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Play—An essential part of children's lives and their computational empowerment

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This article addresses the computational empowerment of children, with an emphasis on the importance of play in realizing it. Although play has been brought up as central for children within numerous disciplines, there is a lack of thorough treatment of the phenomenon in the context of technology design, computational thinking, and computational empowerment. The objective of this research is to open the eyes of adults to see children's play and improvisation as not only an essential part of children's life but also an important part of their computational empowerment. We organized numerous participatory design sessions with children (aged 5–6 years), during which play was supported to obtain material for designing a music game. We analyzed the collected data with a framework combining aspects on computational empowerment and play. Our analysis of the sessions showed that play had numerous important functions in the design sessions with the children. Our examination revealed that play is intertwined with computational empowerment in many ways and it supports different aspects of computational empowerment. We recommend that researchers offer various forms of play for children during design sessions to support children's creativity, narratives, embodiment, and, ultimately, their computational empowerment.

KEYWORDS

children, play, participatory design, education, computational thinking, computational empowerment, music game

1. Introduction

New technology is continuously targeted at children. Ever younger children, even kindergarten students are active users of technology in the digitalized world. In different research communities, an interest has emerged in preparing the children of today for their digitalized future. The children of today should be prepared to manage and master digital technology (Iivari et al., 2020): they should not be seen as mere users of digital technology, but as makers, shapers, designers, developers, and innovators of it (Iversen et al., 2017; Iivari et al., 2018). It is emphasized that everyone should possess basic skills related to computing, not only computer scientists (Wing, 2006) These calls have already influenced children's basic education, both in educational sciences (e.g., Brennan and Resnick, 2012; Angeli and Giannakos, 2020; Iwata et al., 2020) and in child computer interaction (CCI; Chu et al., 2017; Iivari and Kinnula, 2018; Iversen et al., 2018; Dindler et al., 2020), and there is abundant literature on how to educate the young generation for the digital age. Various efforts under the labels of programming, computational thinking, science, technology, engineering, and mathematics (STEM), digital fabrication, and making-based education have emerged around the globe (e.g., Barr et al., 2011; Balanskat and Engelhart, 2014; Iversen et al., 2017, 2018; Pérez-Sanagustín et al., 2017; Angeli and Giannakos, 2020; Iwata et al., 2020; Milara et al., 2020).

In this study, we address the computational empowerment of children, which has been offered as an alternative for the highly computing and technology focused computational thinking (see Iversen et al., 2018; Dindler et al., 2020). The notion of computational empowerment has derived inspiration from the work on computational thinking, while enriching that with the tradition of

participatory design (Iversen et al., 2018; Dindler et al., 2020). Computational empowerment represents a recent and very promising development that should offer valuable avenues for the development of approaches in the educational sciences. In addition to discussing this approach, particularly the participatory design part, we develop it further. Computational empowerment places emphasis on a reflective and critical stance toward computing and on the empowerment of children to shape computing in the future society (Iversen et al., 2018: Dindler et al., 2020); however, we feel there is a need for more child-centered methods to enable this. A child is a special kind of person in many ways. Children's growth and developmental stage should be taken into better account when working with them and when addressing their computational skills. An essential part of a child's development and life—play—has not received as full attention it deserves in the literature on computational empowerment and participatory design, even if play and playfulness have been acknowledged in participatory design methods aimed at children (Yip et al., 2017; Metatla et al., 2020; Superti Pantoja et al., 2020; Vandenberghe et al., 2022), and the concept of playfulness has recently come up quite strongly in the research on digital solutions aimed at children (Hitron et al., 2018; Altarriba Bertran et al., 2022; Zhang et al., 2022). Notably, play as an integral part of the computational empowerment of children and of participatory design with children has not yet been fully scrutinized, even if play is a natural way for children to be and act.

In this study, we show how play can be integrated into the computational empowerment of children, and particularly into participatory design with young children. Our research challenge relates specifically to working with young kindergarten students, meaning that the existing methods and approaches require serious reconsideration. We discuss the importance, meaning, and potential of play in participatory design with young children. We also examine the participatory design sessions we organized with young children, for which we adopted and partly modified some of the well-known methods but also invented novel methods to suit our context and situation (see e.g., [blinded]). We answer the following research question: "How can play be integrated into participatory design with children?"

The paper is structured as follows. The next section discusses literature on computational thinking and computational empowerment of children, as well as the concept of play as an essential element in design sessions involving children. The third section outlines the research method and procedures involved in this study. The fourth section presents examples of design and evaluation sessions that offered play experiences for the participating children. The final section summarizes the findings, discusses their implications and limitations, and identifies interesting paths for future work.

2. Related research

2.1. From computational thinking to computational empowerment

Computational thinking relates to the democratizing of computing; it is maintained that everyone should have some basic computing skills. Computational thinking involves "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (Wing, 2006). Computational thinking is also considered important for the children of today, and the existing literature has addressed it in the context of children's education (e.g., Barr et al., 2011; Angeli and Giannakos, 2020; Iwata et al., 2020). In this context, computational thinking covers "designing computational solutions to problems, algorithmic thinking, and coding. It focuses on skills children develop from practicing programming and algorithms and enables the development of qualities such as abstract thinking, problem solving, pattern recognition, and logical reasoning (Angeli and Giannakos, 2020)." A more detailed specification lists the following to characterize computational thinking in K-12 education: it is a problem-solving process that entails: "Formulating problems in a way that enables us to use a computer and other tools to help solve them • Logically organizing and analyzing data • Representing data through abstractions, such as models and simulations • Automating solutions through algorithmic thinking (a series of ordered steps) • Identifying, analyzing and implementing possible solutions with the goal of achieving the most efficient and effective combination of steos and resources •Generalizing and transferring this problem-solving process to a wide variety of problems "(Barr et al., 2011). Computational thinking in education tends to rely on child friendly means and tools such as games or robotics or easy to use programming environments such as Scratch (e.g., Grover and Pea, 2013; Angeli and Giannakos, 2020). Digital fabrication and making have also been utilized when integrating computational thinking into education of children (Iwata et al., 2020).

Recently, this tradition of computational thinking has been criticized for being too heavily computing-oriented, with a focus on concepts such as algorithms, decomposition, and pattern recognition, and thus a broader view has been called for (Iversen et al., 2018). Brennan and Resnick (2012) broadened the view to cover, in addition to computing concepts and computational practices, the dimension of computational perspectives that includes expressing, connecting, and questioning: they maintain that computational thinking entails self-expression and connecting with others, i.e., computing entails doing something for and with others, as well as questioning computing and making a difference regarding it (Brennan and Resnick, 2012). Continuing with the last dimension, Iversen et al. (2018) and Dindler et al. (2020) recommend introducing a critical, reflective, and empowering stance regarding computing to children: computational thinking fundamentally lacks "a critical and reflective stance towards digitized society; further, it lacks an agenda of empowering children to understand and make informed choices about technology and participate in technological development" (Iversen et al., 2018, p. 1). To tackle this limitation, Iversen et al. (2018) and Dindler et al. (2020) have explored the potential of participatory design for the computational empowerment of children.

Participatory design has aroused interest in human computer interaction (HCI) and, more specifically, in CCI. Participatory design invites children to take part in technology design. Participatory design has its background in the Scandinavian tradition of technology development, which had a strong emphasis on workplace democracy and worker empowerment in relation to computing (Greenbaum and Kyng, 1991; Schuler and Namioka, 1993). During the yeareass, participatory design, which has found its way to children and to the CCI research community, has been used to realize the democracy and empowerment related ideals with children in the design of digital technology. A number of studies show how children can be invited not only into the role of users or testers as regards digital technology and its development but also into the role of design partners and protagonists, acting as equals to adult designers, if not even driving the development of digital technology (e.g., Druin, 2002; Iversen et al., 2017). Along these lines, a variety of methods for requirements construction, for the design

of user interfaces and human computer interaction, and for evaluation of the design solutions have been devised to realize these children's roles (e.g., Druin, 1999; Guha et al., 2004; Kelly et al., 2006).

In this study, we approach computational thinking in a broad sense, entailing computational concepts and practices as well as expressing, connecting and questioning in relation to computing (see Brennan and Resnick, 2012; Iversen et al., 2018; Dindler et al., 2020). In line with Iversen et al. (2018) we see the participatory design of digital technology as an important supplement to the computing concepts and practices discussed in the previous literature (e.g., Wing, 2006; Barr et al., 2011). We explore computational empowerment of children, inspired by participatory design, in which children's empowerment, learning, and skill development in relation to computing are prioritized and children are invited to engage in practices relating to the development of digital technology for others as well as relating to the critical reflection on technology developed by others (see Iversen et al., 2018). In this study, we focus particularly on young children's (especially aged 5–6 years), engagement in practices related to the development of digital technology, experimenting with a set of participatory design methods for requirements construction for and design and evaluation of digital technology, and explore ways by which to include play as an integral element within.

2.2. Play and participatory design with children

Play is an imagination-stimulating and harmonizing function for a human, being an integral part of children's lives (Fails et al., 2005). It is spontaneous, creative behavior, although it has a serious nature as well. Play is typical of mammals and birds, and exists in reptiles, fish, and some invertebrates. It occurs during the extended juvenile period, which plays a critical role in human development (Piaget, 1962) and in developing the complex set of skills necessary for survival in non-human species (Burghardt, 2005). Pellegrini et al. (2007) posited that play affords opportunities for the generation of new, and possibly adaptive, responses to novel environments and therefore affects evolutionary processes.

Being so essential in children's lives, it can be claimed that play is child's work (Morrison, 2004). It is even argued that play is older than culture and that play is at the very center of what makes us humans Huizinga (1955), (2004), Kalliala (2006), and Soler-Adillon et al. (2009). According to Huizinga (1955), play (*spielen*) refers to play, dance, and role and game playing (Heikkinen, 2010). However, the versatile concept of play allows for multiple definitions. The National Institute of Play identified the following elements of play: attunement, body, object, social, pretend, narrative, and transformative-integrative or following formats of play: free play, structured play and mixed-aged play (NIfPlay. National Institute of Play, 2022).

When considering play of 5–6 years old children, child psychologists such as Piaget (1962) and Vygotsky (1978) created a steady basis through their investigations for all child researchers. According to Piaget (1962), sensorimotor/exploratory play can be observed in children during the first 2 years of life. According to him after sensorimotor stage pre-operational stage lasts from 2 years to 7 years. Pretend (imaginative/fantasy), social, and locomotor play of children starts during the second year of life, increases during the preschool years, and declines during the primary school years, when children start to enjoy structured games with rules (Piaget, 1962; Pellegrini and Smith, 1998). Piaget (1962) described imaginative play as highly assimilatory: play allows children to interpret objective experiences in a subjective fashion. Imaginative play can be regarded as a form of expressive creativity, including self-expression, spontaneous singing, drawings, and dance (Runco and Cayirdag, 2013, p. 102). Because young children are spontaneous, playful, and have fewer routines than adults, they are able to think preconventionally, divergently, and imaginatively (Runco and Cayirdag, 2013, p. 102).

Concerning musical development of children under school age, vocal play and rhythmical babbling are typical of infants around 6 to 9 months of age, representing both pre-linguistic and pre-musical forms of development (Papoušek, 1996). The free exploration of sound can be regarded as the earliest form of musical creativity. Musical play is an integral part of intuitive parenting and the infant's social, musical, and linguistic development (Papoušek, 1996). Spontaneous songs and instrumental experimentation/improvisation often start when children play and move in either social or solitary conditions (Sundin, 1998; Marsh and Young, 2016). Spontaneous songs are typically associative chains of musical patterns that the child transforms and combines in the context of imaginative play. With spontaneous singing, preschool-aged children also learn to generate and control relational structures in music (Paananen, 2003, p. 211).

Play changes its form again in the threshold of school age, around the age of seven. Games and rule-based play are typical during primary school years, when spontaneous play becomes socially organized. This is a time when children become also musically more product-oriented. Their improvisations and compositions start to follow cultural conventions, and they are able to modify their creative musical products (Paananen, 2003, p. 212).

The importance of play in children's lives has already been recognized within CCI research and it is already an integrated part of participatory design with children. Among the CCI studies addressing play within this discipline, many have explored how technology can be used to augment children's play (e.g., Papert, 1980; Resnick et al., 1998; Montemayor et al., 2002; Fails et al., 2005; Hoffman et al., 2013). CCI research has emphasized social and pretend play and, during the most recent research, physical play. Verenikina and Herrington (2009) argued that when designing a game, the main aspect of children's play for development is the dimension pretend—referring to action and interaction in an "imagined situation" and to the roles that children are playing. According to interactive tabletop researchers Mansor et al. (2009) and Mansor (2012), a common and important type of play is fantasy play. Fantasy play is an unstructured and spontaneous activity involving imagination that occurs when children move from real into imaginary worlds and give new meanings to the objects they are playing with. According to Dix (2003) and Verenikina and Herrington (2009), play is also one possible origin of imagination in interface and game design. When adult-like rationality and child-like imagination meet in creative play, we can produce effective and innovative solutions (Dix, 2003). Imaginative play has been characterized as a spontaneous, self-initiated, and self-regulated activity, which is relatively risk free and not necessarily goal-oriented (Verenikina and Herrington, 2009).

Physical play has been proposed in the interactive game investigations of Bekker et al. (2007) and the visual programming research of Mattila and Väätänen (2006) and Soler-Adillon et al. (2009). According to these researchers, children develop important skills in interactive playgrounds. Researchers have also developed applications that help children invent and improve outdoor play experiences (Ofer et al., 2019; Dylan et al., 2020) and urban play environments (Altarriba

Bertran et al., 2022). In addition to physical play, the human body is handled as a play from the perspective of embodiment (Mueller et al., 2020).

When speaking about play, researchers have often used the concept of playfulness. Frei et al. (2000) and Ryokai et al. (2009) write about playful toys, and Kam et al. (2009) discuss playability, making comparisons between digital and traditional games. Playing games is a central part of these articles. When thinking about the relationship between game and play, games are an integral part of children's play, and school-aged children love games (Hughes, 1991). Although children participate in the game design process, and play is close to game as a concept, games and gamification (e.g., Dunwell et al., 2014) are not addressed in any depth in this research effort, unless explicitly addressing the aspect of play.

According to researchers from different disciplines, playfulness refers to the essence of play at its core (Barnett, 1991; Guitard et al., 2005, p. 12). Like play itself, playfulness as a concept is complex and extensive, and it makes an appearance in a variety of features. Guitard et al. (2005, p. 12) address the different aspects of playfulness, such as pleasure, spontaneity, curiosity, imagination, and sense of humor. According to Hyvonen (2008, 2011), playfulness is a quality of action in which seven different features can be seen: physicality, emotionality, sense of community, functionality, narrative, creativity, and ingenuity (Read et al., 2002; Hyvönen et al., 2007; Hyvonen, 2008, 2011).

These elements figure prominently in CCI research and participatory design. For example, when speaking about physicality, Peer et al. (2011) support the development of physical skills as well as kinesthetic literacy through exertion games. Tangible interfaces and physical interaction supporting programs and activities for children also bring out physicality as a play form (Creighton, 2010; Freed, 2010; Freed et al., 2010; Meyers et al., 2010; Goh et al., 2011; Soleimani et al., 2014). More generally, studies have examined how tech might or might not support rich forms of urban play (Altarriba Bertran et al., 2022).

The sense of community and communal actions also relate to the phenomenon of play. Research addressing shared play (Cohen et al., 2014), remote play (Hunter et al., 2014), play at a distance (Raffle et al., 2011; Hunter et al., 2014), and multiuser environments (Meyers et al., 2010) indicates the essence of play in connection with games and platforms that are played or used by multiple players. Technology also supports parent–child interaction (Hiniker et al., 2018; Kwon et al., 2022; Zhang et al., 2022).

Playfulness is also associated with the concepts of playful teaching and learning when working with children, especially in research on child development and growth, but CCI research has also approached this issue during the last decades (see e.g., Parton et al., 2010; Bodén et al., 2013). In the educational context, playful learning is often characterized as assumed roles of a teacher and a pupil in different play situations, as a design of different playful teaching processes, and as emphasizing children's creativity, fun, and use and development of enjoyment (Hyvonen, 2008, 2011). CCI research also promotes educational targets from the perspective of play through assistive tools and programs targeting, for example, children with CP (Hernandez et al., 2013), autistic pupils (Bai et al., 2013; Bartoli et al., 2013), literacy (Tewari and Canny, 2014), speech intervention (Hamidi and Baljko, 2014), children with intellectual developmental disabilities (Choi et al., 2022), and social interaction for sick children (Wärnestål and Nygren, 2013).

In this research, playful is used as a characterization of the design process, not of teaching and learning. So far, in the literature discussing the design process with children, the concept of play has moved from the background to the front stage as well. O'Kane (2008) wrote about how approaches of play help research teams enjoy being and working together and sustain the enthusiasm of children, who are usually unpaid volunteers. According to O'Kane (2008) "Young children can be good at listening, questioning, challenging, keeping to the point, and helping each other to learn and develop idea" (p. 283). Superti Pantoja et al. (2020) introduced play-based design, an age-appropriate design method, to give 3–4-year-old children a voice in the design process. In this research, the concept of playful design is seen as an ideal state that should be aimed at when designing with children.

3. Research design

In this research, we organized participatory design sessions with children that we examined from the viewpoint of play, utilizing the research literature presented above. This research was carried out as part of a multidisciplinary, international research project that aims to produce a music application for 3–12-year-old children, together with children. The goal of the project is to support children's social inclusion, musical creativity, and social sharing of music through a music application. The group of CCI researchers working on the project was required to work with children during the design process and create a usable application for the target group. Information technology (IT) and music education experts were also involved in the project. IT developers were responsible for producing the music application, while music educators provided the initial requirements for the design of the application. Different versions of the application are provided for two different target user groups of the application: preschool (aged 3–6) and school-aged (6–12) children. The project also emphasizes children with moderate learning difficulties or immigrant backgrounds. This article focuses on the work done with the younger age group, particularly with 5–6-year-old children. The application under development for this age group is a learning application that contains games for singing and composing.

The CCI researchers worked with children in Finland and in England over two and a half years. This article focuses on the work carried out by the CCI researchers in Finland during those two and a half years. Numerous design and evaluation sessions were organized in several nurseries in Finland and England. The first activities carried out with the children included in this analysis were design sessions with children, involving different kinds of drawing sessions, and an art craft session in which the children constructed a prototype of the future music application. Thereafter, paper prototyping sessions were organized in which the children evaluated the created designs produced by the project participants. Later on, different kinds of music improvisation and music and icon evaluation sessions were organized, as well as more drawing and paper prototyping sessions.

The material gathered from these different sessions was used in the analysis. In these sessions, material was gathered by observing the children during the activities, interviewing them during the work and afterwards, and saving all the drawings and prototypes created by the children. The material includes video recordings, field notes, research diaries produced by the research team, photographs, and the artwork created by the children.

The data analysis concerning the aspect of play during the design sessions relied on a large, rich dataset. All relevant research material was collected and discussed among the research team doing the

analysis. In relation to each aspect, empirical evidence was recorded. The results were categorized according to the type of session from which they were identified. Based on the literature, we formed a framework concerning computational empowerment and computational thinking as well as a framework on play, which we combined to act as a sensitizing device in our empirical analysis. We used this combined framework to analyze all our sessions with children (see Table 1). Later on, it was also noted whether the findings

TABLE 1 Play and computational empowerment (CE).

PD session	PLAY addressed in the session applying, e.g., Hyvonen (2008) and Guitard et al. (2005)	CE/Expressing (self-expression) imaginative play	CE/ Connecting with others social play	CE/ empowerment and making a difference regarding technology	CE/ Questioning computing, Critical, reflective stance	CE/computing concepts and computational practices
Warm-up play and games	Singing, body rhythms, body movements – equipments like scarf, rhyme bag in the play carpet, adventures	Awaking children's imaginative e.g., spontaneous somersault after singing	Creating confidential contact, becoming acquainted with the research group	Empowering influence to be part of a design project with adults		
Art and craft music toy prototyping session	Stimulating video (children playing with invisible device), recycling materials (treasures) when drawing and creating, telling imaginative stories about sketches and prototypes, playing alone and together	An imagination stimulating video, and sketching out and creating from recycling materials own personal magic music toy	Telling actively stories to the adults while creating a prototype and playing, creating own work in a group	Telling indirectly general requirements for a music toy		Requirement specification Low tech prototyping
Drawing sessions informing the design of the music application	Triggers like fulfillment tasks, music, immersion to the task, telling narratives and playing with their creative pictures at the same time. Natural, playful way to work with children	Drawing (when listening music, fullfillment tasks) natural way to wake up children's imagination	Telling actively stories to the adults when drawing, creating own work in a group	Empowering through drawing and creating UI material indirectly and directly, like the opening image of the game and the contents of the planned environment sketches		Visual UI requirement specification
Evaluation of the application of music improvisation	Natural playful way work together with adults, in a safe atmosphere, supporting image of guiding bear appearing gradually to the screen when improvising new music, aloud singing, excited movements, shouting "yeah"	Close atmosphere, music accompaniment and visual support waked imagination	Connecting together with adults and other children when improvising alone and singing together, shared song	Empowering way to work together as a group, join with your own contribution to the common song, showing pleasure	Spontaneous feedback and reactions when evaluating	Audio and visual UI, requirement specification

(Continued)

TABLE 1 (Continued)

PD session	PLAY addressed in the session applying, e.g., Hyvonen (2008) and Guitard et al. (2005)	CE/Expressing (self-expression) imaginative play	CE/ Connecting with others social play	CE/ empowerment and making a difference regarding technology	CE/ Questioning computing, Critical, reflective stance	CE/computing concepts and computational practices
Music application paper prototype evaluation sessions	Playing the game with the concentration, enjoying listening the music loops, moving and playing with her fingers, showing pleasure and curiosity	Child-oriented way to play a game with papers, background voice and music in a confidential atmosphere wakes imagination	Common play with adults, personal quiding, changing the music, and paper screens and reacting to the Childrens movements	Empowering influence of playing prototype of the game; touching the sketches and moving them, listening and playing like piano player and moving	Spontaneous feedback and reactions when evaluating, asking spontaneous questions about content and functionality	Prototype evaluation, usability testing
Music and icon evaluation sessions (singing game)	Moving with the music, body rhythms, alone or together, participating in a playful environment having a red wig and big imaginative magnifying glass, crawling under the chair, mysterious sounds and atmosphere	Movement when listening, music examples supporting imagination, Icon evaluation adventure and playful surrounding and equipments	Music evaluation in a group, moving alone and together (boys connecting together)	Empowering evaluation through movement to music evaluation or playful equipments connecting to icon evaluation	Spontaneous feedback and reactions when evaluating	Visual and audio UI requirement specification, evaluation

concerned the design process alone or whether the product being designed also played an important role in the emergence of the findings. The results are presented in the following section.

3.1. Empirical findings

The following sections describe the participatory design sessions and the methods used for requirements construction, design and evaluation. First, the sections outline the role of play in the course of the sessions. Second, the sections discuss aspects on computational thinking and empowerment: (1) self-expression (see e.g., Runco and Cayirdag, 2013), (2) connecting with others (see e.g., O'Kane, 2008; Cohen et al., 2014), (3) empowerment and being able to make a difference regarding technology through participation in various kinds of computing practices such as requirements specification, design and evaluation; and (4) questioning computing with a critical, reflective stance (see Table 1).

Before starting the whole process, to enable play in all workshops, it was necessary to ensure in advance that the sessions were held in a natural environment for the children—in this case, a kindergarten. Before the actual design sessions, the research team played with the children and got to know the space and the necessary equipment. The daily kindergarten schedule was also taken into account. It was important to ensure that the sessions fitted into the everyday rhythms of the participating children and that the design sessions did not disturb the children's rest and eating rhythms. It was also important to ensure that there were no external stimuli and possible interruptions disturbing play during the sessions and that design environment was as playful and mobile (decorating, fabrics, and playful elements, stories, adventures) as possible.

3.2. Warm-up play and games

Every session with the children started with the children's play to create confidential contact and become acquainted with the children. The children and the research group gathered around a colorful carpet and sung and played a start song. Especially when the session was the first one or when there were new participants in the group, a name game was played and sung. After play, the children were given the information for the coming task and identified what equipment is used, if needed.

The play included gathering the researchers and children around an imaginative sun or cloud carpet. Play was a signal for a new start and a moment for checking on which participants were attending that day. Although the structure of the play session was quite constant, the play changed depending on the group and the nursery. Sometimes, we added body rhythms, motion, or extra equipment like a scarf or nursery rhyme bags to the games. Children enjoyed discovering body percussion rhythms to the songs, like clapping hands together or stamping feet

against the floor. In these exercises, the children used their imagination related to their stage of life, adding, for example, a somersault at the end of the song. It is possible to support children's imaginative worlds in different ways.

In addition to starting with songs and plays, the researchers organized adventure games for the children, which had two different purposes. First, they acted as an introductory task for the actual task. The first adventure was an exercise to open the voice and warm up the body for singing tasks. The purpose of another task was to become acquainted with the actual task environment (room for evaluating) beforehand in a playful way. The adventures had a special meaning, especially when the children were participating in the task alone with the researchers. Although all the sessions were organized in familiar surroundings in the nursery, it was easier for a child to come to the newly organized space when the child had got to know it beforehand.

When thinking about the developmental stage of children aged 5–6, it is very natural for them to be happy to play adventure games. In this case, the first task was a jungle adventure, where children were imitating animals and moving around according to the jungle story told by one of the researchers. At the start of the adventure, the children wandered under a gate and jumped to the jungle as an animal they could decide for themselves, such as "Anna ape" and "Marcus monkey." Moving around in the space and imagining different situations in the jungle is a comfortable way to get the children inspired and ready for the next exercise. Playful exercises help with social connecting, and at the same time function as a warm-up for singing.

In the other adventure, all the children wandered into a mysterious world and became acquainted with two places: a detective agency (the place for an icon evaluation task) and a secret cave (the place for paper prototyping). A researcher guided all children through those places and gave them tasks, such as "invent a secret word." The queue of children sneaked into a familiar room, played a mysterious game, and created a suitable playful atmosphere for the upcoming tasks.

These warming-up sessions belong as a crucial part for a technology design session. However, they are not directly part of computational empowerment, although there may be an empowering influence of these sessions, children being a part of a project together with adults. Emphasis in these sessions is on awaking and creating a contact.

3.3. Art and craft music toy prototyping session

The purpose of this task was to clarify the children's conceptions of music and music devices for the design group. First, the children looked at a stimulating video in which children of the same age played with an invisible musical device. The task was to sketch out and create from recycling materials their own personal magic music toy.

Sketching and making the prototype of the music toy was a very inspirational work for the children. They were enthusiastic about recycling materials. When sketching the music toys, the children did not play that much with their drawings, but the recycling materials, such as milk cartoons, cloth materials, egg cartoons, toilet paper rolls, and crayons, struck a chord. Some children even started playing with the paper sketches: "They are bass things, which batter pam, pam," and continued with their paper prototypes presenting at the same time the technique of how to play the toy: "It's a funny instrument, there are buttons, in which you can blow and hear the funniest sounds in the world." The playful ideas were presented to everyone after the session. In these creations, for example, a zither instrument had a human figure with the body and a face, a musical radio could walk, and many instruments had starting motors where pieces of plastic spoon functioned as the fuel. While the children played with their instruments in the design session, according to the nursery staff, this inspiring task continued in their play for a long time.

When sketching and making the prototype, it is quite obvious to mark the imaginative, self-expressive and social, connecting quality of this kind of session. This session empowers the participants to take part in development of technology by making sketches and prototypes and in this way indicating indirectly requirements for a music toy. These activities belong to requirement specification by using low tech prototyping with children.

3.4. Drawing sessions informing the design of the music application

The design process involved plenty of drawing tasks for the children. In this section, we focus on the tasks that contained elements of play for the participating children. When designing technology with children, it is natural to use drawings to check "Where are we now?" It is innate for children to draw their thoughts and feelings and, at the same time, make sounds, sing, and share their thoughts out loud. In a music-listening task concentrating on the relationship between emotions and music, the original purpose was to draw the sensations that the music awoke in the children. The music was chosen carefully for the task taking the developmental stage of the child into consideration.

When listening to music and drawing, the children concentrated on the task. Little by little, they started to talk to the researchers through their drawing, telling stories and playing with their pictures at the same time. "Here is a castle, and this dog and wasp go at home and they are looking at the window." One of the boys got very excited. He would have continued the story for a long time. When presenting his picture, he played by uttering the sounds coming from his painting: "Smoke, put, put, put." The children's design thoughts come in real time while drawing, not afterwards, as in an interview.

In another drawing session, the goal was to investigate the places where the children would like to be and with whom. The research team used a "stick man" drawing (Figure 1) as an impulse for the children to draw more. This was a success. The pictures the children created were colorful and detailed, and every child had a story to tell about their picture. One girl drew a princess, a chateau, a wall, and a horse, explaining that "those two are servers, and they are going to see the

FIGURE 1
"Stick man" drawing.

FIGURE 2
The jungle landscape.

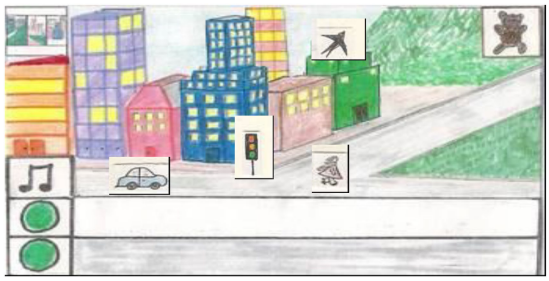

FIGURE 3
A screen of the composition game.

princess." Another girl drew a forest around the figures. She said, "They are in the forest at night. And they are going to pick some berries." Overall, the results showed that the children were interested in this kind of drawing task.

The project team tried another drawing fulfillment task with the children. This time, the aim was to draw different elements into a set of predefined landscapes. The jungle landscape shown in Figure 2 is an example that was used with the children. The children drew fantastic animals in their pictures, including three different monkeys, three different butterflies, three birds, and two lions. The pictures were also filled with coconuts, bananas, flowers, trees, water, etc. The pictures were very colorful and detailed, and the children told playful, imaginative stories when filling up the landscapes: "There is crab living in this coconut and its uttering sounds like click, clack, click, clack"; "This tree has a strange color, because the flower under the tree is singing"; "There are eastern eggs and bananas, where the lingo berry juice is coming, other colors have water on them"; "This lion and this butterfly are arguing yes, no, yes, no…!"

Throughout the design process, the research team investigated the children's relationship with the planned environments and their contents based on the drawing tasks. The children's drawings were used indirectly and directly in the game design. By involving children, the research team could find different kinds of solutions for, for example, the opening image of the game and the contents of the planned environments. Drawing is a natural way to engage in design with a child.

When considering computational empowerment, these sessions belong to the area of requirement specification and user interface design. Self-expression is clear when children are in their comfort zone drawing, creating, for example music and fulfilment tasks triggering their imagination. Connecting together with adults and other children support them as well to tell their narratives and at the same time indirectly to indicate requirements for a music toy.

3.5. Evaluation of the application of music improvisation

In the workshop focusing on improvisation, the research team tested the ideas of an improvisation game for the application with the children. Like drawing and moving, singing is also a natural way to talk with children. Using three different tasks related to creating a jungle story, creating a soundscape through singing, and completing a picture through music (singing) improvisation, the research group became acquainted with the children's skills in that musical area. After a playful run-through of names, the children concentrated on a jungle adventure, which was read aloud by one of the researchers. The story that had been written in advance began when all the children jumped through a gate into a fantasy jungle and created their animal sounds. The sound guided the child through the adventure. After playing, the first improvisation task started with using their animal sounds. The children were invited to utter their own sound to the rhythm and have it played on the background tape.

The next task was to create a song for the chord harmony played by the adult on a guitar. From several ideas, the children chose a soundscape topic, "under the earth." The children then created a song about different animals moving under the ground, and they added body movements to the song. The last task should have been reflected with the projector on the wall, but it did not work, and so the children sat casually on the floor, around a laptop with the adult. The close atmosphere had a positive influence on them playing together. At the beginning, the children saw a work in progress, a teddy bear without feet, hands, eyes, ears, etc., on the screen. The bear was waiting for them to complete its body parts. The only way to do that was to continue the song with adult accompaniment: "Once upon a time, there was a teddy bear, there was a teddy bear, which…." Every sentence that was sung to the bear brought up a new body part. The children enjoyed the task a lot. They sang aloud and moved excitedly when singing together. They shouted, "Yeah!" and clapped hands when new parts appeared on the screen. They liked singing the new song they had created together. They even jumped up and down with excitement.

When thinking about computational empowerment self-expressing when improvising and social connecting is almost self-evident when singing together in a close, safe atmosphere with music accompaniment and visual support on a screen. This preliminary task showed first an empowering way to work together in a design group and a way to contribute to requirements specification and design through own improvisatory part and second a children's way to give possible feedback through their spontaneous reacting when evaluating.

3.6. Music application paper prototype evaluation sessions

The purpose of the paper prototype evaluation sessions was to collect feedback from the children on the early designs the adult designers had produced during the research project. The research team played with the children with the laminated screens of the game (Figure 3). The prototype contained a composition game and a singing game. With the games, the children could sing songs; make, save, listen to compositions; and make video recordings.

The team had an operator responsible for running the paper prototype and a responsible person acting as a mentor, who was available

in the game. The child also had a personal guide. The main idea was that the child touched the screen and made their selections, pretending the screen was a real touch screen. Dragging was executed *via* small individual pictures (e.g., a car, traffic lights, girl, or a bird; see Figure 2), which were moved by hand across the screen. It was clearly seen that the children enjoyed listening to the music loops while playing the composition game. They were smiling and looking at the adults with enthusiastic faces. The children also liked making compositions by moving the little pictures into the white row. One girl liked listening to the song that she had sung so much that her enjoyment could be seen in her whole body. She was kind of dreaming while pretending to be a piano player. She rotated her shoulders, swayed in time with the music, closed her eyes, and moved her fingers against the table surface like a professional piano player. In some paper prototyping sessions, the children first wandered into the mysterious world and became acquainted with the secret cave that was the place used for paper prototyping. The children clearly liked the mysterious atmosphere and surroundings a lot.

Paper prototyping, one way for doing usability testing of technology, showed a children's approach to the playing the game. When thinking about computational empowerment, connecting with adults in the common play with those laminated, playful paper pieces with background music files awakes children's imagination and self-expressive behavior such as enjoying and fingers playing piano. Empowering influence of the playing prototype, being able to touch the sketches and having the power to influence the course of the game captures the kids' attention and inspires them to react spontaneously and give some casual feedback.

3.7. Music and icon evaluation sessions (singing game)

In the music evaluation session, the children were told that they would hear nine music loops and that they should keep their eyes closed until they had figured out what came to mind when listening to the music. The children were also encouraged to start moving with the music at the same time. It seemed that the exercise was easy to understand and that the children were enjoying it. The boys were moving more comprehensively, so it seemed that their imaginations were flying more freely than those of the girls. However, the girls seemed to like the session as well, but they were perhaps enjoying the music more individually, while the boys enjoyed it together. After every music loop playing, the children were asked what issues came into their minds related to the music. Then, one researcher drew the children's opinions on a piece of paper. The purpose was to determine whether the chosen pictures were clear and unambiguous and whether they guided the children to the right songs in the game.

In the icon evaluation session, the children had become acquainted with the place through the adventure game described earlier. This session evaluated whether the song icons produced by a graphic designer were clear to the children. They were asked two questions: (1) What do you see in the picture? and (2) Which song came to your mind? The children were advised to crawl under a chair to the mysterious detective agency. At the agency, they got a big magnifying glass (without real glass) and a red wig to wear (see Figure 4). They could participate alone or with their peers in the task.

Although for adults, it would probably not be very enjoyable to crawl under a chair through a tight funnel to an evaluation session, the children seemed to enjoy it (see Figure 4). The mysterious atmosphere from the adventure game continued during the evaluation. The adult interviewing the children also changed her voice to be a little softer, and she asked questions in a mysterious way, which inspired the children to participate in the task and to concentrate on the questions. A red wig, functioning as a detective hat, also helped the children focus on the task in a playful way. Although the magnifying glass was made of pasteboard, it was very easy for the children aged 5–6 to imagine that it was real, even though the glass did not make the icons bigger. The children looked through the magnifying glass and sometimes swung it before their eyes. It helped the children concentrate on evaluating the current icon. Altogether, the mysterious detective agency was a shared game for the child and the adult. The children enjoyed playing together and being experts in the evaluation.

In computational empowerment area these sessions belong to visual and audio user interface requirements specification, in which the children took part in evaluating music and icons for the game design. Self-expression is self-evident when moving with the music examples or having an imaginative surrounding with playful equipment instead a clean office room. Connecting together with other children when evaluating through movements or with adults when playing together in an evaluation space have an empowering influence on children through play. And there is a possibility to get spontaneous feedback for the game design.

FIGURE 4
The wig + magnifying glass (left) and a chair as a door to the evaluation space.

4. Discussion

In this paper, we focused on the computational empowerment of children from the viewpoint of practices relating to development of digital technology, particularly through participatory design methods. We explored a set of participatory design methods for requirements construction, design and evaluation with children and children's play within. We offered an illustration of the sessions in which play was experienced by the participating children. Next we offer recommendations on what should be considered when designing technology with children and in computational empowerment of children. First, we present practical implications based on our results on the analysis of the role of play, after which we discuss their significance and nature through theories.

4.1. Theoretical and practical implications

Next, we discuss how play can be integrated into participatory design with children. We maintain that in participatory design, play

should have a significant role when working with preschool as well as with older children. We point out how play facilitates children's computational empowerment and enables their participation in and contribution to computing in a natural and engaging way. We have shown how play was an integral part of the participatory design sessions we organized with children. In our study, the significance of play can be connected to several issues before and during the participatory design sessions. Based on our experiences, we recommend the following:

Before the participatory design sessions:

- Hold sessions in a natural play context (kindergarten) and play circumstances (rhythm, rest, and nutrition).
- Exclude external stimuli and interruptions disturbing play.
- Build a playful and mobile environment (decorating, fabrics, playful elements, stories, and adventures).
- Create confidential contact with children (child–adult interaction).
- Become acquainted with children and know their names (familiar adults).
- Rely on playful guiding and songs that are natural for children.
- Gather and check on the participants.
- Provide information on upcoming tasks.
- Prepare children for the design process.
- Identify what equipment is needed.

During participatory sessions, use play:

- As a signal for a new start and an introduction to the next task (motivation).
- As an exercising task for the following task (iterative design).
- To support the developmental stage of children (age-appropriate participation).
- To create a comfortable way to get the children excited.
- To create a basic structure for the session (possible to change and improvise).
- To check, "where are we now?" (development process).
- To help children concentrate on a given task.
- To connect children together.
- Awaken children's imaginations (stimulus).
- To support children's self-expression.
- To find children's movements, stories, spontaneous sounds, and songs.
- To evoke children's ideas (through drawing, singing, role playing).
- To test and evaluate design ideas in a playful way, and collect feedback.
- To help utilize different kind of equipment belonging to test and evaluation process.
- To enable embodiment and playful behavior.
- To support children's mood and state of alertness.
- To bring information about children's skills to work together.
- To give adults possibilities to merge with children (adults' active presence, shared game).
- To get close to children and the world of children.
- To maintain a safe and confidential atmosphere.

This article has shown that play is important in the computing education of children, confirming the existing conception of its relevance in a variety of everyday life contexts. In line with several other researchers (e.g., Dix, 2003; Mansor et al., 2009; Verenikina and Herrington, 2009), we recommend play as an aspect to be offered for children, as regards the digital products they use, as well as the design sessions they are invited into.

Our sessions offered the children play experiences during the requirements construction for and design and evaluation of digital technology and demonstrated the computational empowerment of children; children were empowered to have a voice and a say and build their competence in the design of computing (see Iversen et al., 2018; Dindler et al., 2020). Related to supporting play, we suggest that it is important to have interesting, diverging forms of play, such as movement, hand, and finger play, sound and voice play, and word play. The seven different play features—physicality, emotionality, sense of community, functionality, narrative, creativity, and ingenuity as presented by Hyvonen (2008, 2011)—as well as the different aspects of playfulness—pleasure, spontaneity, curiosity, imagination, and the sense of humor as presented by Guitard et al. (2005, p. 12)—support this interpretation.

We advocate for participatory design and play, both in activities *within a group and alone*. For children, the possibility of playing and improvising alone should be supported so that they are not only working with other children. This is easily accomplishable during technology design and evaluation. It is also important for children to play with adults. According to various research studies (Vygotsky, 1978; Helenius and Savolainen, 1996; Kalliala, 2006; Heikkinen, 2010) related to play, it is important for the adult to be involved in the children's play in some way so that the interaction between them will develop as early as possible. However, Kalliala (2006, p. 26) stated that children's play culture flourishes in places that adults do not reach, while other researchers (Helenius and Savolainen, 1996; Heikkinen, 2010) have discussed the possibilities of play when working together. Playing together, such as parental involvement at home, contributes significantly to children's development and growth (Heikkinen, 2010; Zhang et al., 2022). In the technology design process, play is a method of discussion for children and adults. At the same time, play develops children (Vygotsky, 1978), and performing duties with adults or older children improves children's cognitive development compared to independent performance. This thought supports the close presence of adults when playing in the design sessions, although the adults will continuously be reminded of their limited ability to catch the children's experiences (Gray, 2011). Even if connecting with others has been connected with computational thinking of children (Brennan and Resnick, 2012) it has been so far considered from the viewpoint of connecting with others while using computing, not while designing and developing it. Although we acknowledge the requirements specification, design and evaluation methods to be used with children oftentimes rely on collaboration among children and with adults (see e.g., Druin, 1999; Guha et al., 2004; Kelly et al., 2006), this is an aspect that should be considered in more detail in the literature on computational empowerment (see Iversen et al., 2018; Dindler et al., 2020).

Embodiment is also an evident theme in our empirical data, in which the children engaged in the participatory design and thereby strengthened their computational empowerment. When singing, the children enjoyed creating different body rhythms, and their movements seemed to support their singing. When drawing, the children showed with their fingers, as if to say, "This is magic." When listening to music, the movement of the children started immediately if nobody prevented them from moving. Movement was also emphasized in the research diaries kept by the research team: "The children start to sing, jamming and jiggling their bodies to the rhythm." Moving and embodiment are

parts of multimodal interaction (Haddington and Kääntä, 2011). As Viljamaa (2012, p. 178) and Paju (2013) underlined, children use their senses and body movements to create new things. When designing with children, it should be taken into consideration that they communicate through embodiment and movement. This area connects with a perspective in the field of CCI research, which should be kept in mind: embodiment and physicality are ways for a child to participate. Observing the things that the child does and says are key issues when trying to obtain reliable research information on play. The child's body language tells more than words ever can.

As for children's self-expression in relation to computing, seen as a dimension of computational thinking of children (Brennan and Resnick, 2012), we wish to underscore it as an integral part of design and development of technology, not only related to its usage. We identify children's narratives and their creativity and imagination as associated with self-expression and as significant features in children's play. When discussing with children in the context of the participatory design of digital technology, their *narratives* burst out and had no clear form or structure. The stories started from somewhere and seemed to have no end. The children's narratives reflected their manner of being in a world. When children tell stories in their natural surroundings, the stories are like actions moving in many directions at the same time (Viljamaa, 2012). The narratives also highlighted the children's rich imagination: "This tree is a strange color because the flower under the tree is singing." The significance of ideation in narratives is essential. Children do not necessarily tell what happened but rather what could have happened or what they would hope, believe, or like to happen (Viljamaa, 2012). The data also show areas that were hidden from the adults. Occasionally, the adults could only get some suggestions of the existence of those areas: "There are some instruments inside, but I cannot tell about them; they are secret." Children's narratives make an appearance heterogeneous and resemble hints (Viljamaa, 2012), which implies that the attendance of an educational specialist is important in participatory design sessions with children.

Creativity and imagination arose as connected, significant themes when working with children in the participatory design of digital technology. Children's ideas are very evocative, and they enable their self-expression and interpretation of reality. The children's ideas became concrete in a variety of different workshops in their drawings, paintings, handwork, stories, play, plans, and music (see e.g., Tikkanen and Iivari, 2011). Creativity is mind-occurring thinking, which becomes visible in the children's actions and outputs (Hyvönen et al., 2007). As stated in the workshops, a child's creativity and imagination can be supported by age-appropriate work and it can be awakened with various, especially art based triggers that support the child's action (see blinded). In this research, as an interesting detail, ripped pieces of paper and recycled materials, which the adults considered trash, were treasures for the children. In addition to utilizing art based methods, we recommend using recycled materials because, in our sessions, they seemed to provide a playful basis for the children to start creating and innovating for novel technology now and in the future like Russ and Doernberg (2019) states:" There is great potential pretend play activities to help children to develop processes that are important for later creativity" (p. 615).

Even though supporting play is highly recommended, researchers should keep in mind that every child is different and sees their surroundings differently. It is important that adults support and encourage children as individuals, as some children need more support and encouragement. Therefore, when conducting such research with children, there needs to be someone from the research team sitting near the children to serve their needs and share their moments. An important issue is that the children and the research team members get to know each other well enough before the sessions. Children will feel comfortable and safe when surrounded by familiar adults.

It is highly significant to react to the play in an age appropriate way and take it seriously as an essential part of child's life. Although children's play is very natural and goes on at its own pace, there is also something to be protected from the adult's point of view. A child's play should be handled as a sacred and serious thing for a child (Huizinga, 1955; Heikkinen, 2010). Play reflects the uniqueness of the child in relation to the adult. Furthermore, it is important not only to support play during the participatory design sessions, but also to keep in mind that those plays may continue in the children's lives for a long time. In our case, the art and craft prototypes created in the design session were reported as being part of children's play long after the design sessions. For computational empowerment of children, we consider it essential to study such natural, joyful, spontaneous reactions and usages – they may reveal us interesting issues about children's relationship to computing. They may even offer evidence of a critical and reflective stance towards computing, if analyzed carefully.

Our experiences show that in the participatory design process, it is possible for researchers to throw themselves into different play situations with children. Digital technology design is one way to listen to children, and this should happen as an interaction between an adult and a child playing in a safe and confidential way. Regarding participatory design with children, play should be an integral element, as children's participation, if allowed to emerge naturally, happens especially through play. Overall, we maintain that play combined with participatory design enables the computational empowerment of children; play enables children to take part in and contribute to the complex world of computing in a natural and engaging way. In particular, play empowers children to make a difference in the computing context, and play can be used for facilitating expression and connecting with computing; play encourages children's self-expression and collaboration (*cf.* Brennan and Resnich, 2012; Iversen et al., 2018; Dindler et al., 2020).

Overall, this study contributes to the literature on the computational empowerment of children (Iversen et al., 2018; Dindler et al., 2020) as well as on the computational thinking in education (Wing, 2006; Barr et al., 2011). As for the latter, this study broadens the view on what computational thinking entails, in line with Brennan and Resnick (2012) and (Iversen et al., 2018; Dindler et al., 2020). Computational empowerment includes a variety of practices relating to development of digital technology for others and reflecting on digital technology developed by others as well as expressing, connecting and questioning in relation to computing. We suggest for researchers interested in computational thinking in education to better acknowledge these practices and perspective as they are critical for the children of today, among other aspects of computational thinking. We also wish to highlight expressing and connecting as significant dimensions of technology development practices, not only of their use practices (as in Brennan and Resnick, 2012). As for the contribution to the literature on computational empowerment, we enrich the approach (Iversen et al., 2018; Dindler et al., 2020) toward an even more child-centered form, toward an even more engaging, meaningful, natural, joyful, and exciting approach—through play, which has not yet received the attention it deserves in this literature base. Also, the literature on computational thinking benefits from our insights on play, as play facilitates expressing,

connecting, and questioning in relation to computing in valuable ways (Brennan and Resnick, 2012). Moreover, we think that integrating play into education on algorithmic thinking, coding, pattern recognition, and logical reasoning, i.e., on the more traditional topics of computational thinking education (Angeli and Giannakos, 2020), is also useful. However, our study does not provide empirical insights in that regard.

4.2. Limitations and paths for future work

The definition of play is not self-evident. Play is a concept that has been defined in several different ways. Play nevertheless governs the whole life of a child. Researchers can only interpret play situations from their point of view. In this research, existing theories have been utilized when searching for, inspiring, participating in, and making sense of play. In the future, there are many possibilities to explore our participatory design sessions from other perspectives or to examine, even at a more detailed level, the elements of play, perhaps even focusing on one element at a time. Regarding our research material, although it was gathered from several workshops, these are still only examples from certain nurseries. Children are also individuals, and the customary manner of practice varies from one place to another. When working with children, it is important to adjust the existing methods to the current situation, taking the surrounding conditions into consideration. All in all, paths for future work include deepening our research on the topic. There is a need to develop, evolve, and perfect the methods used and to test the same ideas in different places to confirm the observations. There is also a need to augment computational thinking education with playful methods. Programming and computer science lessons can also be playful and include play for older participants, and even for adults. There are plenty of avenues for future work in this respect. For researchers interested in carrying out similar kinds of work to that reported in this article, we emphasize the importance of making several video recordings of the sessions. Body language and facial expressions provide invaluable real-time research data for researchers interested in supporting play when designing with children.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

In the design project that served as the basis for this study, each author had a significant role. The first draft of the manuscript was written by RT and NI, who also contributed to the study's conception, design, methodology, and analysis. The theoretical portion of the paper was co-written by all the three authors. In similar, the submitted and revised versions of the manuscript were prepared and approved by all authors.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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