Blocks as Symbolic Tools for Children's Playful Collaboration

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Abstract. This paper reports on two intervention studies conducted in two Danish kindergartens where a Digital Manipulative (DM) was investigated in relation to children's interactions, experiences and playful processes. The DM, in the form of physical blocks was developed following a user-centred design approach. Research indicated how children's interaction with the physical blocks generated a democratic collaboration between their peers, which triggered engagement and sustained children's attention for a long time. Children's play with the blocks unfolded two levels of articulation; one level where they used the blocks to create visual narratives and a second level where they used the blocks as construction material. This double function was analysed as fostering playful learning processes indicating that the design conveyed potentials to function as a pedagogical resource.

Keywords: Children · Digital manipulatives · Co-discovery analysis
Collaboration · Designs for play and learning · Pedagogy

1 Introduction

The central aspect of Constructionism is the understanding of children as builders [1]. This understanding is grounded on an assumption that children actively construct knowledge through interactions with their surrounding environment [2]. According to this understanding, children do not "get" ideas but instead they build ideas [3]. This process can be stimulated when children interact with meaningful artefacts that promote active engagements [3]. In particular, culturally rooted objects that can be used by children to express and materialize their ideas strongly support the building of intellectual structures [1]. Papert speaks of "objects-to-think-with", referring to "objects in which there is an intersection of cultural presence, embedded knowledge, and the possibility for personal identification" [1:11]. In this context, he emphasizes the absence of 'learning-richness' of children's activities, such as building and playing

A. L. Brooks et al. (Eds.): ArtsIT 2017/DLI 2017, LNICST 229, pp. 413–423, 2018.
https://doi.org/10.1007/978-3-319-76908-0_40

with sandcastles, LEGO bricks, dolls and collectible cards. This kind of learning activities should be taken into consideration as models for the design of new tools for children's play. In particular, while taking advantage of new technologies, which have the potential to "expand the scope of activities with that quality" [4:6].

However, digital technologies do not always afford potentials for children to creatively express themselves [5]. Indeed, whereas tangible interfaces have features that encourage both individual and social play, the size of the groups of children influences the kind of play that evolves through their interaction with the tool [6]. Difficulties in mastering the technology, such as handling a computer mouse, can have a negative impact on the interaction with technology. This affects children's play and level of creativity, thus their collaborative peer interactions. From a practical side a further hindering can be the size of the technological artefacts that makes it too difficult to fit into the kindergarten environment [5]. This shows how design and pedagogical concerns are interwoven and not only connected to individual or collective interests and desires, but also to the material affordances involved in such situations.

Digital manipulatives (DMs)[1] build on the tradition of using objects as learning scaffolds [7, 8] affording a more natural interaction than traditional interfaces [9] while promoting embodied and exploratory learning [10]. Considering the learning benefits of DMs over their digital counterparts, several works have shown that DMs have the potential to foster creativity [8] providing a higher level of engagement and immersion resulting in more active learning [11–15]. One of the characteristics of digital manipulatives is that they support collaboration [16] encouraging verbalizations and discussion among children while solving tasks, thus, naturally promoting the achievement of social skills [17–19]. Yet, in early childhood curriculum, play as a condition for learning is often separated from the use of digital tools, which are merely seen as facilitators of learning outcomes (cf. [20–22]. This highlights that an understanding of children's play could pave a way about how to best fill the gap between pedagogical understandings of play and children's use of and experience with digital tools.

This paper describes two intervention studies carried in two Danish kindergartens where a Digital Manipulative (DM) was used to investigate (1) how the design of the DM fostered playful processes in a collaborative environment, and (2) the children's collaborative interactions and play experiences. The Digital Manipulative that was used is further described below in Sect. 2. The results provided new insights for the further development of the tool. Section 3 details the method, and Sect. 4 the actual interventions. Finally, Sect. 5 presents the discussion and concludes the paper.

2 Description of the Digital Manipulative

The Digital Manipulative used in this study is named TOK, which stands for Touch, Organize, Create [13]. It is composed as an electronic platform with six or eight slots that connects to a computer or a tablet through USB or Bluetooth (see Fig. 1).

[1] The term Digital Manipulatives has been coined by Resnick et al. [4] referring to objects with embedded computational properties that are used to manipulate digital content, other authors use the term Tangible Interfaces or TUIs.

Additionally, microphone, and a set of 23 physical blocks with images are used to manipulate digital content on the connected unit. In the current implementation, the system can identify up to 250 different blocks. This number can be extended.

The backside of each block as well as the electronic system have embedded magnets on its surface. This correctly snap the blocks into the system, making it easy for the users to place the blocks. Simultaneously, this assures a stable contact between the blocks and the platform. The size of the blocks, 4.5 × 4.5 × 1 cm, offers a good grip and easy manipulation (see Fig. 1). Placing a block on the platform renders the corresponding digital content on the device's screen, creating a direct mapping between input and output. The sequence of blocks placed on the platform unfolds a narrative. The system presents the content of the picture-blocks on the screen following the order in which they are placed, thus enabling the random placement of the blocks on the slots (see Fig. 1). Similarly, when a block is removed from the TOK platform its corresponding animation immediately disappears from the screen. The blocks represent classical scenarios and 'actants' from narratives for children - basically, heroes and opponents [23, 24], composed by characters, objects and nature elements. Five different scenarios (a castle landscape, a forest, a desert, the woods and a circus) allow locating the stories in different settings.

Fig. 1. Two girls grabbing and placing blocks on the TOK platform to build and exploring the corresponding animated narrative.

Children can change the scene, mix and remix the characters, try out different plots, shift direction and start all over again. As the system only provides visual feedback (except for the ambient sounds), children can imagine and create their own spoken narratives. TOK was developed following a user-centred design approach and empirically validated in a long-term study with various groups of children in a Portuguese preschool [13, 19, 25]. The interventions reported here, provided new insights for the further development of the TOK as a tool for fostering non-formal learning processes in a collaborative environment.

3 Methods

The two intervention studies took place in two public kindergartens (KG1 and KG2) in the southwestern part of Denmark. Twenty-two children – twelve from KG1 and ten from KG2 – all at five years-of-age, took part. Both kindergartens regularly use iPads and different educational digital media.

3.1 Procedure

The intervention in each of the kindergartens was carried out in a separate room where also three researchers attended. In KG2 the teacher also was present in the room. Two TOK systems were connected to a computer via USB, a set of 23 blocks and a microphone respectively) were placed on two separate tables, which were facing each other. The blocks were scattered on each table in front of the computer. The DMs were turned on when the children entered the room. In each kindergarten, two groups of children at the time played with the DM for 30 min. They were in groups of two and three, which were counterbalanced with the same number of boys and girls. At KG1 there were four groups of three children: group 1 with three girls; group 2 two boys and one girl; group 3 three boys; and group 4 two boys and one girl. At KG2 the children were divided in two groups of three and two groups of two children: group 1 with two girls and a boy; group 2 two boys and a girl; group 3 two girls; and group 4 two boys. After that children went back to the class and two new groups came to the room to play with the DM. The same procedure was carried in both kindergartens. The three researchers were available to offer support, when and if the children needed, otherwise they were in the background, observing and taking field notes.

3.2 Data Collection and Methodology

The study followed a qualitative, explorative and inductive methodology. Thus, the children were allowed to collaborate with each other, without interruptions from the three researchers, to learn how to interact with the system [26, 27]. The data was collected through (1) field notes; (2) video observations; and (3) situated interviews. Two video cameras were discreetly placed behind each table respectively and synchronized to record each group from the back and from the front to allow different observation angles. The children were informed about and shown the cameras, but did not pay any further attention to them. Following the children's interaction with the TOK a situated interview [28] was carried out with each teacher after the session.

The researchers applied a co-discovery analysis of the observation of the children's activities [29, 30]. Directly after each session, the researchers discussed and noted impressions of the intervention. This was to keep a fresh record from the observations contributing to a reliable analysis of the data [31]. The video recordings were later analysed.

4 Kindergarten Interventions

In the following sections, the results from the two intervention studies are presented. After an initial introduction of the TOK, the children organised themselves into smaller groups (see Sect. 3.1) and were ready to explore the TOK. In line with the co-discovery approach [29, 30], the functioning of the TOK was not explained, instead the children were encouraged to explore and find it out by themselves. It did not take long time until the children found out that they had to place the blocks on the TOK platform to render digital animations. Initially, the children started to place the blocks on the TOK platform very carefully, but they became increasingly confident trying out different blocks and exploring the interactions between the different elements. They also shared their explorations and, thereby, also learnt the TOK functionalities from each other. The following sub-sections focus on how the children in both kindergartens (KG1 and KG2) played with the Digital Manipulative. The children in both kindergartens were divided into four groups (Group 1, 2, 3, and 4), where two groups at the time played with the TOK – first groups 1 and 2 and thereafter groups 3 and 4. While two groups were playing with the TOK, the other two groups were in another room.

4.1 Handling of the Blocks and Group Dynamics

The handling of the TOK blocks interrelated with the way the group dynamics evolved during the intervention sessions. In KG1, Group 1 (three girls), they all took turns and handled the blocks; in Group 2 (two boys and one girl) the girl just observed while both boys handled the blocks; Group 3 and Group 4 were unstable and the members of each group were merging, going apart, and building new constellations, while some of them observed the others handling the blocks with changing roles.

In KG2, all children in three out of four groups handled the blocks. In the fourth group, Group 4 (two boys and one girl), the boys predominantly handled the blocks.

In both kindergartens, the children maintained the groups except in KG1, Group 3 and Group 4, instead of two groups with three children by each of the two tables as planned, the five boys gathered together around one table and the girl was alone by the other table. The boys were visibly excited, three of them manipulated the blocks while one of them spoke into the microphone, and the other boy observed. From time to time they changed roles. After some time, two boys left the table and joined the girl that was alone. One of these boys stayed by this table for the rest of the activity. By doing so, he could easier access and play with the TOK, not having to 'compete' with the other boys about the space closest to the blocks. The other boy moved between both tables. In both kindergartens, sometimes the children from one group joined the other group. This happened when something aroused their curiosity. Sometimes one group called the other group to show something they liked or that had surprised them. After having shared their experiences, the children continued to play with the DM within their own group.

In summary, the evolving group dynamics in KG1 and KG2 showed that the children after only a short while understood how to use the TOK. They were concentrated and placed the blocks on the platform and, accordingly, observed the

interactions. One of the groups (KG1, Group 3), did so in an intense way by enthusiastically and continuously placing and removing blocks.

4.2 Involvement and Collaboration

The way the children were involved in the interactions with the TOK, influenced their modes of collaboration. In particular, the children's collaboration was shown through their negotiations and construction activities while playing with the TOK. At first the children were predominantly observers, placing and removing blocks to explore the interactions between the different elements. Except for the group of five boys, they were all focused and concentrated, taking time to observe what was happening on the screen. After that, they started to systematically replace some of the blocks.

Sometimes children reconstructed an action rendered on the display by repeatedly removing and placing the same blocks on the platform. This was done when the children wanted to understand the interactions that took place as well as when they liked something and repeatedly wanted to watch the unfolded animation. For instance, a girl from KG2, Group 1 placed and removed several times a block of a witch as well as a block of Zorro. Always, after Zorro defeated the witch, the girl lifted both blocks and placed them again, repeating this action several times while commenting the fight together with her peers. A block showing a cloud and its blowing effect created a great interest among the children, generating an intense interaction in KG1, Group 1 and Group 2. They explored the cloud in combination with a lot of other blocks and discussed about different effects that emerged.

Except for one girl from KG1, Group 2 and another girl from KG1, Group 4, all children wanted to continue to play after the time was over. Signs of involvement were visible through children's body movements. For example, they were clapping hands, showing thumbs up, mimicking the movements of the characters. This was done by moving an imaginary sword in the air, mimicking the sound of the cloud blowing wind, or the sounds of the fights, pointing at the screen, to raise the other's attention and commenting on the action, interjections of joy, surprise or disappointment.

Negotiation and Construction

Playing with the TOK generated many verbal interactions between the children. They commented on the actions, called for each other's attention, e.g. regarding specific interactions between block elements that they liked. Some children took blocks from the table and held the blocks in their hands, or to their chest, signalling that they wanted to keep them for their own manipulation. However, generally the children shared the blocks and let each other freely choose which blocks to place. Often, the children applied an implicit agreement by taking turns in choosing which blocks to choose. But sometimes they had divergent opinions and wanted to place different blocks on the platform, or they wanted to handle the same block or the microphone simultaneously (see Fig. 2b). Such conflicting interests led to discussions and negotiations between the children. In general, they negotiated until all in the group were happy with a solution, sometimes the stronger won possession over one block (see Fig. 2c). This behaviour was observable in all the groups.

Fig. 2. Children calling the attention for a specific action (a), fighting for the microphone (b), and fighting for a block (c).

Besides playing with the Digital Manipulative on the computer, five out of eight groups also used the blocks to make their own free-standing constructions (see Fig. 3). In KG1, Group 1 the girls built towers with blocks, all of the piles with the same height. They then placed the piles on the platform slots and lifted the piles to change the block that was in contact with the platform and, thereby, triggering different interactions (Fig. 3d). In Group 4 the girl built piles and divided them into smaller ones followed by ordering the piles in front of the computer. In KG2, Group 1 a girl built piles and then slowly glided the block on the top until all of it fell down (Fig. 3a). In Group 2 a girl built a square with all blocks facing her (Fig. 3c) and in Group 3 the girl ordered the blocks near the platform creating different patterns (Fig. 3b). From there she and the other girl in the group jointly chose the blocks to place on the platform.

Fig. 3. Children's constructions (a) building piles and gliding the block on the top until it falls down; (b) ordering the blocks creating different patterns; (c) building a square with the blocks (d) building piles and placing them on the platform slots; (e) building a pile with all the blocks; (f) holding several blocks.

In summary, during the intervention the children showed interest and involvement in collaborative actions and interactions with the TOK. Their collaboration included negotiations, sharing of the blocks, as well as unexpected ways to, as part of the play, use the blocks for different kinds of constructions.

4.3 Pedagogical Dimensions of the Digital Manipulative

The teacher from kindergarten 2 identified that the blocks representing different settings triggered the children's fantasy and ideas and as such they formed opportunities for the children to create different kinds of stories. According to the novelty factor, she furthermore suggested to increase the number of blocks to maintain children's interest over time.

Relatively to the ideal number of children playing with one TOK, the teachers had different opinions, the teacher from kindergarten 2 preferred to have two children at a time, whereas the teacher from kindergarten 1 considered that three children was a good number. Both teachers thought that it could be a good idea to connect the Digital Manipulative to a projector, as a bigger screen would be beneficial for activities involving bigger groups of children.

Relatively to the ideal number of slots for the electronic platform, the teacher from kindergarten 2 considered that six slots (for placing six blocks) are enough, since she observed that children most often merely used four slots out of six slots.

The teachers also referred the importance of extending the activities into the home context to share the created stories with parents and family. The teacher from kindergarten 1 expressed that the interface due to its visual design, is a good tool to integrate children from different cultural backgrounds into play activities.

5 Discussion and Conclusions

This explorative and inductive study involved 22 children from two Danish kindergartens and investigated how the design of a Digital Manipulative (DM) could foster playful processes among children in a collaborative environment. Furthermore, what kind of collaborative interactions and play experiences that emerged during the use of the DM.

Regarding the ease of use of the TOK system, the children were able to explore the tool and find out its functions without any help. Along the interaction, they created their own play rules [32] through negotiations with each other over the ways of handling the blocks. This experience of being autonomous contributed to the children's sense of 'being able to', which in turn generated playful interactions and collaborations [5].

The children engaged with the blocks at *two levels of articulation* [33]. At one level they used the blocks to create visual narratives on the computer screen, at a second level they used the blocks as construction material. This double function allowed them to engage in a diversity of activities, which were not merely confined to the computer, but independent from it.

The multimodal (tactile, visual, and audio) feedback encouraged exploration and gesturing, generating concentrated activities. Sometimes the children seemed to engage in problem solving, for example when they reconstructed the visual interactions in order to understand what happened. This indicates that playing with the Digital Manipulative supports a 'debugging philosophy' [1: 114].

The blocks, as input devices, generated a form of *democratic interactions*, this is, they gave children equal power to interact with the device. This democratisation

through the sharing of the input devices, encouraged social interaction and collaboration. In this regard, our observational data indicates that the collaboration in the groups with two children from the same gender (two boys or two girls) and the groups with three children (where two of them were girls and one of them a boy), showed a tendency for a more balanced cooperation. However, in the groups with two boys and one girl, the girls tended to take an observer role rather than being active in the interplay. These findings are in accordance with [9].

The Digital Manipulative created a collaborative environment and fostered playful experiences and as such it showed potentials as a pedagogical resource. Regarding the further development of the Digital Manipulative, the intensified interaction among the children when using the block of the cloud, indicates a sensory dimension of the interaction. This influenced the quality of the playful activity in a positive way as it contributed to the collaboration between the children. In other words, the cloud block promoted the children's involvement in the story they were creating and building upon. Furthermore, the physical blocks contributed to the children's awareness, control and accessibility to different kinds of actions [34]. The physical blocks helped the children to coordinate their verbalisations as the child who held a specific block also was in charge of the next coming part of the story that they jointly created. Veraksa and Veraksa [35] and Björklund et al. [36] state that symbolic tools grounded in, for example, fantasy and metaphors, support children's intellectual development. These are all crucial inputs to the further development of TOK, including the need to develop a guideline for the pedagogical use of the Digital Manipulative (DM).

In conclusion, emerging 'design for play' guidelines are based on the above-mentioned two-level articulation wherein children's understanding of DM is emphasized. This through their apprehension of the material, which inspired and fostered joint discussions, sharing and negotiations. Furthermore, the children in this study understood the Digital Manipulative through their collaborative constructions and realisations of ideas, which, in turn, contributed to new and creative knowledge.

Acknowledgments. We would like to sincerely thank teachers and children at Toftlund and Skærbæk Kindergartens, and our host Prof. Eva Irene Brooks, and the Xlab: Design, Learning & Innovation at Aalborg University, Denmark.

The first author was financed by the COST Action IS1410, Digital literacy skills and practices in the early years (DigiLitEY) and the Portuguese Foundation for Science and Technology (FCT) within the Postdoctoral Grant: SFRH/BPD/111891/2015.

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