Ready, Steady, Move! Coding Toys, Preschoolers, and Mobile Playful Learning

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Abstract. This paper introduces a study focusing on preschool children's employment of coding toys as a part of their daily play activities. Twenty preschoolers, aged 5–6 years, and their preschool teachers participated in a three-month study of playful learning and the STEM topic of coding. The main interest was to explore how preschoolers explore, utilize, and challenge the hybrid play affordances of the Dash robot, in relation to coding exercises, and how their teachers concurrently expanded their own knowledge of how a contemporary smart toy can support the learning of 21st-century skills. We approached this two-part research question through a multimethod approach, including diary methods, thematic teacher interviews, and an analysis of preschoolers' own videos of their play sessions. The findings of our study highlight the mobility aspect of the playful learning of coding with Dash. Our study also shows how preschoolers quickly learned to build obstacle courses for Dash by coding them with an app on an iPad, and how the movement of the toy inspired the preschoolers to come up with new play ideas, incorporating themselves as players. In light of these findings, the authors suggest that coding toys, such as Dash, can be evaluated from the perspective of mobile playful learning, which centers around the use of interactive, smart, and mobile toys. Our study also shows that these toys playfully invite and encourage young learners to physical activity while they learn the logic and skills related to coding.

Keywords: Internet of Play · Mobile playful learning · Coding toys · Internet of Toys · Physical activity

1 Introduction

The *Internet of Play* refers to a future in which smart playthings not only relate one-on-one to children, but also represent screenless toys and other interactive experiences that are wirelessly connected to the Internet. Key affordances of the so-called Internet of Toys (IoToys) include linked interaction that is guided by sound, light, and movement. Many of these contemporary, connected toys are, thanks to their technological enhancements, suitable for use in the early learning of STEM subjects, including coding. Furthermore, most of the IoToys, which both enable movement and function as a tool for teaching coding, are composed of playthings that are mobilized by the players through commands simulating coding language. Some of the toys, such as the Dash robot, are coded by the players to move through obstacle paths using an app. Earlier

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studies have demonstrated how elements of the IoToys, such as the coding toy that Wonder Workshop's Dash robot represents, facilitate skill-building related to 21st-century skills such as multiliteracy and transmedia play [1]. In our understanding, coding, as a part of current STEM education, develops capabilities in problem-solving and ludic literacy—playful communication skills essential for understanding how technologies work in the current landscape of playful interactive media.

Play itself, often recognized as the "work" of children, is a "primary affective motivational" activity that facilitates the development of different skills [2]. During the past few years, playful learning, gamified education, and digital learning materials have gained growing interest among Finnish educators [3, 4]. Besides the activity of playing, there is an interest in integrating physical activity into different school subjects. Play supported by gamification, physical activity, and experimental approaches in early education have been highlighted as important means to facilitate playful learning and to strengthen the possibilities of thinking creatively. Physical activity has also been categorized into physical, social, and mental performance, guided by play, the playing of games, or both [5]. In this way, play and games function as tools in the learning of various subjects. For example, according to Downess, the playing of games on the streets steers learning styles toward active exploration. A major part of this playful learning is guided by the use of technologies [6]. Preschoolers—in the context of our research, Finnish kindergarten students between the ages of 5 and 6 years—are very familiar with mobile technology. For example, in some kindergartens, preschool-aged children are being introduced to the use of tablets on a daily basis as part of early education.

This study focuses on the mobility aspect of coding toys, which are an emerging sub-category of the IoToys. Our aim is two-fold: first, in addition to investigating the evolution of play in the digitalized world, our goal is to understand the universal educational value of coding toys as tools for playful learning. Second, we are interested in the toys' particular value for the Finnish early education curriculum. This paper presents a case study in the use of coding toys as a part of playful learning in Finnish kindergartens. In our study, 20 preschool-aged children, each of whom had their own tablets in kindergarten, engaged with the Dash robot over a three-month period. The preschool teachers used this coding toy with small groups of children by first introducing the toy, and then giving the preschoolers an assignment to code with Dash. The preschool-aged children coded the toy using iPads through a coding app, and made the toy move along trails.

The article is organized as follows: we first explain the concept of *playful learning* and describe how current elements of the IoToys, such as coding toys, may be viewed as edutainment that belongs to the ecosystem of connected play, or what we call here the Internet of Play. This is followed by a discussion of the Internet of Play, with a special focus on the learning context and the role of the IoToys in early education. We then present our case study of coding toys, as a sub-category of the IoToys, used in a preschool context. We describe how teachers have used Wonder Workshop's Dash robot toy in early education, and how preschool children have responded by using Dash in their play. In the subsequent section, we discuss the results and limitations of our study and propose further ideas for what should be considered when using coding toys in future preschool education. Finally, we suggest how the phenomenon under scrutiny could be studied in the next phases of research.

2 The Internet of Play as a Context for Playful Learning

The Internet may be viewed as a worldwide playground that presents plentiful opportunities for learning. Play is considered an important part of learning processes, and teachers' responsibilities to facilitate play in preschool learning was elucidated in Scandinavian curricula as early as 1998 by, for example, the Department of Education in Sweden and the Stockholm Ministry of Education and Science. The Department of Education has also pointed out that play and joyful learning stimulate several abilities, including fantasy, empathy, communication, symbolic thinking, collaboration, and problem-solving [7]. The Internet of Play as a learning setting refers to (1) learning that allows, stimulates, and promotes learner creativity and knowledge-collaboration working skills; (2) learning exercises using tools, such as the IoToys, for "edutainment" purposes; and (3) promotion of learning through a variety of playful and physical activities.

Kangas described playfulness, creativity, narration, collaboration, insight, emotions, embodiment, and activity as central to creativity and playful learning. Playfulness refers to an attitude toward learning and a way of learning through play and games within the playful learning environment (PLE) [8]. Creativity refers to creative knowledge that may be developed by learning how to use new technology, such as connected or "smart" toys and games [9]. Narration refers to a storytelling mode of thinking and understanding as a key aspect of meaning-making [10–12]. One way to make sense of experience and the world while learning is through narratives; by using the possibilities of the Internet of Play, we can become involved with global narratives.

Collaboration emphasizes co-design, knowledge co-creation, and play processes. Collaboration helps and motivates children to learn and engage cognitively [13]. Insight refers to the opportunity to explore and solve problems [14]. Emotions are involved in all human activity, which give them a key role in thinking and learning [15, 16]. Embodiment and activity refer to physical activities in which children use the whole body in the learning processes through which embodied knowledge can be achieved [17].

There are many opportunities for social play, whether competing against each other or collaborating to achieve a common goal through physical activities. This can involve having fun with technology, whether it be in peer-to-peer play or collaborative play on tablets with smart toys, or in how children play together and become involved in physical activities. Today, the IoToys have extended children's desire to play with smart toys and coding toys, which makes it possible for children to create their own culture through the Internet of Play, with the help of some guidance from teachers and parents.

2.1 The Internet of Toys and Coding Toys

This paper discusses the IoToys, with a particular emphasis on coding toys, within wider theoretical debates about the affordances of new digital materialities and their employment in toy-based learning. To understand recent transformations of children's digitalizing play practices, following Berriman and Mascheroni, we suggest that it is necessary to consider physical toys' capabilities for connecting to wider digital ecosystems.

The IoToys "has brought talking dolls, interactive pets, and programmable robots into western children's play worlds" [18]. Producers of these contemporary smart toys enhance physical toys with features such as sensors, speech-recognition, and network connectivity and, in this way, offer new interactive and personalized play experiences [ibid.].

Smart toys have also become the subject of increasing research interest. Previous research has focused largely on the suitability of the IoToys in education (see e.g., [1, 19–26]). This paper contributes to this growing research field by proposing new ways of theorizing coding toys in early education as a sub-category of the IoToys. Researchers claim that the IoToys have significantly transformed how children and toys interact, giving rise to new forms of play that challenge boundaries between the material and digital. Moreover, the IoToys increasingly share characteristics with domestic media and computing devices [18], such as the Dash robot. The robot has multiple apps, one of which is the Blockly App, which is in standard use in elementary schools and recommended for children by Code.org. With Blockly, "your child or student can take on coding challenges and make their own programs for Dash. […] you can create your own dance, record your voice, and have Dash play it back, play tag, or even program Dash to follow you around. With the new tutorial section, it is possible to program with no previous experience". [27] While this programmable robot is sold directly to families, Dash and its counterpart, Dot, have become part of schools' curricula and coding clubs. According to Kolodny, some 8,500 schools are now using Dash and Dot around the world for such purposes [ibid.].

In recent years, new learning standards and best practices for integrating technology into early childhood education have gained more interest [28]. To teach technology and engineering to young children in a developmentally appropriate way, robotics and computer programming initiatives have grown in popularity among early education researchers and educators [29]. Earlier research has shown, for example, how the field of robotics holds special potential for early education by facilitating both cognitive and social development [30]. Recent research suggests that children as young as 4 years old can successfully build and program simple robotics projects, while learning a range of engineering and robotics concepts in the process [31, 32]. Using coding toys and computer programming in early education has been claimed to support cognitive and social development; studies with the text-based language *Logo* have, for example, shown that computer programming can help young children with a variety of cognitive skills, including number sense, language skills, and visual memory [33]. It is notable how many robotics activities do not involve sitting alone in front of a computer; rather, they encourage play: robotic manipulatives allow children to develop fine motor skills and hand-eye coordination while also engaging in collaboration and teamwork [34]—a finding that the current case study with Dash also supports. For instance, Dash encourages children to move physically, such as running after the toy. Furthermore, when children learn a programming language, they are not "just learning code, they are coding to learn" [35].

Fig. 1. (On the left). The coding toy Dash by Wonder Workshop moves fast.

Fig. 2. (On the right). Dash is coded to move along paths created by the players.

2.2 Playful Learning

Playfulness, as a part of the learning process, is a broad and complex phenomenon; it involves the learner's attitude, orientation, engagements, and capability for collaboration. "Playfulness as an orientation to activity also has a misbehaving stance, a disposition toward joking, breaking rules, pushing the cover of normal modes of activity, an alternation between serious intent and non-serious probing of possibilities" [36]. In learning, playfulness refers to the learning actions and their qualities [37]. Related literature suggests that playfulness is assumed to have positive effects on learning in different playgrounds; at various school levels, as well as learning in working life [38]. Kangas defined a PLE as a pedagogically validated learning environment that combines information and communication technologies both in the classroom and in the outdoor playground. A PLE is the basis for a variety of learning experiences in local schools, as well as in Internet games, which offer opportunities for learning in globally created learning environments [8]. The point of departure for our study was to evaluate preschool children's play practices and coding exercises with the Dash robot (see Fig. 1). What guided our interest was an investigation of the creative and playful learning processes for which the use of the toy provides. In this study, we extended the PLE to the context of mobility and investigated how preschool children explore, utilize, and challenge the affordances of the coding toy. We were also interested in how preschool teachers build their knowledge of how contemporary smart toys support the learning of 21st-century skills, such as coding.

3 Methods

3.1 Goal of the Study and Research Questions

The goal of the study was to investigate preschool children's play and learning, and their teachers' experiences with a coding toy in an early education setting in Finland. We sought to examine how children approach playful learning with a coding toy, and to contrast the use of the coding toy Dash in learning processes that are based on edutainment, collaborative education, and playing, with a typical coding classroom in which children are usually sitting on chairs.

In our study, we asked the following research questions:

1. How do preschool-aged children play and learn with a coding toy in the context of early education, given opportunities to use the toy in playful learning both (a) solitarily and (b) socially?
2. To what kinds of new knowledge does a coding toy like Dash contribute for preschool teachers, when used as a tool for toy-based learning?

3.2 Research Design, Data Collection, and Data Analysis

In this study, we have used a multimethod approach to understand the complexity of coding toys' play and educational value for children. We used the diary method by creating a Google Drive diary for the preschool teachers, which we followed and analyzed over a three-month period. In the diary document, the teachers wrote about their experiences of the coding toy itself, how they used the toy as a part of their early education processes, how the preschool children played with the toy, and what they learned from playing with the toy.

The study also employed research material collected by the two teachers, who photographed and videotaped the children playing with the Dash robot. The preschool children also made videos of each other playing with the coding toy.

The multimethod approach allowed us to conduct both a narrative and visual analysis of the data. We also analyzed the material using content analysis. The rich data set gave us a comprehensive overview of how the coding toy was used in the Finnish early education environment and a firsthand understanding of what kinds of values the coding toy communicated while being used in playful learning. We analyzed the data using content analysis to form a holistic perspective of the value of coding toys for playful learning. We also compared the children's testimonials of their memorable experiences with the coding toy, which gave a holistic overview of their perspective, especially in terms of how they explained their encounters with Dash the robot, such as the play scenario in which they ran around following it.

3.3 Participants

The study was conducted between November 2018 and February 2019 with two preschool groups at a Finnish kindergarten. The participants (N = 20) were 5–6 years old. All children had their own iPads during their year in preschool, which they used daily for both entertainment and edutainment. We gave the preschool two smart toys—Wonder Workshop's Dash robot and Fisher-Price's Smart Toy Bear—to use in preschool education. In this part of the study, we focus on the programmable Dash robot, which is considered a coding toy. First, the participants were introduced to the coding toy and guided by the researchers to use the *Path* app on their tablets. Smaller groups of children (3–5 participants) then started to play with the robot and practice the coding, which they continued over the three-month research period.

4 Results: Play in the Mobile Playful Learning Environment

Collaborative problem-solving, in combination with play, encourages children to learn. The flipped classroom is a recently emerged and popular technology-infused learning model. Hamdan et al. offered the following definition: “In the Flipped Learning model, teachers shift direct learning out of the large group learning space and move it into the individual learning space, with the help of one of several technologies” [39]. In other words, this is a learning model in which content attainment shifts out of the normal classroom into the mobile context, such as in our case study, which used a coding toy with mobile app-enabled activities.

To analyze the content attainment and application stages of playful learning, we used Bybee’s 5-E learning cycle. The 5-E cycle consists of five instructional phases, which we applied to the insights collected from our research materials related to the *mobile playful learning environment* (MPLE), which we also refer to as the Internet of Play [40]. The first three phases (engagement, exploration, and explanation) facilitate content attainment. The elaboration phase is when preschoolers apply the concepts they constructed in the content attainment stage, and represents the concept application stage [41]. We use these phases to elaborate on the results of our study:

- *Engagement*: The preschool children used the Path app to program the robot using a single line of code on an obstacle course of their own. The preschoolers engaged with Dash by coding the toy, and in so doing made other children run after the toy, and to create obstacles for it (see Fig. 2). In this way, the children discovered “fun learning” experiences by familiarizing themselves with coding.
- *Exploration*: The Path app allowed the preschool children to explore the educational content of the toy and to construct their own understanding, before introducing what they had learned to the other children. In this case study, the preschoolers actively engaged with the coding toy to explore educational patterns (coding exercises), and they also employed the flipped classroom approach by teaching other children what they had previously learned.
- *Explanation*: By playing with the Dash robot through coding exercises on the Path app, the preschoolers learned new ways to code and collaborated by teaching their peers how they had played with the robot. This showed how the preschoolers could link their own constructions to facilitate collaborative knowledge-building.
- *Elaboration*: The coding with Dash also gave the preschoolers the option to learn more about coding if they wanted to create more elaborate obstacle paths for the robot. The preschoolers also wanted to film their own play with Dash and to make short videos of their coding exercises. One of the observations we made was that when a preschooler learned something new, he or she wanted to share this with others, who then wanted to do the same. Creating videos with Dash also demonstrated the children’s willingness to participate in the creation and sharing of documentation of play and, in this way, to participate socially in contemporary play culture.

- *Evaluation*: Coding with the Dash robot serves as an example of the engagement with the Internet of Play, which can take the form of both formative and summative assessments that test preschoolers' understanding of the concepts they have just learned. In this case study, the evaluation took the form of children videotaping their own memorable experiences of the coding exercises and free-form play with the Dash robot. In the research materials collected, the participants described learning coding, teaching others, and creating new games with and for Dash, and for the other children.

4.1 Modes of Mobile Playful Learning: Solitary and Social Play

This study shows that the participating preschoolers experienced *mobile playful learning* when engaging with the coding toy Dash. The engagement happened in three ways: (1) the preschoolers interacted with the Dash robot solitarily through bodily motion (they made eye contact with Dash, which has sensors and voice recognition); (2) the preschoolers coded their own trails and made Dash move; and (3) the preschoolers became socially mobile by running after Dash and trying to catch it, or by coding obstacle paths for it together with other children. Through these forms of engagement, the children not only learned themselves, but also started to teach their peers and, in this way, used what they knew in the flipped classroom approach.

The findings of the study show that by far the most engaging aspects of play were connected to social interaction with Dash, when one child controlled the tablet to move the Dash robot, and the other children in the group ran after Dash. The preschoolers also made their own rules of play for coding the Dash robot's path. For example, they decided that one child would code for about 10 or 15 min, after which it would be someone else's turn, and the first child would get to run after the toy. This example shows how the preschoolers innovated their own play patterns for coding in the mobile playful environment. The children also started to use the flipped classroom idea by teaching others coding, thereby engaging in social playful learning and learning in a collaborative way. The findings of our study also show how the preschool children who participated in the coding exercises became physically active and learned social communication skills while playing with the Dash toy. It is therefore possible to claim that the preschoolers not only became physically mobile, but also became socially engaged by making their own rules for play. This activity, which the preschoolers created themselves, resembles gameplay. Taking turns by changing the person coding, so that everybody gets to run after the toy, is reminiscent of many games in which players alternate. This example illustrates how the preschoolers, while playing with Dash, came up with a gamified exercise by coding the Dash robot to become part of mobile playful learning.

The main contribution of this study is the finding that Dash, as a coding toy, enabled children to become physically mobile in group exercises in which one child was coding and the others were following the Dash robot by running after it and discovering where the toy was heading next. It is therefore possible to claim that the coding robot improved the wellbeing of the preschool children by activating them in various cognitive, social, and physical ways.

This study has also shown that coding toys, such as Dash, increase collaborative physical activity because they mobilize young learners not only through solitary, but also social forms of play. At the same time, it is important to understand that, by coding the toy while playing, the participating children were involved in physical, educational, and technological activities while participating in a learning process. In summary, mobile playful learning that happens with the help of the children enables them to actively take part in learning within a framework of creation, exploration, collaboration, and play.

5 Conclusion and Future Studies

In our study, the researchers allowed two preschool groups to interact with the Dash robot for a three-month period. Our aim was both to create possibilities for free-form, or open-ended, play, and to prompt playful learning by guiding the preschoolers to use the Path app to code different tracks for the Dash robot. In this way, free play, supported by early education professionals, merged the playful learning context with the curricular goals of learning 21st-century skills, such as coding. The results of our study show that, when given a coding toy and allowed to freely interact with it, preschoolers start to learn by themselves by exploring, utilizing, and challenging its hybrid (digital–material) affordances for play. In terms of Bybee's 5E learning model, they are able to engage, explore, explain, elaborate, and evaluate their mobile playful learning experiences.

These findings illustrate how a coding toy, like Dash, suits the goals of the Finnish early education curriculum, which states that exercise should happen at all stages of primary school in a playful way [5]. This paper presents a novel approach to the understanding of the use of coding toys in mobile, playful learning, in which the preschoolers themselves innovated gamified and physically activating approaches. The preschoolers who participated in the study could, in this way, take control of the learning situation by using creativity to employ the coding toy in engaging, mobilizing, and social ways.

As the results of our study have demonstrated, the use of an MPLE, such as the Internet of Play in combination with a smart coding toy like Dash, may be an excellent way to combine situated and active learning with fun in the context of early education. Thus, the learning potential of using coding toys lies in the possibility of embedding educational goals (like the ones related to learning the logic of coding, collaborating, and being physically active in group play in a mobile learning environment), enhancing engagement (using a coding robot to mobilize the children), and fostering learning (by taking on new challenges, such as coding more difficult obstacle paths for the toy) outside traditional and formal educational settings (such as the flipped classroom approach).

Mobile playful learning constitutes an expanding research domain. The main scholarly contribution of this case study is in the use of a coding toy as part of a mobile playful learning process enhanced with toy-based approaches, which had a positive effect on young learners' physical activity. Our study shows that coding toys, such as Dash, can be useful tools in engaging children as young as 5–6 years of age to simultaneously learn about coding and be socially mobile. In future research, we aim to introduce preschoolers to another coding robot, Botley, to determine if this alternative toy invites and encourages preschoolers to code and move, as Dash did, and further, to deepen our analysis about how these coding toys, as part of the IoToys, can enhance children's wellbeing, physical activities, and coding skills on a more general level.

According to recommendations given for physical exercise by the Finnish authorities, children and youth aged 7–15 years should be physically active for more than an hour each day. A recent study has shown how only around a third (38%) of Finnish 7–15 year-olds reach this goal [42]. Consequently, the authors would like to start a dialogue about the usefulness of toy-based learning with smart coding toys, combined with mobile playful learning, for age groups beyond preschool.

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