Digital Manipulatives as Scaffolds for Preschoolers' Language Development

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ABSTRACT The study reported here aims at contributing to a deeper understanding of the educational possibilities offered by digital manipulatives in preschool contexts. It presents a study carried with a digital manipulative to enhance the development of lexical knowledge and language awareness, which are relevant language abilities for formal literacy learning. The study took place in a Portuguese preschool, with a class of 20 five-year-olds in collaboration with the teacher. The digital manipulative supported the construction of multiple fictional worlds, motivating children's verbal interactions, and the playing of words and sound games, thus contextualizing the learning of an extensive collection of vocabulary and language awareness abilities. The degree of engagement and involvement that the manipulative provided in supporting children's imaginative play as well as the imitation, in their own play, of the playful pedagogical interventions that the teacher had designed, shows the importance of well-designed materials that support a child-centered learning model. As such, it sustains a discussion on the potential of digital manipulatives to enhance fundamental language development in the preschool years. Furthermore, this paper highlights the importance of multidisciplinary teams in the creation of innovative pedagogical materials.

INDEX TERMS Digital manipulatives, emergent literacy, learning, oral expression, phonological knowledge, preschoolers, lexical knowledge, tangible interfaces.

I. INTRODUCTION

Well-designed technology has the potential to scaffold learning when it meets children's needs, promotes playfulness, supports open-ended and active exploration, offering opportunities for social interaction, and supporting scaffolding from more skilled peers [1]–[3]. Indeed, collaborative rich digital environments have the potential for creating meaningful contexts that motivate young users, favoring knowledge construction by providing new experiences and interactions that are not possible in the real world [4:8] [5]–[7].

Discussions about the use of technology in the classroom have also shown that such advantages are easily obscured by traditional uses of ICT (Information and Communications Technology), which fail to place the "emphasis on a child-centered model of learning through play rather than instruction" [7], [8]. In the pre-school, which frames the study that we present, instructional models of learning are not favored as pedagogical models by educational policy makers and providers [9], [10]. Accordingly, in order to create educational relevant products researchers and designers need to ensure that teachers can use these materials to design child-centered activities. This is particularly important for children as poor opportunities may hinder their subsequent learning, as MacGregor affirms: "the effects of reduced opportunities for learning established in the preschool years are long-lasting" [11:305].

Digital manipulatives [12], or tangible interfaces - TUIs [13], have emerged as particularly interesting powerful challenges for the instructional paradigm of interaction as they allow exploratory and expressive activities, expanding the range of concepts that children can understand and dramatically improving accessibility to younger children [14], [15]. This paper reports one illustrative case.

Aiming at developing a tool that meets children's and teachers' needs, TOK (Touch, Organize, Create), the digital manipulative used in this intervention, was designed, developed and evaluated in collaboration with various groups of preschool children and their teachers in a Portuguese

preschool[1] [16], [17]. During the evaluation process one of the teachers expressed her will to use the manipulatives to carry a specific intervention with her class of 20 preschoolers (ages five) targeting the development of language abilities, namely lexical development and language awareness (more specifically, phonological awareness), two of the most important correlates with success in learning of literacy in the first grade [10], [18], [19]. We gladly accepted the proposal, as this was a unique opportunity for us researchers and designers to assess in loco the use of digital manipulatives in an educational setting, not only to support children's imaginative play but also specific learning in child-centered (rather than instructional) pedagogical interventions. Thus, the teacher designed and developed the intervention and we acted merely as background observers. The intervention lasted for three months and took place within children's daily learning context, allowing a natural and holistic approach [20].

In order to explore which language competencies could be enhanced using TOK in the classroom context, the teacher applied to each child a language test (as frequently done by school psychologists and educators) before and after the intervention. The tests were used as an instrument to assess children's progression in a descriptive (not prescriptive) manner, with the aim of having different types of data that allowed carrying out triangulation protocols [21]. In fact, like in any other intervention that takes place in real life settings, there are many variables that can influence the study results. Thus, instead of trying to isolate any specific variables, we followed a holistic approach [22] combining both qualitative and quantitative data.

The study reported here aims at contributing to a deeper understanding of the educational possibilities offered by digital manipulatives in preschool contexts. Our central thesis is that, due to their strong collaborative, interactive and playful nature, digital manipulatives are powerful scaffolds for language developments that are expected before children begin to learn literacy in a formal way.

The paper is structured as follows. Section two discusses the importance of lexical knowledge and language awareness in the preschool years. Section three presents an overview of the use of related technology. Section four describes the digital manipulative that was used in the intervention. Section five presents the study illustrating children's interaction with TOK during guided and free-play time. Section six presents the results of the tests that were applied after the intervention, and we finish with the discussion of the results and the conclusion.

II. THE RELEVANCE OF LEXICAL KNOWLEDGE AND PHONOLOGICAL AWARENESS

The pre-school years, which extend up to 7 years of age, are the 'best' period to learn the grammatical components of the language as well as to develop children's lexical

knowledge [23]. Moreover, such development is considered a fundamental factor for literacy learning in the elementary grades [18]. Lexical (or word) knowledge plays a very significant role in learning to read and write [11]. Phythian-Scence and Wagner affirm that "Acquiring the vocabulary we use for thinking and communicating is a linguistic achievement of nearly incomprehensible importance and complexity" [24:1]. Effective lexical development relies largely on social factors. In fact, there is a close connection between shared experience, conceptual development and the learning of new words that label such concepts [25].

Besides grammar and lexical development, phonological awareness is perhaps the most widely acclaimed target of language skills intentionally introduced in the preschool years due to the relationship that exists between the alphabetical written code and the phonological component of the oral language [26]. As in English, letters in the Portuguese written language represent the sounds of words. The more children are able to think about the sounds themselves, the easier they will understand the alphabetic principle and learn how to read and write. Research has shown that children's phonological awareness is directly related with their successful performance in reading and writing during the first and second grades [27], [28].

Yet, phonological awareness does not develop spontaneously in children's minds. With the apparent exception of syllabic awareness, which seems to be sustained by human natural language endowments [29], young children show especial difficulty in achieving phonemic awareness due to the abstract nature of sounds (phonemes) [27]. Research has therefore highlighted the importance of implementing pedagogical approaches at preschool to develop phonological awareness, beginning with syllabic and rhyming tasks, in a playful, gaming-like manner as a starting point to enhance the construction of phonemic awareness [27], [30].

Creative storytelling provides perhaps the most adequate child-based context for stimulating language development, of which phonological awareness and lexical knowledge are no exception [31]. Storytelling is social, draws on and develops shared experience, introduces new vocabulary, and can also include elements that help develop phonological awareness as are often found in repeated patterns, rhymes or playful stories.

III. BACKGROUND AND RELATED WORK

Technology may play an important role in supporting the development of fundamental skills such as oral language and emergent literacy in a collaborative peer context, yet such potential has been "under-explored" [32:81]. From all papers presented at the Interaction Design and Children Conference (IDC) between 2002-2010 merely 8% focused on technology that supports literacy development [33]. Research has also identified a need for more long-term evaluations as well as to investigate whether the technologies remain compelling for the children after the novelty effect is gone [33: 143].

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[1]This work returns to a study presented in the doctoral dissertation of the first author [16].

Although the use of technology in preschool is still uncommon [34], [35], a significant number of teachers consider that children's early contact with technology is beneficial as preparation for school [34], [36].

Tangible technology that supports the development of literacy varies widely, some approaches use books enhanced with embedded sensors and electronics, thus extending the experience provided by traditional books. Some relevant examples here are the MagicBook [37], Telescrapbooks [38], or the Bridging Book [39].

Other tangible systems, such as the "Story Listening Systems" [32], emphasize speaking/listening aspects. Some examples here are TellTale [40], StoryMat [41], or t-words [42], [43]. Other examples that explore the creation of narratives are POGO [44], or Jabberstamp [45]. POGO combines a set of tangible tools, which enable children to create multimedia narratives, encouraging experimentation, and sharing of stories. Jabberstamp allows children to enhance their graphical narratives with voice and sounds.

TOK, the tangible interactive technology presented in this study, uses physical blocks to manipulate virtual content, enabling children to choose among a great range of story elements (up to 250 blocks), empowering them to create their own original narratives.

As we will describe in the following section, one of the great advantages of TOK (and of tangible technology in general) is its potential to support and promote collaboration, as users can manipulate and share the physical elements. This is particularly true for TOK due to its great number of blocks. TOK's robustness, its easy setup and intuitive use are characteristics that differentiate it from other tangible systems. Despite their potential to engage children in storytelling and literacy related activities, many of the referred tangible technology is quite complex to set up and use on a regular basis in the classroom (e.g., Pogo, StoryMat, or the MagicBook) especially in the preschool environment, where robustness and ease of use are core issues; also, some of the referred interfaces represent conceptual prototypes (Telescrapbooks).

IV. TOK, A DIGITAL MANIPULATIVE FOR CREATIVE STORYTELLING

As referred in the previous section the study presented here was carried with a digital manipulative named TOK, which was developed and tested in collaboration with various groups of preschool children and their teachers in a Portuguese preschool [17]. TOK was designed outgoing from the notion that children are "players rather than spectators" [46:95] and that the creation of narratives should be centered on the playful character of language and the pleasure in dealing with words through playful experimentation. It was also based on social constructivist theories of learning embedded within a social context and generated through the interaction with more skilled members, emphasizing guidance and support [46]–[48].

A. SHORT OVERVIEW OF THE TOOL

Presently, TOK is composed by an electronic platform that connects to a tablet through Bluetooth or to a computer via USB, and a kit of 23 physical blocks to manipulate the digital content (see Figure 1-2).

FIGURE 1. The TOK platform running on an iPad with communication via Bluetooth.

FIGURE 2. Examples of characters and objects.

In the current implementation the system reads up to 250 different blocks, however that number can be increased. The surface of the electronic platform has slots for placing the blocks. Both the backside of the blocks as well as the platform have magnets on their surface that correctly snap the blocks to the platform, making it easy for the users to place the blocks while simultaneously assuring a stable contact between the blocks and the platform.

Each block has a sticker with a picture of what it represents on the upper side and a conductive pattern in its base, which is detected by the capacitive sensor on the basis of the electronic platform.

The conductive patterns code the identification number of each block plus a checksum, which is used to distinguish blocks from random touches of the fingers with the capacitive terminals.

Presently there are 23 physical blocks representing sceneries, objects and characters inspired in classical narratives for children (basically heroes and opponents [49], [50] (see Figure 2).

The story world was designed using behavior trees (BTs). There are four types of entities: scenarios, nature elements, objects and characters. Scenarios represent the background image where the action occurs. The nature elements (e.g., moon, cloud) interact with the objects and the characters

allowing the configuration of the story settings, e.g., placing the moon turns the day into night, or the cloud blows everything away from the scene. The objects and characters are classified in good, bad or neutral; bad characters attack the good ones, good characters defend the neutral and help each other; both good and bad characters can join forces to defend or attack their opponents. Specific objects like a caldron or a flowerpot can be used to knock down bad characters and defend the good ones. A bad object (e.g., a poisoned apple) diminishes the health of a character; on the contrary a good object (e.g., a carrot) increases the health of a character. Each entity has a corresponding BT that defines its behavior as well as the interactions with the other entities.

Placing a block on the platform displays the corresponding digital content on the screen. When a block is removed from the platform it also vanishes from the screen. The sequence of blocks placed on the TOK platform unfolds a visual narrative. As each entity behaves according to its own rules, and its behavior depends on the other entities that are also placed on the platform, there are no predefined stories, nor a linear narrative, which brings a certain degree of unpredictability and surprise of the narrative outcome, which allows users to create a wide variety of different stories, strengthening the narrative experience [51]. For a detailed description of the TOK system the reader may refer to [17].

V. TEACHER'S PEDAGOGICAL INTERVENTION

The teacher designed a rich pedagogical language intervention targeting the development of lexical knowledge and phonological awareness. As previously referred, she integrated TOK in her pedagogical procedure and worked with the manipulatives for a period of three months with her class of 20 children (ages five). The teacher carried out some of the activities in the large-group, whereas others, which had a more exploratory character, were carried with small groups of children. Besides using TOK with guided activities, the children also used the manipulatives during free-play time, which takes place during 45 minutes everyday after lunch. During this period children played with TOK in groups of two.

A. EXPLORING WORDS AND PHONETICS
WITH PAPER CARDS

The teacher carried 15-guided sessions with the children to stimulate lexical knowledge and phonological awareness skills. She maximized the potential of the digital manipulatives and used different approaches to introduce and explore lexical items to the class. She started by printing the 23 pictures represented on the blocks creating a set of cards and used them to introduce new vocabulary and to extend children's lexical knowledge, which she addressed and revisited throughout the whole intervention. Children were very enthusiastic from the beginning, naming and defining each of the cards, making associations and comparing them to characters from stories they already knew.

1) INTRODUCING AND EXPLORING NEW WORDS

The teacher clearly intervened when children were unsure about how to define certain cards. The following dialogues (condensed version) exemplify how the teacher scaffolded children to define the elements, while discussing how they should name them.

Example 1: Identifying the settings.

Child A shows her card (see Figure 3a) and says: *it's a theatre*.

FIGURE 3. **The circus (a), one of the four settings that children can use to place their stories; a character (b).**

Teacher to the class: *Do you agree? Why is it a theatre?*

Some children do not agree and say that it is a circus, other maintain that it is a theatre.

Child B: *It's a circus, because all circuses are like that, it has popcorn.*

Other children: *Popcorn is in the cinema!*

Some children are still convinced that it is a theatre, other say it is a circus.

Teacher: *But there is something in the card that tells us directly what the card is.*

Children join all together around the teacher, who now holds the card.

Teacher: *What is this here, with the bars? What could they possibly keep in there?*

Children: *Animals!*

Teacher: *And where do wee see animals... at the theatre?*

Children: *No, at the circus, it's a circus.*

They all agree now.

Example 2: Identifying characters:

Child shows her card (see Figure 3b) and says: *It's a pirate.*

Other children: *No, it's a cowboy!*

Teacher: *Why?*

Child: *Because he wears shoes.*

Teacher: *What do cowboys normally wear?*

Children: *Hat.*

Other children: *It's a cowboy without a hat.*

Teacher: *What else do cowboys normally wear?*

Children: *Pistols, and Horses.*

Children: *It's a pirate; it's a burglar.*

Teacher: *What do pirates use to cover their eyes?*

Children: *An eye patch, and they have a wooden leg!*

Teacher: *So what is it?*

Child: *I think it's a person who is very angry!*

Children agreed and decided to name the card 'the angry man'.

Another task that the teacher carried out was the *guessing game*. She gave one card to each child, asking them to keep it secret; each child would then give some cues to the others. This task compelled the children to think about attributes to define the word represented on their card, and to convey this meaning to their peers. We illustrate this with an example. A child holding a card with the fairy says:

> *What is it that flies?*
> *The witch*, say the others;
> Child: *no, it's not!*
> Teacher: *can you give another hint?*
> Child: *flies and uses a wand,*
> Children: *It's a fairy!*

Another child:

> *What is it that the witch uses for making her potions?*
> *A Caldron!*

As these examples illustrate children engaged in a dynamic process trying to find the correct attributes and words to define and name the cards, whereby peer interaction and teacher's scaffolding played an important part.

2) CREATING RELATIONS BETWEEN THE ELEMENTS

After identifying a card each child was asked to place it on the floor in the middle of the circle, creating different groups (see Figure 4). The children began to create relations between the cards and the stories they knew, and spontaneously started to talk about the stories that they could create using the cards. The more relations they discovered between the cards and stories they knew the more excited and involved they became.

FIGURE 4. Children creating different groups with the cards.

Child: *my card is an apple* (she places it to the group Princess, witch, caldron) *I think we can tell the story of the snow beauty; the witch could use the caldron to poison the apple.*

> *There was once upon a time a beautiful princess and when the witch saw her she noticed that the princess was much more beautiful than herself, thus she poisoned the apple and gave it to the princess. The princess ate the apple and died.*

3) DEVELOPING PHONOLOGICAL AWARENESS

Along the intervention the teacher also developed different language games, targeting the development of phonological awareness. For instance, after giving one card to the children, she asked them to name the element represented on the card, and then to identify the sound at the beginning of that word. Then the children were asked to divide the word in syllables, count them, while clapping hands according to the number of syllables. Children were also asked to group and sort the cards in different rows, according to different categories: characters, locations, objects and food or number of syllables. The teacher also challenged the children to identify the first letter, the sound, to segment the word and to count its syllables, e.g., a child has the card with the *castelo* (*castle*). Child: *Castelo* begins with the sound [K] and the letter C, (clapping hands she does the syllabic segmenting) *cas-te-lo*, and says *Castelo* has three syllables.

B. USING TOK

After the first sessions with the picture cards, the teacher introduced the digital manipulatives to the children and allocated some sessions for the children to explore the tool. This exploration was carried out in small groups of four children and the teacher, who was observing and asking questions about what was happening on the screen, scaffolding children and recalling previously acquired lexical knowledge. Children explored the blocks, verbalizing what they were seeing on the screen, commenting on the characters and the objects, expressing their opinions, identifying characters, and relating them to stories they knew.

> Example:
> Child A: *Let's place the wolf from the Caribbean.*
> Child B: *Oh no, there are no wolfs from the Caribbean, only the pirate comes from the Caribbean.*

By the end of these exploratory sessions children had discovered that the good characters protect their friends, fight the bad ones, and that they help each other; the apple was poisonous; the witch had a magic wand that diminished the size of their opponents; the caldron and the flowerpot could be used to knock down the bad characters; the good characters tried to hide inside the houses to escape danger, etc. They also discovered that by lifting the blocks from the platform and placing them again they would come to life again, and that they could change the place were the stories occured, by using a different scenario.

1) ROUND UP OF THE ACTIVITIES WITH TOK

After the exploratory sessions the teacher carried a set of activities using TOK connected to a projector, involving the whole class, therefore all the children sat on the floor facing the projection (see Figure 5).

During these sessions, the teacher further explored the semantic and the phonological dimension of the vocabulary projected on the screen. Yet, the sessions with TOK added a new dimension to this exploration, as differently from the paper cards the teacher now took advantage of the interactions generated by the different combinations of blocks. Besides expanding the range of vocabulary to explore, this also added a surprise element.

The activities always followed the same principle: each child got a block, and taking turns s/he placed it on the

FIGURE 5. Activities carried by the teacher with the whole class using TOK connected to a projector.

TOK platform, then children individually named the blocks, created rhymes, identified similar sounds, created sentences and finally stories.

During these activities, in case a child did not know a word that rhymed with her picture or was not able to build a sentence, the other children helped with suggestions. The teacher sometimes gave hints to help building more complex sentences, and the children themselves corrected words that did not rhyme, again scaffolding each other mutually. Children recalled vocabulary that they already knew but also learned new vocabulary from each other and from the teacher. Very often they made a brainstorm looking for words that rhymed, and then tried to build variations of sentences. Some of the rhyming words were invented, which indicates that children indeed reflected about the phonological dimension of the words. The teacher also took advantage from the words that the children said and did not rhyme to make them aware of the different sounds.

As more blocks were placed on the platform, the teacher asked the children to create sentences or stories that included all the story elements displayed on the screen. Children drove each other into discovering words and creating stories together building on each other's suggestions and contributions. The last sessions were used to collaboratively create stories based on the animations generated by the blocks. For instance, after placing following blocks on the platform (circus scenery, which they named village, pig, straw house, wooden house, brick house and wolf) children created a variation from the story of ''The Three Little Pigs'':

> *There was a village where there were a wooden house, a straw house and a brick house. There lived a little pig, which had two brothers, he wanted to invite them to visit him but there was also a wolf and the little pig was afraid that his brothers wouldn't come. The brothers came and stood with him, they hide in one house and then went to another one, so they could escape the wolf.*

Another example:

> *Little pig and the fairy went to the circus, as it was night they saw the stars. When they returned home, little pig offered his flowerpot to the fairy, as he wanted to be friends with her.*

The teacher guided the children building on their contributions, stimulating them to collaboratively create sentences and stories.

C. EXPLORING TOK DURING FREE-PLAY TIME

Children also played with the interface during free-play time, during which they were able to interact in groups of two with the tool on their own.

1) CREATING STORIES

Inspired by the vocabulary represented and associated to the use of blocks and the interactions they triggered on the screen, the children created a great variety of narratives. In the following we transcribe some excerpts of children's stories to exemplify their interaction with the tool.

Story by a pair of children using the blocks: castle scenery, witch, princess, moon, carrot, cloud, Zorro, forest scenery, wolf, pig, flowers, and circus scenery:

> *Once upon a time there was a witch that lived in a castle, it was a haunted castle* [places the moon block], *suddenly a princess appeared and then she found a carrot. Then it became very windy* [places the cloud block, which blows characters and objects away] *and they all run away. Suddenly Zorro appeared; he was in a haunted forest that had lots of birds. Then a witch, a wolf, a princess and a little pig appeared and also the fairy that made magic to heal the princess. There was a fight and the wolf died. Then flowers appeared, they were all very happy and ate a carrot and went to the circus.*

Another example created by a different pair of children using the blocks: castle scenery, princess, house, witch, fairy, cloud, and prince:

> *Once upon a time there was a princess, called Flora, and she was observing a shooting star. Everything was so calm, but then she wondered because there was a little house. Suddenly, a witch appeared, but the fairy was ready to face her. There was a fight, and the wind helped, the fairy thanked the wind: "Thank you very much wind", and she thanked the prince too, who also helped to fight the witch, "Thank you mister wind, you are very kind". And the wind "Whoo, whoo, whoo, it was a pleasure, when I find bad guys, I like to help by blowing".*

2) PLAYING LANGUAGE GAMES

Besides creating stories, children also invented and played different games with the manipulatives. One of these games consisted in turning the blocks upside down (so that they did not know which block they were going to pick) and then to build piles with the blocks or scatter them over the table (see Figure 6).

Afterwards by taking turns each child would take a block from the pile or the table and place it on the platform and create a rhyme with the representation on the screen e.g.,

FIGURE 6. Children playing language games.

FIGURE 7. Children in the library playing with the TOK set of cards.

Child A placed a house on the platform and said (example adapted from Portuguese):

There's a mouse in the house! Yes, mouse rhymes with house,

Child B: *You're right, that's a real rhyme*!

Children had great pleasure in playing these language games, whether they knew the right word or invented a new one to rhyme. They also explicitly discussed if the word existed or was invented, and scaffold each other to find a matching rhyme. Thus, children reflected about the words they wanted to say and whether they were creating real rhymes (using existing words) or inventing new words.

Now and then, children explicitly integrated rhyming in the active construction of narratives, as illustrated by the following example:

The stepmother was very angry [zangada] and said: "now you [referring to the princess] are our employee [empregada]" (pair of rhyming words in Portuguese).

The way children conceived these games that they played during free-play time (several children spontaneously engaged in the same kind of activities that were carried by the teacher), shows their degree of involvement with the learning subject as well as the potential of the tool to support children's imitation, in their own play, of the pedagogical interventions designed by the teacher. This is also supported by the comments about what the children using TOK were doing made by the children that were playing in the library area (which was adjacent to the computer area). They often made remarks, giving their opinions and sometimes scaffolding their peers. Motivated by seeing their peers using TOK very often the children in the library area also used the printed cards to create stories (see Figure 7). Moreover, they sometimes just became interested in traditional storybooks as for instance ''The Three Little Pigs'', and some times pretended they were reading the story.

VI. TESTING CHILDREN'S LANGUAGE SKILLS

In order to detect potential language difficulties (when necessary) the preschool applies standardized language tests to the children. The teacher took advantage of these tests and applied them to the children expecting to gather more solid information about their learning progress while using TOK. In fact, the aim of the tests was not to draw definitive conclusions, but to understand to what extent the interface could be integrated within the classroom to develop activities targeting children's oral language skills. The focus of the study was to understand whether the use of the interface for an extended period of time (and integrated in the normal school environment and activities) would be a useful technological tool that could be integrated into high quality learning practices. In real life settings, a rigorous test designed to compare the effect of the use of the interface with other methods between groups depends on a wide range of variables (the teachers involved, the methodology used, students' skills, parents' mediations, etc.), such an intervention would deem very complicated and logistically demanding for the school.

The teacher applied individual tests to each of the 20 children before the beginning of the study and applied the same tests at the end of the intervention. She used the following Portuguese standardized tests: the *Oral Language Assessment Test* (OLAT) [52] to access lexical knowledge and the *Observation Grid of Language* (OGL) [53] to evaluate phonological awareness skills.

A. SUBTESTS OF LANGUAGE DEVELOPMENT

The *OGL* test is composed of two subtests: *nomination* and *verbal definition*, and evaluates children's conceptual development as well as the extent and accuracy of their lexicon. The *subtest of nomination* assesses children's lexical knowledge by trying to characterize the breath of children's vocabulary knowledge. A set of images representing frequently used oral words was used. The *subtest of verbal definition* evaluates the depth of the semantic representation that the children have of words.

The *OLAT* test evaluates the phonological awareness and is composed of the *subtest of discrimination of word pairs and pseudo-words* (a), the *subtest of discrimination of words that rhyme* (b), the *subtest of discrimination of word pairs and pseudo-words* (c) and the *subtest of syllabic segmentation*. (a) Evaluates the auditory discrimination of minimal pairs, thus testing the capacity of paying attention and distinguishing words that only differ in one sound, involving real and invented words. (b) Evaluates children's capacity of paying attention to the sound component of words that end with a similar sound identifying them. (c) Evaluates the ability to paying attention and identifying the syllabic units of words.

Each phonological awareness subtest (OLAT) presented 10 items, which were scored using a scale between 0 and 10 points. Each correct answer was assigned 1 point. The subtests of nomination and verbal definition were composed by 20 items and were assigned following scores (table 1):

TABLE 1. Classification of the Tests.

Categories of responses	Score	Example
Assignment of correct label	2	Cow
Classificatory attribute	1	Gives milk
No answer / wrong answer	0	

Nomination subtest

Categories of responses	Score	Example
Categorical definition particularized	2	It is an animal that gives milk
Categorical definition	1,5	It is an animal
Perceptual definition and/ or functional/synonymous	1	Gives milk
Exemplification	0,5	*Cornélia* (famous Portuguese cow)
Generic exemple/no answer /or wrong answer	0	It is something

Verbal definition subtest

B. RETESTING AFTER THE USE OF TOK
The teacher applied the same subtests in the same conditions as the ones applied before the beginning of the study.

1) ORAL LANGUAGE ASSESSMENT TEST (OLAT)
A descriptive and inferential analysis was applied to the scores obtained in the pre and the post-test to assess whether there was a positive evolution regarding children's semantic and phonological skills. Relatively to the scores of the subtest of nomination, the minimum value improved 12 points from the pre to the post-test, and the maximum value improved 8 points. The mean value between both tests improved from 48.30 to 58.70. The values of the subtest of verbal definition also improved from the pre to the post-test by 4, 5 points for the minimum value and by 2 points for the maximum value. The mean value between both tests improved from 37,37 to 44,75 (Table 2). As the boxplots charts illustrate (see Figures 8, 9), the shape of the sample distribution was similar in the two moments, i.e., the interquartile range was identical in the pre-and the post-test, showing a

TABLE 2. Results of the Pre and Post-Tests.

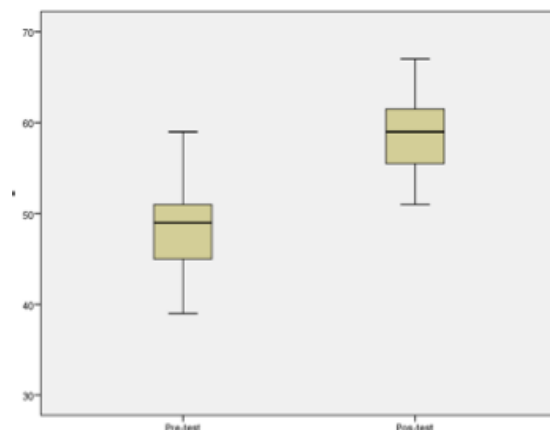|		Min.	Max.	Mean	Median	Std. Devi.
Nomin.	Pre-T.	39	59	48,30	49	5,079
	Post-T.	51	67	58,70	59	4,244
Verbal Defin.	Pre-T.	23	53	37,37	37	7,781
	Post-T.	27,5	55	44,75	46,2	7,585

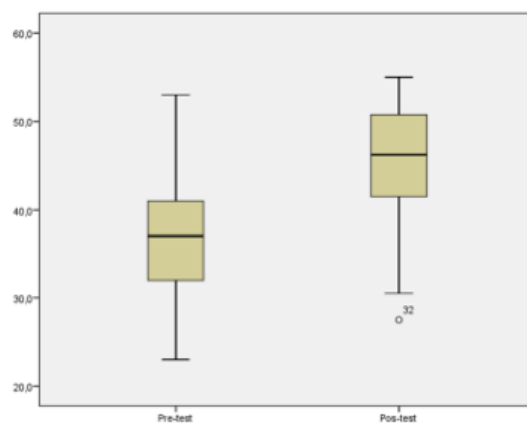**FIGURE 8. Boxplots for nomination in the pre and post-test.**

FIGURE 9. Boxplots for verbal definition in the pre and post-test.

normal distribution. However, there was a significant evolution of the mean values, from the pre to the post-test.

We can also verify that for both tests the values of the mean and median are very close to each other, which is a characteristic of the normal curve [21].

As the distribution was normal, to assess the significance of the mean differences the Student *t*-test for paired groups was applied. The obtained value of significance for nomination was less than 0.05, revealing that the difference on mean values of the pre and post-tests are significant to a level of less than 1%. Similarly, the significance value for verbal definition was also of less than 0.05. As such, the results show that there was a significant evolution at the level of nomination and verbal definition after the intervention with the tool.

2) OBSERVATION GRID OF LANGUAGE (OGL)
Concerning the subtests that evaluate the phonological dimension of the language (the *subtest of discrimination of word pairs and pseudo-words,* the *subtest of words that rhyme*, and the *subtest of syllabic segmentation*), following results were obtained: relatively to the minimum and the mean values obtained (except for the syllabic segmentation)

there was always an improvement of the scores from the pre to the post-test (Table 3).

TABLE 3. Results of the Phonological Pre and Post-Tests.

		Min.	Max.	Mean	Median	Std. Devi.
Word pairs	Pre-T.	3	10	8,9	10	1,917
	Post- T.	8	10	9,85	10	0,489
Pseudo words	Pre- T.	4	10	8,50	9	1,701
	Post- T.	5	10	9,40	10	1,188
Rhyming words	Pre- T.	5	10	8,55	9	1,877
	Post- T.	7	10	9,50	10	0,889
Syllabic Segment.	Pre- T.	5	10	7,45	8	1,432
	Post- T.	5	10	8	8,50	1,414

Except for the subtest of syllabic segmentation, the analysis of the boxplots charts revealed asymmetric distributions for the discrimination of word pairs, discrimination of pseudo-words and discrimination of words that rhyme.

The nonparametric *Wilcoxon Signed Rank test* was applied to assess the differences on the means for these three dimensions of phonological knowledge and the results showed that:

- For the test of discrimination of word pairs its was less than 0.05 ($p = 0.04$), revealing a significant evolution in this skill;
- For the test of discrimination of pseudo words, the results showed no statistical significance for the level of 5%;
- For the test of words that rhyme the value of significance obtained ($p = 0.017$) was lower that 0.05 showing a significant improvement on children's scores after interacting with TOK.

To assess the significance of the values for the test of syllabic segmentation a Student *t*-test for paired groups was applied, as the distribution of the values revealed a normal curve. The results showed that there was no significant progress in terms of syllabic segmentation ($p = 0.164$). The overall results lead to the conclusion that there was a statistical significant improvement from the pre to the post-test in the scores for naming, verbal definition, discrimination of word pairs and identification of words that rhyme, but that for discrimination of pseudo words and syllabic segmentation no significant evolution was found. According to the teacher the group already had a very good performance in syllabic segmentation, which may explain the scores relatively to this dimension; besides as described in section two, syllabic awareness, seems to be sustained by human natural language endowments [29].

Outgoing from these results the pedagogical strategy used by the teacher revealed that naming, verbal definition, discrimination of word pairs and identification of words that rhyme were the most representative items. However, we are aware that a different pedagogical intervention or a different teacher could have led to different results. Relatively to the high scores obtained in the tests this is explained by the fact that when it comes to testing preschool children, commonly teachers evaluate their skills through direct observation, the

tests merely evaluate competencies and do not intend to evaluate children's knowledge, instead they allow teachers to check whether a particular behavior / action / competence occurs or does not occur. As such the presentation of the test results intends to show readers that the acquisition of early literacy can be highly stimulated by combining a child-centered pedagogical intervention with well-designed child-centered technology as an alternative to outdated instructional models of learning.

VII. DISCUSSION

The results of the study show children's language development in the context of use of a digital manipulative, thus bringing the educational potential of manipulatives for language development as well as teachers' role to the forefront line of discussion.

The use of TOK had a clear impact on children's lexical knowledge and phonological awareness developments. The digital manipulative opened up a motivating context to explore and stimulate the language dimensions under research. It created a variety of meaningful interactive situations that served as the background for the learning and refinement of an extensive collection of concepts and related lexical labels (thus developing breath and depth of lexical knowledge, respectively) as well as the exploration of semantic networks between them. Children learned about the world and learned the language that is used to represent that world. The words that were learned and the meanings of which were negotiated among children were constant throughout children's interactions.

The use of TOK also favoured children's playful engagement with phonological awareness games. Very often, children created sequences of rhymes when manipulating narrative blocks, but they also spontaneously integrated rhyming when interacting to creatively enrich their narratives, which reveals that they integrated language awareness abilities in narrative meaningful construction.

TOK offered a rich interactive set of simultaneously virtual and embodied situations, offered creative and playful possibilities that stirred children's curiosity, which is a powerful way to promote learning [2], [54], [55]. The collaborative work among the children themselves, which was sustained by the tangible blocks, was also a major motivating and learning factor [1], [3]. We believe that the results clearly point into the positive role that digital manipulatives can play in pre-school children's interactive language development, which, in turn, contributes to validate the educational potential of use of such innovative tools.

The teacher's intervention showed that it is possible to integrate these tools in routines and spaces in a close socio-constructivist manner, allowing children to physically interact and learn: TOK was a tool for actual learning and actual play. The teacher placed the emphasis on a child-centered model of learning, instead of an instructional mode of interaction, supporting exploratory, expressive and collaborative activities. Her intervention also showed the importance of patiently and

gradually intentionally exploring the manipulative's potential for children's development.

After 15-guided sessions and after using the manipulative during free-play time, the interface did not lose its motivational appeal. The fact that the children transferred the learning abilities learned with the teacher to the activities that they themselves autonomously realized during free-play time showed their involvement with the learning tool, and the combination of a pedagogical approach supported by well-designed materials.

Outgoing from these observations we can conclude that pedagogical materials, which promote "exploratory and expressive activities" [14], rather than explicit instruction, do have a great potential to fostering learning, as the results of this intervention have shown. Such insight may also inform the design of future technology development.

VIII. CONCLUSIONS

The results of the study allowed strengthening our knowledge about the educational potential that such tools hold for important language development. Our research also showed us the importance of close collaboration between ICT developers, language researchers and pre-school teachers that mediate the integration of ICT in the pedagogical activities in order to fully understand its educational potential. Such a serious collaboration made this research possible.

To strengthen this investigation in future research we plan to use a comparison group, as well as more discriminating evaluation instruments, we also expect to work more closely with researchers from the field of education. Further, we will continue our investigation on how to design and integrate innovative learning materials in the school curriculum, gathering information on how to best integrate digital manipulatives in the pre and primary school curriculum, trying to assess advantages and drawbacks of such integration, and creating a set of guidelines for future interventions. Further, and building on the experience that we have gathered along this research we will continue to design and develop other digital manipulatives to address different aspects of children's development.

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