Emma, who is playing the shopper, what they should get.

Vincent who is playing the baker says: "French Bread." Jill, who is playing the grocer, then says: “And here are some fresh oranges.” She gives two round props and says: “Two oranges!”

The example above also inspired us to use our technology to set up the activity such that children could play complementary roles that would lead to harmonious collaboration.

Overall this project contributed to further developing a design activity to collaborate with 3-4 year old children during the design of a technology that supports collaboration and play. In the next chapter I present the second setup of design activities with another group of young children that explored designing tangible voice agents.
CHAPTER 5: TANGIBLE VOICE AGENTS

This chapter presents an exploration of designing tangible voice agents with a group of 8 children under the age of five. This set of design sessions investigated how to better support adults to prompt children in order to keep them engaged in ToM style play. We explored using a voice agent to support fluid communication between adult researchers and children. The voice agents could redirect children’s behaviors and promote social interactions. This section is based on an Extended Abstract published in the 2019 ACM Human Factors in Computing Systems Conference (CHI) and a full paper accepted to the 2019 ACM Interaction Design and Children (IDC) conference.

Voice User Interfaces (VUIs) allow users to interact with computer systems using speech commands. Researchers have mostly studied VUIs with children under the age of five in the context of understanding communication breakdowns, controlling media, asking factual questions, pursuing highly-structured activities, or understanding the perception of VUIs’ personal qualities, such as intelligence (Cheng et al. 2018, Druga et al. 2018, Lovato and Piper 2015). There is an opportunity to begin exploring less structured contexts, such as supporting make-believe play, which has been associated with multiple positive outcomes (Bergen 2002, Blair and Raver 2014, Mullineaux and Dilalla 2009).

To begin filling this gap, we conducted 24 sessions with eight children to explore the wider opportunities of VUIs for 3-4 year old children focusing on facilitating make-believe play activities. Our partnership with children guided the exploration and led us to investigate making voice agents tangible and enabling children to control what voice agents say. In this section, I present a qualitative description of our explorations, which provides findings related to voice agents supporting social play and design recommendations for future VUI applications for this age group. Our analysis suggests that context-aware, tangible, portable voice agents may help keep
children socially engaged in play and that children like to integrate voice agents in the physical aspects of their play. We also identify challenges associated with children’s interest in controlling voice agents and provide other useful findings (e.g., need to slow down speech synthesis) for future VUI design for young children.

5.1. Research Goals
Our research goal was to explore the design of voice agents to support high-quality social play in the style of ToM (Blair and Raver 2014, Bodrova and Leong 2007). In our previous experience facilitating ToM play, we identified a challenge in keeping children socially engaged in play. Therefore, we wanted to explore using voice agents to augment what adult facilitators can do to scaffold ToM play activities, learn about each design’s impact on key ToM play components that arise from Vygotsky’s theories, such as social engagement in role-play and the use of physical props, and understand the characteristics of children’s interactions with the agents.

5.2. Participants
We recruited eight children (4M, 4F) from a preschool located in a city with a population of about 100,000 people in the United States. All the participants used a mobile device at home and their favorite apps reported by parents were: Osmo, PBS Kids, Amazon prime, Netflix, YouTube Kids, and varied games. The average number of children in their households was 1.77. We obtained permission to conduct research from our institution’s Human Subjects Office and obtained consents from all parents. Children only participated in a given session if they wanted to.

5.3. Research Activities
Our research activities adapted participatory design methods developed with elementary school children (Guha et al. 2013) to work with children under the age of five by enabling them to
contribute ideas both verbally and by acting out their experiences. We conducted 24 design
sessions at the children’s small preschool (one classroom per age level), as described in Table 13,
video recording every session. All research team members had prior experience facilitating 11
sessions of play in the style of ToM with another group of 3-4 year old children. In addition to the
children, two to four research team members and one teacher were always present in the room
where we conducted the sessions.

We used StoryCarnival to set up play, which took 2 to 5 minutes and, after that, the children
proceeded to engage in play using generic physical props, as recommended by the ToM curriculum
(Bodrova and Leong 2007). This portion of the design sessions typically took about 15 minutes.
Our exploration of voice agents occurred in this portion of the activities, as well as all the
observations we discuss in this paper. As described in Table 1, we explored a variety of
configurations for voice agents, led by children’s suggestions, including researcher-controlled-
speech agents where researchers typed text to control what voice agents said (a static and a portable
version, see Figure 17), portable and screen-based agents with speech controlled through an app
(see Figure 18) that could be used by children or researchers, and using a “turned-off” portable,
tangible agent with no speech. Only one voice agent was active in any given design session.

In the first three sessions, we worked with all the children together. In the remaining
sessions, we worked with no more than four children at a time. After completing a session, the
adult members of the design team met to debrief, to note any lessons learned, and to decide on the
next directions for the research activities. We leveraged an existing app designed to support ToM
style play (Hourcade et al. 2017) that introduces children to stories and characters to provide a
common context for play (see Figure 16). The same app included a play planner that enabled
children to plan play by selecting the character they wanted to role-play (Hourcade et al. 2017), an
activity encouraged by the ToM curriculum (Bodrova and Leong 2007). We always presented the app on a tablet. Below we provide a detailed description of each configuration:

Table 12. Outline of Design Sessions.

<table>
<thead>
<tr>
<th>Session Number</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3, 6</td>
<td>Warm-up sessions intended for children to get used to ToM style play and working with our team of researchers (no voice agents).</td>
</tr>
<tr>
<td>4, 5, 7, 8</td>
<td>Researcher controlled static voice agent (see Figure 17).</td>
</tr>
<tr>
<td>9 - 14</td>
<td>Researcher controlled portable, tangible voice agent (see Figure 17).</td>
</tr>
<tr>
<td>15 – 17, 19-22</td>
<td>Tablet app for child/researcher to control portable, tangible voice agent (see Figure 17).</td>
</tr>
<tr>
<td>18</td>
<td>“Turned-off” portable, tangible agent.</td>
</tr>
<tr>
<td>23, 24</td>
<td>Tablet app for child/researcher to control screen-based, animated agent (see Figure 18).</td>
</tr>
</tbody>
</table>

Figure 16. Screen capture from Space Explorers story.

3.3.3.1 Researcher controlled static, voice agent. Our initial exploration of voice agents involved a setup where researchers typed text to control what a voice agent said with the purpose of encouraging children to stay engaged in ToM style play. Our first static iteration consisted of a small Bluetooth speaker inside a paper box that looked like a character (the voice agent characters looked like small versions of the characters in the stories, see Figure 17). Because the paper box representing the voice agent was too delicate to pick up, we told children they could talk to it and touch it, but not move it, similar to the way they would interact with a device like the Amazon Echo Dot.
3.3.3.2 **Researcher controlled portable, tangible voice agent.** During the use of the static version of the voice agent, it became clear through children’s actions and requests that they wanted an agent they could pick up. Hence, we replaced the paper boxes with foam blocks. We printed the face and top of the character on thick paper (see Figure 17) and attached it to the foam block with Velcro. The top portion secured the Bluetooth speaker, which fit inside a carved space in the foam block. We continued using the same physical setup for the voice agents in our remaining sessions, except for the last two where we explored a screen-based representation.

3.3.3.3 **Tablet app for child and researcher to control portable, tangible voice agent.** When children realized that we were controlling the voice agents, some insisted on wanting to control the agents’ speech. We then iteratively developed a tablet-based speech-control app. The initial app prototype allowed participants to select random comments from a set of four categories: 1) new events to expand play, 2) feelings about the play environment, 3) facts about the play environment, 4) reactions to play. The final version of the app generated speech based on three sets of choices: to whom the speech was directed (from the set of characters being played by children), a subject related to the story on which the play was based (e.g., food, drink, nature), and a theme (e.g. events, facts, feelings) (see Figure 18). It was set up with the goal of having the voice

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Figure 17. On the left, static versions of voice agents we called miniBear, miniCat and miniBot. On the right, the portable tangible voice agent with closed top and Bluetooth speaker on the front.
agent say something relevant to the play activity that could encourage continued engagement. Making the same selections multiple times yielded different speech, as the voice agent would, for example, speak about a different type of food and express a different feeling about it. Both children (after brief instruction and demonstration from researchers) and researchers used the app to control the voice agents.

![Image of tablet app controls](image)

Figure 18. Tablet app to control voice agent enabling selection of to whom the speech is directed, the topic, and feeling, fact, or event. The last screen shows the image of the animated agent used in the 3.3.3.5 setup.

3.3.3.4 “Turned-off” portable, tangible agent. Given the limitations of a tablet app to control speech through a small set of options, we decided to explore “turning off” the voice agent and encouraging children to use their own voices instead to make the voice agents speak.

3.3.3.5 Tablet app for child/researcher to control screen-based, animated agent. To understand the impact of the tangible aspects of voice agents, we also decided to conduct sessions where the representation of the agent was on the screen. We used sprite animations for the screen-based agent and incorporated them into the existing tablet app to control agent speech described in section 3.3.3.3. The animated agent appeared on the screen speaking after children made speech choices. In both sessions, the facilitator held the device for children and supported children taking turns making the agent speak.
5.4. Technical Setup

The technical components to our system included: 1) an Ancord Micro Bluetooth speaker (shown in Figure 17), 2) two laptop computers (to run the researcher-controlled system), 3) two tablets to run the apps (Microsoft Surface Pro 4, or an iPad 4th generation). We used the Amazon Polly Text-to-Speech service to generate all voice agent/character speech (Amazon Polly), which allowed us to create different voices and personalities for all characters. Additionally, Amazon Polly supports Speech Synthesis Markup Language (SSML) (SSML Tags Supported by Amazon Polly) so we could fine-tune the generated speech using breaks, emphasis, prosody, and so forth.

5.5. Analysis

We conducted a qualitative analysis of our design sessions by coding 430 minutes of video data using BORIS (Friard and Gamba 2016). Two researchers coded the videos identifying children’s interactions with the voice agents and the periods of time when individual children were not engaged in play. Interactions with voice agents included children conversing, reacting to, or physically manipulating the voice agents. Non-engagement in play included children interacting with mobile devices instead of playing with their peers or with the physical props or getting distracted from the play activity (e.g. using props out of the play context). The Cohen’s Kappa demonstrate a strong level of agreement of .849 (for 131 codes for different events) between two raters. Four researchers transcribed all portions of the videos that the coding identified as including children’s interactions with voice agents. Three researchers grouped the resulting 127 excerpts into themes using affinity diagramming and group discussions, focusing on children’s social engagement in play and the use of physical props, both key aspects of ToM play (Bodrova and Leong 2007), as well as characterizing children’s interactions with the agents in an activity that is less structured than those studied in the past.
5.6. Findings

Below, we present the themes identified through our analysis organized in three areas: social engagement in play, use of physical props, and interactions with agents. We present each theme with respective subthemes illustrated through corresponding excerpts (all names in each excerpt are pseudonyms), followed by related design recommendations including discussions of links to prior research.

5.6.1. Social Engagement in ToM Style Play

The introduction of voice agents in the social play environment impacted social interaction dynamics, with varying outcomes depending on how we structured activities.

5.6.1.1. Voice agents promoted peer interactions.

We observed situations where the voice agents stimulated children to communicate and engage in social activities with their peers. Simple compliments or suggestions involving something a child was making were usually good avenues for promoting peer interactions, such as the one portrayed below from session 6:

Agent miniCat: *Cat, can you give a piece of cake to Horse and Monkey?*
Dora gives a prop to Eduardo, who is playing Monkey.
Eduardo pretends to eat the prop and then puts it aside.
Dora holds a prop.
Dora: *Here is my slice.*
Agent miniCat: *Monkey, did you like the cake?*
Dora goes toward Eduardo.
Dora: *Did you like the cake, Monkey?*
Eduardo: *Yes.*
Then, Dora turns back to agent miniCat.
Dora: *He said yes.*

5.6.1.2. Voice agents could redirect behavior to keep children socially engaged in ToM style play.

When children listened to a voice agent, they tended to reply to prompts by either conversing with the agent or acting on its suggestions. Voice agents were thus a good avenue to redirect children’s
focus to participate in story-oriented play activities. In the following example from session 7, agent miniCat redirected children to re-engage with a shelter that was part of the play storyline:

Ahmed places a prop on agent miniCat’s head.
Ahmed: Do you like your hat?
Agent miniCat: That’s too big.
Jessica: That’s too big. He doesn’t like it.
Agent miniCat: What about the shelter?
Eduardo goes to the floor, arranges some props, and sits down.
Eduardo: I am in the shelter!
Ahmed looks at his peer and follows him by sitting down too.

5.6.1.3. Children reacted best to a combination of task-oriented suggestions and positive reinforcements.

We observed that when voice agents made suggestions or expressed compliments for behaviors that fit ToM style play, these tended to promote positive interactions with the voice agent as well as positive play outcomes. On the other hand, authoritarian comments (e.g., “I want food now”) caused surprise in children and made them complain to the researchers about the agent (e.g., “He is not being nice”). Here is a positive example that happened on session 10:

Agent miniBot: Bear, could you get me a drink?
Michael: He said Bear give me a drink.
Michael gets a prop.
Michael: Here is your apple juice.
Agent miniBot: Yummy.
Michael approaches agent miniBot.
Michael: What did you say?
Alice: I think he said yummy.
Agent miniBot: Yummy.
Michael pretends to give juice to agent miniBot.
Michael: Here is some milk!
Agent miniBot: Sorry, I broke!
Agent miniBot: Help me monkey!
Michael: He said, ‘Help me Monkey.’ ‘Who is the monkey?’
Alice: Okay!

5.6.1.4. Children as mediators of voice agents.

We observed children acting as mediators of voice agents, by repeating what agents said to their peers. It is another way in which the voice agents promoted social interactions. Potential reasons
for this behavior include their peers not listening to or understanding the agent’s comments, or that
they wanted peers to collaborate or take some action regarding what the agent said. Here are
excerpts from sessions 6 and 9 illustrating this behavior:

Agent miniCat: You broke the shelter.
Maggie approaches agent miniCat.
Maggie: What?
Agent miniCat: You broke the shelter.
Maggie goes toward the boys.
Maggie: She says that you broke the shelter.

Agent miniCat: Looks great! Good job, Horse.
Michael ignores agent miniCat.
Dora: He said, good job Horse.
Michael smiles and brings a prop to put on agent miniCat’s head. The kids then place hats on
agent miniCat’s head.

Michael: Do you like your new hat?

5.6.1.5. The tablet app to control speech could distract children from ToM style play
activities.

While children took ownership over their control of the speech-control tablet app, the mobile
device competed for children’s attention and distracted them from playing with their peers.
Children issued speech control commands through the tablet app an average of 1.96 times per
minute during sessions 15-17 and 19-24, and our coding confirms that they typically spent more
time off task in the sessions where they had access to the app to control speech, than in the ones
they did not (see Figure 19). There was also more variability in time off task for sessions where
children had access to the app to control speech.
Among the reasons we observed for time off task was children’s strong interest in using the app to control voice agents and the resulting inability of researchers to use voice agents to reach out to children who were off task. Below is an example from session 24, where one child was only interested in interacting with the tablet app. That behavior influenced the quality of play:

The researcher holds the device and Michael keeps making agent miniCat speak.
Agent miniCat: I heard a baby animal crying.
Researcher: Did you guys hear that too?
Maggie: Where is the baby animal?
Researcher: Are you going to find the baby animal?
Maggie: Jessica, do you want to go into the jungle and find the baby animal crying?
Jessica: No. I will stay here and make a house for miniCat.
Maggie: Michael, do you want to go into the jungle and find the baby animal?
Michael ignores Maggie and keeps interacting with the tablet app.
Jessica keeps building with the physical props and Maggie joins her.

On the positive side, the excerpt below from session 21 shows a child taking ownership of his control of the voice agent while exploring the speech options of the interface:

Michael interacts with the tablet.
Agent miniCat: Listen cat, let’s build a boat using the trees.
Michael: Dora, that’s you, he just talked to you, because I made him to.
5.6.1.6. Design recommendations

Designers can use voice agents to enhance young children’s high-quality social play by promoting social interactions and redirecting activities toward social role-play. Voice agent interventions are likely to work best by making suggestions and providing positive reinforcement for behavior that fits high-quality social play, such as collaborating with a peer or re-engaging with a storyline. Previous research found that it was important to offer children a good mix between task-oriented speech and positive reinforcements (Strommen 1998), and this lesson still applied to the young children who participated in our research activities. In addition, considering children are more likely to use polite social exchanges with speech systems (Brush et al. 2011), voice agents should attempt to be polite in their interactions with young children (e.g., saying “please” and “thank you”) and avoid authoritative comments. The children who participated in our explorations tended to respond well to compliments, task-oriented suggestions, and humor.

Likewise, designers should carefully consider the appropriateness of the use of tablet apps during high-quality social play. Previous research suggests that visual design, sound effects, and even the touchscreen interface can either engage or distract young children (Radesky et al. 2015). During our design sessions touchscreen interfaces distracted some children from interacting with their peers even when an adult was facilitating their interactions by using prompts and holding the device. However, it is important to note that in other contexts, such as healthcare, distractions may be welcome (Breitbach et al. 2017).

5.6.2. Use of Physical Props

When we introduced voice agents to children, they were interested in physically interacting with them right away, which included the use of physical props. With the static version of the voice agents, children could physically bring props to them, but they could not move the agents. Once
we made the voice agents portable and tangible, the type of interactions with physical props changed. Below, we outline some of the ways in which children interacted with the voice agents through physical props.

5.6.2.1. Children augmented interactions with the voice agents by using physical props.

One of the characteristics of our design sessions was the physical props that children used to represent a wide variety of objects (e.g., fish, cake, a glass of water) and build whatever they could imagine (e.g., houses, caves, trees, spaceships). Throughout both the static and portable, tangible voice agent design sessions, we observed many instances when children incorporated physical props with the voice agents. For example, they used hats to cover them; or they used blocks as hats, as food, or as beverages, to pretend they were feeding the voice agents, as these excerpts from sessions 5 and 9 show:

Agent miniCat: *I like that blue hat on you.*
Dora: *Thank you.*
Dora: *That’s funny.*
Eduardo covers agent miniCat with a black hat.
Dora smiles.
Dora: *Let’s cover him up!*
Agent miniCat: *It’s dark in here.*
The kids keep putting one hat on top of the other, and Eduardo approaches agent miniCat to check if he can still hear it.

Maggie approaches agent miniCat.
Maggie: *Hey, let’s see if this hat fits you!*
Maggie puts the hat on top of agent miniCat.
Maggie: *Oh, it fits you!*
Ahmed and Michael approach agent miniCat and both pick up props and pretend to feed agent miniCat.

Once we made the voice agents portable and tangible, the children started to place them inside of their constructions, or built shelters and cities around them as shown in the excerpt below extracted from session 20:

Agent miniBear: *Horse, will you make something new for me?*
Richard: *Something light for me?*
Researcher: *Something new!*
Richard: *Okay, miniBear, making something new. Are you sure miniBear?*
Richard: *Okay you go right there...*
Richard places agent miniBear down.
Richard: *...and I’ll build all around you.*

### 5.6.2.2. Comparison with screen-based animated agent

In the last two design sessions, we introduced children to the screen-based, animated version of our voice agent miniCat (see Figure 18). They responded with a mixture of surprise and disappointment for not having the tangible agent. Here is a sample reaction from session 23:

*Researcher:* You said you wanted to make miniCat say something. What do you want to make miniCat say?
*Eduardo:* Where is miniCat?
*Researcher:* miniCat is right here.
*Researcher* points at the tablet.
*Eduardo* selects speech options on the tablet and the animated version of agent miniCat appears and speaks.
*Eduardo and Ahmed:* Whaaaaat?!

### 5.6.2.3. Design recommendations

Young children clearly favored interacting with a portable, tangible voice agent, over a screen-based one, or a physical representation they could not pick up and incorporate in their play. Therefore, it is important to consider the tangible affordances of a physical representation of a voice agent for young children such that it can be part of physical play, including the use of physical props. This recommendation resonates with previous research findings suggesting that tangible interfaces were better at supporting children’s active collaboration and more appropriate for younger children to refine their fine motor skills (Antle and Wise 2013, Baykal et al. 2018, Horn et al. 2012, Sylla et al. 2016, Sylla et al. 2015).

We also discovered that a minimal physical representation of a character was good enough for young children to have an interest in engaging with it. This outcome is similar to a previous study that examined 4-10 year-old children’s interactions with conversational characters (Hyde et al. 2014), finding there was no need for perfectly realistic-looking human characters to elicit natural behaviors from children. Another advantage of physical representations of agents is to
evoke basic social expectations of face-to-face communication (Cassell 2001). In our experience, even though our voice agents only had a static facial expression, young children were able to relate to them affectionately.

5.6.3. Interactions with Voice Agents

During our extensive explorations, there were other relevant aspects that arose from children’s interactions with voice agents that may inform future design of voice agents for this age group beyond applications to high-quality social play. Below we outline the general findings related to young children’s interactions with the voice agents.

5.6.3.1. Children’s stereotypes affected their interactions with the characters depicted by the voice agents.

The characters in the stories children experienced depicted gender-neutral animals or robots (see Figure 16). All had similar levels of importance and differed only in their unique ability. The voice agent physical representations looked like mini versions of these characters (see Figure 17). Despite the similarities in the way in which we introduced children to story characters and voice agents, children treated voice agents differently depending on the character they were depicting. For example, we observed great affection from both girls and boys toward miniCat, with behaviors such as petting the tangible agent, verbally expressing their love (e.g., “I love you, miniCat”), and holding it carefully. Here are two examples of physical and verbal exchanges between miniCat, a girl, and a boy, from session 7:

Maggie picks up a prop and places it on agent miniCat’s head.  
Maggie: Here’s your hat.  
Agent miniCat: Nice hat!  
Maggie pets agent miniCat once more and then removes the hat.

Eduardo (who is playing the horse character) approaches agent miniCat.  
Agent miniCat: Horse, you are so skilled.  
Eduardo pets agent miniCat while smiling. Then, he gives a prop to agent miniCat.  
Eduardo: There you go little guy! Here is a nice cake.
Children were just as likely to interact physically with miniCat (mean=35% of the time over all sessions) and miniBot (mean=31% of the time over all sessions). They were also just as likely to interact verbally with the two voice agents (miniCat mean=9.1% of the time over all sessions; miniBot mean=10.0% of the time over all sessions). However, the quality of the interactions was different. Children displayed less warmth in their interactions with miniBot, which translated into a tendency to be rougher on the physical handling of the voice agent. Here is one example of physical and verbal interactions that happened between children and miniBot during session 8:

Agent miniBot: Hello friends, miniBot here to say hi.
All the kids turn to miniBot and approach it.
Dora and Jessica: Hi!
Ahmed waves at agent miniBot and Richard smacks agent miniBot with a prop.
Dora places a prop on top of miniBot.
miniBot: Nice to meet you!
Dora: Nice to meet you too.
Richard places a hat on top of agent miniBot and agent miniBot falls off the table.
Researcher picks agent miniBot up.
Researcher: Be careful with miniBot.
Ahmed: Richard, you are being really mean.

5.6.3.2. The voice agents’ lack of context frustrated children when using the tablet app to control speech.

When we switched the control of the voice agents from researchers to the first version of the tablet app, which generated random speech related to a story, children noticed the difference calling the voice agents “weird”, getting frustrated, and even shouting at the voice agents. The challenges had to do mainly with the tablet app lacking the contextual information that researchers had in the previous sessions. These challenges led us to provide more control in the tablet app (see Figure 18) over what the voice agents would say, solving some, but not all problems. Below are two examples of interactions lacking context from sessions 15 and 21, respectively:

Alice puts a hat on agent miniCat.
Alice interacts with the tablet app to control speech.
Agent miniCat: Hi, I am miniCat.
Alice lifts the hat to shout at agent miniCat.

Alice: I already know you are miniCat!

Maggie: Wait, wait, wait.

Alice: Let’s cover him all up.

Dora interacts with the tablet app to control speech.

Agent miniCat: Did we get enough trees for building?

Dora: Noooo! [Exasperated]

Agent miniCat: Guess what bear, I’d like to eat some fresh fish.

Michael: Okay...you already ate a fish!

Researcher: Apparently, you’ve got to get more.

Michael: Ugggh

5.6.3.3. Children were curious about how the voice agents worked and who controlled them.

During sessions with researcher-controlled-speech agents, children expressed curiosity about how the voice agents were speaking. Once they discovered that researchers were controlling the voice agents, they continued interacting with the voice agents with the same level of interest and engagement, with the only added difference being occasional requests for the agent to say something. As we moved forward with our sessions, children’s desire to control the voice agent evolved into requests of specific phrases they wanted the voice agents to say. Here are excerpts from sessions 6 and 24 illustrating the kinds of speech that interested children:

Ahmed looks at the researcher.

Ahmed: Hey, make it say, “I like cake!”

Agent miniCat: I like cake.

Ahmed laughs aloud.

Ahmed: I love cake with a yolk.

All three children are close to agent miniCat smiling and laughing.

Michael opens agent miniCat’s top lid and shows Eduardo the speaker inside it. Then, he turns to researcher.

Michael: Can you make him say, “I hate cake?”

Agent miniCat: I hate cake.

The kids laugh.

Maggie: I wish you would say, “I have a big fear of water.”

5.6.3.4. Children expected voice agents to say something at specific times.

Children’s initial requests mostly related to making the voice agents say something in a particular moment (e.g., when physically approaching the agent). On average, children made 0.33 requests per minute to control the voice agents’ speech during sessions when researchers were controlling
it. Here are two examples of children’s requests for the voice agent to say something, extracted from session 4:

The kids start building with props, and Michael covers agent miniCat with a hat.
Michael: *Say something!*

Maggie approaches agent miniCat, putting her ear close to it.
Maggie: *Say something, cat.*

5.6.3.5. **Children disliked playing with “turned-off” portable, tangible voice agents.**

Since the tablet app gave children limited control over voice agents’ speech, we explored telling children to use their own voices instead, as if controlling a puppet. The result was a hectic session with a lot of interventions from researchers and the teacher who was present. Children did not accept the idea very well, the boys in particular. While there were many physical interactions with the agents (58.2% of session time), their verbal interactions were very low (3.4% of session time as compared to other similar sessions where children verbally interacted with the agent for an average 12.31% of session time). That said, toward the end of the session, two girls played as we suggested, as exemplified by the following excerpt from session 18:

Jessica gets agent miniCat from the pair of boys.
Together with Maggie, they show off the house they had been building for agent miniCat.
Maggie: [to agent miniCat] *This is your house that we built for you.*
Maggie as miniCat: *It's wonderful.*
Jessica as miniCat: *This is amazing.*

5.6.3.6. **Difficulty understanding speech synthesis.**

In our initial sessions, we used *Amazon Polly’s* default speech settings (*Amazon Polly*). We noticed children sometimes had difficulty understanding what the voice agents said. We later slowed the speed of the voices by adjusting prosody settings, which solved the problem. Below is an example of a misunderstanding extracted from session 14:

Agent miniBear: *You are making great use of materials.*
Michael (shouting): *She wants some Cheerios!!!!*
The whole room laughs.
5.6.3.7. Design recommendations

Children are likely to bring with them stereotypes about voice agents based on their perceived characteristics or personality. For instance, a recent study found that 5-12 year-old children were more willing to ask a variety of questions to personified interfaces (Yarosh et al. 2018). Another study with 5-8 year old children focusing on robot voices (Sandygulova and O’Hare 2018), indicated that children could not reliably assign gender to a robot based on its voice, but preferred robots that matched their gender. In our experience, children’s stereotypes about the type of being the character represented impacted their behavior toward the voice agent, similar to what has been observed with adults extending gender and ethnic stereotypes to computers and reacting to personality traits (Hadesky et al. 2015). Designers should carefully select appearances and other outward characteristics that are likely to elicit constructive behavior from children (ref 5).

Additionally, voice agents that lack contextual information can be counterproductive and may not be a good fit for supporting lightly-structured activities. This finding indicates that it is important to young children that agents be aware of context and able to converse, which is consistent with previous recommendations for embodied conversational agents (Cassell 2001) and older children’s expectations of intelligent user interfaces (Druga et al. 2018, Woodward et al. 2018). Systems with context awareness could take into account prior events in their speech (Leite et al. 2017) and initiate speech at socially appropriate times.

Children’s interest in controlling the speech of voice agents could be leveraged for a variety of empowering activities (e.g., programming, learning about grammar), but our experiences suggest such control may not be appropriate for social activities. Regardless of the setting, designers should be aware that default speech synthesizer settings for adults may not work well for young children. These were likely tested with adults and intended for tasks such as providing directions while driving, which require quick speech. Designers should experiment with the wide
range of options available from modern speech synthesizers (Amazon Polly, SSML Tags Supported by Amazon Polly) to find ideal settings for their target audience.

### 5.6.4. Design requirements

After each session discussion the research team recorded notes and design requirements. Two researchers later identified the sessions and events that led to each requirement and distinguished between two ways in which children contributed during the design process, similar to what we did while developing *StoryCarnival* (see section 4.6 Results). Table 14 displays a list with 21 design requirements we identified throughout the second setup of design sessions focused on exploring voice agents. The second column refers to the sessions where we identified the requirement. The third column indicates if the requirement was based on observing children's behaviors, if children suggested or acted out their ideas, or a combination of both.

#### Table 13. Design requirements based on our design sessions exploring voice agents.

<table>
<thead>
<tr>
<th>Design Requirements</th>
<th>Example from Design Session (S)</th>
<th>Observing Behaviors (OB) Suggestions/Actions (SA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Play groups should have at least 2 and at most 5 children</td>
<td>S1, S2, S3</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Ability to select number of children playing</td>
<td>S1</td>
<td>OB</td>
</tr>
<tr>
<td>Design clear collaborations between the characters in the stories</td>
<td>S2, S3, S4</td>
<td>OB</td>
</tr>
<tr>
<td>Stories should promote open-ended events that can be explored in play</td>
<td>S2, S3, S4, S5</td>
<td>OB</td>
</tr>
<tr>
<td>Stories should always be played before role selection</td>
<td>S13, S14</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Eliminate gender roles in characters</td>
<td>S2, S3, S7</td>
<td>OB</td>
</tr>
<tr>
<td>Voice agents should be designed to be picked up by the children</td>
<td>S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14</td>
<td>SA</td>
</tr>
<tr>
<td>Design a visual interface for controlling the voice agent’s speech</td>
<td>S7, S8, S9, S10</td>
<td>SA</td>
</tr>
<tr>
<td>Manage use of mobile device for controlled speech so that it is not disruptive to the play</td>
<td>S19, S20, S21, S22, S23, S24</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Give visual feedback of disabling controls while speech is playing</td>
<td>S15, S16, S17</td>
<td></td>
</tr>
<tr>
<td>Voice agent’s speech should be contextual to the activity</td>
<td>S15, 16, S17, S21, S23, S24</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Requirement</td>
<td>Code(s)</td>
<td>Type</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>---------------</td>
<td>-------</td>
</tr>
<tr>
<td>Voice agent’s speech should avoid non-polite, bossy, or proud sayings (e.g., “do my bidding”)</td>
<td>S8, S9, S10, S11, S12</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Voice agent’s speech should make funny comments, be polite, and encourage peer interactions</td>
<td>S9, S10, S11, S12, S13, S14, S15, S16, S17, S19</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Voice agent should prompt children by their roles throughout play for continuous engagement</td>
<td>S2, S3</td>
<td>OB</td>
</tr>
<tr>
<td>Support options for adult-driven and children-driven speech control</td>
<td>S19, S20, S21, S22</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Incorporate audio-visual preview of role during role selection</td>
<td>S1</td>
<td>OB</td>
</tr>
<tr>
<td>Incorporate rapid support for positive reinforcement to encourage interaction</td>
<td>S21, S22, S23</td>
<td>OB</td>
</tr>
<tr>
<td>Encourage actions that result in the sharing of physical characters / taking-turns</td>
<td>S4, S7, S9, S14, S17, S18</td>
<td>OB</td>
</tr>
<tr>
<td>Create physical objects that work with the story-play and are suited for physical interaction</td>
<td>S2, S7, S8, S9, S13</td>
<td>OB</td>
</tr>
<tr>
<td>Support ability to change speech speed (slow speed works better)</td>
<td>S4, S5, S13, S14, S16</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Create ability to pause speech/story to re-engage children</td>
<td>S15, S19</td>
<td>SA</td>
</tr>
</tbody>
</table>

### 5.7. Conclusions

Our second set of design sessions involving 3-4 year-old children explored designing voice agents to support make-believe in ToM style. Throughout 24 design sessions, we were able to gather 21 design requirements for both the play activity and the design of voice agents. These sessions confirmed our observations during the development of *StoryCarnival* and enabled us again to gain design ideas with young children.

During these explorations we kept experimenting with our method as well, by trying to conduct sessions with a bigger group of children at the same time. We found that the ideal number of children should range from 2 to 5 in the same play group. We also tested inverting the order of our activities by having children choose their roles first and then watching the story. However, that proved to disrupt the activity and made us see the importance of following the right steps during the setup of the activity.
Moreover, we improved the design of our stories by promoting open-ended events for children to pursue their creativity during play and improving the design of our characters by eliminating gender roles and focusing on animal characters only.

Children’s actions and suggestions directed our explorations to spaces we might have not thought of. For example, children made many suggestions for the voice agents to speak specific things and that led us to try to provide them a tool for controlling the agent’s speech. In the context of play this path was disruptive but there is potential for exploring this activity in other contexts.

This second round of design sessions was helpful to identify another way for adults to communicate with children during play that is effective for redirecting their attention, making suggestions, positive reinforcements, and promoting interactions among peers. The addition of the voice agent also added another physical element that integrated well in their creative play and promoted more opportunities for creativity.

In the next chapter I discuss our final step developing Play-based Design with two groups of children exploring getting ideas for Internet-of-Things technologies.

CHAPTER 6: INTERNET OF THINGS TECHNOLOGIES

This chapter discusses the repurposing of StoryCarnival to facilitate design sessions with children, which we call Play-Based Design. These sessions also investigated the effectiveness of Play-Based Design when collaborating with two different age groups separately. We applied the same setup of the method, using StoryCarnival to plan play and a voice agent to support communication between adult researchers and children during role play.

The Internet of Things (IoT) is a concept that refers to everyday objects connected to each other through wireless sensors attached to them (Li et al. 2011). These objects communicate, learn and can even control each other (Cui 2016). Most of the focus of IoT technologies has been on
“smart homes” with varied appliances that direct their own operations and can be controlled remotely through the Internet, enabling a variety of monitoring and control applications (Li et al. 2011, Cui 2016). IoT devices can sense and record user activities, predict future behavior, and promote actions for the future according to the user’s preferences (Li et al. 2011).

Similar to mobile devices, IoT objects were not initially designed for children but are becoming more prevalent in families’ homes and increasing their reach to become part of products targeted at children. IoT objects offer embodied forms of interaction such as touchscreens or gesture recognition devices (Manches et al. 2015), which sometimes are more appropriate for children.

There is an increasing number of IoT devices that can capture children’s interactions and behaviors, such as wearables for tracking physical activity (Manches et al. 2015) or for informing parents of their children’s location (hereO). There are also IoT devices aimed at increasing children’s health awareness such as baby monitors that can capture and provide feedback about children’s sleeping patterns (Sproutling baby wearable), plush toys that can capture and communicate health information like heart rate, oxygen saturation, body temperature, and stress levels (Teddy the Guardian) and increase children’s health awareness (Vazquez-Briseno 2012).

Manches et al. (2015) conducted a study to investigate the influence of IoT video games in children’s interpretation and interactions with characters, how children’s data is captured, and if children and their caregivers are aware of IoT video games. They conducted fieldwork with 10 participants aged 4 to 8 years-old in their homes and two workshops at school with participants aged 10 and 11 years-old. Their findings revealed children’s potential to understand and design with this kind of technology (Manches et al. 2015). This finding is encouraging to our exploration and it emphasizes the need for involving children in the design of technologies they will use. It is important not only to understand their needs, abilities, and interests but also to empower young
children as technologies users who might later be more equipped to understand the effects of ubiquitous technologies in their everyday lives.

We also selected IoT technologies because they have characteristics that are a good match for Play-based Design. They are technologies that often have physical user interfaces through a variety of sensing devices and can be used in a social environment.

We conducted 19 Play-based Design sessions with a total of thirteen 3-4 year-old children to validate the range of the method for evoking design ideas for Internet-of-Things technologies for the home. Our partnership with two groups of children guided the investigation and led us to make adaptations in the way we scaffold the theme and facilitate the sessions. In this chapter, I present a qualitative description of our explorations, which provides findings related to the effectiveness of using Play-based Design for getting ideas for IoT technologies for the home. I also explore the findings from our videos to better understand the implications of using the method with younger and older children. Our analysis suggests that both age groups have good engagement during Play-based Design sessions and can offer the creative ideas for the design of a complex technology. Finally, I provide guidelines for implementing Play-based Design with young children for developing future technologies that explore social interactions and the physical environment.

6.1. Research Goals

The goal of this investigation was to validate the effectiveness of Play-based Design by answering the following questions:

**RQ4**: Is Play-based Design effective for getting ideas for IoT technologies?

**RQ5**: Are there practical adjustments needed Play-based Design when working with 3-year-old children?
6.2. Research Activities

We conducted a total of 19 Play-based Design sessions prompting two different groups of children to express their ideas for Internet-of-Things (IoT) technologies for the home. We started working with the 4 year-old group, conducting two warm-up sessions for children to get used to us and the activity and 10 IoT themed sessions. For introducing the IoT theme to the 4 year-old children, we developed a story that could be informative of some of the possibilities of using sensors in a home environment. Our story was called “Clue Hunters” (see Figure 20) and we used the same characters as before but this time they were investigating an empty spaceship with the help of MiniBird (see Figure 21), the new version of the voice agent. The stories were presented on a tablet to the group of children, which was later broken down into two smaller groups of up to four children who used StoryCarnival to select the roles. After the play started, we used the voice agents controlled by a researcher (one per group) to scaffold activities during play.

![Figure 20. Screenshots of the Clue Hunters story used with 4-year-old children during design sessions.](image)

For these activities, we redesigned the voice agent by using cardboard and a laser cutter (see Figure 21). The idea was to improve on previous findings and designing a sturdier version that would be better suited for children to manipulate during the design sessions. The same prototype was used with the two age groups, with exception of the first warm-up session with 4 year-old children where we used a foam version of MiniCat (see Figure 17).
After conducting the sessions with 4 year-olds, we realized the story we developed for 4 year-olds would be too complex for younger children. Therefore, we developed another story that was inspired by fairytales and explored the idea of imagining magic items to inspire IoT concepts (see Figure 22). We conducted 3 warm-up sessions with 3 year-old children, adjusting a previous story we developed called “Party”. We made the story shorter and adjusted the speed and pitch of the narration, which also uses Amazon Polly to make the experience consistent. After that, we conducted 4 IoT themed sessions with the 3 year-olds.

6.3. Participants
We conducted 12 sessions with seven children aged 4 years-old, 4 boys and 3 girls, and 7 sessions with six children aged 3 years-old, 1 boy and 5 girls. Children were from the same preschool where
there is one classroom per age level. All children had access to smartphones or tablets at home. We obtained permission to conduct our research from our institution’s Human Subjects Office and obtained consent from all parents. In addition, children only participated in activities on a given day if they wanted to. If they were not sure, we gave them the option of observing the activities and joining in if interested.

6.4. Analysis

We conducted a qualitative analysis of our design sessions by coding 396 minutes of video data using BORIS (Friard and Gamba 2016). One researcher coded the videos identifying the periods of time when individual children were off-task, meaning they were not engaged in the activity. Non-engagement included children getting distracted from play (e.g. using props out of the play context or disrupting the group).

The researcher also identified adult’s participation in play, by coding the videos for the times adult facilitators played make-believe with children, made suggestions for play, or repeated what the voice agent said to prompt children during play.

Finally, the researcher coded children’s engagement in play by marking physical engagement, verbal engagement, reactions, and desire to control the voice agent’s speech. Physical engagement refers to anytime a child was touching or physically interacting with the voice agent (e.g. holding it, carrying it, building on top of it, trying to feed it, or any use of the props with the voice agent as the direct target). The marker ended if the child moved away from the agent or if there was no direct interaction (e.g. if the child put it in a hat as a nest and then moved to use other props or do something else).

Verbal engagement refers to a child verbally interacting with the voice agent (e.g. asking agent a question and receiving a response, telling it to play a song, telling the agent about what
they were doing). The agent's response is included in the verbal interaction time anytime there was one. Reaction refers only to reactions directly caused by the voice agent prompts. Examples include reacting to something the voice agent said with surprise, excitement, laughter, repeating what the agent said, carrying out an action as a direct response to something the vocal agent said (e.g. building a nest for mini bird), or speaking a verbal response to the vocal agents prompts (e.g. saying something like "okay mini bird" or telling peers "let's build mini bird a bed").

The Cohen’s Kappa value of agreement for a randomly selected session was .742 (for 107 codes for different events).

6.5. Findings

Below, I present the findings from our analysis organized in three subsections according to the two research questions we aim to answer. First, I present the ideas provided by the groups of children for IoT technologies for the home. Then, I present the analysis of the videos to better understand the differences and similarities of conducting Play-based Design with two different age groups. Finally, I present the design requirements and lessons learned throughout 19 sessions.

6.5.1. Getting ideas for Internet of Things technologies for the home

During our Play-based Design sessions with 4 year-old children, we explored getting ideas for different rooms in the house. The story they watched in StoryCarnival offered two examples of IoT objects in a living room: a lamp and a chair. We later prompted them to think about objects in their bedroom and kitchen. We also experimented presenting three specific objects (e.g. a table, a mirror, and a rug) and asking children to think about what kind of “magical” properties these objects could do.

We gathered a total of 32 ideas from both groups of children and overall 4 year-old children provided more ideas for IoT technologies, 19 came from 4-year-old children’s suggestions and
actions and 13 ideas came from the 3 year-old group. However, during SO9 and S10 we prompted older children for ideas for the bedroom and they were not interested in magic items in this setting. We picked three objects to prompt them for ideas for the bedroom: a bed, a bookcase and a closet. However, in one group the bed moved while it was just comfortable and warm in another group. The bookcase and the closet did not incite any special ability in either group and children just took miniBird to see it and then they went back to some of the themes from previous sessions that related to transportation, motion, and flying. It is important to notice that we had three warm-up sessions with 3 year-old children and only four IoT sessions with the younger group, which is one of the reasons they provided fewer ideas than the older group.

With younger children, instead of predefining three objects for them to provide ideas, we experimented using treasure hunt by having them search for an item with miniBird’s help and we also prompted children to ask miniBird to play songs.

Table 14. List of ideas for IoT technologies provided by both groups of children.

<table>
<thead>
<tr>
<th>IoT ideas</th>
<th>Example from Design Session with older (SO) and younger (SY)</th>
<th>Observing Behaviors (OB) Suggestions/Actions (SA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magic table makes breakfast</td>
<td>SO3, SO4</td>
<td>SA</td>
</tr>
<tr>
<td>Magic hat provides a variety of treats (e.g., hot chocolate, candy)</td>
<td>SO3, SO4</td>
<td>SA</td>
</tr>
<tr>
<td>Magic closet that gets you clothes of your preference</td>
<td>SO3, SO4</td>
<td>SA</td>
</tr>
<tr>
<td>Magic chair makes princesses</td>
<td>SO3, SO4</td>
<td>SA</td>
</tr>
<tr>
<td>Magic shower (portable)</td>
<td>SO5, SO6, SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>Magic volcano</td>
<td>SO5, SO6</td>
<td>SA</td>
</tr>
<tr>
<td>Magic map</td>
<td>SO5, SO6</td>
<td>SA</td>
</tr>
<tr>
<td>Magic ocean</td>
<td>SO5, SO6</td>
<td>SA</td>
</tr>
<tr>
<td>Magic tunnel</td>
<td>SO5, SO6</td>
<td>SA</td>
</tr>
<tr>
<td>Rug that flies, is submersible, and catch users as they fall</td>
<td>SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>Dinosaur transforming into a table</td>
<td>SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>Magic coats that keep children warm, turn into parachutes, and drive magic rug</td>
<td>SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>Monkey created tools to start the rug (magic wand and joystick to control rug)</td>
<td>SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
<td>-----</td>
</tr>
<tr>
<td>Lamp that follows you</td>
<td>SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>Chair lets you watch tv and read (light for reading)</td>
<td>SO7, SO8</td>
<td>SA</td>
</tr>
<tr>
<td>Mixing bowl that could make food (or blend) from ingredients, knew when to stop, and self-cleaned</td>
<td>SO11, SO12</td>
<td>SA</td>
</tr>
<tr>
<td>Toaster for making toast related foods and used as a pillow that made toast for you in the morning as you wake up</td>
<td>SO11, SO12</td>
<td>SA</td>
</tr>
<tr>
<td>Made an oven and stove to make hot chocolate</td>
<td>SO11, SO12</td>
<td>SA</td>
</tr>
<tr>
<td>Strong interest by children in kitchen technologies</td>
<td>SO11, SO12</td>
<td>SA</td>
</tr>
<tr>
<td>Disappearing bed</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Disappearing chalkboard</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Disappearing roof</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Hat that transformed into a seat and vice versa</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Quick baking oven to make cake</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Hat turned into a castle</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Castle made kings and queens</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Magic table</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Auto cleaning equals disappearing</td>
<td>SY4, SY5</td>
<td>SA</td>
</tr>
<tr>
<td>Scavenger hunt works to engage children in IoT</td>
<td>SY6, SY7</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Provide ability to request songs to sing along</td>
<td>SY6, SY7</td>
<td>SA</td>
</tr>
<tr>
<td>Sing-a-long with the character</td>
<td>SY6, SY7</td>
<td>SA</td>
</tr>
<tr>
<td>Control of light, temperature, and wind as part of play</td>
<td>SY6</td>
<td>SA</td>
</tr>
</tbody>
</table>

Regardless of the number of ideas and sessions we held with each age group, the structure of the activity was flexible enough to adapt to children’s needs in the context of a more complex design setting. We observed that even older children needed adult guidance with a complicated theme, so in this case it was important to have one adult facilitating the session and another controlling the voice agent.

Overall, Play-based Design was effective to get young children from both age groups to provide ideas for a complex technology that is unrelated to play. The right combination of story, characters, prompting, and task-oriented activities, such as brainstorming with preset objects or
engaging young children in a treasure hunt, promoted creativity through social play and yielded design ideas that can be incorporated in IoT technologies for children, such as sensors that can control the physical environment of play by changing the light color.

Note that while many of the suggestions are impossible to implement, this has been reported as a common situation when getting ideas from children in elementary school, so it is not surprising that it also happened with children under the age of five. There is still value in all the ideas in that they give clues as to children’s goals. For example, many of the 3 year-olds suggestions for disappearing items had to do with wanted help in cleaning up. Flying rugs could be immersive virtual reality environments.

6.5.2. Comparing Play-based Design Between 3- and 4-year-old Children
The 12 Play-based Design sessions with 4 year-old children yielded a total of 250.8 minutes, with an average length of 20.9 minutes and average use of screen-based device with StoryCarnival of 1.46 minutes. The 7 Play-based Design sessions with 3 year-old children yielded a total of 145.3 minutes, with an average length of 20.7 minutes and average use of screen-based device of 0.97 minutes. Even though we had fewer sessions with 3 year-old children, the average length of sessions was similar to the 4 year-olds with the shortest session lasting 17.5 minutes as opposed to 16.5 with older children. Some of the reasons for some sessions being short relate to lack of engagement in play or disruptive behavior close to the end.

To the contrary of our expectations, the time off-task between 3 and 4 year-olds was different. We calculated time off-task by dividing the sum of time off-task for every child in a session over the number of children in a session divided by session length to get percent of session. Older children had more variability throughout the sessions and tended to spend more time off-task during play (see Figure 27). The total time off-task for 4 year-olds was 55 minutes (out of
250.8 min), with an average of 17% of total time, while the total time off-task for 3 year-olds was 10.5 minutes (out of 145.3 min) with an average of 7% of total time. This finding surprised us because we hypothesized that young children would have a harder time staying engaged in the activity.

![Time Off-task per child for 3- and 4-year-old children](image)

Figure 23. Time off task per child for 3- and 4-year-old children.

The adults’ engagement had an average of 13% of session time participating in play and 1% suggestions for 4 years-old and the average for repeating what the agent said was close to 0% of sessions. During sessions with 3 year-old children, adults engaged more with an average of 23% of session time participating in play, 2% making suggestions and 1% repeating what the agent said. During session 12, there were two adult facilitators engaging in play with two voice agents and 5 children at the same time. During session 5, there were many instances of disruptive behavior, which explains a higher level of play participation from the adult facilitator.
We also investigated children’s engagement with the voice agents to better understand the role of this technical component. The level of engagement with voice agents was similar between the two different age groups (see Figures 23 and 24), with physical engagement accounting for the highest percent of the sessions with an average of 61% for 4 year-olds and 52% for 3 year-olds.
Verbal engagement with the voice agents was also similar between both age groups with an average of 23% of session time for 4 year-olds and 21% for 3 year-olds. During the first Play-based Design session with the 3 year-olds their verbal engagement was actually higher than their physical engagement (47% of verbal engagement and 40% of physical engagement), as opposed to the first session with the 4 year-olds (8% of verbal engagement and 72% of physical engagement).

Overall, younger children tended to react slightly more often to the voice agent with an average of 3% of session time as opposed to 2% for the older group. Some of the common reactions of 3 year-old children were laughing, smiling, and dancing with miniBird.

There were few occasions children expressed the desire to control what the voice agent say and that happened more during the three initial sessions with the older group and the last two with the younger group.

![Graph showing 4 year-old children's engagement](image)

**Figure 26.** Level of engagement of 4 year-old children during Play-based Design for IoT.
6.5.3. Design Requirements for StoryCarnival and Play-based Design

Similar to what we did while developing StoryCarnival (see section 4.6 Results) and the Tangible Voice agent (see section 5.6.4 Design Requirements), one researcher identified design requirements for StoryCarnival and Play-based Design, together with events that led to each requirement and distinguished between two ways in which children contributed during the design process. Table 16 displays a list with 13 design requirements we identified throughout the Play-based Design sessions with the two age groups. These requirements are different from the design ideas children provided for IoT and relate to some technical adjustments needed such as using a longer delay for starting the voice agent’s speech and slowing the speech of the voice agent even more for 3 year-old children. The requirements also relate to the adaptations we did for exploring IoT, such as providing more reinforcement and scaffolds for the IoT theme and using two voice agents with a bigger group of children.

Figure 27. Level of engagement of 3 year-old children during Play-based Design for IoT.
Table 15. Design Requirements from IoT Play-based Design sessions.

<table>
<thead>
<tr>
<th>Design Requirements from IoT sessions</th>
<th>Example from Design Session with older (SO) and younger children (SY)</th>
<th>Observing Behaviors (OB) Suggestions/Actions (SA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need sturdier prototype for voice agent</td>
<td>SO1</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Need longer delay starting speech</td>
<td>SO1</td>
<td>OB</td>
</tr>
<tr>
<td>Two adults per group needed to run IoT design session</td>
<td>SO3, SO4</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Reinforcement of the story needed from both adults and voice agent</td>
<td>SO3, SO4</td>
<td>OB</td>
</tr>
<tr>
<td>One group story if stories are the same</td>
<td>SO3, SO4</td>
<td>OB</td>
</tr>
<tr>
<td>Request that miniBird gets wings</td>
<td>SO3, SO4</td>
<td>SA</td>
</tr>
<tr>
<td>Asking questions about story comprehension can work well after children watched story three times</td>
<td>SO5, SO6</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Two mini bird setups worked well with one group of five children and two researchers</td>
<td>SO11, SO12</td>
<td>OB</td>
</tr>
<tr>
<td>Context for where they should have their ideas is important</td>
<td>SO11, SO12</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Mini characters are motivators for activity</td>
<td>SO11, SO12</td>
<td>OB/SA</td>
</tr>
<tr>
<td>Need to slow down speech more for agent</td>
<td>SY1</td>
<td>OB</td>
</tr>
<tr>
<td>Need to prompt kids to engage more with the story</td>
<td>SY1</td>
<td>OB</td>
</tr>
<tr>
<td>Children are activity oriented and do not question the technology</td>
<td>SY2, SY3</td>
<td>OB/SA</td>
</tr>
</tbody>
</table>

6.5.4. Lessons Learned for Play-based Design for IoT

During the 12 Play-based Design sessions we conducted with 4 year-old children, we observed some of the same behaviors from our previous explorations with the tangible voice agents. Children listened to miniBird, they held it and cared for it, whispered to it, and used physical props creatively with the voice agent. We also observed attachment and curiosity toward miniBird. The overall creative use of physical props was good and children built houses, nests, magic hats, bedrooms, and pretended they were food. Communication among peers was good and they tended to negotiate and plan what they were building together.

We held our sessions in the same room by splitting the children into two groups. However, we had problems while running the stories with two different tablets at the same time. The noise
was confusing to the children and we adapted the setup by having all the children together watching the stories and then splitting them into two groups to choose the roles separately. We used this setup with the 3 year-old group of children and it also worked nicely.

The major adaptations we did for exploring Internet-of-Things technologies with 4 year-old children were related to the way the adults facilitated the sessions. Due to the complexity of the theme, we felt the need to provide more scaffolds for children to explore their creativity. However, we did that in a simple way, by providing 3 objects as a starting point for them to brainstorm their ideas and that was successful to some degree. We did not get ideas for the bedroom, which could be because they are not interested or used to having technology in this setting, or it could be because our choice of objects were not inspiring enough to scaffold their creativity.

During the 7 Play-based Design sessions we conducted with 3 year-old children, the activity worked naturally and young children had a significant buy-in with a clear enjoyment expressed by a lot of laughing and smiling and not questioning the technology. They were more activity oriented and attentive than their older peers. The overall use of physical props as symbols was similar to the older children, and they used the props to stand for various objects such as food items, castle, chair-hat, magic hats, bed, sheets and rugs, sled, slide, bathroom, table, and hair. However, they built fewer structures than the older kids. The verbal communication with the voice agent was also good, with young children offering food, asking if miniBird needed to go potty or needed to sleep, helping miniBird fly, and showing what was outside the window. They also talked about things they were making, talked as they searched for items, and made requests for the voice agent to play specific songs.
The adaptations we did for exploring Internet-of-Things technologies with 3 year-old children were more broad. We first adapted the story language by making it more relatable to fairytales and exploring the idea of magical objects. We also adapted the way the adults facilitated the sessions, by engaging more in play and providing familiar activities to scaffold their creativity. Younger children tended to repeat the same activity many times, but their engagement was higher than expected.

6.6. Conclusions

Through a systematic analysis of Play-based Design sessions with two groups of children, I provide evidence the method worked for developing a wide range of ideas for IoT applications. By making some adjustments in the way adults facilitate the sessions, the method yielded both ideas and design requirements for facilitating IoT design sessions, suggesting it is effective for exploring a broad and complex design topic. Next, I provide guidelines for other researchers to implement Play-based Design to support fluid communication between adults and 3-4 year-old children.

6.6.1. Ideal Design Activities for Young Children

While developing Play-based Design, we favored activities that would potentially benefit children through some combination of exposure to appropriate academic material (e.g., in literacy and numeracy), social activities, physical play, and creative endeavors. Other human-computer interaction researchers have cited similar types of activities, although in the context of what technologies should support (Wyeth and Purchase 2003). Conducting design activities that expose children to literacy and numeracy skills they need to learn, such as a wide range of vocabulary, counting, or geometric shapes (CDC) is one way to make it more likely that these activities will
have a positive impact on them. These activities may occur, for example, if the focus of the technology being designed is learning one of these skills.

Social activities are important not only for developing social skills, but also for learning in general. Both Vygotsky (1967, 1980) and Piaget (2008) for example, cited the importance of social interactions in children’s learning and development. Both also cited the importance of interactions with the physical environment (Piaget and Inhelder 2008, Vygotsky 1967, Vygotsky 1980), something echoed in sociocultural theories of development (Brown et al. 1989, Greeno 1998, Lave and Wenger 1991), and in embodied cognition theories (Wilson 2002). Therefore, we considered that social design activities including interactions with the physical environment are likely to have a positive impact on participating children.

Creative activities, such as role-playing, can also have a positive impact on three to four-year-old children’s development, helping them gain abstract thinking and self-regulation skills (Blair and Raver 2014, Bodrova and Leong 2007, Diamond et al. 2007), and predicting adolescent creativity (Mullineaux and Dilalla 2009). The importance of creative activities has also been highlighted by Papert’s constructionist approach (Hourcade et al. 2018, Papert 1999, Papert and Harel 1991). Hence, design activities that involve children being authors, makers, or actors of some kind are likely to benefit children.

We also believe the design activity should be enjoyable for participating children. Three and four-year-old children may have difficulty understanding the process involved in the design of interactive technologies, and most are likely unable to give proper consent for participation (consent should be obtained from parents). Therefore, given the power imbalance between adults and young children, we consider important not only to stop children’s participation at any sign of distress, but also to set up activities the children can enjoy and in which they want to participate.

6.6.2. Play-based Design Guidelines

Play-based Design is a novel participatory design method that resulted from two distinct explorations of design sessions with 3-4 year-old children, and a validation with two groups of
children. Play-based Design has three basic steps (see Figure 28), two technological components, and two adults running the session with one facilitating the activity and the other controlling a voice agent.

Firstly, an adult facilitator sets the context for design using interactive stories presented in StoryCarnival. The stories can be adjusted according to the context where the technology will be used and the design goals, and they should suggest an open-ended activity to be explored during play. Preferably, the stories should have four characters with different skills that collaborate with each other in a given context. During the IoT sessions, we explored asking questions about the story to 4 year-old children after they watched it for 3 times in previous sessions and their comprehension and recall was good. Therefore, this is a technique that can be further explored by adult facilitators if needed.

Secondly, after children split into groups of no more than four, adults use the StoryCarnival planner with children taking on specific roles based on the characters from the stories. The adult facilitator should hold the mobile device and prompt children to take turns while they choose their roles. If a child decides they want to be the same role as another peer, the adult can try to negotiate and prompt the child to choose another role and switch roles later during play. It is also possible to let more than one child play as the same role.

Thirdly, children play pretending to be in the context presented to them, using generic physical props to stand for objects and the voice agent controlled by an adult. During make-believe play, children will interact with their peers, with the voice agent, and with the adult facilitator who might participate in play, give suggestions, or repeat what the voice agent said to prompt children to remain engaged in play. During the application of Play-based Design to IoT technologies, we explored using two voice agents with a bigger group of five children playing together and that
worked well with two adult facilitators. However, these setups could in some cases require either that more than one child play the same character, or stories with more characters.

![Figure 28. Illustration of the basic steps of Play-based Design.](image)

The method is inspired by Tools of the Mind style play, but include a technological technical setup involving a combination of StoryCarnival and a Tangible Voice Agent that are used in two distinct steps of the process. These technologies have the goal of reducing the barriers for others to use the method for developing technologies with children aged 3-4 years-old. The input to the method is structured planning and negotiation at the beginning of the activity in order to setup a common context or setting for play and present collaborative characters to children (see Figure 29). The output of the method is design requirements for technologies that fit a social context.

![Figure 29. Components of Play-based Design.](image)
6.6.3. Play-based Design Analysis

The analysis of Play-based Design sessions findings involves using video data as a source a main source of documentation. We also used notes based on group discussions occurring after the sessions that focused on observing children’s use of props, their verbal and non-verbal communication and behaviors, requirements generated during sessions, and adults’ participation. The method of analysis chosen depends on the purpose of research. In the three projects developed in this research, we used video analysis by coding behaviors we defined in our inquiries.

CHAPTER 7: DISCUSSION

This chapter discusses the contributions and limitations of Play-Based Design in relation to existing participatory design techniques.

7.1. Play-based Design in the Context of Participatory Design

In 1999, Druin (1999) established Cooperative Inquiry, which is a method of design partnering for intergenerational teams of adults and 7 to 11 year-old children. The method combines Contextual Inquiry (Beyer and Holtzblatt 1998) by having both adults and children observe, take notes, and interact with child users, Participatory Design techniques that use low-tech materials for prototyping ideas for technologies (Druin 1999), and Technology Immersion, which provides children concentrated and free access to technology to make their own choices while using it (Druin 1999). The philosophy behind this approach comes from Scandinavian Participatory Design to respect and actively involve users in the design process and give them a more equal partnership and responsible role to contribute with their unique needs, abilities, and interests (Ehn 1988, Greenbaum and Kyng 1991, Schuler and Namioke 1993, Druin 1999).

In 2002, Druin (2002) proposed four roles that children can play in the technology design process: user, tester, informant, and design partner (see Figure 30).
While reflecting on children’s roles for designing technologies, the two roles that are more similar to the level of involvement used in Play-based Design with 3-4 year-old children are informants and design partners. Informant design entails working with children at specific stages during the design process when their input is the most valuable (Guha et al. 2013, Scaife et al. 1997). By treating children as informants, researchers expect to discover new things from children rather than confirming what they thought they knew (Scaife et al. 1997), and children are called when their thoughts and advice is needed (Guha et al. 2013). On the other hand, design partners are equal stakeholders throughout the design process, as children enter into a long-term agreement involving a training to learn design methods and techniques for elaborating new technologies in partnership with adults (Guha et al. 2013). According to Guha et al. (2013), the goals are different between the two roles. Design partners build ideas together with adults, while informants have dialogue with adults who then go back to work to create the ideas (Guha et al. 2013).

However, considering that design partnerships often involve children aged 7 to 10 years-old, can children under the age of 5 be design partners? Farber et al. (2002) explored using Cooperative Inquiry with children aged 4 to 6 as design partners and they found the need to
implement a series of adaptations to the design method. For instance, there was a need to reduce the amount of writing, use less sticky notes reflections, work in small groups with adults, do fewer whole group presentations and more design exploration, and include more adult facilitation while adapting techniques they used with older children (Farber et al. 2002). In spite of the difficulties the researchers concluded that it is possible to work in partnership with kindergarten children as long as the methods are specifically developed for young children (Farber et al. 2002).

Even though other researchers were optimistic about including young children as design partners, my analysis of the literature revealed there is still a gap while implementing this idea with children under the age of 5. Play-based Design starts to fill this gap, by introducing a new method for involving 3-4 year-old children in the design process. When young children participate in Play-based Design, they go a step beyond being informants because they are involved in a long-term process and given an outlet to express their own ideas, which can be iteratively incorporated in the design of technologies. However, they are not exactly design partners because there is no training to learn design methods and techniques and young children are not necessarily aware that they are helping adults to design something. This idea was not included in Play-based Design because it did not seem to fit young children’s developmental stage.

In Play-based Design, young children are empowered to act out their ideas in a similar way that older children are able to do through sketching or building prototypes, and they do so in a role that goes beyond informant and below design partner, as represented in Figure 31.
7.2. Play-based Design Contributions

Through a systematic analysis of three projects of developing and implementing Play-based Design with different groups of children, I provide evidence that the method worked well for developing design ideas for three types of technologies that promote social and physical activities. Table 17 summarizes the three projects with respect to the purpose, the stories we developed, and the results found.

Table 16. Summary of the three projects that informed the development and implementation of Play-based Design.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Play Context</th>
<th>Results</th>
</tr>
</thead>
</table>
| *StoryCarnival* Develop a technology to support make-believe play in the style of *Tools of the Mind* | • Supermarket  
• Farm  
• Space  
• Party | 1. Understanding the steps necessary to support make-believe play  
2. Development of web-based technical component to support Play-based Design |
In a similar way to Fictional Inquiry (Dindler and Iversen 2007), Play-based Design uses storytelling to create a common stage for young children to act out the experiences they want within the design context. Fictional Inquiry uses stories to add fiction to children’s current context, but children do not pretend to be someone else or to be in a different location. Play-based Design explores the motivational aspect of plots and narratives to allow young children to express their ideas through make-believe play, which is a developmentally appropriate activity for this age group. Play-based Design’s make-believe play, unlike that in Fictional Inquiry, involves imagined locations and children playing characters. Future work could explore hybrids between the two approaches.

Conversely, Play-based Design relates to the idea of setting the stage and providing props for collaborative generation and exploration of design ideas (Brandt and Grunnet 2000, Guha et al. 2013). Other researchers used drama techniques and props in participatory design sessions with adults to successfully evoke ideas for future artefacts and their use (Brandt and Grunnet 2000). Play-based Design contributes with a lightly structured play activity that enables children to act out design ideas or verbally express them by conversing with researchers or voice agents during play. The play context makes children more comfortable to communicate with adults facilitators while the voice agents are helpful to support fluid communication between adult researchers and children while they are engaged in play.
Play-based Design can inform the design of technologies that facilitate activities that have social and physical components. During my research, I collected design requirements for a web-based mobile app that promotes physical play and for tangible voice agents. I also gathered design ideas for IoT technologies.

7.3. Limitations

In this section I discuss some of the limitations of the method.

Since Play-based Design is a highly social and collaborative activity, the first limitation to consider is that it might not be suitable for developing screen-based technologies that promote single user activities.

In terms of logistics, other researchers must consider that Play-based Design might be time consuming. There is a need to plan for one or two warm-up sessions for children to become acquainted with researchers and feel comfortable in the activity, before exploring the actual design context. There is also a limitation in the number of children that can participate in the activity at the same time. Even though we found that larger groups of children can watch the stories together, choosing roles and playing with props work better in small groups of children.

In terms of the technical components, we plan to make StoryCarnival publicly available in the future and the voice agent prototype is cheap and easy to construct. These technologies were helpful for lowering the barriers for adults to support Play-based Design, but they might not be necessary to run the design sessions. If adult facilitators have experience in storytelling, they might be successful in developing a common context for play. The role planning can be done with printed characters on sheet of paper and simple turn-taking facilitation, and an experienced facilitator can prompt children to effectively engage during play without voice agents. However, these tools were a good way to scaffold the activity and they are flexible enough to be adapted to different needs.
For instance, the tangible voice agents added a new layer to children’s creative play. Young children constructed homes, museums, and other imaginative spaces to engage with the voice agent. Even though the voice agents are not necessary for running the design session, they were a fun addition to the activity. In addition, StoryCarnival and the voice agents address the common gap of facilitators with strong storytelling and make-believe play facilitation skills.

7.4. Future Research Opportunities

The design explorations my research group and I conducted with 3-4 year-old children revealed many research opportunities for future investigation.

The tangible voice agents, for example, could be further explored with other populations including neurodiverse children and children with cognitive impairments. It would be interesting to use voice agents as a tool for adults to communicate with other groups of children. For instance, we believe there is great potential for adults to use voice agents to communicate with children with autism. We observed that young children were interested in controlling the voice agent’s speech, therefore, another potential exploration could be to give control of the voice agent’s speech through an augmentative and alternative communication device (AAC) to children with autism to communicate with caregivers and other peers.

A different direction for lowering barriers for other facilitators to use Play-based Design could be improving voice agents with contextual recommendations for text based on different play contexts. It would also be interesting to explore using Play-based Design with children from other cultures possibly translating the stories and adapting the voice agent’s speech to different languages. Finally, another opportunity could be to expand on the existing experiences with Play-based Design and use it for other types of technologies and possibly making more variations to the method with hybrids closer to Fictional Inquiry.
REFERENCES


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Results for. (n.d.). Retrieved July 12, 2018, from PBS LearningMedia website: [https://www.pbslearningmedia.org/search/?q=&order=&selected_facets=media_type_exact%3AInteractive&selected_facets=&selected_facets=grades_exact%3APreK](https://www.pbslearningmedia.org/search/?q=&order=&selected_facets=media_type_exact%3AInteractive&selected_facets=&selected_facets=grades_exact%3APreK)


Turkle, S. (2017). Alone together: Why we expect more from technology and less from each other. Hachette UK.


APPENDIX A: LIST OF SELECTED PAPERS FOR ANALYSIS

This appendix includes the list of 99 papers included in all the analysis presented in chapter 3.


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