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Developing and Evaluating Pedagogical Digital Manipulatives for Preschool: the Case of TOK - Touch, Organize, Create

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Developing and Evaluating Pedagogical Digital Manipulatives for Preschool: the Case of TOK - Touch, Organize, Create

ABSTRACT

This work aims at contributing to a deeper understanding of the educational value provided by the use of digital manipulatives in preschool. Outgoing from the need expressed by educational professionals and researchers for learning materials that meet children's physical and cognitive needs, and the lack of longitudinal studies involving digital technology in the preschool context, this work describes the design and development of TOK, a digital manipulative for tangible narrative creation. TOK, which stands for *Touch*, *Organize* and *Create* is a collaborative digital environment, which offers young children a playful and rich environment, for embodied collaborative language exploration, experimentation and tangible narrative creation. TOK is composed by an electronic platform, and a set of 23 picture-blocks, which represent scenarios, characters and objects from familiar stories. Following a Design Based Research methodology, the design - and later the evaluation - of TOK were carried in a Portuguese preschool for a period of four years, involving eight groups of 25 pre-schoolers - ages five - and six preschool teachers. Children and teachers participated from the very beginning in the design process, which followed an iterative, cyclical process of designing, testing, and redesigning, always incorporating the feedback and the suggestions provided by the children and the teachers in the development of new prototypes.

The motivation to address storytelling within a collaborative environment emerged out of the understanding that language development is essentially social and interactive. In fact, the development of the language is among the major challenges that children face during the preschool years. Moreover, during the preschool years children experience the 'best' learning period to formally learn the language.

Following TOK's implementation three interventions at preschool were carried for a period of around one year. The first was accomplished with 24 pairs of children from two preschool classes, who interacted with TOK during free-play time. This intervention sought to investigate how children used the system and the kind of

activities in which they involved. The results showed that children engaged mostly in literacy related activities, creating stories and playing language games. Further, TOK revealed to encourage peer collaboration motivating children to involve in collaborative language activities. The second intervention was carried with a group of 20 children in collaboration with their preschool teacher, and included also a comparison group from a parallel class. The intervention sought to investigate the effect of the use of TOK in the development of language abilities that are relevant for formal literacy learning, namely lexical knowledge and phonological awareness. The construction of multiple fictional worlds generated through children's embodied interaction with the manipulative, motivated children's continuous verbalizations, contextualizing the learning of an extensive collection of vocabulary and the playing of language games. The results of a pre and a post-test applied to the children showed significant improvements in terms of the targeted language dimensions, sustaining a discussion on the potential of the use of digital manipulatives as powerful scaffolds for fundamental language development in the preschool years. Finally, the last intervention presents an analysis of the narratives created by 27 groups of pre-schoolers, while using TOK for a period of six months. We observed that children's narrative construction occurred in two levels, as children shared the stage, (controlling the characters, defining the location, the props, and the nature elements) and simultaneously performed on this stage. The sharing of the input devices (blocks) gave children equal control of the performance and *orchestration* of their stories, while promoting and supporting peer collaboration.

Indeed, TOK enabled the performance of embodied stage-narratives, promoting children's imagination and creative thinking, as well as fostering early literacy skills and metalinguistic awareness. Moreover, we confirmed that well-designed tangible interfaces do support the development of curricular activities, having the potential to be integrated in the official preschool curriculum.

Further, our research showed us the importance of a close collaboration between ICT developers, interaction designers, language researchers and preschool teachers that mediate the development and integration of ICT in the school context.

Desenvolvimento e Avaliação de Manipulativos Educativos Digitais para o Pré-escolar: o Caso TOK - Tocar, Organizar, Criar

RESUMO

Este trabalho visa contribuir para uma compreensão mais profunda do valor educativo proporcionado pela utilização de manipulativos digitais no ensino pré-escolar. Partindo da necessidade expressa tanto por professores como investigadores, de materiais tecnológicos adequados às necessidades físicas e cognitivas das crianças, assim como a falta de estudos longitudinais dedicados ao estudo do uso da tecnologia digital no contexto de aprendizagem do ensino pré-escolar, este trabalho descreve a concepção e desenvolvimento de TOK, um manipulativo digital que visa promover a criação de narrativas. TOK, que significa *Tocar*, *Organizar* e *Criar* é um ambiente digital colaborativo, que proporciona às crianças um espaço lúdico e rico, para a exploração, experimentação e criação de narrativas. TOK é composto por uma plataforma electrónica, e um conjunto de 23 blocos que representam cenários, personagens e objetos de histórias familiares.

A interface foi desenvolvida e avaliada numa pré-escola localizada no norte de Portugal, durante um período de cerca de quatro anos, envolvendo oito grupos de 25 crianças - com cinco anos de idade - e seis professores do ensino pré-escolar. O estudo seguiu uma metodologia de Design Based Research, onde crianças e professores participaram desde o início seguindo um processo iterativo de desenvolvimento, teste e redesenho, sempre incorporando os comentários e as sugestões fornecidas pelas crianças e os professores no desenvolvimento de novos protótipos. A motivação para abordar a criação de histórias num ambiente colaborativo surgiu do conhecimento de que o desenvolvimento da linguagem é essencialmente social e interativo. De fato, o desenvolvimento da linguagem é um dos principais desafios que as crianças enfrentam durante os anos pré-escolares. Adicionalmente, durante o pré-escolar as crianças experimentam o "melhor" período para a aprendizagem formal da língua.

Após a implementação do TOK foram realizadas três intervenções que se estenderam por um período de cerca de um ano. A primeira foi realizada com 24 pares de crianças de duas turmas do pré-escolar, que interagiram com TOK durante o “tempo da áreas”. Esta intervenção procurou investigar como é que as crianças

usaram o sistema e o tipo de atividades em que se envolveram. Os resultados mostraram que se ocuparam principalmente em criar histórias e realizar jogos de linguagem. Uma das características mais salientes do TOK foi a medida em que promoveu a realização de atividades colaborativas. A segunda intervenção foi realizada com um grupo de 20 crianças, em colaboração com a educadora, incluindo também um grupo de comparação de uma turma paralela. A intervenção procurou investigar o efeito do uso do TOK no desenvolvimento de dimensões linguísticas, relevantes para a aprendizagem formal da língua, nomeadamente o conhecimento lexical e a consciência fonológica. A construção de vários mundos ficcionais gerada através da interação física com a interface promoveu verbalizações contínuas, contextualizando a aprendizagem de uma extensa coleção de vocabulário e a prática de jogos de linguagem. Os resultados de um pré e um pós-teste aplicados às crianças mostraram melhorias significativas no desenvolvimento das dimensões linguísticas mencionadas, sustentando uma discussão sobre o potencial do uso de manipulativos digitais na aprendizagem formal da linguagem. Finalmente, a última intervenção apresenta uma análise das narrativas criadas por um grupo de 27 pares de crianças que interagiram com TOK, durante cerca de seis meses. Observou-se que a construção das narrativa ocorreu em dois níveis, sendo que dividiram o palco, (controlando personagens, definindo a localização da história, os adereços, e os elementos da natureza) e, simultaneamente, atuaram nesse mesmo palco.

A partilha dos dispositivos de entrada (blocos) promoveu uma participação colaborativa, e permitiu às crianças planear, controlar e orquestrar as suas narrativas. Na verdade, TOK atuou como um placo para o desempenho de narrativas, promovendo a imaginação e criatividade, bem como a aprendizagem linguística. Os resultados do estudo reforçaram a noção do enorme potencial que os manipulativos digitais têm no desenvolvimento de competências linguísticas, suportando o desenvolvimento de atividades curriculares. O nosso estudo permitiu-nos também reforçar a importância de uma estreita colaboração entre investigadores de diferentes áreas de saber, assim como professores a fim de desenvolver e compreender plenamente o potencial educativo destes materiais tecnológicos inovadores.

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CHAPTER 1 - Introduction

1.1 Introduction

Discussions about the use of technology in the classrooms have disclosed how technology often fails to exploit the affordances of the medium, by merely transposing traditional learning materials to the corresponding electronic format (Plowman et al., 2012:5,6). In fact, while it is widely recognized that technology can have significant impacts on learning in early education (Van Scoter, 2008:158; Voogt, 2008), there seems to be a lack of well-designed materials, as well of studies that investigate the role of digital media in early education (Plowman et al., 2012:2). Moreover, studies involving children less than eight years of age are even rarer (Kamil & Intrator, 1998; Kamil et al., 2000; Lankshear & Knoebel, 2003; Yarosh et al., 2011).

Exposing children to rich contexts and situations stimulates their natural need for exploration and discovery (Van Scoter et al., 2001:8), offering an enormous opportunity for the development of pedagogical materials that target learning in the early years. Well-designed technology has the potential to create rich environments, providing challenge and adventure, while encouraging exploration and imagination (Van Scoter et al., 2001:12; Plowman, 2012; Resnick et al., 2005). Indeed, technology has the potential to provide new experiences and interactions that go beyond what is possible in the real world (Van Scoter et al., 2001:9). However, in order to have pedagogical value, technology needs to convey the learning subject in a way that meets young children's needs (Howard-Jones, 2011).

Plowman et al. define the affordances - a term coined by Norman (1988) - of good technological tools as follows: "Materials should be compelling, encourage creativity, develop curiosity, bear repeated re-use, be accessible for all children, and promote interaction with and away from the technology, and with others" (Plowman et al., 2012:6). Resnick et al. (2005) suggest that well-designed materials ought to support exploration, be intuitive, so that users immediately understand how to use them; have a “low threshold”, and a “high ceiling” (be easy to start, but also support increasingly sophisticated projects); have “wide walls” (support creativity); support different leaning approaches, promote collaboration, while being as simple as possible. In addition, well-designed technology needs taking into account children’s age, as well as children’s physical and cognitive development, be visually appealing, provide feedback, and be informed by formative and iterative research (Glaubke, 2007:23). As Schön (1983) suggests “learning is designing, and designing is a conversation with - and through - the artifacts” (Schön, 1983:76 as cited in Ackerman, 2007).

In the digital or knowledge society, in which we live, the benefits of integrating technology in early education have been widely acknowledge, as a way of preparing children for the demands of the future society, in which people continuously need to discover new creative solutions to solve unexpected problems, and where knowledge alone is no longer enough (Resnick, 2007). Resnick highlights the importance of interacting with the right materials, which promotes a “creative thinking spiral”. By doing so children “*imagine* what they want to do, *create* a project based on their ideas, *play* with their creations, *share* their ideas and creations with others, and *reflect* on their experiences” (Resnick, 2008:18).

School needs to adapt to the complexity and the demands of today's world and prepare children for the future that lies ahead, this means using new tools and new forms of learning, from which technology is definitely part (Amante, 2007; 2013). According to Van Scoter (2008) and Roschelle et al. (2000) technology has the potential to offer four key characteristics of effective learning environments: active engagement, collaborative learning, frequent and immediate feedback, and connections to real world contexts.

In the preschool context, one of the areas that can potentially benefit from the use of technology is the development of early literacy skills (Van Scoter, 2008: 149), which is also one of the core areas formally targeted in preschool education.

1.2 New Materials for Exploring the World

Digital manipulatives[1] (Resnick et al., 1998) also referred to as tangible interfaces - TUIs (Ishii & Ullmer, 1997; Ullmer & Ishii, 2001) or tangible systems have emerged as powerful challenges to the way users interact with digital technology. This new paradigm employs physical objects, surfaces, and spaces to interact with digital information, freeing users from traditional keyboard and mouse, thus providing a more natural interaction, stimulating sensory and whole body perception, giving users freedom of movements, while creating richer experiences. Moreover, digital manipulatives have the potential to expand the range of concepts that children can understand (Ainsworth, 1999; Glenberg, 2010; Glenberg et al., 2011; O'Malley & Fraser, 2005; Zuckerman et al., 2005), promoting peer collaboration and negotiation (Hornecker, 2005; Hornecker & Buur 2006; Zuckerman et al., 2005) particularly supporting exploratory and expressive learning activities (Marshall, 2007).

The use of objects to scaffold learning and facilitate the comprehension of abstract concepts has a long tradition that can be traced back to educational theorists like Fröbel and Montessori (Brosterman, 1997; Montessori, 1912; Resnick, 2007; Zuckerman et al., 2005). Indeed, digital manipulatives allow shifting from an "instructional mode of interaction" towards a technology that supports children's open-ended and active exploration, providing opportunities for social interaction and supporting scaffolding from more skilled peers (Eagle, 2012).

Zaman et al. (2012:368) summarize the affordances of tangible interfaces as follow:

> Specificity of input devices, which reduces modality on the interface;
> Improved accessibility of the interaction, building on everyday skills and experiences of the physical world;
> Employment of bi-manual and haptic interaction skills;
> Facilitation of spatial tasks through the inherent spatiality of TUIs;
> Tight coupling of control of the physical object and the manipulation of its digital representation.

[1] The term digital manipulatives has been coined by Resnick and the lifelong kindergarten at the MIT, Media

Given the enormous possibilities provided by technology, which embeds computational properties in every day objects, a great part of the research on the field of tangible interfaces targets children. In fact, these systems are particularly appropriate for young children to interact with digital content, as children's fine motoric skills are not yet fully developed, freeing them from the use of traditional mouse and keyboards. However, the great part of research still focuses on computer related technology (Plowman & Stephen, 2003).

1.3 Motivation

Research on the field of educational tangible interfaces, has revealed that the great body of investigation consists of small-scale, single case studies (Garzotto et al., 2010; Zaman et al., 2012). The majority of the studies focus on the innovative possibilities offered by tangible interfaces, often missing empirical evidence to support the benefits of tangible technology (Cassel, 2004; Marshall, 2007; Yarosh et al., 2011:143; Zaman et al., 2012).

Further, a great part of research (43%) concentrates on the design (and often the evaluation) of novel systems for children. In their extensive analyses of research papers presented at the Interaction Design and Children Conference during the period from 2002 to 2010, Yarosh and colleagues (2011:143) found out that rather few papers inform their work with existing theory. Relatively to the investigated topics, literacy was the focus of 8% of all papers, with an apparent decreasing tendency (Yarosh et al., 2011:139).

Additionally, research on technology and children over the last decade found out that the great part of research addresses older children (Kamil et al., 1998; 2000; Lankshear & Knoebel, 2003, Yarosh et al., 2011).

Further, with few exceptions, most of these technological systems have not been used in real classroom settings, and very often after an experimental phase they remain within the lab.

Continuing a line of research on the learning benefits of digital manipulatives for preschool children, in which we developed and evaluated a pedagogical tangible manipulative for promoting young children's awareness of a good oral hygiene, and motivated by the pedagogical potential of such interfaces, as revealed in the referred study (Sylla, 2009; Sylla et al., 2012c), this work aims at investigating and contributing to a deeper understanding of the educational value provided by the use of well-designed technology in preschool.

The motivation to develop a digital manipulative for pre-schoolers emerged out of the current research and educational landscape:

The need expressed by educational professionals and researchers for learning materials that meet children's physical and cognitive needs;

The lack of longitudinal studies involving digital technology in the preschool context;

The potential of digital manipulatives to involve children in expressive and exploratory learning activities.

1.4 Research Questions and Objectives

The research questions addressed in this inquiry were following:

- To which extent is the use of educational digital manipulatives likely to bring an added value to preschool education, meeting objectives formally targeted in preschool education?

RQ 1 - How should a digital manipulative be designed in order to support a child-centred approach, fulfilling children and teachers' needs, while bringing an added value to the preschool curriculum?

RQ 2 - How to integrate digital manipulatives in the preschool curriculum, which support free activities?

RQ 3 - How to integrate digital manipulatives in the preschool curriculum, which support guided activities? Can digital manipulatives stimulate the development of relevant language dimensions, namely language and phonological awareness?

RQ 4 - Can digital manipulatives contribute to the development of early literacy, promoting creative thinking and the construction of narratives?

RQ 5 - What are the constraints associated with the integration in the classroom context of such technological developments?

Objectives targeted in each of the four studies:

Design and evaluate multiple iterations of a digital manipulative according to children and teachers' needs, which supports curricular activities;

Involve children in the design of the digital manipulative;

Access the kind of activities in which children would involve, the challenges they would face, and how they would solve them;

Use a digital manipulative to scaffold fundamental language developments in the pre-school years, namely language knowledge and phonological awareness;

Access the kind of narratives children would create using the digital manipulative;

Identify difficulties and constrains of the integration.

1.4.1 TOK a Digital Manipulative for Preschool

To address our research questions and objectives we developed a digital manipulative for creative narrative construction. The choice of narratives as the global learning domain, was motivated by the fact that narratives are a privileged mean for targeting personal and social development as well as the development of language and communication dimensions, which we together address in our study.

The development of the language is among the major challenges that young children face during the preschool years. Language develops primarily to communicate with others, and through the interaction with others, in a process that is essentially social and interactive (Snowling & Hulme, 2009:103), while at the same time mediating learning, and being a tool to organize the world (Bruner, 1966:6). Language empowers children to express themselves, to communicate with others and to participate actively in educational activities (Bruner, 1966; Van Scoter, 2001:8; Vygotsky, 1962).

The acquisition and development of language is a long and particularly complex process, which reaches its critical development during the preschool years, a period of rapid conceptual and lexical acquisition (Sim-Sim, 1998:110). Although linguistic knowledge is implicit and emerges naturally by interacting and communicating with others, it needs to be stimulated and to grow in order to reach its full potential. Indeed, it is precisely during the preschool period that language development is encouraged and expanded and some language dimensions, which for children where merely implicit, gradually begin to become conscious. This transition from an implicit (epilinguistic), to an explicit level (metalinguistic) allows the isolation and manipulation of language units (Seymour, 2009), helping children to structure their discourse and also their world. In this process children gradually acquire the ability to create more structured and elaborated language, while learning to think in more abstract categories (Bruner, 1966; Vygotsky, 1978).

The importance of this period for the development of "emergent literacy skills" (Phillips & Lonigan, 2009; Sulzby & Teale, 1996; Teale & Sulzby, 1989; Whitehurst & Lonigan, 1998), which are defined as "developmental precursors to conventional reading and writing skills" (Lonigan, 2007:21), has been highlighted by a growing body of research. Emergent literacy evolves through the interplay of "inside-out" and "outside-in" skills (Whitehurst & Lonigan, 1998). Inside-out skills refer to phonological awareness and letter knowledge; outside-in skills refer to the conceptual knowledge of the language. Research on emergent literacy considers that there is no clear boundary between pre-reading and reading (Lonigan, 2007:18), and that the acquisition of emergent literacy takes place spontaneously and without formal instruction. As Seymour explains, "Language is the key environmental factor that is likely to influence the development of the cognitive systems underlying reading and spelling" (Seymour, 2009:300). However, the development of emergent literacy is strongly determined by children's degree of exposure and active participation in literacy environments, where they can interact with meaningful materials, within social contexts that scaffold and encourage emergent literacy attitudes (Lonigan, 2007; Phillips & Lonigan, 2009; Sulzby & Teale, 1996; Teale & Sulzby, 1989; Whitehurst & Lonigan, 1998). In fact, the variety of rich literary experiences is critical for the development of emergent literacy. Storytelling is a creative and playful way of linguistic exploration (Paley, 1991; 2004), indeed, telling stories helps children practice important literacy skills, fostering the development of oral language (Collins, 1999; Morrow, 1985; Paley, 1991), while providing opportunities for creative thinking and social interaction

(Paley, 2004), helping children learn how to express themselves and to communicate with others, gradually acquiring the discourse rules (Ackermann, 2001b).

1.4.1.1 Short Introduction of the System

The design of the digital manipulative was based on the assumption that narrative construction should be centred on the playful character of language, and the pleasure in dealing with words through playful experimentation, where children are "players rather than spectators" (Bruner, 1966:95).

Figure 1-1 Two girls using the digital manipulative.

The interface is composed by an electronic platform, which connects to a computer or a tablet through USB or Bluetooth, a microphone, and 23 physical picture-blocks to manipulate the digital content. The blocks represent characters, scenarios and objects from traditional stories, allowing the creation of traditional stories or original narratives (fig.1-1).

The tangible nature of the system, led us to name it TOK, which stands for Touch, Organize and Create. Indeed, *Touch* describes the embodied manipulation of the digital content, *Organize*, refers both to the physical, as well as to the mental process of ordering the picture-blocks, in which users involve when they *Create* their narratives (fig 1-2).

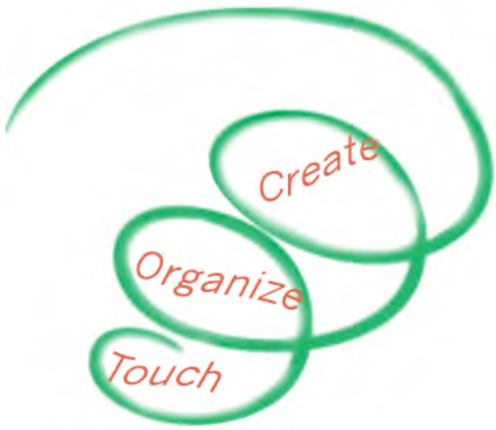

Figure 1-2 interaction with TOK, based on Resnick's creative thinking spiral (Resnick, 2007).

1.5 Thesis Overview

Following the introduction, the formulation of the research questions, and the objectives of the study presented in chapter one, the work progresses by giving an overview of the development of the language in the preschool period in chapter two. Chapter three discusses the educational theories that support the use of objects and of digital manipulatives for learning. Chapter four gives an overview of related work in the field of tangible interfaces, and chapter five gives an account of the role of children in the development and evaluation of technology, followed by an overview of evaluation methods used with children. Chapter six presents the methodology used during the study. Chapter seven describes TOK's design and development process. Together these chapters comprise the first part of the study.

The second part of the study, reports the findings of three interventions carried with the digital manipulative at preschool.

Each intervention tried to access different aspects, namely the first one, presented in chapter eight investigated how children used the system, and the kind of activities in which they involved during free-play time; the second, described in chapter nine, was carried in collaboration with a preschool teacher and her class, and sought to access the impact of the use of TOK in the development of language abilities involved in formal literacy learning; the third intervention, described in chapter ten, analysed children's narrative construction. The reflections and conclusions of the research are presented in chapter eleven.

All the interventions – the design and later the evaluation of TOK - were carried in a preschool located in the North of Portugal, involving the classes of the five years old children. In Portugal, children usually enter preschool at the age of three and the groups stay together with the same teacher until the end of preschool, by the age of six children then enter primary school. The interventions were all carried with the group of children during their last preschool year.

CHAPTER 2 - Language Development in the Preschool Period

2.1 Portuguese Curricular Orientations for Preschool Education

The Portuguese curricular orientations for preschool education[2] focus on three main areas: expression and communication, - which include fostering the development of oral language and a first approach to reading and writing - knowledge of the world, and personal and social education.

According to these orientations the development of oral language and emergent literacy (Clay, 1966; Whitehurst, 1998) is one of the core areas targeted in preschool education. The strategies for the development of language and literacy propose:

Talking with others about significant personal experiences;
Describe objects, events and relationships;
Listening to stories and poems, making up stories and rhymes.

Further, the guidelines suggest that the mastery of different forms of expression implies diversifying the situations and learning experiences so that children gradually learn to master and use their body trying out different materials that they can explore, manipulate, and transform. Moreover, communication ought to be fostered through the interaction with other children in the group and with the educators, as well as be extended to different contexts that may lead children to acquire greater ownership of the different functions of the language.

An introductory approach to writing is also advised as part of preschool education, - which is to be promoted through contact with the written code - enlargement of vocabulary, and increasing complexity of sentences. Learning

[2] OCEPE, Despacho n° 5220/97- 10 Julho

ought to be based on the playful character of language, the pleasure in dealing with words, sounds, as well as inventing and discovering relationships.

From three years on children know the difference between drawing and writing. At this age many children take pleasure in pretending reading and writing, an activity that ought to be stimulated, and that familiarizes children with the written code. Children's pretended reading should be promoted, fostering the interpretation of images or prints from a book, or other kinds of text. The reading strategies comprise reading the title of books to children and asking them to infer from it information about the book. Further, to identify and verbalize names and activities of the characters.

Additionally, teachers ought to stimulate and develop reasoning and critical thinking, allowing children to build a more elaborate and accurate understanding of reality (e. g. promote knowledge of different areas of the world, thinking about the world, organize experience, look for patterns).

Through the contact with literature and storytelling and the interaction with the group children gradually acquire the discourse rules, extend their vocabulary, elaborating more complex sentences that enable them to higher forms of expression and representation.

Relatively to the use of Information and Communication Technology, (ICT) at preschool, the guidelines for preschool education, highlight that the emphasis should *not* be placed on learning how to operate technological equipment, programs or digital resources, but on providing children better and richer learning experiences, valuing relationships and interactions, paving the way for a successful school performance.

2.2 Developing Lexical Knowledge and Phonological Awareness in Preschool

Language is a fundamental tool to communicate with others and, through them, to learn about the world (Bruner, 1966; Vygotsky, 1978). The preschool years are a complex and crucial period of language development, which imply the nurturing of natural linguistic development, as well as children's introduction into cultural dimensions of language (Pereira, 2012 a, b).

Language is a biological endowment (Chomsky, 1965), which in order to fully develop, needs scaffolding through situated interaction (Lentin, 1981; Wood et al., 1976). Though naturally sustained, language development is essentially social and interactive (Snowling & Hulme, 2009:103). Moreover, the preschool years coincide with the critical period of the natural development of language (Lenneberg, 1967), which extends up to seven years of age, in which children experience the 'best' learning period to learn the grammatical components of language as well as to develop their lexical knowledge.

The development of language has been reported as a fundamental factor in the formal learning of reading and writing in the elementary grades. Lexical (or word) knowledge plays a very significant role in such learning (MacGregor, 2004). Phythian-Scence and Wagner (2007:1) affirm that "Acquiring the vocabulary we use for thinking and communicating is a linguistic achievement of nearly incomprehensible importance and complexity", and MacGregor (2004:302) helps us to understand why, by saying that "to read is to access the lexicon via print. Therefore, reading depends, in part, on a well-developed lexicon".

In effect, in the early stages of learning how to master the written code, a vast lexical knowledge allows children to succeed in identifying the meaning of unfamiliar written words that they have to decode (Coltheart et al., 1993; Lonigan, 2007). For the very same reasons, the breath of lexical knowledge is relevant for reading comprehension throughout all our lives, besides, the depth of the lexical knowledge also influences our reading comprehension. The deeper (that is, more fully developed) semantic representations of words we keep in our lexicon, the more semantic networks we can create among the words we read, the more able we are to make inferences, which in turn result in more complete mental representations (Kintch & Van Dijk, 1978) and a deeper comprehension of texts that we read (Carlisle, 2007; Lonigan, 2007; MacGregor, 2004; Nagy, 2007; Nation, 1990; Perfetti et al., 2009).

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 (Vygotsky, 1978). The rhythm with which conceptual and lexical knowledge develop during the preschool years is unparalleled in our language development (Pinker, 1994). Although at the end of preschool, children know many words, their vocabulary domain is still in progress (Phythian-Scence & Wagner 2007:5), continuing to expand and refine more formally during primary school, and throughout the whole life.

However important the nurturing of the innate capacity and the lexical expansion are, language development in the preschool years is expected to further extend 'basic' language capacities to introduce children to socially specific, non-spontaneous and non-universal dimensions of language knowledge and use (Pereira, 1012a,b). It is nowadays indisputable that emergent literacy plays a decisive role in the formal learning of reading and writing in the elementary grades (Clay, 1966; Downing, 1971; Ferreiro, 1986; Mata, 2008; Phillips & Lonigan, 2009; Sulzby & Teale, 1996; Teale & Sulzby, 1989; Whitehurst & Lonigan, 1998).

Language awareness is central in current conceptions about emergent literacy construction and literacy learning. It refers to the non-communicative ability to take language as a detached and conscious object of voluntary attention and analysis (Adams et al., 1998; Blevins, 1999). Such ability demands more cognitive effort than the required by the automatic use of language to communicate.

Phonological knowledge is perhaps the most widely acclaimed target of language awareness to be initiated in the preschool years due to the relationship that exists between the alphabetical written code and the phonological component of the oral language (Adams et al., 1998; Alves Martins, 1996). As in English, Portuguese written language represents the sounds of the 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 the degree of children’s phonological awareness is directly related with their successful performance in reading and writing during the first and second grades (Seymour, 2009; Troia, 2004; Whitehurst & Lonigan, 1998).

Yet, phonological awareness does not develop spontaneously, young children show especial difficulty in achieving phonemic awareness due to the abstract nature of sounds (phonemes) (Seymour, 2009). Research has therefore shown the desirability that preschool teachers implement intentional pedagogical approaches to develop phonological awareness by first stimulating the easiest ways into phonologic awareness. This can be done in a playful, gaming-like manner, beginning with syllabic and rhyming tasks, and later through phonemic tasks.

The complexity of language development in the preschool years is perhaps suitably illustrated by referring that there is a close relationship between lexical development and the development of phonological awareness (Lonigan, 2007:16). Lexical knowledge seems to influence phonological awareness, as children “with larger vocabularies tend to do better on phonological awareness tasks” (Troia, 2004:277). On the other hand, vocabulary knowledge also seems to have a positive influence in the development of phonological awareness (Lonigan, 2007:21).

2.3 Language Development and Peer Interaction

The interaction with peers is particularly important for the development of language and literacy. Both, constructivist and social constructivist theories, consider that learning is embedded within a social context and generated through the interaction with more skilled members, emphasizing guidance and support (Bruner, 1966; Lave & Wenger, 1991; Vygotsky, 1978). Piagetian researchers have underlined the role of cognitive conflict between peers, as a factor that promotes learning and cognitive growth. In fact, explanations on the benefits of peer collaboration emphasize the role of communication, particularly, verbal communication (Ellis & Gauvain, 1992:157), as a way of facilitating conceptual understanding (Phelps & Damon, 1989, cited in Ellis & Gauvain, 1992:159). Research has shown clear benefits of collaborative learning activities (Rogoff, 1990;) and the importance of the social environment for the development of cognitive processes (Wood & O'Malley, 1996).

2.4 Language Development through Storytelling

Storytelling is a discursive format that official guidelines for preschool education refer to as objects of intentional development (Pereira, 2012a), and indeed one of the most beloved language related activities carried at preschool. Moreover, besides being an acknowledge dimension of linguistic development in childhood, storytelling is also considered to be a key dimension of cognitive and affective development (Bruner & Haste, 1988; Eagle, 2012). Indeed, storytelling provides opportunities for social interaction (Speaker et al., 2004) and innovative thinking, and offers children a "nourishing habitat for the growth of cognitive, narrative and social connectivity" (Paley, 2004:8).

Although narrative has the status of a privileged discourse format, it is part of the "domain of language use, and narrative development is a subcomponent of language development" (Bamberg, 1997:65). From a constructivist and constructionist point of view, language provides "the building blocks" and narrative is the domain in which these blocks are assembled together creating new experience and knowledge (Bamberg, 1997:86). Certainly, due to their linguistic structure, and children's emotional bond with stories, stories are a privileged means for the development of language abilities, implying decontextualized use of the language, as the narrator always places himself at a distance from the related events (Dehn et al., 2014).

Studies on children's early exposure to narratives have disclosed that hearing or telling stories has a major influence on the development of children's early literacy skills, being a creative and playful way of linguistic exploration (Collins, 1999; May, 1984; Paley, 2004; Speaker, 2000, 2004). At the same time stories offer a "memory framework", namely, the ability to remember and effortlessly analyse new stories, providing anticipation of information, helping children to understand new stories and retell them (May, 1984), which in turn facilitates the construction of meaning, and the creation of new stories (Morrow, 2005).

As Morrow explains: "Young children who have stories read to them develop more sophisticated language structures, accumulate more background information and have more interest in learning to read. In addition active participation in literary experiences enhances the development of comprehension, oral language and a sense of story structure" (Morrow, 1985:646). Collins suggests that hearing and telling traditional stories may be "appropriate educational tools for engaging the senses in memory and recall" (Collins, 1999: 88).

In fact, retelling or creating stories implies a mental reconstruction of the story events, which fosters the development of metanarrative consciousness (Brown, 1978), and the emergence of more advanced language skills, enhancing grammar, vocabulary, and sentence formation (Speaker, 2004). Confirming that vocabulary and syntactic complexity in oral language are more advanced in children who are frequently exposed to a variety of stories (Phillips, 2000; Speaker, 2000).

Storytelling is a social activity (British, 1992), which helps children to develop their ability to imagine alternative possibilities and work out their implications, while learning to handle contributions made by their peers, and responding to them adequately (Harris, 2000). Definitely, the importance of narratives goes beyond developing language abilities, encompassing other developmental dimensions. Unquestionably, stories help children to create their own identity, providing a gateway to the minds of others, their emotions and experiences, offering children a model and a way to project, handle and eventually solve their own existing conflicts. As such, narratives help children to clarify their emotions, anxieties, fears and aspirations (Cooper, 1993; Engel, 1999; 2005, Paley, 2004; Wright et al., 2008), offering a safe place to confront and explore their worries and insecurities.

2.4.1 Narrative Performance

The fictional nature of stories, which places them in an imagined time and space, clearly signalized by the *magic words*, "Once upon a time"..."A long time ago"... provides the ideal territory for exploration and experimentation. Similarly to a theatre performance (Burke, 1945), where agents act upon a stage, encompassing particular social interactions (Goffman, 1959), narrative performance (Langellier, 2003; Langellier & Peterson, 2004; Todorov, 1977), is essentially an act of embodied communication (Madison & Hamera, 2006; Peterson, 2009), constructed and negotiated with others (Bamberg, 2014), acting as social mediator, while helping to structure the self and understand the world (Bamberg, 1997; Bruner, 1966, 1991; Collins, 1999). Paley (1991, 2004) approaches children's language and thought development through the dramatic play of children's narratives, Van Scoter (2008: 154) proposes using props for dramatic play.

2.4.2 Narrative Structure

The framework for these "performances" is provided by chronological organized events in well-defined moments that comprise a beginning, middle and an end. Labov and Waletzky (1967) define a minimal narrative as consisting of two sequential events. According to Todorov (1977) in narratives there is always a change of state, which happens throughout five narrative stages: equilibrium, disruption, recognition of the disequilibrium, resolution and new achieved equilibrium.

The different moments of the narrative are organized according a temporal and causal consistency and coherence, linked by networks of causality between the different story events. These causal relations are created by external elements, or inner motivations of the characters, resulting in actions; or are themselves a result of such external events or inner motivations. Propp (1928/1968) identified a number of 31 always recurring "functions", or plot elements in fairy tales that form the structure of the narrative, which traditionally relays on binary oppositions, like heroes and opponents, good and evil, light and darkness, or life and death (Levi-Strauss, 1979).

2.4.3 Children's Creation of Narratives

At the level of the discourse, narratives are for children by far, more demanding than the discourse they use in daily life, presupposing the use of the past tense and a more elaborated and structured language.

At the age of four, children's narratives are mainly sequences of events with no explicit relation between them (sometimes there is still some confusion regarding the temporality of events) (Sousa, 2010:96), which normally relate their daily life experiences. At the age of five, children continue to create their stories according to a sequencing principle, rather verbalizing sequences of events that are organized temporally, and connect by the prepositions, "and then... and then..." without presenting an outcome, the resolution of a conflict, or an explicit end (Sousa, 2010:103). Indeed, young children's narratives are hardly explicit, giving only little information about the characters and events, without explicitly creating causal relations between them. It is around the age of six that children are able to tell a story following the classical narrative structure, with a beginning, middle and an end. By the age of seven, children begin to organize their narratives according to events that depend on each other, establishing causal relations between the character's actions and their inner motivations, and relating them to their actions. This makes the stories more coherent and understandable for others (MacCabe, 1997; Sousa, 2010:99). By the age of ten, the strategies that began to emerge with seven are consolidated and children's stories are longer, displaying more information about the motivations of the characters, creating relations within the story plot, which also becomes more complex.

As suggested by Van Scoter (2008:154) a good way of helping children to structure their stories is through the use of props; while it is common to use verbal props to foster the structured flow of a narrative, objects can also act as elements that promote creativity and learning.

Creating stories, acquiring relevant linguistic abilities, such as lexical knowledge and phonological awareness, all are fundamental dimensions for the later development of reading and writing skills, as well as the acquisition of early literacy, paving the way for a good school and learning performance. The use of objects to scaffold learning in the early years has a long tradition, which indeed goes back to visionary educators like Pestalozzi, Fröbel and Montessori (Brosterman, 1997), the next chapter presents an overview of the importance of using objects to facilitate learning.

2.5 Summary

In this chapter we have discussed the process of language development during the preschool years, referring the Portuguese curricular orientations for preschool education. Further, we have pointed out the importance of literacy rich environments capable of stimulating young children's active participation in the acquisition of early literacy, and the importance of stimulating phonological awareness and lexical knowledge, as these two dimensions play a key role in the later acquisition of reading and writing. In this context, we have also emphasised the importance of storytelling for the development of language and early literacy. Although language development is naturally sustained, it is mainly a social process, which takes place within a community of practice; therefore we have underlined the importance of peer collaboration in the development of these dimensions.

In the following chapter we will present the theoretical foundations that support the use of digital manipulatives in preschool. First used by educational theorists at the end of the 19thcentury, physical objects have been successfully used in preschool as learning scaffolds to facilitate the comprehension of abstract concepts and principles. Besides highlighting the fundamental role of objects in the learning process, we will present the cognitive theories, which support and underlie the development of TOK.

CHAPTER 3 - Theoretical Foundation that Support the Use of Digital Manipulatives in Preschool

3.1 Using Objects as Scaffolds for Learning in Preschool

Friedrich Fröbel, the creator of the world's first kindergarten – 1840 in Germany - investigated the relation of children's play with the development of cognitive structures. As an educational theorist, Fröbel was convinced that the use of objects helped children to better understand and learn abstract concepts. Aiming at helping children in arithmetic and geometry, Fröbel developed a collection of 20 physical objects, which he named *gifts* (fig. 3-1), and included balls, strings, sticks and blocks. The concept behind the *gifts* was that the manipulation of familiar forms, present in everyday life and in nature, facilitates the comprehension of abstract concepts (Brosterman, 1997). Moreover, the *gifts* were used as play materials to help children think about and express ideas. Fröbel developed a curriculum for young children – ages three to seven – where they could engage in *self-activity* and *self-expression* through play (Fröbel, 1909: vi).

Figure 3-1 Simulation of a Fröebel's gif.

Maria Montessori shared Fröbel's pedagogical ideas; both educators were visionaries and convinced that the best way for children to learn was by actively engaging in exploring their environment. Fröbel's children worked at kindergarten in small groups, while in Maria Montessori's *Children's Houses*, children were taught in groups between 40 to 50 children, from three to seven years of age.

Montessori promoted children's active exploration of the environment, at the *Children's Houses*, children engaged in different activities, playing with different materials; some children sat at tables, other on the floor; some worked individually, other in groups, according to their interests and development stage. Teachers, whom Montessori named *directresses*, were instructed to guide and encourage learning by making the necessary tools available at the right moment, observing without interfering in the learning process. "It is precisely the error that makes the tool important, for the child has to observe and try out different possibilities, therefor she observes the dimension and learns about dimensions" (Montessori, 1912:177).

Montessori considered that there was a strong connection between cognition and the senses, and her method, based on the *Didactic Materials*, addressed the stimulation of every sense (Montessori, 1912). The design principle behind each of the objects, from the *Didactic Materials* set, was to raise children's interest and curiosity. Montessori designed her collection of objects based on the notion that children like to handle objects, and that they could recognize forms and figures through their senses, even before being able of recognizing them by looking at them. Montessori considered the touch as the most precious sense (Montessori, 1912: 205).

Through the senses, the *Montessori method* addressed various aspects of knowledge, from reading and writing to mathematical concepts. An example of an object to train the vision consisted of a wooden block with ten different sized cylinders. Children could take the small cylinders out of the wooden block, mix them and then try to place them in the right location again. By engaging in this activity children learned concepts of area, dimension and volume. The objects were self-contained in the sense that they controlled the error, so there was no need of a teacher to teach children where to place the cylinders; they just needed to try until every cylinder was in the block.

Montessori's learning method for writing was also based on the senses, it consisted of the alphabet letters cut in sandpaper, children first felt the contour of each letter with their fingers, and then with a little wooden stick. The method revealed to be very effective, as Montessori describes in her writings, almost all children in the various *Children's Houses* could read and write by the age of four.

3.2 Children's Cognitive Development and Learning

3.2.1 Piaget and the Constructivism

Similar to Montessori, Piaget considered the acquisition of knowledge to be a self-regulatory process, which cannot be transmitted through didactic teaching, but has to be directly experienced by the child (Piaget, 1977). Considering that it is through their exploratory actions on the environment that children *construct* their own knowledge. Actions can be both physical, through the manipulation of objects as well as mental. According to Piaget all knowledge has its origin in the actions taken upon objects during the first years of life.

Intellectual growth means gradually becoming independent from the perceptual world of objects and being able to conceptually manipulate symbols, moving away from the particular to the general through the creation of "cognitive invariants" (as Ackermann, 2004 says describing Piaget's work), which are rules that help children to organize their experience by creating their own models of the world. These models are particularly important for cognitive development, helping children to mentally organize and bring order in their experiences. Children's models of the world are very different from the one's adults have, but they are highly consistent in themselves, revealing children's actual cognitive development at a certain time.

Piaget's theory roots on four basic cognitive principles: *Schema/schemata* (plural), which are mental structures, where all information - perceptual, motor and conceptual - with which the individual is confronted is introduced and stored. This information is then categorized and sorted according to common characteristics, and then generalized. Schemata begin to be built by the very young child and never stop growing and changing under the influence of new experience, and they always show the actual cognitive development of the child at a given period (Piaget, 1962).

Schemata are not innate structures; they are built slowly, step by step through the interplay of two mental processes, *assimilation* and *accommodation*. When children are confronted with new stimuli they try to incorporate them into their existing schemata, which is done through *assimilation*. If a stimulus does not fit into existing schemata the child tries to modify already existing schemata or creates new ones. This is done through *accommodation.* Thus, assimilation refers to the process of integrating new incoming events into already existing schemata; accommodation is the creation of new schema or modification of already existing ones. When there is a conflict between *assimilation and accommodation* a state of *disequilibrium* arises. *Disequilibrium* occurs when the information present in a schema is contrary or different from new incoming stimuli, in such a situation the child tries to understand and solve the conflict, seeking for *equilibrium*. *Equilibrium* is achieved when the child is capable of integrating the new stimuli into existing schemata whether by changing already existing schemata or by creating new ones (Piaget, 1977). Piaget considers collaboration one of the main sources of disequilibrium; especially the interaction with peers often raises different points of view triggering the mechanisms of assimilation and accommodation. It is this continual interplay between *assimilation* and *accommodation* that results in intellectual development and growth of intellectual structures.

3.2.2 Piaget's Stages of Intellectual Development

Piaget considered that cognitive development is a linear process that happens slowly little by little, each new accomplishment building on the previous ones. He outlined four decisive periods in children's development that he named *stages*. According to Piaget there are three kinds of knowledge: physical, logical-mathematical and social knowledge. Physical knowledge is constructed through sensory motor exploration of the objects, and it is acquired though physical actions performed upon the objects (Piaget, 1952). Logical-mathematical knowledge is accomplished through physical and mental actions upon the objects.

Initially children perceive the world through their senses, and their actions upon the objects, however these merely exist as long as they are visible, thus when an object vanishes from children's field of vision it also stops to exist for her. It is only by around 18 months of age that children achieve the notion of *object permanence*, by then children know that objects exist even when they are not visible. Piaget called this first period of cognitive development the *sensorimotor stage*, which extends till around two years of age.

Towards the end of the sensorimotor period children gradually become able of symbolic representation and begin to master spoken language, entering the *preoperational stage*, which goes approximately until around age seven. From now on, children begin to represent and manipulate objects conceptually through symbols and drawings, however their thought is still mainly perceptual (Piaget & Inhelder, 1969). The *preoperational stage* is marked by the acquisition of spoken language and the rapid development of the cognitive structures. Reasoning gradually becomes independent from the physical actions upon the objects, as actions can now be performed mentally. According to Piaget, the acquisition of language is only possible when children are able of mentally manipulating symbols - language itself is a system of symbols -, and it is only when children are able of symbolic representation that they begin to learn the language. In the *preoperational stage*, children have fully acquired the notion of *object permanence*; in fact they now are able of thinking of the objects even when they are not present. However, it is only by around seven years of age that children fully acquire the *conservation principle*, becoming able to dissociate the notion of space and quantity (Piaget & Inhelder, 1969).

Approximately by the age of seven, and until around eleven, children enter the *Concrete Operations Stage*, in which they are able to think logically about concrete problems, although not yet in an abstract form.

The capacity of thinking in abstract categories is only achieved in the next and last stage of children's cognitive development, namely during the period of the

Formal Operations, which begins approximately by the age of eleven and extends until age 15 or later. In this period children's cognitive development reaches its highest level, and children are now able of thinking abstractly and logically being able to apply this kind of thought to all sorts of problems.

3.2.3 Critics on Piaget's Theory

Piaget's child is often referred to as a "little scientist operating in the laboratory" (Ackermann, 2001a), emphasising logical-mathematical intelligence in detriment of other forms of intelligence (Ackermann, 2001a; Gardner, 1993; Papert, 1993). Piaget considered the isolated child, overlooking the importance of the context, traditions, media as well as individual preferences (Ackermann 2004).

Differently from Piaget's self contained stages, research building on Piaget's work considers that cognitive development is not a linear and simultaneous process across every domain of knowledge, but a gradual and more heterogeneous process, with some competences being achieved earlier in some children, other competences never being completely achieved (Bruner, 1966; Gardner, 1993; Papert, 1993). Instead of a smooth continuity these researchers consider that learning is rather a succession of breakthroughs and setbacks. Similarly to Montessori, Papert considers that making errors, and "debugging" (Papert, 1993:114) provide opportunities for learning, bringing knowledge forward, as learners look for new solutions. Moreover, individual differences, context and media are considered to play an important part in knowledge acquisition (Ackerman, 1991; Lave & Wenger, 1991; Papert, 1993).

3.2.4 Bruner's Theory of Development

Bruner defines intellectual growth as an increasing independence of response to immediate incoming stimuli; as the capacity to internalize new events into a *storage system* that represents one's model of the world, as well as developing an increasing capacity for dealing with different possibilities and considering multiple possible solutions (Bruner, 1966).

Bruner considers three modes of processing information, through *enactive, iconic* and *symbolic* representations (Bruner, 1968). Differently from Piaget's stages, Bruner considers that these forms of representation do not follow a linear progression they rather overlap following a non-rigid sequence. Children's first forms of representations are *enactive,* through physical actions on objects (action-based); followed by the iconic representations, which depend on visual and perceptual images (image-based), *symbolic* representation develops later when signs and symbols represent words, allowing the manipulation of ideas and the creation of abstract concepts (language-based).

For Bruner mental development and instruction are two poles of the learning process. His theory of development is closely linked to a theory of knowledge and instruction; as he considers that intellectual growth depends on a systematic interaction between a teacher and a learner (Bruner, 1966, 1968).

Learning depends on the exploration of different alternatives encompassing three phases, *activation*, *maintenance* and *direction* (Bruner, 1966:43). Bruner proposes a *spiral curriculum*, in which the different subjects are revisited regularly and every time at a higher level. Language is not only a form of communication between a teacher and a learner but also a powerful instrument for the learner to organize the environment. Bruner (1975) coined the term scaffolding referring to the support parents give to their children by joint problem solving.

During the interventions carried in the scope of this work, TOK served as a communication platform between the teacher and her class of pre-schoolers, revealing its appropriateness for carrying guided activities targeting particular curricular topics. Indeed, one of the preschool teachers used TOK to stimulate and develop children's phonological awareness and lexical knowledge. Following a pedagogical approach based on Bruner's spiral curriculum, the teacher frequently revisited the content that had been learned before extending it into a higher level, as children progressed through the learning subject. The results of the intervention, which we describe on chapter nine, revealed a noticeable improvement in the targeted language dimensions, as well as TOK's potential to scaffold the development of language dimensions, which are formally targeted in preschool education.

3.2.5 Vygotsky

Similar to Piaget and Bruner, Vygotsky also considered knowledge acquisition to be an active process. However, whereas Piaget believed that the child constructs knowledge through self exploration in a self-regulated process, Vygotsky - like Bruner - considers that knowledge acquisition takes place within a social environment, embedded in an existing culture. According to Ackermann, Vygotsky considers that the child develops through an *outside-in* process from the other to the self (Ackermann, 2004:22). Consequently, the child does not create his own personal model of the world but overtakes the model *transmitted* by society (Vygotsky, 1962, 1978). Learning is driven by the social and cultural heritage, which provides the learning models, and it is the interaction among its members that leads to knowledge acquisition and the development of intellectual structures. Key to this development is the achievement of spoken language, which acts as a tool for cognitive development, allowing higher forms of thought.

Vygotsky (1978) marked the concept of the Z*one of Actual Development* (ZAD) and the *Zone of Proximal Development* (ZPD). The ZAD defines the level at which children are able to develop on their own, whereas the ZPD defines children's development potential when assisted by a more knowledgeable person. Although, the concept of scaffolding is closely related to the *Zone of Proximal Development*, (ZPD) emphasizing guidance and support from a more knowledgeable person (Vygotsky, 1978), the concept was used for the first time by Bruner (1975) and Wood, Bruner & Ross (1976, as cited by Stone, 1988:345) referring to an aid provided by parents to their children during joint problem-solving activities. The first connection between scaffolding and the *Zone of Proximal Development* was established by Cazden, (1979, as cited by Stone, 1988:345), in which the initial concept of didactic parent child interaction was extended to the teacher-student interaction. Bruner and Wood explicitly acknowledged the linking of scaffolding to the *Zone of Proximal Development* (Stone, 1988:345).

The term scaffolding is now used in different disciplines and contexts, referring among others to scaffolding through peer interaction, as shown by Zimmerman (2000, 2002) and by Azevedo and collaborators (Azevedo & Hadwin 2005; Azevedo & Jacobson 2007), or Wood and O'Malley (1996). And, indeed, children sometimes may even learn more from their pears and unrelated teachers than from their teachers (Gardner, 1993:388; Lave & Wenger, 1991:91). Similarly, scaffolding can take place through the interaction with technological tools, allowing children to perform in their zone of proximal development (Crook, 1998; Van Scoter, 2008:152).

Particularly referring to TOK, the digital manipulative supports different ways of scaffolding, on one hand the manipulative itself is self-contained like Montessori's objects, as it only functions when correctly used, further, throughout the study, TOK supported scaffolding from more skilled peers, as well as teacher's scaffolding, as we will show in the interventions presented in chapter eight, nine and ten.

3.2.6 Papert and the Constructionism

Papert highlighted the importance of providing the right materials to support children (1993:154), empowering them to perform meaningful projects that make sense in a larger social context (1993:54), referring to *Piagetian learning*, as the natural spontaneous learning of people in interaction with their environment (Papert, 1993:7,156).

Papert sees children as *builders* of their own intellectual structures, who need materials for their constructions (Papert, 1993:7). Similar to Montessori, he considers that objects play a major role in facilitating and conveying learning, and, it is when objects are able to relate to people, both in a sensory and an abstract level, as provided by *transitional* models or objects that children can involve themselves with *body and soul* in doing science. LOGO, a programming language for children, developed by Papert (1977), was associated to a physical turtle, as a means of making symbolic manipulation more intuitive and accessible for children, while supporting the development of new ways of thinking and learning. As Papert explains (1993:53-54) "Turtle geometry started with the goal of fitting children. Its primary design criterion was to be *appropriable*". And he continues, "the primary learning experience is not one of memorizing facts or of practicing skills. Rather, it is getting to know the Turtle, exploring what a Turtle can and cannot do. It is similar to the child's everyday activities, such as making mudpies and testing the limits of parental authority – all of which have a component of" getting to know."" (1993:136).

Papert suggests that everything is easy to learn when it can be integrated in the models that children have. When confronted with new ideas children compare them to their models, and then make them their own, assimilating and appropriating the new ideas. It is when children appropriate what is new, compare it to something they already know, and "Make something new with it, play with it, build with it", that intrinsic learning takes place (1993:120).

Informed by these learning theories and in accordance with Fröbel, Montessori, Bruner and Papert, TOK provides a learning environment based on the manipulation of objects, which is carried through exploratory actions over those objects (Bruner, Papert, Piaget). The manipulation of the objects displays symbolic representational models of the world, while the physicality of the input devices supports and promotes peer collaboration, as well as scaffolding from more knowledgeable peers or teachers (Bruner, Vygotzky) (table 3-1).

Table 3-1 Learning approaches.

	Objects	Models	Exploration	Social	Scaffolding
Fröbel	x	x	x		
Montessori	x	x	x		
Piaget	x	x	x		
Vygotsky				x	x
Bruner	x	x	x	x	x
Papert	x	x	x	x	
TOK	x	x	x	x	x

3.3 Examples of Cognitive Theories that Sustain Human Computer Interaction

3.3.1 Distributed Cognition

An important object of study in cognitive psychology is the study of learning as mediated by computational devices. One area that studies the individual cognition in technological environments is the Distributed Cognition, an anthropological and psychological theory of information processing, developed by Hutchins (Hutchins, 1995). Distributed Cognition is part of the Post Cognitivist theories and has several implications in educational research and human-computer interaction. It is based on the principle that human cognition is not only an internal learning process, instead it has a hybrid character being influenced by internal and external factors such as technological artefacts, and the environment. In contrast to a traditional view of cognition as a localized process that analyses information processing at an individual level, distributed cognition emphasizes the distributed nature of cognitive processes considering cognition a communicational collaborative and interactive process with media resources that are external to the individual, and sustained in practices of interaction (information exchanges) across individuals (Lave & Wenger, 1991; Rogers & Ellis, 1994). Those practices allow for the development of different cognitive skills, due to the presence of multiple agents in the exchanges with the external environment, enriching the flow of information, as well as learning.

"Thus, distributed cognition continues to use concepts derived from traditional cognitive theories of the mind (i.e., representations, processes), but applies them to cognitive systems at large, notably, the interactions between people and the artefacts they use for a given activity. In addition, other concepts derived from the social sciences are utilized to account for the socially distributed cognitive phenomena" (Rogers, 2006[3]).

The integration of new information and collaboration are essential factors for structuring knowledge acquisition. Distributed cognition synthesizes the integration

[3] The available version of this article provides no page numbers.

of information processing and the external environment – including in these systems both human cognition in a *strictus sensus* (internal) as well as the technological artefacts that are used in tasks that require cognitive skills. By embracing all those elements – human agents, artefacts, standards and competences, distributed cognition allows for an inclusive analysis of information flow and interactions that take place in the real classroom (Sutton, 2008), (fig. 3-2).

The studies carried with TOK confirmed, as defended by Hornecker (2005), that collaboration is one of the distinctive affordances from tangible systems, in line with Distributed Cognition, children learn from their interactions within their peers and the artefact.

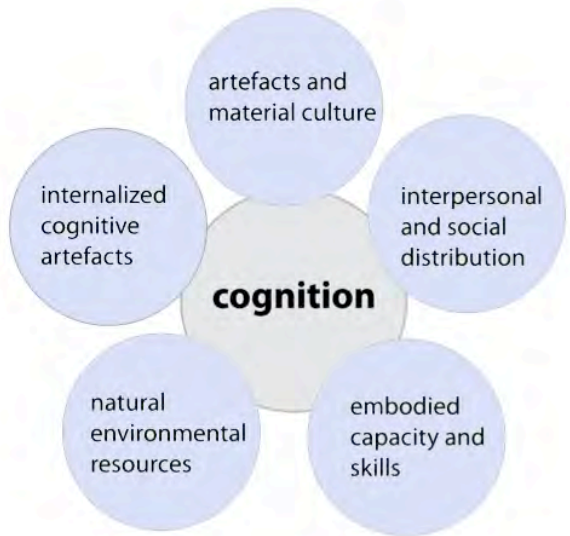

Figure 3-2 Factors influencing cognition (adapted from Sutton, 2008: 47).

3.3.2 Gardner's Multiple Intelligence Theory

According to Gardner the development of the various symbol systems is inherent to human cognition, and as Gardner explains "The advent of symbol use has enormous implications for the development of the personal intelligences" (Gardner, 1993:246). During the period between two to five years of age children develop what Gardner calls *basic symbolisation*, becoming able to create and manipulate different symbol systems, like linguistic, gestural, musical, dramatic (pretend play), as well as basic mathematical operations (Gardner, 1993:305). Gardner and his colleges propose to study the different symbol systems beyond linguistic, logical and numerical systems (as Piaget did) and to focus upon a full range of symbol systems encompassing “musical, bodily, spatial and even personal symbol systems” (Gardner, 1993:26).

For Gardner, each individual has a multiplicity of intelligences, from linguistic, logical-mathematical, musical, spatial, bodilykinestesic, naturalist, interpersonal and intrapersonal intelligence (Gardner, 1993; Gardner et al., 1996; Gardner, 2000), (table 3-2). Gardner considers multiple intelligences as natural or potential talents that are inherent to the individuals (Gardner, 1993). Accordingly, the environment in which individuals are inserted ought to stimulate such potential, so that it can fully develop. Especially at school where cognition and cognitive processes play a key role, it ought to be a priority to stimulate multiple intelligences, instead of merely encouraging those intelligences which involve logical reasoning.

Table 3-2 Gardner’s Multiple Intelligence types.

Types of intelligence	Description and examples
Linguistic Intelligence	Linguistic knowledge (poets and lawyers).
Logical mathematical intelligence	Abstract thinking (mathematicians, computer programmers, engineers).
Musical intelligence	Ability to play and compose music (musicians, composers).
Spatial intelligence	Ability to perceive visual or spatial information (architects, geographers and navigators).
Interpersonal Intelligence	Ability to communicate with others and establish good relationships (social workers, nurses).
Intrapersonal intelligence	Ability to understand states of mind, emotions and motivations.
Bodilykinestesic intelligence	Control over fine and gross motor skill as well as the ability to manipulate external objects (gymnasts, jugglers and other athletes).

The use of TOK supports the development of Gardner’s multiple intelligence promoting a more holistic way of learning, as it shown on table 3-3.

Table 3-3 Analogy between TOK and Gardner's Multiple Intelligence types.

Types of intelligence	Stimulating multiple intelligences with TOK
Linguistic Intelligence	Children's creative narrative construction.
Logical mathematical intelligence	Grouping, seriating, classifying and ranking the blocks.
Spatial intelligence	Spatial construction of the narrative through the positioning of the blocks (on table and platform).
Interpersonal Intelligence	TOK promotes collaborative task performance.
Intrapersonal intelligence	TOK supports embodied communication and awareness of the other.
Bodilykinestesic intelligence	Embodied construction of the narratives.

3.3.3 The Dual Coding Theory

Paivio (1971,1983) proposes a conceptual model of multimodal communication, which is well supported by digital manipulatives. In his Dual Coding Theory, Paivio refers that children codify information in two different systems, one system codifies icons/images, and the other codifies words. The simultaneous use of both symbolic systems facilitates and strengthens the understanding of the conveyed content. According to Paivio, this dual coding system offers two learning advantages: the first one is redundancy, since the information that may be difficult to retain by one channel can be retained by the other channel; the second advantage resides in the uniqueness of each symbol system, as the human mind possess separate information processing channels for verbal and visual information.

As shown by Levin et al. (1987) different types of images have different functions in the learning process; for instance realistic images are good to identify real life objects, schemas and graphics are good to show relationships and structures, words or written text are good to learn abstract concepts. In this context the studies of Levie and Lentz (1982) are relevant to the research on the relationship of pictures versus text and its influence on cognition, as well as Levie's research on visual memory and image processing (1987) and Pressley and Miller's work on the effects of pictures on oral and auditory text comprehension (1987).

According to the Multimedia Principle, people learn better when pictures complement words, and the Temporal and Spatial Contiguity Principle adds that people learn better when the related words and pictures are presented at the same time (Antle, 2013). TOK's environment stimulates vision, hearing (verbalizing) and sensing. Montessori considered the touch to be the most important of our senses, as it is through it that we first grasp the world, which shapes all our later understanding.

3.3.4 Multimodal Learning Environments

Mayer's Interactive Multimodal Environments (Mayer, 1997) and Moreno's (Moreno & Mayer, 2007) Cognitive Affective Theory base on the same principles. A multimodal learning environment, can be defined as one that includes two or more modes of representation, suggesting that learning from a traditional verbal mode is enriched from (at least) one non-verbal mode (pictures, video, etc.). Accordingly, effective learning environments combine verbal and non-verbal representations, and mixing modes of presenting that target different channels, thus overcoming the limited information processing capacity of each channel (Low & Sweller, 2005). Since the human mind has different channels through which information can be conveyed and each channel has a limited capacity to absorb the information flow, it is important, especially in learning environments, to propose different strategies stimulating different channels.

On the one hand, to take full advantage of the potentiality of each channel, and on the other hand to avoid overloading just one channel, however, traditional learning praxis and environments often target just one channel.

According to Mayer and Moreno (2003), when cognitive processing establishes connections between pictorial and verbal representations, more meaningful learning is promoted and students are more apt to transfer acquired knowledge to new situations. According to Mayer's taxonomy there are five interactivity levels of interaction in multimodal environments (table 3-4).

Table 3-4 Mayer's taxonomy.

Dialoguing	The system gives feedback to the user's input.
Controlling	The user establishes speed and order of presentation.
Manipulating	The user is able to simulate and to establish certain parameters for the simulations.
Searching	The user is able to access a database and select among several options.
Navigating	The user moves between different content, is able to choose between different sources of information.

Although Mayer's taxonomy has been conceived for traditional graphical interfaces we find the same characteristics in TOK, as we can see in the following table (table 3-5).

Table 3-5 Analogies between TOK and Mayer's taxonomy.

Dialoguing	Placing a block on a slot it gives immediate feedback.
Controlling	The user has *control* over the system since s/he can define his own pace, being able to make his/her own choices.
Manipulating	Virtual and physical manipulation, users makes choices using tangible blocks for triggering digital content.
Searching	The user has a database of characters, actions, and scenarios that s/he can explore. The choices made by the user offer new elements and information.
Navigating	The user is able to navigate between different story elements

Drawing on Mayer's Interactive Multimodal Environments, Moreno (2005) developed the Cognitive-Affective Theory of Learning with Media (CATLM), defining a set of guidelines for developing multimodal interactive systems. According to CATLM learning activities are more effective if they are guided, promote reflection, feedback, are adaptable to the pace of each individual, and take into account the knowledge that the user already has. Interactive Multimodal Environments not only take advantage of different symbolic systems and address different channels, thus taking full advantage of a user's potential to learn, they also promote the development of different skills that are inherent to each individual.

As accessed in the three interventions carried with the digital manipulative (presented on chapter eight to ten), TOK supports autonomous and collaborative work, which can also be *guided* by a teacher. The blocks give visual *feedback* after being placed on the platform; they help children to *reflect* over their narratives, whereby they can learn how to build logical sequences, enhancing their vocabulary and literacy. The digital manipulative acts as an experimental space, where children can explore the language, in a game like manner. The blocks, which represent the story elements, can be manipulated by the children, supporting an a priori selection and organization of the content, allowing children to define their own working *pace*.

3.3.5 Embodied Cognition

The relation between body and mind has ben extensively investigated by Embodied Cognition, which has highlighted that our bodily experiences are the basis of all cognition, and that even higher cognitive processes ground on embodiment (Johnson, 1987; Lakoff & Johnson, 1999). The body is deeply involved and plays a central role in human cognition (Barsalou, 1999; Barsalou et al., 2003), and "all psychological processes are influenced by body morphology, sensory systems, motor systems, and emotions" (Glenberg, 2010: 586).

In the field of tangible computing, embodiment refers to the kind of interaction used to manipulate digital content through the use of physical objects (Ainsworth, 1999). Indeed, instead of placing the emphasis on the tool itself, the interaction provided by tangible interfaces focus primarily on the manipulation of the objects (Ishii & Ullmer, 1997; O'Malley & Fraser, 2005; Ullmer & Ishii, 2001).

Papert's LOGO Turtle (Papert, 1977, 1993) is a good example of how by relating concepts to our body, facilitates the understanding of abstract principles. Ackermann (2004) explains that the physical LOGO turtle acts as a mediator of children's bodily knowledge about space and movement, facilitating the understanding of abstract concepts about spatial relations and transformations. By programming the turtle, relating it to the own body movements, the physical turtle becomes an extension of children's bodies, encouraging the children to reflect about what they already know and transfer it to the programming language (Papert, 1993).

Further, research in the field of Child Computer Interaction has investigated the connection between body and mind, how the bodily experience is involved in meaning making (Antle, 2009, 2013; Hornecker, 2005; Hornecker & Buur, 2006), and how body position, gaze and access to interaction shapes multimodal action flow (Price & Jewit, 2013). Antle and colleagues (2009; Antle, 2012) investigated how the physical manipulation supported by tangible interfaces facilitates spatial task resolution. O'Malley and Fraser (2005) have pointed out that it is the physical activity itself, which takes place when manipulating digital information using objects that helps to build representational mappings, which facilitates the understanding of more symbolically mediated activity. According to Ackermann "Tools, media, and cultural artifacts are the tangible forms, or meditational means, through which we make sense of our world and negotiate meaning with others" (2004:15).

One of the main characteristics of TOK, as revealed in the interventions carried with the interface, was that great part of its pedagogical value relied in the extent to which it promoted embodied creation of narratives. Indeed, as we will describe in chapter ten, children's narrative performance occurred in two levels, as children directed and *orchestrated* their narratives, while simultaneously embodying the characters.

3.4 Summary

This chapter was dedicated to the presentation of the cognitive theories, which build the theoretical foundations that underlie the development of TOK. We began by referring how Fröbel and Montessori's educational model greatly relied in the use of objects to scaffold learning, and then went on presenting Piaget's development stages, highlighting how children capture the world through their exploratory actions upon the objects. We proceed by referring how Papert pointed out the importance of the personal dimension and the environment for the acquisition of knowledge, as well as the work of Bruner and Vygotsky, which highlight the role of the social and cultural environment and the importance of collaborative tasks.

We then went on discussing Gardner's Multiple Intelligences theory, the Dual-Coding theory, the Distributed and the Embodied Cognition theory, arguing that together these theories support the design, development and use of TOK, as it stimulates various symbol systems, as well as targeting various learning channels, from sensory, to visual, and auditory. Further, the physical manipulation of the digital content provided by TOK has a high level of embodiment, simultaneously supporting and promoting collaboration. For an overview of TOK's relation with the different learning theories see table 3-6.

Table 3-6 Overview of TOK relations with the different learning theories.

TOK	THEORETICAL FRAMEWORK								
	Piaget	Bruner	Vygotsky	Papert	Distributed Cognition	Multiple Intelligence	Dual Coding	Multimodal environments	Embodied Cognition
Exploratory actions on objects	x	x		x					x
Social environment		x	x	x	x				
Peer /Teacher's Scaffolding		x	x		x				
Stimulation of different intelligences						x		x	
Manipulation of objects/symbols	x	x	x	x		x	x	x	
Different interactivity levels								x	
Addresses different channels						x	x	x	
Embodied interaction	x	x		x					x

In the next chapter we will give an overview of related work, beginning by discussing the use of technology in preschool, and its particular use in the Portuguese schools, after which we will present some examples of educational technology for preschoolers, as well as examples of pedagogical digital manipulatives for young children.

CHAPTER 4 Overview of Related Work

4.1 The Use of Technology in Preschool

Although digital manipulatives have shown to promote collaborative, exploratory and expressive tasks, which are particularly relevant in preschool settings (Resnick, 1996; Yarosh et al., 2011), as they promote a child-centred learning approach, the great majority of tangible interfaces have not yet found its way in the classroom (Garzotto et al., 2010; Marco et al., 2013; O'Malley & Fraser, 2005; Zaman et al., 2012). Research on the use of technology in preschool education is mainly related with the development of language and literacy (Amante, 2007; Mioiduser et al., 2000; Voogt, 2008). Nonetheless, research in this area, as well as current use of technology in preschool is still very limited (Plowman et al., 2012), although it is becoming more relevant and part of the public debate in many countries (Amante, 2007; Voogt, 2008).

Kamil and Intrator's (1998) seminal literature review of scientific articles on literacy and new technologies with children under nine years of age, for the period between 1990 and 1995, found merely a total of 12 research articles, and these were related to reading and writing. Outgoing from these studies Lankshear and Knoebel (2003) and in order to see whether there had been changes to the trend reported by Kamil and Intrator (1998) and Kamil et al. (2000), - namely, that the research area concerned with literacy and technology is a peripheral research area under-represented in literacy-related journals, specially concerning children under nine years of age - concluded that the trend "of extreme marginalization within specialist reading and writing journals of research articles concerned with new technologies and literacy continues, with this marginalization exacerbated for the early childhood years" (Lankshear & Knoebel, 2003:64).

One of the reasons that may account for the lack of technology use in school education may be as Voogt explains, “although constructivist approaches to teaching and learning are popular among today’s scholars, one must realize that mainstream schooling often reflects a more traditional approach to education” (Voogt, 2008:121). Despite the growing awareness of the importance of using ICT (Information and Communication Technologies) at school the integration of computers in schools is still limited and confined (Voogt, 2008:121). This panorama is partially explained by curriculum related issues, as the implications of integrating technology in school implies revision of the curriculum content and goals, as well as the revision of examination programs, which clearly is beyond the scope of teachers, who already have to deal with long curriculums and short time to cover all the issues during the school term (Voogt, 2008:129).

Van Scoter found evidence that “teachers are more likely to adopt technologies that fit their current practices or can be easily adapted” (Van Scoter 2008:158), concluding that the use of technology for its own sake, or as an add-on, does not bring any advantages in terms of intrinsic learning. In line with Plowman (2012) and (Yelland, 1999), for children to “actively engage in learning, software and contexts for learning must support and encourage authentic, creative, and meaningful opportunities” (Van Scoter, 2008:158).

However, despite the difficulties and the lack of longitudinal studies, Yarosh et al. (2011) underline the importance of designing technology that meets children’s needs, and the need of its evaluation in real classroom settings (Resnick et al., 2005; Robertson et al., 2013; Yarosh et al., 2011). As Yarosh and colleagues affirm, “The difficulty of deploying and evaluating a system over a longer period of time cannot be underestimated, however neither can the importance of doing so.” (2011:143). Cox et al. claim the need for more in depth case studies to measure the quality and extent of the learning and teaching experience mediated through technology (Cox, 2008:977).

Although technologies to foster children’s storytelling have become increasingly common (Benford et al., 2000; Druin et al., 1997), the great part of these systems still relies on desktop computers (Cassel, 2004).

Specifically considering research on the field of tangible interfaces, the research panorama is not very different from the above presented, as the great body of investigation consists of small-scale, single case studies (Garzotto et al., 2010; Zaman et al., 2012). The majority of the studies focus on the innovative possibilities offered by tangible interfaces, often missing empirical evidence to support the benefits of tangible technology (Marshall, 2007; Zaman et al., 2012). Cassel (2004) claims that most systems that target storytelling are not informed by theories of language and literacy development (Cassel, 2004). This trend was confirmed by Yarosh and colleagues after analysing 137 long papers presented at the Interaction Design and Children Conference for the period between 2002-2010. According to their findings “it still seems that relatively few papers that contribute a study are informing their work with existing theory” (Yarosh et al., 2011:143).

Further, the authors report that a great part of research (43%) focus on the design (and often the evaluation) of novel systems for children, a trend, which seems to have increased in recent years. The authors also observed, in the later years of IDC, a strong trend towards a decline in papers that examine research methods. Relatively to the investigated topics, a great part of research was devoted to social interaction (40%) and collaboration (28%), literacy was the focus of 8% of all papers, which apparently seems even to show a decreasing trend (Yarosh et al., 2011:139).

Relatively to the theories and learning models that informed the analyzed research, 22% of all papers were informed by the cognitive theory of Embodiment, with a growing trend in the last years of research related to developmental theory and embodiment. Considering research focusing on learning the authors report that 82% of the papers were informed by *Constructivism*, (children actively construct their own knowledge through exploratory actions) and 36% were informed by *Constructionism* (children learn by creating meaningful projects) (2011:141).

Additionally, the great part of research addressed older children, with a pick around ten years of age, which confirms the trend reported by Kamil and colleagues (1998; 2000) and Lankshear & Knoebel (2003).

Regarding the integration of technology into school praxis, the authors refer that, "13% of papers explicitly talk about the importance of integrating into the existing curriculum. 2% focus on involving the entire class in the activity planned. However, only 5% of papers explicitly stated that they involved teachers in the design of their systems" (Yarosh et al. 2011:140).

4.1.1 The use of Technology in Portuguese Schools

Relatively to the integration of technology in Portugal, the situation is similar to the above described. Amante (2007) pointed out a set of relevant factors to successfully integrate computers at preschool, first of all she stresses the importance of having computers in the classroom, ideally with two chairs, to promote collaboration (in opposition of having computers in the "laboratory"), like any other material computers should be accessible to every child in the room. Further, educational software needs to be carefully chosen, in order to foster open-ended activities, be friendly and intuitive to use, promote active exploration and discovery, be multisensorial, and support and promote collaboration (Amante, 2007:53,54). The author defends that "ICT in the school should be understood as a cultural instrument at the service of educationally relevant experiences and learning" (Amante, 2007:54).

Another important aspect is that only very few teachers are able to creatively and constructively integrate the use of technology in their classroom practices. A change of paradigm implies collaboration from researchers, educational professionals, families and government.

Currently there are following initiatives promoted by the Portuguese Ministry of Education to foster the use of Information and Communication Technologies at school, targeting elementary and secondary education:

The eTwinning[4] platform, promoted by the "Lifelong Learning Program of the European Union", aims at creating collaborative networks between European schools through the development of joint projects, using the Internet and ICT tools. The project does not focus on the development of technological competencies;

[4] http://www.etwinning.net/en/pub/index.htm

instead, the use of ICT is understood as a communication and product development tool. Although the majority of the projects involve secondary schools, 16% of the projects come from pre- and primary schools (Crawley et al., 2008/2009:13). Currently there are a total of 245217 registered European teachers, 32938 projects and 121063 schools. Relatively to the Portuguese participation there are 2077 schools registered in the platform, with 5302 members, 552 running projects and 2379 closed projects. In case of the preschools the focus seems to be an interest in learning English and in joint collaboration in creative activities, as well as exchange of projects and materials, namely drawings and stories.

The GO Project - Mobility in Education[5] is a project developed in schools and explores the use of mobile technologies in education. The types of activities fall into three areas: Geo-referenced routes, Mobility, and Environmental Science, as well as Sports Activities.

The SeguraNet[6] project, targets primary and secondary school education and aims at promoting a safe use of the Internet.

The KidSmart[7] Early leaning Program aims at bringing together and facilitating the access of pre-schoolers to the new technologies in the preschool context, making the computer an integral part of the school environment and the educational program. The program originally created in the United States in 1998, was launched in Portugal in 2003. The KidsSmart report suggests a policy for early education based on the expansion of the available resources for professional training in ICT in early education, the need to fully integrate ICT resources into the preschool curricula, as well as to promote participation and collaboration and the creation of networks of parents and teachers.

The @rcaComum[8] is an online community of practice for professionals in early childhood education, university teachers and researchers, involving Portugal and Latin American countries, in which experiences and projects are shared.

[5] http://www.ccems.pt/tabid/223/Default.aspx?PageContentID=71
[6] http://www.seguranet.pt/1_2ciclos/
[7] http://www-05.ibm.com/dk/ibm/ibmgives/pdf/kidsmartEvalueringsreferat.pdf
[8] http://arcacomum.pt/

The project schoooool[9] is a collaborative and social learning environment, developed and validated in several Portuguese schools (Simões & Aguiar, 2011), which targets children from six up to twelve years of age based on the principle of learning through playing. The environment offers educators and schools a set of educational tools to improve motivation and learning outcomes (Domínguez et al., 2013; Simões et al., 2013).

The “eescolinha” program, similar to the One Laptop Per Child initiative, aimed at equipping schools with computers by giving each child a “Magalhães” laptop when entering primary school. The initiative intended to widespread the use of ICT and the Internet, as a way of facilitating access to knowledge. The programs, which run from 2009 to 2011, also sought to involve teachers and parents as facilitators of the integration of ICT at school.

Relatively to the use of digital manipulatives we refer two projects, which involved two Portuguese preschools in the design and development of two educational manipulatives, namely, Virtually Brushing my Tooth (Sylla, 2009; Sylla et al., 2012c) and the Digital Flannel Board (Medeiros et al., 2012), in section 4.2 we give a brief description of both projects.

Together these initiatives clearly reveal that there is a need for meaningful creative and collaborative technological use in preschool education, however the use of ICT at preschool is still very limited. From this educational landscape we can easily infer that the use and integration of digital manipulatives at preschool is even more difficult, and to our knowledge it simple does not yet happens.

4.2 Technology for Pre-schoolers: Some Examples

Regarding earlier works of technologies to support children’s storytelling, some of the pioneering work has been carried by Druin and colleagues (1997) involving children, technologists, and educators in a design collaboration. Benford et al. (2000) developed the KidStory’s project, a study carried in two schools in England and Sweden involving more than 100 children aged between five and seven.

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[9] http://schoooools.com/

Another study, which took place at preschool involving children and teachers was carried with the PictoPpal (McKenney & Voogt, 2009), a system designed to foster the development of emergent reading and writing skills in four and five years old children. The study focused on the understanding of the nature of written language, promoting the recognition of the relationship between spoken and written language, examining young children's abilities to use the technology, the degree of engagement and literacy learning. The results also showed that pre-schoolers were able to use the technology independently, after initial coaching.

Resnick and the Lifelong Kindergarten[10] group at MIT Media Laboratory further developed LOGO (Papert, 1977), creating the LEGO Mindstorms, followed by the Crickets (Resnick, 1998; Resnick et al., 1996, 1998), and more recently the programming language Scratch (Resnick et al., 2009), which has been successfully used all over the globe. Following Papert's principle that programming languages should have a "low floor" (be easy to get started) and a "high ceiling"(provide opportunities to create increasingly complex projects), besides having "wide walls" (supporting a great variety of different projects) (Resnick et al., 2009:63), Scratch aims at making programming accessible to everyone. The programming language is based on graphical "programming blocks", which children snap together to create interactive programs. Similar to Lego blocks, the virtual programming blocks have connectors, which indicate how to bring them together. According to Resnick et al. (2009:60) each day, more than 1,500 new projects from around the world are uploaded to the Scratch site, with free source code, and available for sharing and remixing.

Inspired by the huge success of Scratch, where users range from eight to 16 years of age, with a pic at twelve, the LifeLong Kindergarten group has recently created ScratchJr (Scratch Junior), (Flannery et al., 2013), which is an introductory programming language for children aged five to seven. ScratchJr allows young children to create their own interactive stories and games, by snapping together graphical programming blocks children can make characters move, jump, dance, and sing. Additionally, children can use the paint editor to modify and personalize

[10] http://llk.media.mit.edu/

the characters, their own voices and sounds, and insert photos, using the programming blocks to animate their characters.

4.2.1 Pedagogical Digital Manipulatives for Young Children

Taking advantage of the possibilities opened up by this new interaction paradigm and its potential for involving users in a wide range of different learning experiences, moving away from systems that rely on desktop computers technology, or tablets, research groups like the Lifelong Kindergarten or the MIT Tangible Media Group[11], among other, have developed several digital manipulatives, targeting different subjects and user groups.

Curlybot (Frei et al., 2000) was one of the first tangible interfaces developed for children from age four (fig. 4-1 left). The interface consists of an autonomous two-wheeled vehicle with embedded electronics, which is able to record the way it is moved on a flat surface, and accurately and repeatedly play the movements afterwards. Although apparently very simple, the interface supports the creation of complex movements. The concept behind its development was to facilitate and promote children's exploration of movement, space and repetition, as well as developing notions of points of origin, direction and magnitude.

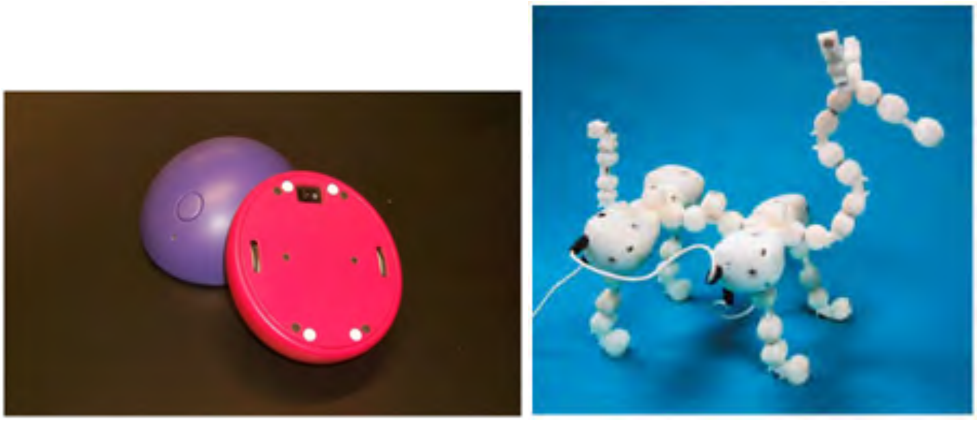

Figure 4-1 Top and bottom of curlybot, reproduced from (Frei et al., 2000) (left), animal built with Topobo, reproduced from (Raffle et al., 2004) (right).

Topobo (Raffle et al., 2004) is an interface that supports expressive learning (Marshall, 2007), aiming at teaching concepts of movement and locomotion (fig. 4-1 right). The interface is a 3D system with kinetic memory able to record and play

[11] http://tangible.media.mit.edu/

physical movements. Topobo combines passive and active components, which can be fit together to form models of animals, geometric or abstract shapes. It allows children to build their toys and associate them with movements that they then play.

The I/O brush (Ryokai et al., 2004) aims at promoting children's creativity, consisting of a *brush* that allows children from four years of age to explore colours, textures and materials present in their environment. A small webcam embedded with light and touch sensors in the brush allows children to take samples of colour, textures or patterns, and use these elements to create their own paintings.

Virtually Brushing my Tooth (Sylla, 2009; Sylla et al., 2012c), is a digital manipulative that targets young children, and aims at making children aware of the importance of tooth brushing. VBMT consists of a large physical tooth with a projection of virtual germs on its surface, which children clean by using a 70-cm long toothbrush. By removing all the germs with the brush, the tooth turns into a happy "smiling face" (fig. 4-2). The results of the study, which involved two classes of preschoolers, suggested that the digital manipulative was capable of promoting a long-lasting involvement having the potential to engage children, therefore potentially promoting learning.

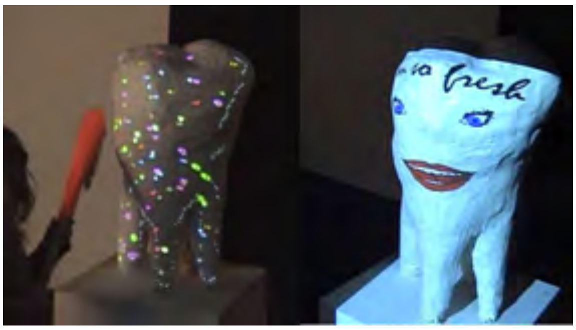

Figure 4-2 Child cleaning the tooth (left), and the cleaned tooth (right).

Marco et al. (2013) developed a game based on tangible interaction, which aims at bringing together computers and physical activities for young children, by coupling tangible interaction with virtual reality. The development of the technology involved children throughout the whole process as testers and users. The results showed a positive impact of these technologies in terms of physical and co-located playing, highlighting the possibilities offered by the technology to promote children's autonomy, however reinforcing the idea that the use of the interface was not to substitute but rather to assist teachers.

4.2.2 Digital Manipulatives for Storytelling

Approaches addressing the structure of the language and the construction of narratives have resulted in the development of various interfaces for storytelling.

StoryMat (Cassell, 2004; Cassell & Ryokai, 2001) consists of a soft play mat with sewed objects where children can play using stuffed toys. The gestures and the story told by the child on the mat are recorded and then compared with stories from children that have previously played on the StoryMat. The story with a similar pattern is than recalled and played, acting as inspiration for the creation of new stories.

TellTale (Ananny, 2001) is a digital manipulative that resembles a worm with a body of five pieces and a head (fig. 4-3 left), which gives children control over the structure and content of their verbalizations. Children can record audio into each part of the body, and hear it by pressing a button. The pieces are independent of each other, can be randomly sorted and rearranged, and a new story can be created at any time. The interface was tested with over 80 children aged four to ten, identifying socio-economic based language differences.

Cassel (2004) investigated the role of “story-listening systems” in supporting emergent literacy, focusing on the importance of emergent literacy attitudes, and the potential of technologies that encourage active instead of passive use, among other interfaces she carried studies with TellTale and StoryMat.


Figure 4-3 TellTale Prototype, reproduced from (Ananny, 2001) (left) and t-words (right).

Similar to TellTale, t-words (tangible words) (Sylla et al., 2012b; 2013a) consists of a set of rectangular blocks, which can be used to playful engage with sounds and words, mediating children's oral expressions in novel ways (Ackermann, 2001b). The system has two functions, one enables the users to record and store audio; the other enables them to play the recorded sounds (fig. 4-3 right). The interface supports a variety of language related activities such as creating rhymes, recording sounds, words or sentences, inventing and playing language games, exploring tongue twisters, or creating narratives. The recorded t-words' blocks can then be snapped together to play the recorded audio. Reordering the blocks also changes the played audio sequence, allowing exploring different sound and speech combinations and eventually fostering reflection over the language. Additionally the interface encourages collaboration, promoting interpersonal language use (Chisik et al., 2014).

Jabberstamp (Raffle et al., 2007) allows children to enhance their narratives by adding sounds and voices to their drawings (fig. 4-4 left). The drawings, collages or paintings are created on a layer of paper placed on a Wacom tablet; by pressing a special rubber stamp on the paper, children can record sounds into their drawings. The system promotes the exploration of different discourses, allowing integrating direct speech (speech of the characters), indirect speech (presentation of the characters), and contextual information (narrator).

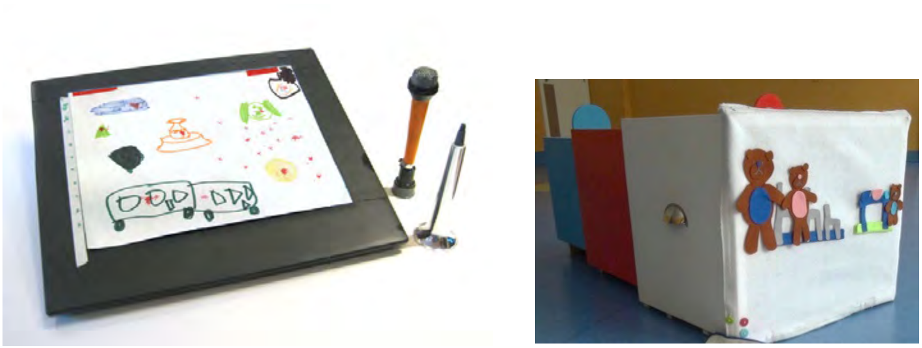

Figure 4-4 The Jabberstamp interface, reproduced from (Raffle et al., 2007) and the Digital Flannel board, reproduced from (Medeiros et al., 2012).

The digital flannel board (Medeiros et al., 2012), (fig. 4-4 right) consists of a flannel board augmented with audio and video recording capabilities, which supports the recording of children's narratives, the manipulation of figures and the playback of audio and projected "shadows". The development of the prototype followed a participatory design methodology involving a group of five years old preschoolers over a period of six months. This approach to storytelling revealed to promote children's creative construction of narratives, as well as the verbalization of various stories.

POGO (Decortis & Rizzo, 2002) allows children to create stories by connecting physical and virtual environments. A set of different tools allows capturing, manipulating and combining pictures, drawings or collages, as well as sounds.

Make a Riddle and TeleStory (Hunter et al., 2010) are educational language-learning applications developed for the Siftables[12] platform. Make a Riddle teaches children spatial concepts and basic sentence-construction skills; TeleStory teaches vocabulary and reading, through the manipulation and combination of story elements, such as a cat and dog, that live in a fanciful land.

The "1001stories", is part of the PoliCultura project, which involved since 2006 almost 500 classes with 10,000 pupils aged between five and 18 in creating digital multimedia "narratives", as a class effort supported by their teachers (Di Blas et al., 2009).

4.2.3 Hybrid Books

A particular kind of digital manipulatives that has gain some attention more recently are books that combine the traditional book format with digital elements. Over the years, books have been explored from many perspectives considering its form, affordances, materials, purposes and content, as well as aesthetics. This exploration, combined with new technological possibilities, has allowed the development of a great variety of innovative projects such as augmented books or books with embedded sensors and electronics, which have emerged in the last 20 years. Among the vast number of mixed media book projects, the following are some significant examples:

[12] http://www.ted.com/talks/david_merrill_demos_siftables_the_smart_blocks.html

The MagicBook (Billinghurst et al., 2001) is an augmented reality book where different media, including 2D and 3D graphics and animations, are integrated within the book pages and the surrounding space through a handheld device with a screen and a camera that recognizes visual markers.

The SequenceBook (Yamada, 2010) is an interactive picture book, consisting of a physical book, which is placed on a table, with a projector over it and a speaker under the table. The system is a magnetic bookbinder, allowing users to easily shuffle the pages to make several patterns of stories, when the user thumbs through the book, the pages are recognized, triggering background music, while projecting images and text on the pages.

The Electronic Popables (Qi & Buechley, 2010) is an interactive pop-up book that explores paper-based computing, integrating traditional pop-up mechanisms with thin, flexible, paper-based electronics: it looks and functions like an normal popup book, but is enhanced with interactive elements such as sound, light and mechanical movement (fig. 4-5 left).

The Telescrapbooks (Freed et al., 2011) are remote communicating electronic sticker books. They are constructed to look and feel as much as possible like traditional books, and to be completely customizable and craftable (fig. 4-5 right).

Figure 4-5 The Electronic Popables (Qi & Buechley, 2010) (left), and the Telescrapbooks (Freed et al., 2011) (right).

The TinkRBook, which targets children between two and five years of age combines shared reading with active creation of the narrative itself through voice and touch (Chang & Breazeal, 2011), and aims at promoting children's emergent literacy.

t-books (Sylla et al., 2012a) is a toolkit consisting of an electronic platform, a paper book with slots, and a set of picture blocks that children place on the book to create and explore narratives (fig. 4-6 left). The educational goal behind the interface was to create a "playground" that allows children to explore a certain narrative and alternative storylines by manipulating the story elements, while simultaneously taking advantage of the traditional book, which serves as a framework and a guide for the construction of the narrative.

Figure 4-6 Children using the t-books (left), the BridgingBook (right).

The Bridging Book (Figueiredo et al., 2013) is a children's mixed-media picture book that blurs the line between printed and electronic books, and consists of a printed book with embed magnets and a digital device, placed side-by-side, with synchronized content (fig. 4-6 right). Thumbing through the pages of the book triggers the digital content displaying it on the iPad, and extending the printed illustrations on each page of the physical book into the device's screen, offering further interaction. The content can be explored both linearly by reading and thumbing the printed book and/or by exploring the interaction on the digital device.

The interactive sticker book (Horn et al., 2013) supports emerging computational literacy skills for preschoolers and early elementary school children. The sticker storybook aims to introduce notions of computer programming and robotics, by presenting the story of a lonely boy named Roberto who travels across a city in search of new friends. Each encounter between Roberto and the characters in the story prompts a programming activity. Dashed sticker outlines on the pages of the book suggest the structure of the programs that can be created, as well as the types of stickers that can be used.

Although each of the presented systems addresses storytelling differently, they all have shown to positively influence and stimulate children's natural aptitude to involve in creative narrative construction. Unfortunately, with few exceptions as Topobo or the Siftables, most of these tangible systems have not been used in real classroom settings, and very often after an experimental phase they remain within the lab. There are various reasons for that, often the systems are first prototypes and not robust enough to be used in the school context, or they are too complicated to set up and use. Additionally, as we have referred before, the majority of schools still follows a very traditional curriculum, and is not open to such innovative materials; moreover, teachers may also be reluctant to use and operate new technology. In sum, their innovative character, and the wide variety of approaches makes it difficult to use and integrate tangible interfaces in the school context.

4.3 Summary

This chapter was dedicated to the discussion of related work; we began by referring the use of technology in preschool, and its particular use in the Portuguese school context. We then presented some examples of educational technology for preschoolers, as well as examples of pedagogical digital manipulatives for young children. The versatility of tangible interfaces and their appropriateness for carrying child-centered activities, fostering exploratory and collaborative tasks, indeed show their potential for supporting a new learning paradigm, shifting from an instructional towards an exploratory model, where learning is not merely mediated by a teacher but where the use of well-designed technology can open up a space where active intrinsic learning may take place.

CHAPTER 5 - Designing and Evaluating Technology with Children

5.1 Introduction

Following the discussion of related work, and the presentation of some examples of educational technology for young children, we now proceed by presenting an overview of the role of children in the design and evaluation of technology, starting with a brief outline of conceptual frameworks that inform the design of digital manipulatives.

5.2 Conceptual Frameworks for the Design of Digital Manipulatives for Children

Different conceptual frameworks have informed the development of digital manipulatives. Inspired by Fröbel and Montessori, Zuckerman and colleagues (2005) proposed following classification: “Fröbel-inspired Manipulatives” (FiMs), which enable modelling of objects and structures of the real world; and “Montessori-inspired Manipulatives” (MiMs) manipulatives that enable modelling of abstract concepts such as the representation of numerical proportions, and relationships between quantities.

Hornecker proposes a framework focusing on the quality of the interaction itself (Hornecker, 2005, Hornecker & Buur, 2006), suggesting that the most noticeable feature of tangible interfaces is probably cooperation. Hornecker expands the taxonomy proposed by Ullmer and Ishi (2001) emphasising the embodied interaction provided by tangible interfaces, instead of the system itself. According to Hornecker, the nature of tangible systems “embodies facilitation methods and means” (Hornecker, 2005:24) providing physical and procedural structure and rules, which shape behaviour and social configurations. Hornecker (2005:27) proposes a design framework for collaborative use, defining the affordances of tangible systems as follow:

Tangible systems shape users' virtual and physical interaction with the system providing "Embodied Facilitation";

Influence and shape collaboration and physical interaction, shaping social interaction (Eden et al., 2002) providing "Embodied Constraints";

Support simultaneous interaction, which speeds up interaction creating "Multiple Access Points";

Display shared understanding, which build on the user's experience, promoting communication and negotiation creating "Tailored Representations".

Building on Hornecker's framework, Yuill and Rogers' conceptual framework for collaborative tangible interfaces considers social-psychological properties of shared intentionality, outgoing from "three core mechanisms of behaviour that underlie interactions of users doing collaborative tasks: awareness, control, and availability" (2012:4).

Antle (2007) proposes a Child Tangible Interaction Framework (CTIF) applying theories from child development, considering spatial and perceptual relations, behavioural and semantic mappings as well as collaboration.

Resnick and colleagues (2005) suggest ten design principles for designing construction kits for children, placing the emphasis on promoting exploration and creativity:

Design for designers
Low floor and wide walls
Make powerful ideas salient – not forced
Support many paths, many styles
Make it as simple as possible – and maybe even simpler
Choose black boxes carefully
A little bit of programming goes a long way
Figure out what people want – but don't ask direct
Invent things that you would want to use yourself
Iterate, iterate – then iterate again

Marshall (2007:163) suggests an analytic framework of six perspectives: typical learning domains, learning activity, integration of representations, concreteness and sensory-directness, effects of physicality and possible learning benefits. Although he questions that many tangible interfaces offer more cognitive advantages for learning over traditional graphical interfaces he refers that "exploratory and expressive activities" might be "particularly well supported" by tangible interfaces. Through an exploratory process of discovery the learners interact with an existing model of the world trying to understand the underlying mechanisms; whereby the model can reflect the learners own experiences and his "existing level of understanding", or in the other hand conflict with it, which can lead to a process of reflection and learning. In "expressive activities" the learners can give physical form and materialize their ideas thus making them concrete and clear having the possibility of reflecting upon how accurate their models are in their representation by comparing them to the real world (Marshall, 2007).

Horn et al. (2011) propose a hybrid approach to leaning, which combines tangible and traditional learning, based on the observation that although in some situations tangible interaction seems to offer advantages for learning; in other situations an alternative interaction style may be more appropriate. The advantages of such a hybrid approach leave teachers and students more room to choose the most appropriate interaction style to meet the needs of a specific situation.

5.3 Involving Children in the Design of Technology

One of the most effective ways, of creating child centred technology, is to involve children in the design process. Indeed, children's participation in the evaluation of technology goes back to the 1970's, where children were involved as users in the development of new technology (Papert, 1977). One of the first works that describe HCI guidelines for designing technology for children dates from the early 1980's (Malone, 1982).

Today it is common practice to involve children in the development of new technology. Based on the relation that children and the research team have, as well as the stage at which children integrate the design process, children can be users, testers, informants, or design partners (Druin, 1999, 2002).

As users, children test the technology after it has been released. By observing children's use of the technology, the researchers can merely gather information about the final product, which they may incorporate in future products.

As testers, children often try out different versions of a prototype. By observing the children and talking with them about the product, the researchers gain new insights for the development, which can still be incorporated in the final product. Logo and Smalltalk were two of the first products that involved children as testers in the development of new technology (Goldberg, 1984; Papert, 1977).

In the mid 90's, children became involved as informants in the design of new technological products, and their contributions started to be incorporated in the various product iterations, informing the final product. Scaife and Rogers, established an informant design framework, defining the different stages of the design, identifying the informants and the kind of contribution they are expected to give, as well as the methods suitable to be used (Scaife et al., 1997; Scaife & Rogers, 1999). They concluded that the interaction between the design team and the children, allows the research team to "discover what we did not know rather than simply trying to confirm what we thought we already knew" (Scaife & Rogers, 1999:24).

Druin and Salomon (1996) extended children's participation involving them as design partners. As design partner's children have the highest involvement in the design process, being actively involved through out the whole design stages; also, their contributions are considered as having the same value as the ones given by the adults (Druin, 1999). When working with children as design partners the methods include sticky note critiquing, low-tech prototyping, and mixing ideas (Druin, 1999, 2002; Guha et al., 2004, 2013). Also, the teams often use the Cooperative Inquiry, a method that builds on the "idea elaboration", in which shared ideas originate new ones (Druin, 1999; 2002; Guha et al., 2004, 2013).

The decision to work with children in their different roles depends not only on the kind of information the researchers want to access, or the extent of children's contributions, but also on a wide variety of factors. Often, difficulties in creating the conditions that allow working regularly with children determine that decision, as it is not always easy to find children, parents and schools willing, or having the conditions to be involved in often time consuming research activities. Mazzone et al. (2011) propose a framework with guidelines to support practitioners coordinating co-design sessions with children, addressing dimensions such as who, where, when, what and how.

5.4 Evaluating Technology for and with Young Children

5.4.1 Historical Overview

In parallel with the development of new interfaces for children, in the last 15 years, there has been, a growing interest on the evaluation of interactive technology for children, which can be traced back to the influential work of Hanna et al. (1997). However, despite the growing interest in this area, most evaluation studies of the benefits of tangible interfaces for learning are rather informal (Marshall, 2007) and limited to a small number of case studies (Garzotto et al., 2010; Zaman et al., 2012).

Jensen and Skov (2005) conducted an extensive survey of publications on research methods, reviewing 150 papers on children's technology design; their results show a strong focus on engineering of products and on evaluation of developed products; they also found out that most research is conducted in natural environments setting with strong focus on field studies.

The evaluation methodology with children between four to five years of age poses some additional challenges given their limited ability of verbal or written expression. In addition, the majority of assessment methods are generally suitable for use with older children (Markopoulos et al., 2008).

5.4.2 The Visual Analogue Scale

One of the methods that have been adapted for children is the Visual Analogue Scale (VAS), a psychometric response scale, which can be used to measure the level of agreement with a statement by indicating a position along a continuous line between two end-points. Wong and Baker adapted the (VAS) creating the Wong-Baker FACES Pain Rating Scale, to access pain in children. The scale presents a series of faces ranging from sad to happy, and was originally developed to evaluate children's degree of pain, due to the difficulties of young children in understanding how to use a traditional scale. Some researchers find the scale appropriate to be used with children older than seven (Shields et al., 2003), however other researchers consider that it can be used with younger children, yet when evaluating technology with younger children, they tend to choose the highest score (Read et al., 2002).

5.4.3 The Sticky-Ladder Rating Scale

Airey et al. (2002) developed a scale, to be used with children from four to six years of age, which consists of a Velcro ladder and tangible objects that children can stick to the ladder, according to their preferences. The method was found suitable for the targeted age rank since children did not have to deal with difficult vocabulary or instructions; however the authors claim that further research still needs to be done to validate the method.

5.4.4 The Fun Toolkit

Read and MacFarlane (2000) have investigated the measurement of the fun component as a method of evaluating children's preferences, defining three dimensions of fun, "Expectations", "Engagement", and "Endurability". Read and MacFarlane (2006) developed a set of evaluation tools to measure children's opinions about technology, which they named "The Fun Toolkit". The kit is composed of four tools: a Funometer, a Smileyometer, a Fun Sorter, and an Again-Again table. The tools are very simple using pictures and only essential vocabulary.

The Funometer consists of a vertical scale with a smiley face on the top and a sad one on the bottom joined together by a vertical ruler (fig. 5-1 left). Children can draw a vertical line inside the ruler showing the amount of fun they had. The Funometer can be used by very young children of three to four years of age

(Markopoulos et al., 2008); but it seems to be more useful to be used with older children (Read et al., 2002).

The Smileyometer, a Likert type scale adopted for children, is a variation of the Funometer designed with the participation of children; it has five faces that go from "awful" to "brilliant" (Zaman et al. 2013), (fig. 5-1 right). Children mark the face that better suites their preference; since the faces are labelled, the Smileyometer gives extra information when used with children that can read.

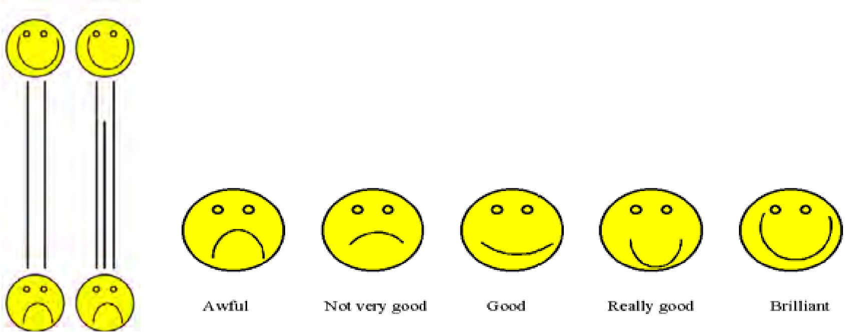

Figure 5-1 The Funometer - before and after completion (left), and the smileyometer reproduced from (Read et al., 2002).

Research on the Funometer (MacFarlane et al., 2005; Read & MacFarlane 2006; Read et al., 2002) showed that the Smileyometer is of limited value when used alone with very young children, as they tend to choose the highest score. Kam and colleagues (2007) reported that children tended to always pick "brilliant" and "very good", because these emoticons are aesthetically more appealing to them than "frowns".

The Fun Sorter is used to measure different types of things, such as fun, likes and dislikes or grade of difficulty (fig. 5-2 left). The tool consists of a grid with activities or things to be rated. Children are asked to rank these in order to their preferences. The Fun Sorter seems to work better when comparing a small numbers of activities. The method can also be used with younger children, if only one construct is used and picture cards instead of words, older children can write their preferences. Very important is that the children understand what they are evaluating, thus being necessary to use simple words (Read et al., 2002).

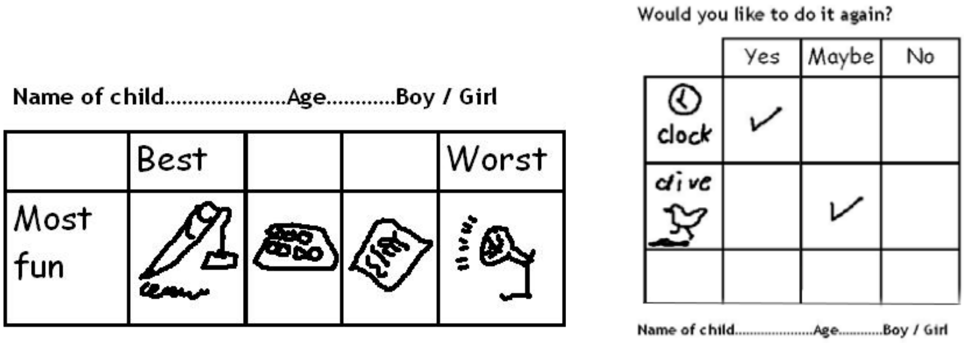

Figure 5-2 A completed Fun Sorter with only one construct (left), completed Again-Again table (right) reproduced from (Read and MacFarlane 2006).

The Again-Again table can be used to measure “endurability” based on the principle that people are more likely to remember things that they liked to do, and the belief that people would like to do things again that were fun (Read et al., 2002) (fig. 5-2 right). The table consists of a grid with the activities listed on the left, and three columns on the right. Children mark their answers to the question *would you like to do it again?* in different columns with yes, maybe and no, according to their opinion.

5.4.5 The Think Aloud Method

Other usability testing methods such as Think Aloud, where children verbalize their thoughts while interacting with a product, have been considered appropriated to be used with children from eight years of age. A variation of Think Aloud is Talk Aloud (Donker & Reitsma, 2004), where children are asked to verbalize their thoughts while using the technology. However, researchers have pointed out that younger children may have difficulties in expressing themselves clearly through words (Donker & Markopoulos, 2002), or don’t like to speak while exploring the technology, yet by thinking aloud children provide more relevant information about their interaction than when asked specific questions.

Children’s capacity of verbalizing their thoughts depends not only on their language skills but also on children’s experience in talking to adults; on the other hand, as logical reasoning and abstract thinking are not yet fully developed, children may have difficulties when doing multiple tasks and abstract task formulations (Markopoulos & Bekker, 2002), which is specially truth for children as old as four to five years of age.

5.4.6 Peer Tutoring

A method specially designed to assess children's opinion is Peer Tutoring (Höysniemi et al., 2002), in which one child teaches another how to use a product. The method involves two phases, first the tutor child becomes familiar with the product and learns how to use it, and then in following sessions, the tutor teaches a tutee child how to use the product. The method allows checking to what extent the child giving the instructions understood the functioning of the product and is able to convey it to his/her peer.

Van Kesteren and colleagues (2003) carried a study about children's ability to provide verbal comments in usability evaluation sessions applying six evaluation methods to test an interactive toy with children aged six and seven. They concluded that children are able to verbalize their thoughts during usability evaluations, but the results depend on the method used and on children's personality. The most comments were provided using the Active Intervention method, where children are asked questions while interacting with the technology. The Think Aloud method showed that children were able to provide useful comments during their intervention and managed to explain their peers the functioning of the tested product when using Peer Tutoring.

5.4.7 Wizard of Oz Technique

The evaluation of interactive technology is often carried with prototypes that simulate the real product, as it is often not yet developed. By simulating how the product works the researchers are able to collect data from the potential users and incorporate it in the final product. Wizard of Oz defines a technique, in which users interact with a technological system that they believe to be autonomous, but which is actually being operated or partially operated by a person, who simulates the system responses to the user's input. The designation *Wizard of Oz* comes from the book The *Wonderful Wizard of Oz*, by L. Fran Baum (1900), in which the characters believe that the main character of the book, called Wizard of Oz, can solve all the problems. The Wizard does not like to be seen and he always appears with disguises. At the end of the book it comes out that in reality he is a common person, who uses disguises and props to appear powerful (Marcopoulos et al., 2008:220). The term was then used in experimental psychology, and in the field of Human Computer Interaction, where the technique is often used to access information on early prototypes.

5.4.8 Drawing Intervention

A more recent evaluation method is Drawing Intervention (Nicol & Hornecker, 2012; Sylla, 2010; Sylla et al., 2012c; Xu et al., 2006, 2008, 2009). Drawing is one of the essential activities undertaken at preschool, and is often used to access the degree of what children have learned after a particular activity. Drawing allows children to represent their thoughts, feelings and interpretation of their lived or imagined experiences. Children retain visual elements and details that they are able to draw; however, they may have greater difficulties if they have to describe these elements in spoken or written words. However, despite the difficulty in evaluating drawings they may give important additional information, complementing other quantitative and qualitative data, thus providing a method of self-expression that verbal measures may not allow (Malkiewicz & Stember, 1994).

5.5 Summary

In this chapter we have presented some frameworks that inform the design of tangible interfaces, followed by an overview of children's participation in the design of new technology, and a presentation of evaluation methods, which are suitable for being used with young children. In the following chapter we describe the methodology that underlies the development of TOK, as well as the methods used for data collection and analysis.

CHAPTER 6 - Methodology

6.1 Design Based Research

Given the young age of the study participants and the multiplicity of contexts where the interventions took place, the choice of the research methodology that allowed answering the research questions, posed some challenges, which we addressed by using Design Based Research. Indeed, more “traditional” research approaches, such as experimental designs, surveys or correlational analyses, which focus on descriptive knowledge, hardly provide guidelines to address a variety of design and development problems in the field of education (Van den Akker, 1999; Van den Akker et al., 2006). Design Based Research, first named Design Experimentations (Brown, 1992; Collins, 1992) emerged out of the need to adapt research to practice and bridge the gap between design and theory in the study of formal education contexts. Relatively to “traditional” research methodologies, there seems to be a gap between research and practice, either because the theory is too abstract to guide practice, or because the practice requires an adequate theory to follow. As a research methodology, Design Based Research (DBR) seems to be able to fill this gap.

DBR proposes a new approach to scientific research, as well as a new articulation between theory and practice, between knowledge and practical intervention in order to design a solution to a problem. According to the Design Based Research methodology, research in education is considered as being driven by a problem, which is addressed following an interdisciplinary approach, concerning both the choice of the instruments used to collect the data as well as the design of the intervention. Design Based Research applies a variety of mixed methods, which have the potential to cross “traditional ‘boundary’ lines in order to advance our understanding of learning across the various theoretical lenses” (Bell, 2004:25).

Further, Design Based Research involves an interrelationship between theory and practice, in order to create a sustainable and effective intervention to a specific problem, which requires not only its analysis, but also the construction of a particular process or product. As such, a theoretical background informs the design and in turn the design itself contributes to theory, creating new knowledge, frameworks, prototypes or products (Anderson & Shattuck, 2012; Bell, 2004).

Design Based Research involves many different approaches, as it is carried by researchers from different disciplines, with different theoretical backgrounds, that address a wide variety of different research questions, with interventions that take place in a multitude of different contexts (Bell, 2004). Indeed, context plays a fundamental role, taking place in naturalistic real world settings with all its complexities and variables, e.g. physical, social, and cultural. Common to all this different variations of Design Based Research is that the design is theory grounded, and has an innovative character. In fact, it is this connection between theory and practice that differentiates Design Based Research from other formative evaluation methodologies or instructional research designs (Barab & Squire, 2004; Bell, 2004)[13].

As such, Design Based Research is practice driven, pragmatic, flexible and iterative involving an engineering component (Barab & Squire, 2004; Cobb et al., 2003). In the field of didactics, the emphasis relies on an iterative, cyclical process of designing, testing, and redesigning, always incorporating the feedback provided by the users in the new iterations. This process eventually leads to new theoretical and empirically founded products, whereby the researchers get new insights, ultimately bringing the state of the art a step forward (Van den Akker et al., 2006). Accordingly, one of the goals of Design Based Research is to support the development of prototypes that can then be tested providing feedback for further development. Such approach, aims at contributing to scientific knowledge growth, which in turn, is seen as equally important as the product improvement and the practical contribution (Van den Akker et al., 2006).

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[13] For an overview on Design-based research variants, methods and characteristics see (Bell, 2004; Wang & Hannafin, 2005).

Given its iterative nature, Design Based Research is often carried out over long periods of time, however this often surpasses time and resources assigned for the research. A recent study (Anderson & Shattuck, 2012) - outgoing from a research body of the five most cited articles of Design Based Research during the period between 2002 and 2010 - refers that the great majority of the studies reported about initial exploratory studies, with the exception of one single study, which discussed the final stage of the research. Further, the authors identified that only 16% of Design Based Research targeted elementary level (ages 5-10), and from this number merely 4% of the studies addressed the topic literacy.

The relatively small number of Design Based Research carried with children reflects the difficulties in working for long periods of time with a young public. Indeed, the difficulties rise concomitantly with the degree of involvement that children have in the design process, as it becomes more time consuming. Except for some works (Benford et al., 2000; Hourcade et al., 2004; Stanton et al., 2001) most of the research involving young children in the design of new technologies has been limited to small groups and has not been set in real school environments (Marco et al., 2013). Instead, research is often limited to small groups of children carried in after school centres, in the laboratory, or in science museum settings (Horn et al., 2008), and most of the systems do remain in a limited context of use (Garzotto et al., 2010; Zaman, 2012).

This work presents a longitudinal study, carried for an extended period of time in a Portuguese preschool, involving various groups of pre-schoolers as well as their teachers. Besides resulting in the development of an educational product, - which is being used since over one year in the preschool by different teachers in their classes - the longitudinal intervention aims as well at contributing for evaluating the potential of the Design Based Research methodology in the preschool context.

6.2 Context of the Research

The study took place in a Portuguese preschool within children's learning context, allowing a natural and holistic approach (Miles & Huberman, 1994). It involved eight classes of pre-schoolers, of five years of age and six pre-school teachers, for a period of around four years, namely three years were dedicated to the design and development of the digital manipulative, and one year was dedicated to the evaluation of different aspects of the developed interface. The study was based on a close collaboration between the school board, the preschool teachers, the children, and the researcher. Although the teachers were always the same, the researcher worked every year with two new groups of children, namely the class attending the last preschool year, just before entering primary school the year after.

The preschool follows the High-Scope Curriculum, a constructivist model, developed in the 1960s (Schweinhart & Weikart, 1991), which is based on active participatory learning through hands-on experiences (Papert, 1993; Piaget, 1952; Piaget & Inhelder, 1969). According to this model, the preschool room is divided into four distinct areas (house, constructions, library and computer) with a central space between them where the activities in the large group – involving the whole class – take place.

Depending on the activity and the teachers' program, some of the activities carried during the study took place during regular classes, involving all the children; other activities were carried in small working groups (Sylla, 2013a,b; Sylla et al., 2011, 2013b;). Some of the sessions took place during the "areas time", which takes place everyday in the beginning of the afternoon and goes for around 45 minutes. During this period of time children can freely play in the five different "activity areas". Further, some of the sessions took place in the preschool's painting room, where just the children and the researcher were present. This way it was possible to access information from the children avoiding any bias caused by the presence of the teachers, as children's participation might otherwise be influenced by children's whish to pleasure their teachers (Markopoulos et al., 2008).

6.3 Methods for Data Collection

The design process was driven by the need to obtain information about how to address different aspects. Thus, the research integrated both "theoretical embedding" and "empirical testing". Indeed, throughout the study, and development process the design of the interface underwent multiple iterations, which based on a collaborative partnership between researcher, teachers and children, who were involved as informants and testers in the various stages of the development throughout the whole study (Scaife et al., 1997; Scaife & Rogers, 1999). Following an iterative design process the researcher gathered feedback from the children and the teachers for the development of several prototypes. This feedback was then incorporated in following versions of the prototypes, in a cyclical process of developing, testing and redesigning (Barab & Squire, 2004; Cobb et al., 2003; Resnick et al., 2005).

Along the design, various methods for data collection were used (Bell, 2004), such as participant's direct and indirect observation, field notes, video recordings, transcription and analyses, semi-structured interviews, tests, Wizard-of-Oz techniques, and low-tech prototyping. Other methods used were think aloud, talk aloud and peer tutoring. Indeed, the children often verbalized what they were doing, and engaged in peer tutoring when their colleagues need help, spontaneously using these methods. And, definitely, this way we were able to collect relevant data for our analyses.

During the sessions, the researcher had informal conversations with the children about their likes and dislikes, what they found important or which features they would like the tool to have. Additionally, the researcher carried informal semi-structured interviews with the teachers in a regular basis, who contributed to the choice of characters, settings and objects used, helping to define the interactions and relations between the different elements.

The iterative process of evaluating the digital manipulative, followed mostly a quasi-experimental approach, the instruments used for the gathering and analyses of the data were observation techniques, video recordings and transcriptions, which were later analysed and coded through content analyses. This allowed preserving the data for reviewing and eventually redesigning the evaluation. In order to guarantee the reliability of the coding process (Coutinho, 2013a) and according to the defined categories, all the videos were independently analysed and coded by two researchers. As suggested in the literature (Coutinho, 2013b) the two coders previously discussed together the content of each category analysing and discussing video samples in order to attain the maximum consensus. Afterwards, each coder codified the videos independently. The inter-coder coefficient of agreement was calculated using Cohen's kappa formula (Cohen, 1960; Coutinho, 2013b). Additionally, descriptive and inferential statistic techniques were used and again peer tutoring, think aloud and talk aloud.

6.4 Methods for Data Analyses

6.4.1 Content Analyses

As above referred children’s interactions with the digital manipulative were all video recorded, and later investigated through content analyses. In a broad sense, and according to Weber (1990), content analysis is a technique that allows the classification and reduction of data, allowing isolating valid inferences from the collected data, or as Kolbe and Burnett (1991:243) affirm, “content analysis is an observational research method that is used to systematically evaluate the symbolic content of all forms of recorded communications”. This technique is widely used in the analysis of data in form of written text (Krippendorf, 1980; Marshall & Rossman, 1989) and in this case, it aims at reducing the many words in a text to a small set of categories (Bardin, 1993). The method can also be successfully used in quantitative surveys, in which the questions are "open " originating data, which has to be categorized, and of course, in the analyses of interviews (Ghiglione & Matalon, 1997), further content analyses can also be used for processing visual data such as video recordings.

According to Coutinho (2013a) content analysis is a technique that consists of systematically evaluating a body of text, or audio-visual material in order to unravel and quantify the occurrence of words/phrases/topics, which are considered benchmarks within the analysis. Accordingly, the researcher looks for structures and regularities in the data and makes inferences based on those regularities (Krippenford, 1980). The basic idea is that signs/symbols/words, which are the units of the analysis - can be organized into conceptual categories, which constitute representative aspects of a concept to be analysed.

Usually there are two types of content analysis: those, which depart from pre-defined categories, already established before the analysis itself, and those, which have a purely exploratory nature (Ghiglione & Matalon, 1997), as it was the case in this study. In the first case, the analysis is structured, being associated and informed by a theoretical framework, whereas in the second case, the analysis is open, and it solely derives from the analysis itself, being independent from any reference or an established theoretical framework (Ghiglione & Matalon, 1997:210).

According to Bardin (1993), exploratory content analysis undergoes following stages: i) pre-analysis, ii) exploration of the material and iii) processing of the results (inference and interpretation). The pre-analysis aims at establishing a first approach to the content and capture the most recurrent ideas. The exploration of the material begins with the encoding, which consists of transforming - according to pre-defined rules - the raw data by clipping, aggregating and enumerating it. This allows obtaining a representational sample of the content, outgoing from its relevant characteristics (Bardin, 1993). The coding is usually organized according to three essential steps: i) the cut - which consists in the choice of the analysis units, ii) the enumeration - which consists in choosing the counting rules, and, finally, iii) the classification, which consists in the choice of the categories.

In order to produce valid results, the process must be objective and reliable, and the analysis ought to be processed according to the same principles, even when carried at different moments or by different coders. Reliability is an essential attribute from which the scientific quality of the obtained data in an investigation depends, and it is intrinsically linked to the instruments used and the processing of the collected data (Coutinho, 2013a). Krippendorf (1980) considers three types of reliability in content analysis: *stability*, *reproducibility*, and *accuracy*. *Stability* also referred to as "consistency" refers to the degree of invariability of a coding process over time. This occurs in situations where a single encoder repeats at a later time, the coding procedure that was applied to a data set. When there are no relevant differences in the results from each coding, than it can be concluded that the results are reliable. In case there are differences between the two codifications that may result from various factors, such as inconsistencies in the encoding process, unclear coding instructions, difficulties of the coder to properly understand the instructions, ambiguities in the data, or merely coding errors. *Stability* is the weakest form of reliability and should not be used as the sole indicator of acceptability of content analysis. The *reproducibility*, also called ''inter-coder reliability'', ''intersubjective agreement'' or merely ''consensus'', refers to the degree to which it is possible to recreate a recoding process in different circumstances, with different encoders. The most typical example is the test-test situation, in which two coders independently apply the same encoding instructions to the same material at a given moment in time. The differences, which may eventually occur between the two encodings, will reflect the inconsistencies explained above, as well as the differences between the coders (e.g. each coder may interpret the encoding instructions differently), or reflect simple random coding errors. *Accuracy* is the degree to which a coding process conforms to a known standard. It is determined when the performance of an encoder or a means of encoding is compared to a known standard of proper performance previously established. In fact, this is the strongest form of reliability measurement, however, comparative standards that would allow the calculation of this type of reliability rarely exist. Since, in most cases, it is not possible to opt for this modality, the best solution is to choose the highest possible quality: the *reproducibility*, in which other encoders following the same encoding instructions must reproduce the results provided by an encoder. An essential condition for the existence of *reproducibility* (inter-coders reliability) is that the coding is independently carried. This implies that the coders do not change opinions and do not seek to previously reach an agreement, further it also implies that a higher positioned encoder does not use her/his status as a source of legitimacy to impose own interpretations to the other. The existence of communication between the encoders during the encoding process artificially inflates the consensus.

6.4.2 Quantitative data analysis

The diversity of the collected data required different analyses methods, thus besides using content analyses with the video recordings, part of the data analysis was carried using descriptive statistic techniques. As such, in the intervention presented on chapter nine, in order to access children's lexical knowledge and phonological awareness skills, a pre and a post-test were applied to an experimental and a comparison group. The results of the tests were accessed through a descriptive and inferential analysis.

Accordingly, the data collected in the *Oral Language Assessment Test* (OLAT) and the *Observation Grid of Language* (OGL)[14] was statistically evaluated through the SPSS data processing program (Statistical Package for the Social Sciences) and the results were examined using a descriptive statistical analysis and conveyed in tables and/or charts of absolute frequencies and/or percentages. When necessary the variables were crossed using crosstabs and the *Chi Square* test was used to test the significance of the relations obtained in case the variables were nominal. To compare the results obtained from the application of those tests in the two groups, we additionally recurred to the statistic values of the central tendency (mean and median) as well as the indicators of variability (maximum and minimum values and standard deviation). The Student *t*-test was used to compare means when the dependent variable was numeric and interval scale, and the distribution of the values revealed to follow the normal curve. When necessary the nonparametric *Wilcoxon Signed Rank test* was applied to assess differences on the means of the results whenever the values of the distribution did not correspond to the normal curve attributes in terms of skewness and kurtosis (Coutinho, 2013a). The level of significance considered was <0.05 or 5%, a standard value accepted in the social sciences and educational research (Coutinho, 2013a; Moore, 1983). Table 6-1 gives an overview of the different methods used throughout the study.

6.5 Summary

In this chapter we have described the methodology and the methods used in our study. Design Based Research provided a theoretical framework for the design, development and evaluation of TOK, informing a cyclical process of designing, testing and redesigning until the completion of TOK's development process. Due to the young age of the study participants and the multiplicity of contexts where the interventions took place, various methods were used to collect and evaluate the study results. Thus, the research integrated both "theoretical embedding" and "empirical testing". Indeed, the development process of the interface underwent multiple iterations, in which low-tech prototyping, Wizard-of-Oz techniques, participant's direct and indirect observation, field notes, video recording,

[14] To consult the tests please see the attachments

transcription and analyses, qualitative surveys, and semi-structured interviews were used to collect and analyse the data, as well as think aloud, talk aloud and peer tutoring. The evaluation of TOK, besides following the same methodology, and using the same methods, also recurred to descriptive and inferential statistic techniques.

The next chapter is dedicated to the description of the design and development of TOK.

Table 6-1 Overview of the methods used for the carried studies.

	TIME	METHODS FOR DATA COLLECTION									METHODS FOR DATA ANALYSES		
RESEARCH QUESTIONS Interventions		Wiza. Oz	Low-fi Prot.	Dirt. Indirt obsv.	Field notes	Video recording. transcpt. analyses	Semi-structd. Intevws.	Talk/ Think Aloud	Peer Tutor.	Tests	Cont. Analy	Qualitati. Descript. Statistics	Inferent. Statist.
How to design DMs to support a child-centred approach, bringing an added value to preschool curriculum? [1st intervt.]	Sept. 2009 July 2012	X	X	X	X	X	X	X	X				
How to integrate DM in preschool to support free activities? [2nd intervt.]	2013 4 MThs			X	X	X	X	X	X		X	X	X
Can DM stimulate the development of language and phonological awareness? [3rd intervt.]	2013 3 MThs			X	X	X	X	X	X	X	X	X	X
Can DM contribute to develop early literacy, stimulating creative thinking and construction of narratives? [4th intervt.]	2013 6 MThs			X	X	X	X	X	X		X	X	X

CHAPTER 7 - Designing a Digital Manipulative for Storytelling

7.1 Introduction

Outgoing from the educational and research landscape presented in the previous chapters, which stress the lack of well-designed educational materials that meet young children's needs, building on previous work, and conscious of the need of involving children and teachers in the design of new materials in order to successful meet their needs, this chapter describes the design and development process of TOK.

TOK aims at creating a platform where children can play around with story elements, creating their own narratives. According to Ackermann in order to learn how to create stories in a linear and coherent way, children need "elaboration spaces (playgrounds) in which the children can mess around with story elements, combining and recombining them until they form meaningful configurations (or sequences)" (Ackermann 2001b:44). The author stresses the advantages of tangible systems as their physicality facilitates manipulation and rearrangement of the story elements, while providing immediate and reliable feedback, helping young children "to create and organize narrative events embodied in tangible building blocks" (Ackermann, 2001b:44).

7.2 Context

As previously referred in the methodology chapter the development of the digital manipulative took place in a Portuguese preschool, involving six classes of pre-schoolers, of five years of age and six preschool teachers, for a period of around three years (Sylla, 2013a,b; Sylla et al., 2011; 2013b). During this period the design underwent multiple iterations, and the feedback provided by the children and the teachers was incorporated in the development of several prototypes, always following a cyclical process of developing, testing and redesigning (Barab & Squire, 2004; Cobb et al., 2003). As Resnick et al. (2005) suggest, in order to develop tools that support children's creativity, it is fundamental to develop rapid prototypes, testing them iteratively.

7.3 Initial Explorations

In the first design iterations with the children we wanted to access how they would use a set of tangible props to create their stories. To test this idea we used a low-fi prototype that consisted of a set of cards with drawings representing animals, objects, places and nature elements, (table 7-1) and a large format *book*, with a grid of rectangular marks drawn on it for placing the paper cards. Following a Wizard-of-Oz technique, using a small program developed in Processing[15], by pressing a certain key on the computer, we simulated audio feedback for each card that was placed on the prototype (fig. 7-1).

Table 7-1 Cards used to test the audio interaction.

Cat	Ball of yarn	Meadow	Sun
Dog	Bowl of milk	House	Moon
Mice	Piece of cheese		
	Bone		

The syntax of the objects was linked to the verbs that support the action related to it, e.g. the audio of the card representing a "ball of yarn" was "plays with the ball of yarn", the card "bowl of milk" was "drinks a bowl of milk", and so on.

Figure 7-1 Children creating and changing their stories.

[15] http://www.processing.org/

By placing the picture cards on the *book*, children could create very simple narratives, such as: “The sun is shinning, the cat drinks a bowl of milk at the meadow”.

The prototype was tested in two following days during class with small groups of three children each; each session lasted about one hour. The researcher explained to the children that each card had an audio identification and that they could create a story by placing the cards on the paper platform; according to the sequence of cards that they placed they could create variations of the narrative.

The children were enthusiastic about the prototype and surprised about the interaction and the audio feedback. They placed the cards on the *book*, dealing with each other, which card fitted better the narrative, trying to create a story. They personalized and extended the narratives, adding their own ideas to the very simple stories they were hearing.

7.3.1 Reflexions on the First Design Iterations

The sessions with the children showed that the use of tangible picture cards generated new ideas for the creation of narratives, promoting a very dynamic peer interaction. Relatively to using audio with the cards it seemed that it constrained children’s imagination and consequently their narratives, and indeed, children seemed to prefer to create their own spoken version of the stories. Following those observations, we decided to remove the audio in future versions of the prototype, giving children the freedom to use their imagination.

The observation of children’s use of the prototype, showed that the tangible cards promoted peer collaboration, greatly increasing children’s motivation; definitely, part of children’s involvement and enthusiasm arouse by earing each other contributions (Wood & O’Malley, 1996) and handling with each other which cards they should use. One idea or a comment generated another one, moving the story forward, and involving the children in collaboratively creating different variations of the narrative. Additionally, children exchanged opinions about which cards would make sense to place, discussing with each other which cards would be better to use. For instance, in one of the groups there was a discussion between the children about when they ought to use the card picturing a moon, as one child defended that the moon should be placed to finish the story. Such kind of argument illustrates how children reflected about the sequence and structure of stories, which they were able to verbalize and discuss with their peers.

7.4 Follow-up

After the initial design explorations we wanted to gather more detailed information about how children would use the cards to create a story. Therefore in the following iterations we used a paper prototype that consisted of an A4 coloured cardboard to simulate an electronic platform, and a set of picture cards with drawings representing characters, places and actions. In two following sessions, with the duration of one hour each, we tested the prototype with four groups of three children each. The sessions took place in the painting room with the children and the researcher; the children sat in groups of three around a table, where the picture cards were scattered (fig. 7-2).

Figure 7-2 Children interacting with the paper prototype.

Each child was given a cardboard and the researcher proposed each of them to create and tell a story using the cards. All the children used the platform, creating a total of 30 stories. The content of the cards was in general very clear to them. Some of the children took the cards they liked and began to place them on the platform; other took time to reflect about what they wanted to tell and looked for very specific cards. Most children began to place the cards on the platform aligning them horizontally, some on the top, others on the bottom of the platform. Three of the children used the platform like a drawing, placing the sun, the clouds and a flying bird on the top and the characters on the bottom (fig. 7-2 middle row right).

Almost all the children filled the paper platform; most of them felt the need to align the cards, arranging them in straight lines while telling the story (table 7-2). Very often and before beginning to tell the story, the children removed some cards from the platform replacing and adjusting them to the narrative.

Table 7-2 Spatial positions of the cards on the paper prototype.

Stories	Begin1st card top of page		Begin left to right		Follow cards when telling story		
30	Yes	No	Yes	No	Yes	No	Sometimes
	14	16	20	10	15	8	7

7.4.1 Reflections on the Follow-up Iteration

Observing the children placing the cards in rows on the paper platform and noticing that many of them were concerned with their alignment, suggested that having slots to place the cards would facilitate children's task offloading extra cognitive processes, as children would not have to worry about alignment issues.

Relatively to the size of the platform, some children felt compelled to fill the complete cardboard with the cards, clearly showing the need to reduce the size of the platform.

Given that the children used the space differently - e.g. some began to place the cards on the top left side, others on the bottom right side, others placed the cards on the middle of the platform, and some used the space as a drawing - the system needed to identify three things:

The content of each card;
Its location;
The order each card enter the system.

This would allow users to place a card on the bottom of the platform and then continue placing the next card on the middle of the platform, jumping back and forth as they created their story. Additionally the system needed to support connections between cards, or groupings of cards.

7.5 Functional Prototype

The next design stage was to investigate how to develop a robust tangible interface that recognized physical content and displayed it digitally, generating an environment for the creation of narratives, as well as to define the physical interaction with the digital content.

7.5.1 Physical Manipulation

Relatively to the manipulation of the content, it needed to be intuitive and direct, placing the emphasis on the interaction between the users and the task (Djajadiningrat et al., 2004; Forlizzi & Ford, 2000; Hornecker & Buur, 2006), offloading cognitive processes to the perceptual system (Scaife & Rogers, 1996), and creating a direct mapping between input and output (Anderson & Shattuck, 2012; Antle et al., 2011). Outgoing from the idea of using picture cards, we chose tangible blocks for defining and manipulating the story elements. Blocks are simple, intuitive objects, familiar to every child, easy to handle, manipulate and store, and represent a very natural means to support complementary strategies (Antle et al., 2011; Kirsh, 1996). A complementary strategy can be defined as "any organizing activity, which recruits external elements to reduce cognitive loads" (Kirsh, 1995:212).

Additionally, blocks allow multiple users to simultaneously manipulate the content, supporting peer collaboration, and "facilitating communication and "transparency" of interaction between multiple collocated users" (Ullmer & Ishii, 2001:12), providing "multiple access points" (Hornecker, 2005).

The design of the interaction followed three development principles: visibility, rapidity and reversibility of actions (Schneiderman & Plaisant, 2004). Following these principles, the tangible blocks make the interaction explicit and open (Hornecker, 2005; Ullmer & Ishii, 2001); give rapid feedback of the performed actions (placing a block on the platform immediately displays its digital content) and every performed action is reversible by simply removing the block from the platform, a feature particularly relevant for content exploration (Hourcade, 2008).

7.5.2 Detection of the Physical Content

Having defined the physical manipulation we considered several methods for the detection of the blocks, ranging from optical recognition, radio identification, physical properties and embedded circuitry (fig. 7-3).

Figure 7-3 Proof of concept (top left); first functional electronic prototype (bottom left); prototype with blocks (bottom centre) and backside of two blocks (bottom right).

The first electronic prototype consisted of a platform and a small number of blocks with printed stickers on the upper side, representing fantasy characters, objects and settings.

The platform had an electronic circuit with six slots to place the blocks; each block had an ID, created by different patterns of conductive aluminium on the backside of each block. Placing a block on a slot closed the electronic circuit on the board according to the block's ID and displayed the corresponding animation on the computer screen. To indicate the right placement of the blocks, the slots on the electronic platform and the blocks were square shaped with the left corner cut off.

We tested the new prototype, with small groups of two children each, in the preschool's painting room. To access how intuitive the system was for the children, we briefly explained the functioning to the first group, and remained in the background of the room, observing how they used it. Children immediately appropriated the prototype, and when the following group came in the room the children were excited and eager to show the functioning to the new comers.

7.5.3 Reflections on the Functional Prototype

The feedback from the children was very positive, and in general the system was easy to use, as the observation from children's interaction revealed, however, some refinements of the prototype were still needed. The connection between the slots and the blocks were designed following a puzzle principle, which did not provided a smooth interaction. Indeed, the placement of the blocks ought to be easy, direct and quick. Also, there were some problems with the recognition of the block's ID due to the oxidation of the contacts, therefore a different technical solution had to be implemented.

7.6 The Digital Manipulative

After testing several solutions for the detection and considering different designs for the blocks, we developed a prototype that uses capacitive sensing for the recognition of the blocks. Accordingly, the final system is composed by an electronic platform, which connects to a computer or a tablet through USB or

Bluetooth, a microphone, and 23 physical blocks to manipulate the digital content. In the current implementation, the system can read up to 250 different blocks, but that number can be extended.

The surface of the electronic platform has slots for placing the picture-blocks. The backside of the blocks as well as the electronic platform have magnets on their surface that correctly snap the blocks to the platform (instead of the puzzle approach), making it easy for the users to place the blocks while simultaneously assuring a stable contact between the blocks and the platform. The size of the blocks 4,5 x 4,5 x 1cm gives children a good grip and easy manipulation (fig. 7-4).

Figure 7-4 Children interacting with the system; block, front and backside (bottom right).

Each block has a sticker with a picture of what it represents on the upper side and an electronic tag on the backside, which provides the system its identification (fig. 7-4 bottom, right).

Placing a block on the platform displays the corresponding digital content on the computer screen, creating a direct mapping between input and output; the sequence of blocks placed on the platform unfolds a narrative.

Outgoing from the observations gathered during the design iterations with the children, the system presents the content of the picture-blocks on the screen, following the order in which they are placed, enabling the placement of the blocks on the slots, without having to follow any order. Similarly, when a block is removed from the platform it simply disappears from the screen.

Following suggestions from the teachers, the blocks represent classical scenarios and actants in narratives for children, - basically, heroes and opponents (Greimas, 1973, Propp, 1928/1968) – and are composed by characters, objects and nature elements (fig. 7-5).

Figure 7-5 Some of the characters and objects.

The familiarity of the characters allows recreating narratives, variations from the original stories, or to create completely new stories. Five different scenarios (a castle landscape, a forest, a desert, the woods and a circus) allow locating the stories in different settings (fig 7-6).

Figure 7-6 Some scenarios that can be used to place the story in different settings, a scenario placed together with the moon, which makes the night appear (bottom right).

The narrative unfolds according to the sequence of blocks placed on the platform; as such there are no predefined stories, a characteristic that sets the interface apart from other tangible storytelling systems (Budd et al., 2007; Hengeveld et al., 2013; Hunter et al., 2010).

Figure 7-7 Children creating a narrative with the digital manipulative, setting the story at different times of the day (by placing the *moon* block).

We will illustrate this with an example: when children place the combination of blocks as pictured on fig. 7-7 (left) (*witch*, *fairy*, *princess*), the witch attacks the princess and the fairy tries to help her. As the fairy alone is not strong enough to defeat the witch, the princess dies. Before the princess dies, and in order to help her, children can use different strategies, such as placing an extra-character to help the fairy, placing a house for the princess to hide, removing the princess or the witch from the platform, or trying to hit the witch with the caldron, indeed always creating different narratives. Resnick et al. (2005) stress the importance of creating digital manipulatives placing a "high priority on tinkerability", as by stimulating children to explore different possibilities, they are encouraged "to try out multiple alternatives, shift directions in the middle of the process, to take things apart and create new versions." TOK allows children to change the scene, mix and remix the characters, as they like, since there is only visual feedback (except for the ambient sounds), children can imagine and create their own spoken narratives.

To extend the interaction beyond the interface itself, pressing the Enter Key in the computer keyboard (or an icon on the tablet version) generates snapshots of the created narratives saving them as digital images (fig. 7-8), which are automatically sent to a blog and also stored in a special folder in the computer. These representations, which look like a comic book, can be visualized together, printed and shared with family and friends, involving them into a collaborative storytelling experience.

Figure 7-8 Automatically generated snapshots of a narrative.

Extending the activities that are carried at preschool to the home environment, has been pointed out as way of enhancing communication between home and school, fostering oral language development as children and families talk about the activities (Van Scotter, 2008:156).

7.6.1 Storytelling Engine

The above-presented concepts require a storytelling engine that automatically animates the plot from the story elements selected by the children. The engine is also responsible for triggering the rendering of the scene and the animation of the entities. In interactive storytelling, two initially opposite philosophies on how to create such narrative experiences can be distinguished: plot-based and character-based approaches.

Plot-based approaches rely on pre-authored plot elements, which are (re-) combined and adapted based on user interactions, thus providing direct reactions to user choices. Corresponding approaches typically use representations such as story graphs or story grammars. Often, story events are described in terms of facts and operators with pre- and post-conditions (Porteous & Cavazza, 2009) allowing for the application of planning technologies (Cavazza et al., 2001; Young, 1999) to develop larger interactive storylines.

Character-based approaches, on the other hand, target to generate stories based on the simulated behaviour derived from parameter sets of virtual characters or actors, and ontological world descriptions. In extreme cases, this may result in emerging storylines, where users may engage in terms of co-authoring the story. Examples in this area include systems such as FearNot! (Aylett et al., 2005) and Storytron (Crawford, 2004). In terms of technology, these systems are often based on agent technologies and multi-agent platforms.

Both philosophies may depict limitations when followed strictly. While plot-based approaches may fail to provide a sufficient variety in plots and their endings, character-based approaches often fail to leverage coherence in stories. As a result, there are approaches trying to integrate these two philosophies and to exploit the benefits of both. Examples in this direction are Façade (Mateas & Stern, 2003) and Thespian (Si et al., 2008), where a multi-agent platform simulates the characters in the story world based on the specified goals according to their authored character profiles, while a director agent takes care of an overall narrative storyline.

Our model can also be linked to such an integration of plot- and character-based approaches, since we provide elements of both, general story elements describing for instance tale-related courses, as well as specific character-based behaviours. However, the development of a sophisticated storytelling engine is clearly not the focus of this work. We rather targeted to find a pragmatic approach to allow children developing a wide variety of narratives, while at the same time providing story elements from well-known fairy tales.

7.7 Modelling the Story World

The story world was modelled through behaviour trees (BTs), a concept well known in the field of computer games to model character behaviour, reactive decision-making and control of virtual characters.

BTs describe general actions of entities, thus each entity interacts with the environment according to a set of predefined rules that define its behaviour. Since the behaviour triggered for each entity depends on the other entities that are also present in the scene, and the properties of those entities, for instance the level of health, there is a certain degree of unpredictability in the outcome of a given situation.

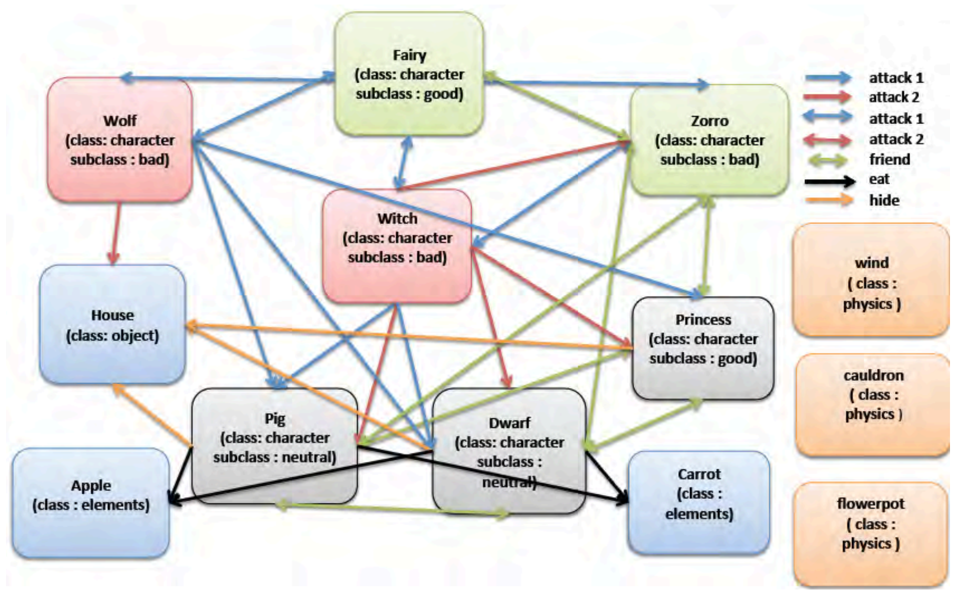
The principle followed in the design of the BTs was to model a world that would be understandable for young children, by creating a set of rules that they know from traditional story plots. As before mentioned we created four types of entities: scenarios, elements, objects and characters. Scenarios represent the background image where the action occurs. The elements interact with the objects and the characters bringing a dimension of change to the story. Some elements are: day, night and wind.

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 the caldron or the flowerpot can be used to knock down bad characters and defend the good ones. A bad object - like a poisoned apple - diminishes the health of a character, on the contrary a good object - like a carrot - increases the health of a character.

The nature elements allow the configuration of the story settings, e.g. the use of the moon turns the day into night, or the cloud blows everything away from the scene. Additionally, there are ambient sounds according to the different scenarios, e.g. birds singing in the forest at dawn, frogs croaking or an owl singing at dusk.

Each entity has a corresponding BT that supports a number of actions for that entity. In case some specific rules or actions are needed they can be added to the entities' BT. In case it becomes necessary adding a new object or character to the story engine, it only has to be associated with the corresponding BT and include the corresponding animations, as well as the picture-block. The new entity will automatically interact with the other entities. The BT's interaction model rules each class and subclass; basic indicators of the class are e.g. health, velocity, or symbiosis (entities that belong to the same class join forces to achieve a common goal) chart 7-1.

Chart 7-1 Relations between the entities.



When the users place the blocks on the platform, the BT gets the inputs of the entities that are present (we will refer to the blocks that are placed on the platform as the state of the world). Regularly at a predefined time stamp the BT performs updates about the state of the world, and checks the defined priorities before triggering any actions. As a result, there are no predefined stories, nor a linear narrative. The users create their own narratives according to the sequence of blocks and the order in which they place them on the platform.

We will illustrate this with an example: starting with three entities (blocks) on the platform, a witch (bad), a fairy (good) and a dwarf (neutral), the first priority here is that the good characters fight the bad ones. When there is a fight, the entities involved on it may die or just lose some health. This mechanism allows three pigs to win a fight against the wolf, as their health together is higher then the wolf's health alone. Even a single pig might be able to fight the wolf, in case the wolf's health has already suffered damage from previous fights. This may be a surprise factor for the users, as they are not necessarily aware of how strong the health of a character is; some children may consider this when they are creating their narratives, other, might be surprised by the unfolding of the plot.

Another example: the little pig is alone on the scene, where it is on idle behaviour; as soon as a second block is added to the system, the BT detects the new entity and triggers the little pig's behaviour. If the second block represents a character classified as good or neutral both characters will interact, for instance, by playing together (table 7-3).

Table 7-3 Behaviour tree of a pig.

Entities (blocks placed on the platform)	Behaviour (result on screen)
	Idle
 	Play together
 	Pig tries to escape, runs
  	Pig tries to hide inside the house

Table 7-4 Behaviour tree of a wolf.

Entities (blocks placed on the platform)	Behaviour (result on screen)
	Idle
 	Attacks
  	Attacks, if pig reaches the house wolf tries to blow the house away

On the contrary, if the added block represents a bad character, for instance the wolf, the little pig will try to run away. On his turn, the wolf, as it detects a little pig, attacks. The result on the screen is an animation of a wolf chasing a little pig, which tries to escape. Now, suppose a block of a house is added to the platform, the little pig's BT detects that there is a shelter, so the pig tries to reach the house to hide inside. Assuming the little pig manages to do it before the wolf catches him, the wolf will try to blow the house away (tables 7-3, 7-4).

7.8 Summary

In this chapter we have described the design and development process of TOK. The first design iterations with the children showed that the use of tangible picture cards generated new ideas for the creation of narratives, promoting a very dynamic peer interaction, greatly increasing children's motivation. Based on this feedback, we decided to use tangible picture-blocks for the manipulation of the content. The follow-up design iterations gave us information about how children used the cards to create their narratives, suggesting that the system need to identify the content of each card, its location, as well as the order they entered the system, thus enabling the placement of the cards on the slots, without having to follow any order. Additionally the system needed to support connections between cards, or groupings of cards. In order to generate different plots according to the blocks that are placed on the platform the story engine is based on behaviour trees, modelling a world that is understandable for young children, by creating a set of rules that they know from traditional story plots.

The design iterations with the functional prototype revealed that the blocks and the electronic platform needed to have a perfect connection. Indeed, the blocks should be easy to place, immediately providing feedback, while creating a direct mapping between input and output.

After concluding the development process the next step was now to evaluate the digital manipulative, and understand first of all whether TOK was well-designed, if it would motivate children, and the kind of activities it would promote; therefore two digital manipulatives were assigned to two preschool classes, and a first intervention at preschool was carried, which is described in the following chapter.

CHAPTER 8 - Bringing TOK into Class

8.1 Introduction

This chapter is dedicated to the presentation of an intervention that took place in the preschool where we developed our study, involving 24 pairs of five-years-old pre-schoolers, who interacted with the interface during free-play time. The intervention investigated how children would use the system after the novelty aspect had faded away, by conducting an intervention over four months. As Yarosh et al. affirm, "IDC[16] rarely investigates whether the technologies we design remain compelling to the child after the novelty has worn off" (20011:143). Further we sought to access the kind of activities in which children would involve, the challenges they would face, and how they would solve them.

The results showed that children engaged mostly in literacy related activities, creating stories and playing language games. Children quickly understood and used the various mechanisms behind the system, to create their stories, and the digital manipulative revealed to encourage peer collaboration motivating children to involve in a creative process of planning, reflecting, sharing and expressing their ideas[17].

8.2 Method

The intervention described in this chapter involved two preschool classes, and as previously described in the methodology chapter, it took place in children's learning context, allowing a natural and holistic approach (Miles & Huberman, 1994). After a first introduction to the system the interface was set up in the computer corner as an educational material that children could explore on their own during the "areas time", which takes place everyday in the beginning of the

[16] IDC refers to the research community on Interaction design and Children.

[17] To see a sample video of children using TOK please visit https://sites.google.com/site/hybridlearningmaterials/videos

afternoon and goes for around 45 minutes. During this period of time children can freely play in the five different "activity areas".

The classroom rules for the computer were also applied to the digital manipulative. Accordingly, the children could use the manipulative in pairs of two as long as they wanted; when they finished, another pair could use it. Depending on how long the first group used the manipulative, the other children eventually did not have time to use it and had to wait until the next day, or until it was their turn. The second rule was that on the following day new children would use the manipulative, so that all the children had a chance to use TOK.

The intervention took place during a period of four months. In the whole 24 groups of two children from two parallel classes were participants in the intervention. As always several children wanted to use the interface, the pairs were mostly assigned by the teachers, and consisted of 5 groups of girls, 7 groups of boys and 12 mixed groups.

8.3 Data Collection and Analyses

To minimize the fact that children were being observed, the researcher remained in the background, observing and collecting notes from a strategic position. A video camera was discretely placed behind the system, recording all the interactions for later analyses. Although the children knew that they were being filmed, they were so involved in the task they were performing, and with each other that they seemed to forget the presence of the camera. Besides the video recordings, data was also collected through direct observation, notes, as well as semi-structured interviews carried with the teachers and the children.

The videos were coded using Content Analyses (Bos & Tarnai, 1999). A set of categories was created outgoing from direct observation of the children, notes taken during the interaction and the analysis of the videos. The created categories included type of group, interaction time, kind of activity carried, quality of collaboration, strategies used to solve technic related issues, strategies used to create stories, embodied creation of the narrative, as well as metanarrative reflections (table 8-1).

Table 8-1 Coded categories of the interaction with the interface.

Type of group	Girl-Girl / Boy-Boy / Boy-Girl
Interaction time	Minutes
Want to play longer	Yes / No /
Collaboration	Balanced (no one dominates)/ Unbalanced (one child dominates)
Play language games	Yes / No
Tell story	Yes / No
Change Scenarios	Castle Forest Lake Circus Desert
Interaction strategies (Technical)	Solve Bugs Lift/ place blocks that are not detected When two scenarios placed remove one Place a scenario to become night
Interaction strategies (Plot)	Use characters to help others Remove characters from the platform to help others Remove characters from the platform to escape danger Use objects to knock down characters Lift blocks from the platform to bring characters to life Order/sort blocks to have a good overview
Embodied construction of the story	Address characters with direct speech Incorporate songs in the story Use different voices for the different characters
Metanarrative reflections	Need to choose a scenario to locate the stories Implications of the choice of characters or elements on the story plot Need to explicitly finish the narratives

As previously reported in the methodology section the videos were independently analysed and coded by two researchers of the team, who discussed together the content of each category analysing and discussing video samples. Afterwards, each coder codified the videos independently. The inter-rater coefficient of agreement was calculated using Cohen's kappa formula, and revealed a degree of agreement of (0.953), for a total of 361 pairs of observations that were considered for the analysis (table 8-2).

The high level of agreement obtained – 95.3% - assured the reliability of the coding process and the prosecution of the intervention.

Table 8-2 Results of the inter-rater agreement using Cohen's kappa coefficient.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	,953	,012	39,887	,000
N of Valid Cases		361			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

8.4 Results

The data was analysed through descriptive statistic techniques; when necessary the variables were crossed using crosstabs and when the variables were nominal the Chi Square test was applied. The Student *t*-test was used to compare means when the dependent variable was numeric. The level of significance considered was <0.05 or 5%.

8.4.1 Interaction Time and Collaboration

The amount of time a user interacts with a system is an important indicator of the degree of involvement that the system is able to provide. Overall, the children interacted with the interface 399.4 minutes, an average of 16.64 minutes per child. From that number 75% of the children expressed the wish to play longer. In order to verify if there was a relation between the interaction time and the way children collaborated together using the digital manipulative, we analysed whether the groups collaborated together, and whether the collaboration was balanced or unbalanced. We considered that the collaboration was balanced when both elements equally contributed to the interaction; this means that there was not a dominant element.

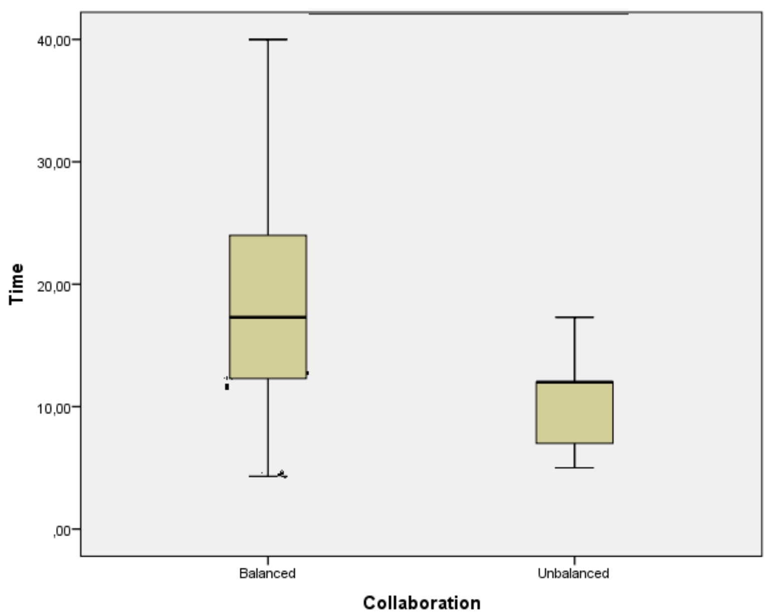
The results showed that 71% of the groups collaborated together. Relatively to the time of interaction and type of collaboration (balanced vs. unbalanced), the distribution of the interaction time showed that the balanced groups had a mean value (of interaction time) of 19.24 minutes against 10.3 minutes in the unbalanced groups (table 8-3).

Table 8-3 Group statistics, interaction time vs. type of collaboration.

Collaboration		Mean	Std. Deviation	Std. Error Mean
Balanced		19,2412	9,95628	2,41475
Unbalanced		10,3286	4,27267	1,61492

Additionally in the balanced groups the highest value of interaction time was 40 minutes, while in the unbalanced groups it was just of 17.3 minutes (chart 8-1).

Chart 8-1 Distribution values of the interaction time vs. collaboration – balanced (left)/ unbalanced (right).



These values revealed a significant difference between the two groups of children, which was confirmed by the Student's *t*-test for independent groups, with a value of proof of 2.261 that is significant for the level of $p>0.05$ (table 8-4). Accordingly, the results show that the collaborative groups spent significantly more time interacting with the digital manipulative than the groups that did not collaborate while using the interface.

Table 8-4 Student's *t*-test for independent groups.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Time	Equal variances assumed	3,610	,071	2,261	22	**,034**	8,91261	3,94257	,73622	17,08899
	Equal variances not assumed			3,068	21,855	,006	8,91261	2,90499	2,88569	14,93952

8.4.2 Interaction Strategies

The system posed some challenges to the young users; one of them was a technical bug that was not detected during testing, which proved to create situations that triggered children's problem solving skills. Table 8-5 gives an overview of the situations children had to face and how they counter around them. Indeed, the children were able to identify and autonomously solve the technical challenges, rearranging the blocks when the system did not detect them.

Table 8-5 Technical challenges faced by the children and solutions.

Category	Situation	Solution
Solve Bug	Sometimes an image appeared on the screen without the corresponding picture block being placed on the platform	Placing the picture block on the platform and removing it again removed the picture from the screen
Lift/ place blocks that are not detected	Sometimes the capacitive sensors did not recognize a block	Lift and place the block again or rearrange it, so that it could be detected
2 scenarios placed	The system was only able to display one scenario at a time	Removing one scenario before placing the next one
Place a scenario to become night	It would not become night, although the moon-block was placed on the platform	Necessary to place first a scenario and then the moon-block

Relatively to the bug, they recognized that something was not working as normal, as suddenly a character appeared on the screen, although the corresponding picture-block was not placed on the platform. “How is it possible?” they wondered. After working out how to solve the situation children immediately knew what to do, as the example shows. Eva: “Little pig is again on the screen”. Gil: “quickly, quickly give me the pig block”. In fact, to remove the “intruder” from the screen, users needed to place the corresponding picture-block on the platform and remove it again (like using a magnet that would withdraw the intruder). Some groups took longer to realize this was a bug, and also took longer to solve it, but their peers told them how to handle the situation and ultimately they all managed the problem. After understanding how the system worked, the children did not like thinks to happen that were out of their control, they wanted to choose the elements that were present on their stories, and did not accept any intruders.

Another challenge was posed when the children placed one scenario while there was still another one placed on the platform; in this case it was necessary to remove the first scenario, so that the new one could be recognized by the system. Similarly, children learned that to turn the day into night it was necessary to place the picture-block of the moon together with a scenario. Some times more skilled peers helped the others with these issues.

Around a third of the groups ordered or sorted the blocks to have a good overview of all the elements, or to plan the stories in advance (37.5%), showing a metanarrative reflexion over the actions they wanted to perform (fig. 8-1).

Figure 8-1 Children ordering the blocks during the interaction with TOK.

Relatively to the strategies used to create narratives, the most used one consisted in lifting and placing the blocks again on the platform to bring characters to life again (70%); very popular was also knocking down characters with the caldron or the flowerpot (50%). To achieve this, children had to coordinate the position of the character and the exact moment when to place the object, which fell from the top of the screen hitting the target. Some groups even managed to knock down two characters simultaneously, which meant they needed to synchronize the placement of the two characters and the object, which requires concentration and rapid reaction, promoting team work, as children need to synchronize their movements.

Children also used the objects to identify the nature of the characters, as they realized that the objects would only hit the bad characters. As illustrated by following example: two boys try to knock down the princess with the caldron, which doesn't work as the princess belongs to the group of good characters:

Filipe - She makes magic.

The other boy, Gonçalo keeps trying.

Filipe - Only the bad ones can be knocked down with the caldron. Now we try with the angry man, wait, wait…1…2…3 now! Oh, we failed!

Gonçalo - Is he bad?

Filipe - I think so, he has an angry face… but maybe he is good [they begin to wonder, and have another try with the *caldron*]. No he is good!

8.4.3 Language Development with Digital Support

Children engaged mostly in creative narrative construction and playing language games (71%); 29% of the children used the interface as a game, trying to knock down different characters or playing different fight combinations. Children liked to place their stories in different settings; except for two groups (8.3%) all the children used different scenarios; locating the great majority of the stories in the castle landscape 34%, or the forest 23%. This preference may be explained due to the fact that the great part of children's traditional stories take place in such scenarios.

8.4.3.1 Children's Metanarrative Reflections

Metacognitive processes define the ability to think about one's thinking (Brown, 1978), with metanarrative awareness we refer here to the ability of thinking about the process of narrative creation, which may encompass different dimensions. Children often began by explicitly verbalizing the wish to define a location for their stories, using different scenarios according to the unfolding of the plot. Most children tended to place the scenario on the first slot, starting by defining the location of their narratives. Children were aware of the fictional character of narratives, locating them in a fictional time and place: "Many million years ago there was a forest "... or "Once upon a time" ...

In some groups, the children agreed with each other that one would define the scenario and the other would place the corresponding block. Following examples illustrate our statements:

> Boy - The witch transformed that place [*circus*] into an enchanted forest [remove the *circus* and place the *forest*]
>
> Girl - Once upon a time there was a pig that was dead in the forest, and a frog was jumping around him. And the pig had a bunch of flowers, suddenly the great witch appeared, and then a strong wind came and took the pig and the witch to a place far, far away...
> Girl - [whispering to the boy] - now you'll take the forest, and place the lake.

Following story was named "Walking along the long paths" by their authors:

> Once upon a time there was a prince who wanted to marry a princess. He was walking from one side to the other, looking for her. So he decided to travel, and travelled and travelled, there were strong winds, until he came to a village [places block with the *circus landscape*], but he didn't like that village. He came to the desert [places block with the *desert landscape*] and

> finally he came to a castle [places block with the *castle landscape*]. It was a beautiful day and he had the feeling he was going to find a princess and he was going to marry her, but suddenly the witch appeared. They run to the forest [places block with the *forest landscape*] and the witch died. He returned to the castle [places block with the *castle landscape*] with the princess and they finally got married".

Children considered consequences and implications for the unfolding of the narrative, e.g. when placing certain elements that had magic powers, such as the apple, which killed the good characters. They reflected over the implications of choosing certain characters or elements for the story plot, e.g. they preferred to place the brick house instead of the straw or the wooden house since it offered a secure shelter. Children supported their narratives, explaining the unfolding of the plot, e.g. "the fairy became little, but she grew again as she took a magic portion".

Metanarrative awareness was also visible in the variations that children created of familiar stories, as this story created with the characters from the "Three little pigs" story:

> 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.

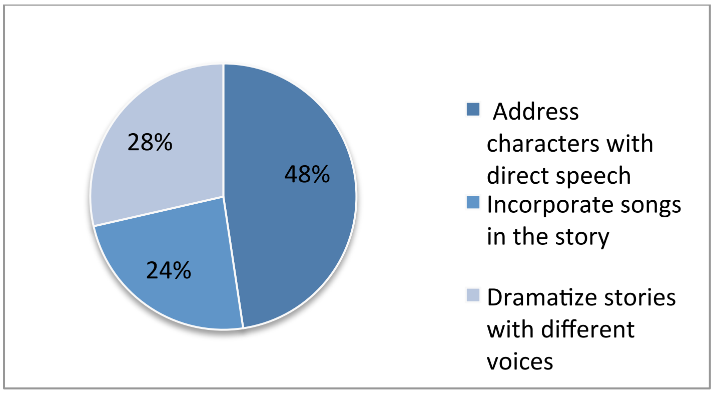
Children reflected about the narrative outcome, trying to understand the development of the plot, indeed they sometimes reconstructed the story with the blocks to analyse what happened.

Some children clearly finished their stories, by using traditional narrative ends e.g. “and they all lived happily ever after”, or “victory, victory, here ends our story”, or “and this is the end of our story”.

8.4.3.2 Embodied Construction of the Narrative

The physicality of the input devices allowed children to embody their stories, creating an involving atmosphere, whereby they immersed in the story world (chart 8-2).

Chart 8-2 Children’s embodied construction of the stories.



Children played different voices for the different characters (28%); sang songs or mimicked ambient sounds (24%), they spoke with the story elements addressing them with direct speech (48%), as following examples illustrate:

Matilde - In the castle there was a princess walking

Joana - and who protected that kingdom? It was a fairy that walked around, one day a witch appeared and a caldron fell over her!

Matilde - and there was a lot of wind, and they all were very surprised as in that place never was windy.

Joana - Suddenly the wind disappeared and night came [removes the *wind*, places the *moon*].

Matilde - Hey night, appear! Night appear!

Joana: she is coming, wait!

Matilde - The night is playing a prank on us!

Or another example, the girl placed the *circus*, which took a little longer to appear on the screen: “come on circus!”

Children expressed their feelings of enthusiasm - (e.g. when their favourite characters managed to win against their opponents, or when they successfully used the objects to knock down certain characters) -, of anxiety - (e.g. when a character was in danger), standing up from their chairs, waving their arms or jumping joyfully. In fact, children extended this embodiment to the characters simulating their movements with the blocks, e.g. they draw flight trajectories for the witch or the fairy with their arms (fig. 8-2 third row); or hold and drove the *princess*, as “she came down the stairs”. For instance, a boy, who managed to hit the witch with the flowerpot, expressed his joy saying: “Touché” and he and his peer began to dance and sing (fig. 8-2 middle row).

Figure 8-2 Children gesturing and standing up, rejoicing and simulating movements of their characters.

8.5 Interviewing the Teachers

At the end of the intervention the researcher carried semi-structured interviews with the preschool teachers. The following summarizes their opinion about the system. Both teachers related that the use of the tangible manipulative motivated the children to engage in creative narrative construction, as well as playing various language games. The use of the tangible blocks stimulated children's imagination, giving them new ideas for the creation of their stories. According to both teachers, the interaction with peers (which was promoted by the physicality of the input devices) was a major factor for stirring and maintaining children's motivation. As referred by (Buur & Soendergaard, 2000), touching and manipulating an object creates a sense of ownership resulting in cognitive and emotional appropriation, while acting as a motivational factor.

Indeed, as the teachers told us, the digital manipulative was always in use in both classes, and children never used the computer during that time. The teachers opted to create a list of users, where they had an overview of the children that had already used the interface, so that everyone had a chance to use it. According to the teachers some children spent the whole 45 minutes interacting with the manipulative, verbalising stories or language games. Both teachers pointed out that the tangible system was a good complement of the traditional storybook, as children established relations with the stories they knew but also expanded them creating new story versions. Additionally they referred that through the use of TOK children got interested in hearing familiar stories again such as "The three little pigs", or "Snow white". Retelling stories is a good way of acquiring a sense of the story structure (Morrow, 1985; Collins, 1999), involving children in tasks that promote language development and emergent literacy. Further, the teachers highlighted that the use of the microphone was a central motivating factor for verbalizing the stories, as children liked to speak into the microphone, which gave them a sense of mastering their creations. In fact, the groups always shared the microphone when they were speaking.

In addition, the interface helped children that were shyer and quieter as it promoted peer collaboration, but also supported individual interaction. The teachers expressed the wish to use the interface from the beginning of the following school year, starting with a couple of blocks and gradually introducing more. Therefore they expressed the need to have different sets of blocks to explore different contents, moreover they thought it was useful to use the system with guided activities proposed by the teachers as well as to use it freely, without any guidance.

8.6 Discussion

Children explored the digital manipulative and created their stories autonomously. The great majority of the groups involved in activities that promote language development and emergent literacy, such as telling stories or playing language games. The collaboration with peers was a strong motivating factor, which was visible in the groups where collaboration was balanced; these groups also used the manipulative significantly longer than the groups, in which the collaboration was unbalanced.

Children quickly understood and appropriated the various mechanisms behind the system to create their stories; they were able to contour bugs and they lifted and placed the blocks when they were not detected. Indeed, these problem-solving situations revealed to promote peer collaboration, and children were happy to show each other how to handle the different problems.

The tangible blocks, with the different story elements stimulated children's imagination, triggering new ideas for the creation and development of narratives. Indeed, children went beyond just reproducing a story, creating their own personal narratives, using different strategies to achieve their goals, such as placing characters to help others when they were fighting (e.g. the *fairy* to help *Zorro* fighting the *wolf*); or removing characters from the platform to help others, or to escape danger (e.g. they removed the *witch* when she was attacking the *princess*; or removed the *little pigs* when the *wolf* was attacking them); children used objects to knock down characters, and lifted the blocks to bring characters again to life.

The use of a microphone strongly motivated the children to verbalize their actions and thoughts. Children embodied their stories creating an involving atmosphere, and immersing in the story world, using their voice as an expressive tool (Collins, 1999:82; White, 1954). They mimicked ambient sounds, introducing new elements to the stories; played different voices for the characters, sang songs, and spoke with the characters addressing them with direct speech. Actually, children personalized the characters giving them different names and character traits (e. g. *Zorro*, was sometimes *Prince, Super Hero, Knight, Fighter, Rider, or Magician*; another character was named *Angry man, Ogre, Giant Louis or Giant Tricolinius*). Other aspects of embodied story creation were gesturing, standing up, waving hands or jumping. Moreover, children sometimes used the physical blocks mimicking the actions of the story characters.

8.7 Summary

The importance of the social environment and the benefits of collaborative learning environments have long been acknowledged (Bruner, 1966; Lave & Wenger, 1991; Vygotsky, 1978). Certainly, children learn more effectively when they are involved in the interaction, establishing goals, than when adults take alone the responsibility in the learning process (Ackermann, 2001b, 2004, 2013; Eagle, 2012; Papert, 1993). The data obtained during children's free interaction with the digital manipulative confirm that the combination of tangible elements and the integration of a plot- and character-based approach supported and promoted the creation of a great variety of different narratives, allowing children to locate the stories in different settings, combining the characters and the objects in numerous ways, always creating original stories. In fact, children not only created their stories by adding elements to the platform, they also recurrently applied different creative strategies to achieve a specific goal, such as removing certain elements from the scene, revealing that they understood the functioning of the underlying system and that they were able to subvert its rules.

This exploratory approach to storytelling may provide an environment for children to reflect on the narrative's conceptual and semantic context - promoting metanarrative awareness (Brown, 1978) -, as children share and create their story world, while simultaneously, looking for possible solutions to achieve a certain narrative outcome. The digital manipulative promoted the creation of structured narratives where the placing of the blocks was not merely random, but the result of peer collaboration. In fact, research has shown that effective, intrinsic learning involves being able to reflect upon, objectify and reason about the learning subject (Ackermann, 1991, 1996). As stated by Ackermann (2013:2) “becoming an expert requires first hand and sustained engagement, and teaching is always indirect”.

The interaction and collaboration supported by the system created an open playful environment where children mobilized and extended their language, developing interpersonal language use, learning to express themselves and to communicate with others (Ackermann, 2001b). Indeed, by externalizing their feelings and thoughts, children create a shared knowledge of the world (Ackermann, 2001b, 2004; Paley, 2004), learning to share, handle, divide, respect and accept the opinions from each other, while at the same time developing language dimensions that ultimately lead to read and write.

The results of this first intervention lead us to conduct a second one, which aimed at investigating the pedagogical potential of the digital manipulative, for the development of relevant language abilities.

CHAPTER 9 - Digital Manipulatives as Scaffold for Language Development

9.1 Introduction

This chapter presents an intervention that aimed at accessing the effect of the use of TOK in the development of language abilities that are relevant for formal literacy learning. The preliminary pedagogical use of the manipulative, as described in the previous chapter, revealed TOK's potential for the development of relevant language abilities, namely lexical knowledge and language awareness. The intervention, reported here aimed at researching such potential and was carried out with a preschool teacher and her class of five-year-olds; a small comparison group was also studied.

The construction of multiple fictional worlds motivated children's continuous verbal interactions with the learning tool, contextualizing the learning of an extensive collection of vocabulary and the playing of language games.

The results of pre and post-tests applied to the children showed significant improvements in terms of lexical knowledge and phonological awareness skills. The results sustain a discussion on the potential of the use of digital manipulatives as educational materials that bring an added value to preschool education, meeting objectives formally targeted in preschool education. A final statement is made on the advantages of collaborative, multidisciplinary design and research of educational digital manipulatives.

9.2 The Impact of the Digital Manipulative in Language Learning

The aim of this intervention was to access the effect of the use of TOK - by integrating it in curricular activities - in children's language abilities that are relevant for literacy learning, namely lexical knowledge and phonological awareness. The intervention involved a specifically designed pedagogical intervention to stimulate these abilities, and a pre-and post-testing.

The intervention was negotiated with the preschool teacher, whose class already was using the digital manipulative during free-play time. Indeed, it was the teacher's own initiative to develop a rich pedagogical language intervention targeting the above-referred language abilities using the digital manipulative, integrating it in her regular pedagogical procedure.

The teacher worked with TOK during a period of three months. She 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. As described in the previous chapter, besides using the system with guided activities that targeted lexical and phonological awareness, the children also used the interface during free-play time, which takes place everyday after lunch for 45 minutes. During this period, each child chooses one of the four areas for playing. Children played with the interface in groups of two.

A second digital manipulative was also available for a parallel class in the school. Both classes followed the same curriculum, each teacher being free to choose the working materials according to the children's dynamics and her preferences. In the parallel class, the digital manipulative was used during free-play time under the same conditions as in the class of the experimental group, however the teacher did not carry out guided activities with TOK. At the end of the intervention a small comparison group of seven children from the parallel class was tested and the results compared with the experimental group.

9.3 Teacher's pedagogical intervention

The teacher carried 15-guided sessions with the children to stimulate lexical knowledge and phonological awareness skills.

9.3.1 Introducing the Tool with Paper Cards

The first four sessions were dedicated to introduce the elements of the interface to the class (characters, objects and scenarios). The teacher printed the

23 pictures represented on the blocks and created a set of cards with them (fig. 9-1). She used the cards 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.

Figure 9-1 The 23 printed cards.

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

Figure 9-2 Circus (left), men (centre), princess (right).

Example 1: Identifying the settings.

Child A shows her card (fig. 9-2 left) and says: it's a theatre

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 (fig.9-3). What is this here, with the bars? What could they possibly keep in there?

Figure 9-3 Children talking about the *circus* card.

Children: Animals!

Teacher: And where do we see animals… at the theatre?

Children: No, at the circus, it's a circus, they say now all together, happy to have identified the card.

Example 2: Identifing characters:

Child shows her card (fig. 9-2 centre) 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.

Child: It's a pirate; it's a burglar.

Teacher: What do pirates use to cover their eyes?

Children: An eyepatch, 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'.

Example 3:

Child shows her card (fig. 9-2 right) and says: I'm not sure; maybe it's a queen!

No, it's a princess! Some children disagree.

Teacher: Why is she a queen?

Another child: Because she has the hair up and a crown.

Teacher: But princesses also use a crown;

Another child: It's a princess because she stands, queens always sit on the chair.

Other child: And if she was not sitting?

Child: Then she was a princess not a queen.

Teacher: What distinguishes a queen from a princess? Is it only the chair? What's the difference between both?

Child: It's because she has a skirt.

Teacher: And queens don't wear them?

Other child: By the way, it's not a skirt; it's a dress.

Child: Queens use lipstick to be beautiful.

Teacher: Are there no more differences? Tell me, who are the parents of the princess?

Children: The queen and the king.

Teacher: So, and do you think that the princess' mother could be a princess?

Children: No;

Teacher: Because she is...

Children: Older

Teacher: So, the card has a princess or a queen?

Children: A princess because she is young.

Another task that the teacher carried out was the *guessing game*. The teacher 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!

These examples illustrate children's efforts to think, refine and verbalize their conceptual knowledge, and how they engaged in an active process trying to find the correct attributes and words to define and name the cards through peer interaction and teacher's scaffolding.

In her intervention, the teacher also targeted the development of phonological awareness besides lexical knowledge. She developed different language games. For instance, after giving one card to children, the teacher 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.

Figure 9-4 Children creating different groups with the cards.

Children were also asked to group and sort the cards in different rows, according to different categories: characters, locations, objects and food; number of syllables and same beginning sound (fig. 9-4).

9.3.2 Using the digital manipulative

After the first introductory sessions with the picture cards, the teacher introduced the digital manipulative to the children and allocated some sessions for the children to explore the interface. This exploration was carried out in small groups of four children and the teacher, who was observing and making questions about what happened on the screen, scaffolding the children to verbalize what they were seeing, 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:

Teacher: The princess fainted. Why?

Child: Because I placed the apple and she ate it, it's a poisoned apple.

Later, the wolf and the witch fight against the fairy, the fairy dies.

The teacher asks: Why did that happen?

Child: Because they were two against one.

Another example:

Child A says: Lets place the wolf from the Caribbean.

Child B: Oh no, there are no wolfs from the Caribbean, only the pirate comes from the Caribbean.

A third one:

Boy: Look, this is my grandpa, he is also in the sky! [After placing the block with the *moon* and pointing to a star on the screen].

By the end of these exploratory sessions children had discovered that the good characters (fairy, knight) protect their friends (three little pigs, princess, man), fight the bad ones (witch, wolf), and that they help each other; that the apple was poisonous; that the witch had a magic wand that diminished the size of their opponents; that the caldron and the flowerpot could be used to knock down the bad characters; that the good characters tried to hide inside the houses to escape danger, etc., and that the stories could be placed in different sceneries.

The following sets of activities were again carried within the large group. During these sessions the teacher further explored the semantic and the phonological dimension of the vocabulary presented by the tool. In order to involve the whole class in the tasks, the teacher connected the interface to a projector and all the children sat on the floor facing it (fig. 9-5). The activities always followed the same principle: each child got a block, and taking turns s/he placed it on the platform, then children named the blocks, created rhymes, identified similar sounds, created sentences and finally stories.

Figure 9-5 Activities carried with the TOK platform connected to a projector.

In case a child did not know a word that rhymed with her picture or was not able to build a sentence using both words, the others 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. 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 elements present on the scene. The last sessions were used to collaboratively create stories based on the animations generated by the blocks. The following example illustrates a sentence created by the children (by using the *lake, wind, Zorro*).

> Once upon a time there was a strong, strong wind at the lake, and Zorro was also there, and a little frog that was jumping around the lake, it was raining and the night wasn't pleasurable at all.

A more detailed narrative (by using the *princess, house, witch, wind, night, 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 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". And she thanked the prince too, who also helped to fight the witch.

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, an indicator that children indeed reflected about the phonological dimension of the words. In sum, children drove each other into discovering words and creating stories together building on each other's suggestions and contributions.

9.3.3 Exploring the Interface 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. Several children engaged in the same kind of activities that were carried by the teacher (an indicator of children's degree of involvement with the learning subject and the tool). When they created rhymes and sentences with the blocks, they usually followed the same approach as the teacher: children started by dividing the blocks between the two of them, then by taking turns each placed a block on the platform, named the element represented on it, and verbalized a different word that rhymed with it; after that they tried to create a sentence with the two words. Children thought about what they wanted to say and whether it was a real rhyme or not (an existing word or an invented one) and scaffold each other to find the right word. 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 use of a microphone, which was connected to the computer, stimulated children to verbalize their rhymes and stories, and they took turns holding the micro while talking. Very often the other children that were in the library area (which was adjacent to the computer area) commented on what the children using TOK were doing, giving their opinions and sometimes scaffold their peers, helping them. Others used the printed cards from the digital manipulative to create stories, or engaged in pretending reading (fig. 9-6).

Figure 9-6 Children in the library area observing their peers while using TOK (top left), children playing rhymes with TOK (top right), children in the library area using the printed cards (bottom left) and engaging in pretend reading (bottom right).

9.4 Reflections on the Pedagogical Intervention

The use of the digital manipulative clearly motivated children to engage in the learning subject, while providing the teacher an educational tool that supported a wide variety of approaches to explore a curricular learning topic. Indeed, TOK 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 the digital manipulative also favoured children's playful engagement with phonological awareness games. Most times, 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 meaningful narrative construction.

TOK offered a rich interactive set of simultaneously virtual and embodied situations, full of creative and playful possibilities that stirred children's curiosity, which is a powerful way to promote learning (Brosterman, 1997; Bruner, 1999:116; Montessori, 1912). The collaborative work among the children themselves, which was sustained by the tangible blocks, was also a major motivating and learning factor. Interaction and motivation to communicate are fundamental factors for language development. When referring to the development of language abilities in the preschool years, MacGregor (2004:305) affirms, "the effects of reduced opportunities for learning established in the preschool years are long-lasting". We believe that the results of our intervention clearly indicate that digital manipulatives can play a very positive role in children's language development, supporting free as well as guided activities.

In effect, the teacher's intervention showed that it is possible to integrate digital manipulatives in routines and spaces in a close socio-constructivist manner, allowing children to physically interact and learn: the digital manipulative was a tool for actual learning and actual play. The teacher placed the emphasis on a child-centred model of learning, instead of an instructional mode of interaction, promoting exploratory, expressive and collaborative activities. Her intervention also showed the importance of patiently and gradually 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 loose its motivational appeal. The fact that the children transferred the learning abilities learned with the teacher to the activities they realized during free-play time showed their involvement with the learning tool, and the combination of a pedagogical approach supported by well-designed materials.

9.5 Accessing TOK's Effect on Children's Language Skills

The aim of the intervention in the school discussed so far in this chapter was to address our third research question (RQ 3), namely, how to integrated digital manipulatives in the preschool curriculum, which support guided activities, and further, whether digital manipulatives can be used to stimulate the development of relevant language dimensions, which are formally addressed in preschool education. In this section we present an attempt to measure these competencies, which we describe as merely indicative due to methodological limitations. First of all and according to literature, as previously referred in section 6.1, we would like to highlight once again that research in education, as it takes place in natural real world settings, with all its complexities and variables, e.g. physical, social, and cultural does not allow to control several variables, thus compromising the internal and external validity of experimental studies (Gall et al., 2005, 2007). A way of controlling these variables is by randomly assign the study participants in groups; however, this method was certainly not practicable in the scope of our intervention. Obviously, the children were already grouped into classes, besides, one of the preschool teachers had expressed the whish to design a set of pedagogical activities adapted to the preschool's curricular goals, which she wished to carry with her class, as described in section 9.3.

Given the natural context of the intervention described in this chapter, we certainly were aware of the methodological limitations inherent to it, however, we could not lose the opportunity of evaluating the impact of using TOK in the development of children's language skills. Indeed, the evaluation was part of the teacher's approach, as she wanted to access whether the new method had been fruitful, in terms of learning outcomes.

This was possible by measuring the targeted language dimensions before and after the pedagogical intervention, by applying a set of standardized tests, commonly used in the preschool to access possible difficulties at the level of phonological awareness and lexical knowledge. The Oral Language Assessment Test (OLAT) (Sim-Sim, 2006) targets children at the end of preschool, and was applied to access lexical knowledge, the Observation Grid of Language (OGL) (Sua-Kay, 2003) was applied to evaluate phonological awareness skills. The teacher applied individual tests to each of the 20 children before the beginning of the pedagogical intervention; the same tests were applied again after the end of the intervention.

9.5.1 Subtests of Language Development (OGL) and (OLAT)

The subtests of naming and verbal definition *(OGL)* were applied to evaluate 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 child has of words. Children were asked to define familiar words.

The other tasks were developed from *OLAT* and assessed phonological awareness. The *subtest of discrimination of word pairs and pseudo-words* 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. The *subtest of discrimination of words that rhyme* evaluates children's capacity of paying attention to the sound component of words that end with a similar sound and identify them. Finally, the *subtest of syllabic segmentation* evaluates the ability to pay attention and identify the syllabic units of words.

Each phonological awareness sub-test presented 10 items, which were classified using a scale between 0 and 10 points. Each correct answer was assigned 1 point. The tests of nomination and verbal definition were composed by 20 items and were assigned following scores (table 9-1):

Table 9-1 Scores attributed to the nomination and verbal definition tests.

Nomination test

Categories of responses	Score	Examples
Assignment of the correct label	2	Caw
Designation of classificatory attribute	1	Gives milk
No answer or wrong answer	0	

Verbal definition test

Categories of responses	Score	Example
Particularized categorical definition	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 caw)
Generic exemplification /no answer /or wrong answer	0	It is something

9.5.2 Retesting after the Use of the Interface

At the end of the activities the teacher applied the same subtests in the same conditions as the ones applied before the beginning of the intervention. A small comparison group of seven children from the parallel class was also tested. A descriptive and inferential analysis was applied to the scores obtained in the pre- and the post-test to access whether there was a positive evolution regarding children's semantic and phonological skills.

9.5.3 Oral Language Assessment Test (OLAT)

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 (table 9-2) see also chart 9-1 and 9-2.

The values of the *subtest of verbal definition*, also improved from the pre to the post-test, by 4.5 points (minimum value) and by 2 points (maximum value). The mean value between both tests improved from 37.37 to 44.75.

Table 9-2 Performance of nomination and verbal definition in the pre and post-test.

Experimental group		Minimum	Maximum	Mean	Median	Std. Deviation
Nomination	Pre-Test	39	59	48,30	49	5,079
	Post-Test	51	67	58,70	59	4,244
Verbal Definition	Pre-Test	23	53	37,37	37	7,781
	Post-Test	27,5	55	44,75	46,25	7,585

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 (Coutinho, 2013a).

Chart 9-1 Performance evaluation pre-test vs. post-test of nomination and verbal definition.

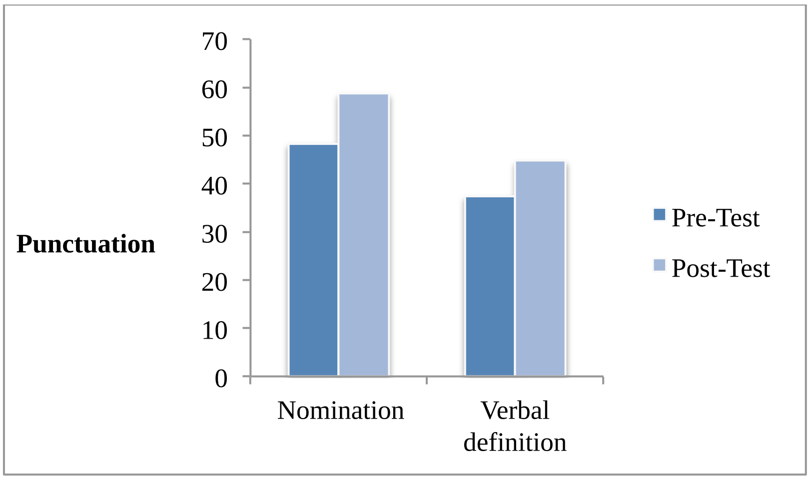


Chart 9-2 Performance evaluation pre-test vs. post-test of the other categories.

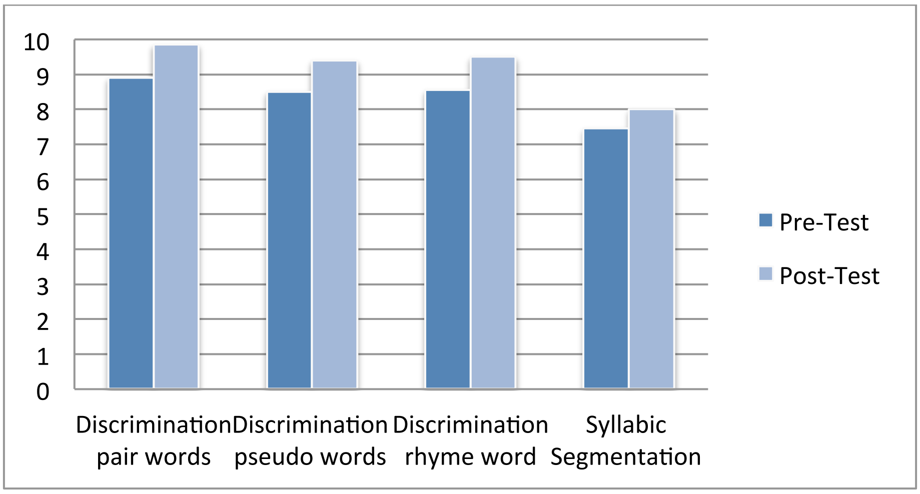


Chart 9-3, 9-4 present the boxplots results of the pre and post-tests for nomination and verbal definition; as the charts illustrate, the shape of the sample distribution was similar in the two moments, i.e., the interquartile range was identical in the pre-and the post-test, showing a normal distribution. However, there was a significant evolution of the mean values, from the pre to the post-test.

Chart 9-3 Boxplots for nomination in the pre and post-test.

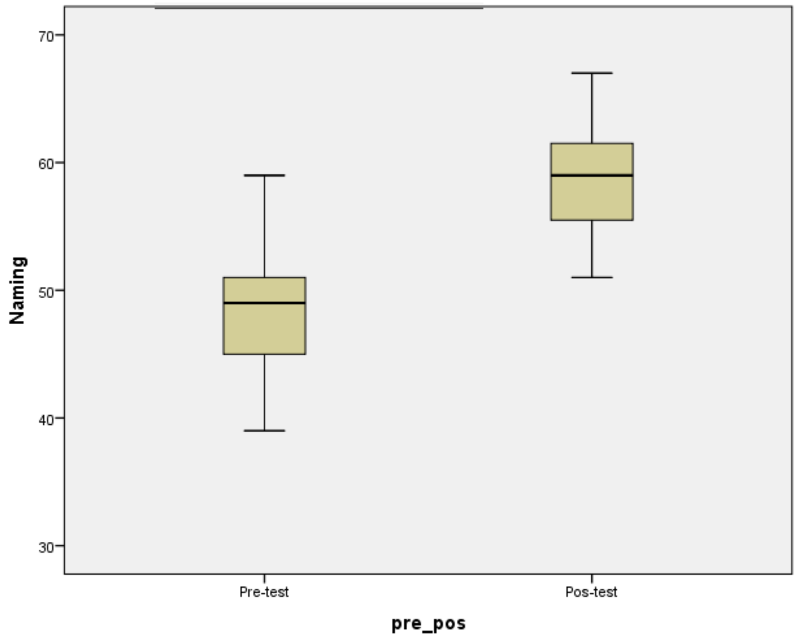
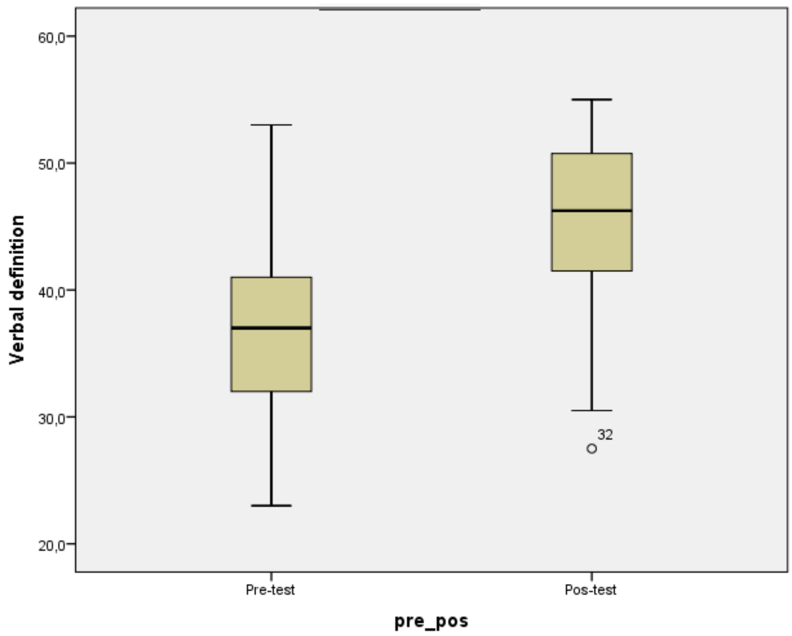


Chart 9-4 Boxplots for verbal definition in the pre and post-test.



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 (p = 0.000), revealing that the difference on mean values of the pre and post-tests are significant to a level of less than 1%. Relatively to verbal definition the significance value was also of less than

0.05 (p = 0.000). The results show that there was a significant evolution at the level of nomination and verbal definition after the intervention with the interface (tables 9-3).

Tables 9-3 results of the Student *t*-test for nomination and verbal definition.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Nomination Pre-test - Nomination Post-test	-10,4000	6,4433	1,4408	-13,4155	-7,3845	-7,218	19	,000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Verbal Definition Pre-test - Verbal Definition Post-test	-7,3750	5,0598	1,1314	-9,7431	-5,0069	-6,518	19	,000

9.5.4 Observation Grid of Language (OGL)

Concerning the set of subtest, which focus on 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 found (table 9-4).

Table 9-4 Evaluation results of the phonological awareness tests.

Experimental group		Minimum	Maximum	Mean	Median	Std. Deviation
Discrimination of pairs of words	Pre-Test	3	10	8,9	10	1,917
	Post-Test	8	10	9,85	10	0,489
Discrimination of pseudo-words	Pre-Test	4	10	8,50	9	1,701
	Post-Test	5	10	9,40	10	1,188
Discrimination of words that rhyme	Pre-Test	5	10	8,55	9	1,877
	Post-Test	7	10	9,50	10	0,889
Syllabic Segmentation	Pre-Test	5	10	7,45	8	1,432
	Post-Test	5	10	8	8,50	1,414

Concerning 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.

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 the significance value was less than 0.05 ($p = 0.04$), revealing a significant evolution in this skill;
- For the test of discrimination of pseudo words the value of significance obtained ($p= 0.73$) showed no statistical significance for the level of 5%, only for the level of 10%;
- For the test of words that rhyme the value of significance obtained ($p = 0.017$) was lower that 0.05 or 5% showing a significant improvement on children's scores.

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 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 the 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.

9.5.5 Experimental Group vs. Comparison Group

In the scope of the intervention we had the opportunity to compare the experimental group with a small group from the parallel class. Indeed, the teacher from the parallel class was targeting the same language skills with her group, as they are part of the curricular orientations for preschool education, however instead of using TOK she used different materials. The comparison group was composed by seven children, as previously referred the teacher from the parallel class did not carry any guided activities with TOK, however, the children interacted with the digital manipulative during free- play time under the same conditions as the experimental group.

As the application of the tests involved a major effort to the teachers and the children, it was not feasible to apply the test to more than seven children from the comparison group. We assumed that both groups had the same level of linguistic knowledge, since the classes are formed with no specific criteria as children enter preschool at the age of three. Moreover, although each teacher has the freedom to address the curricular topics the way she prefers, the programs and curricular goals are the same for the two classes, and additionally the teachers often work together. For this group of children we only had access to the measurement carried out with the OGL and OLAT tests after the conclusion of the classroom activities.

The results from the post-tests showed that the experimental group had higher scores than the control group in all the tested dimensions (charts 9-5, 9-6),

Chart 9-5 Performance evaluation of nomination and verbal definition.

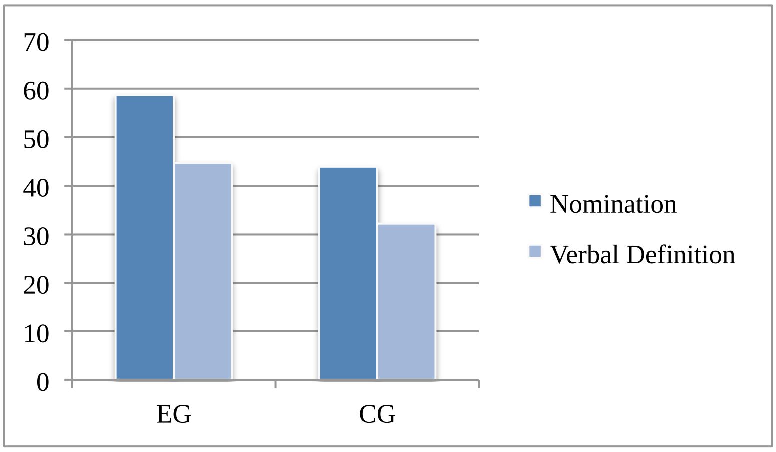
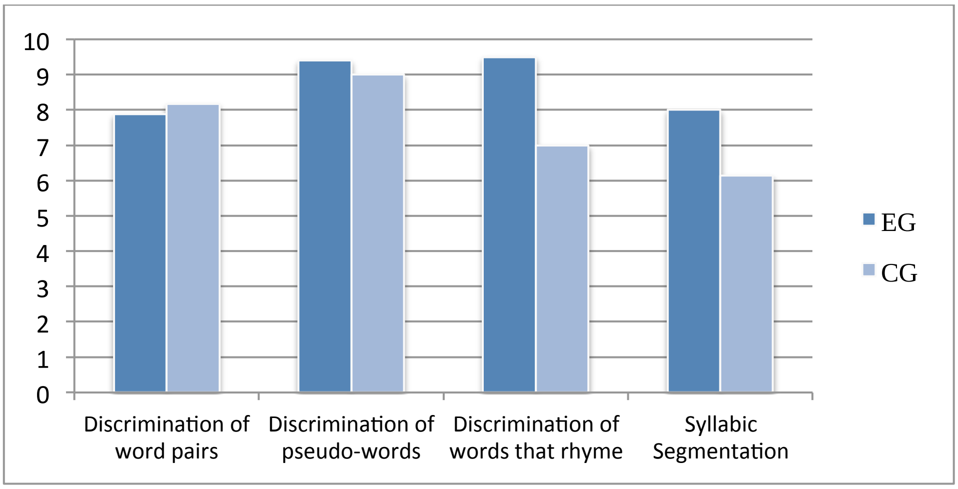


Chart 9-6 Performance evaluation of the other categories.



To test the statistical relevance of the results, a nonparametric *Wilcoxon Mann Whitney* test for independent groups was applied to the results of both groups (table 9-5). The differences on performance on the tests of nomination, verbal definition, discrimination of words that rhyme showed to be significant at the 5% level. The test of syllabic segmentation showed a value of significance of p= 0.081 that is significant only to a level of 10 % a value also accepted on educational research. In the tests of discrimination of word pairs and discrimination of pseudo words no significant differences were found between the two groups.

Table 9-5 Group statistics of both groups.

		Mean	Std. Deviation	Level of Significance
Nomination	EG	58,70	42,44	,000
	CG	43,86	8,214	
Verbal Definition	EG	44,75	7,586	,008
	CG	32,14	10,889	
Discrimination of word pairs	EG	9,85	,489	,130
	CG	7,86	1,574	
Discrimination of pseudo-words	EG	9,40	1,188	,341
	CG	9,00	1,155	
Discrimination of words that rhyme	EG	9,50	,889	,019
	CG	7	2,582	
Syllabic Segmentation	EG	8	1,414	,081
	CG	6,14	2,911	

We could conclude that the experimental group performed significantly better than control group on the tests of nomination, verbal definition, discrimination of words that rhyme and syllabic segmentation.

9.6 Discussion

Given the disparity of the groups we consider that the test results merely indicate tendencies. In fact, the comparison of the two groups revealed that the experimental group obtained higher scores in the targeted language dimensions, reinforcing the idea that the structured orientation designed by the teacher was effective. These results may not necessarily be surprising, but they show the importance of well-designed educational tools, and the importance of teacher's guidance, for taking full advantage of the potential of educational tools. Equally important is that the tools need to be easily integrated in the context of the classroom, which in turn implies a set of prerequisites, such as ease of handling and use.

In sum, TOK revealed to be an educational tool that motivates children to engage in the learning subject, allowing the teacher to design and carry a series of activities, in which she addressed curricular topics targeted in preschool formal education, thus positively answering our third research question. At the same time this intervention allowed us to compare a structured orientation carried by the preschool teacher and an unstructured activity, in which the results revealed that the former was more effective in terms of learning outcomes.

9.7 Summary

The main conclusions we have reached with this intervention elaborate on the following statement by Plowman (2012:6):

"In no particular order, the digital media best suited to the needs of children provide challenge, delight, enchantment, play value, and adventure. [...] Taking design seriously means that there is potential for digital media to meet the needs of young children but, with some exceptions, this has so far largely been unrealized".

Before we began testing the interface, we had indeed underappreciated the full potential that TOK had to offer to *the language needs of young children*. The results of the intervention allowed us to deepen our knowledge about the educational potential that the interface holds for important language development.

The development of language during the preschool years is a fundamental and complex cognitive process, and we have observed that the interactions supported by manipulatives do have an important role to play in such development. Besides, we are now aware that there is more to explore through the digital manipulative and, without a doubt, through the use of other tangible systems, which may promote the development of other language dimensions beyond those that we have investigated.

Moreover, our research highlighted the benefits of a close collaboration between ICT developers, language researchers and pre-school teachers that mediate the integration of ICT in the pedagogical activities.

Following chapter is devoted to the analyses of another dimension of language, namely the narrative.

CHAPTER 10 - Embodied Stage-Narrative Creation

10.1 Introduction

The observations and the data collected during the different interventions with TOK in the classroom revealed that children were very closely involved in the stories that they created. Indeed, sometimes the children began to improvise and sing songs, assumed the role of a character, or exchanged the roles of the characters among themselves, revealing their degree of involvement with the performed task. Outgoing from these observations we realized that the use of TOK may favour children's immersion in the story world, which undoubtedly, is an important aspect that facilitates and promotes learning. As such, the intervention presented in this chapter tried to capture these aspects more closely, and to quantitatively analyse aspects of involvement and immersion, trying to ascertain whether these were isolated situations, or instead whether there were consistencies in the way children embodied their stories.

We observed that by using the digital manipulative, children's narrative construction occurred in two levels, as children shared the stage, (controlling the characters, the location, the props, and the nature elements) and simultaneously performed on this stage. The sharing of the input devices (blocks) gave children equal control of the performance and orchestration of the story, while promoting and supporting peer collaboration. We conclude that TOK enables the performance of what we call embodied stage-narratives, promoting children's imagination and creative thinking, as well as fostering early literacy skills and metalinguistic awareness.

10.2 Context and Methods

The intervention presented in this chapter investigates the narratives created with TOK spanning a period of time of six months, and focus on children's embodiment of their narratives, outgoing from the premise that embodiment is directly related with children's involvement and immersion in the performed task. The intervention involved two preschool classes, in a total of 27 pairs of children. As previously described in chapter eight and nine, both classes had a TOK interface in the computer area, where children could use it during the "areas time", which takes place everyday in the beginning of the afternoon and goes for around 45 minutes. During this period of time children can freely play in the five different "activity areas". According to the classroom rules the children could use the manipulative in pairs of two as long as they wanted; when they finished, another pair could use it.

The children interacted with the interface in groups of two; as always several children wanted to play with TOK, the groups were assigned by the teacher, or the children themselves asked the teacher to play together with the digital manipulative. Common to all interactions was that the children interacted with the interface on their own; there was no interference or any suggestions given by the teacher or the researcher, who remained in the background. A video camera was discretely placed behind the system, recording all the interactions for later analyses. The children were so involved in the interaction with TOK and with each other that they seemed to forget the presence of the camera.

The data collection process, followed mostly an observational approach, the instruments used for the gathering and analyses of the data were direct observation techniques, field notes, video recordings and transcriptions, as well as peer tutoring, think aloud and talk aloud. The collected data was evaluated through content analysis techniques (Bos & Tarnai, 1999), and in a second phase, as suggested by Bardin (1993) and Amado (2013) the counting of the scores obtained in each category was examined through descriptive and inferential statistical analyses in order to find regularities and patterns in children's behaviour that could help to unravel the educational affordances of TOK for storytelling.

The categorization used in the intervention was based on the work of Wright (2007), and adapted to our intervention - also taking into account the initial exploratory pre-analysis of the corpus of transcriptions. Thus, following categories were created considering three aspects or levels of embodiment:

- Speak with characters - children addressed the characters with direct speech, as if they were talking with them (example: "run, run, little pig, hide inside the house")
- Sing songs – children incorporated songs in their stories, inventing songs related to the created stories.
- Embody the characters – the children themselves became the characters that they were playing, like in a theatre play (example: two boys were telling a story with a piggy and the wolf, one was playing the wolf the other the pig, as the pig died, the boy said to his friend: "Now you have killed me!")

Further we considered the interaction time and the type of group in our analyses.

In accordance with Bardin (1993) the exploratory content analysis underwent three stages: i) pre-analysis, ii) exploration of the material and iii) processing of the results (inference and interpretation). In the pre-analysis the researchers established a first approach to the content and captured the most recurrent interaction patterns. This first approach allowed obtaining a representational sample of the content.

In order to assure the reliability of the coding process two independent coders discussed the content of each category analysing and discussing video samples in order to attain the maximum consensus (Coutinho, 2013b). Afterwards, each coder codified the videos independently. The inter-coder coefficient of agreement was calculated using Cohen's kappa formula (Cohen, 1960; Coutinho, 2013b). The number of occurrences obtained in each category was registered in a table. In order to analyse the data, which was done using descriptive and inferential statistical techniques, each coded category of embodiment was assigned an additive number, as such *Speak with characters* was given number 1, *Sing songs* number 2, and *Embody the characters* number 3. We presumed that the level of embodiment was progressive, and so if a pair of children, during the interaction, spoke with the characters (category *Speak with characters*), it was assigned 1 point; in case the group in addition also sang songs (category *Sing songs*), then the group was assigned 3 points (1 point for *Speak with characters* and 2 points for *Sing Songs*); finally if the group, besides attaining the above levels of embodiment, would embody a character (category *Embody the Characters*) then the pair of children would attain a level of 6 points (1+2+3). This way we could quantify values for embodiment that varied from a minimum of 0 and a maximum of 6.

10.3 Orchestrating a Play with Peers

To better illustrate how children embodied their narratives in the following we present three examples of groups interacting with TOK, which are representative for the way children used the digital manipulative to create their narratives.

Figure 10-1 Luis explaining his peer what is happening (top left), children standing up anxiously hoping that the piggy reaches the house on time, escaping the wolf.

Interaction 1: Luis[18] and Gil begin to use TOK. Luis begins by placing the

[18] The names of the children have been changed for anonymity.

scenery, the wolf, a house and a pig; Gil joins a little later (fig. 10-1).

Gil: What's going on?

Luis: It's the bad wolf blowing, because the little diligent piggy hides inside the house, and the wolf is trying to catch him.... Now, this is for him to learn, the house will not fly away because it is made of bricks. These two [shows the blocks of the straw and wooden house] would fly away. Now help me Gil, it's more funny"!

[They remove the *wolf* and place the *houses*].

Gil: ... but they are not hiding!

Luis: No, only when the wolf appears [places the *wolf*], you see?

Gil: oh, he is going to eat the piggies! [Stands up anxious]

Luis: No, no, piggy, hide in the house! Now I will teach the wolf a lesson, he'll see. Now take this wolf! You are not going to destroy this house wolf, this house is very strong! Let's try the night, now. "Piggy, hide yourself, hide yourself, run, run" [they weave their arms, and stand up anxiously]

Luis: Now the wolf will learn a lesson [places the *cloud*, which blows the wolf away from the screen].

Gil: Look; only these two houses were blown away, not this one

Luis: Yes, because it is made of bricks [mimics with his arms that the house is very strong].

Luis: Now we are going to do something very funny! Hide little piggy, hide yourself!

Gil: "Now you are dead Luis!"

Researcher: Oh! Was Luis a piggy?

Gil: Yes he was, and I was the wolf!

Luis: Now you'll have it wolf! [Places the *wind* that blows the wolf away

Ana (a girl that was observing their peers playing with TOK) addressing the researcher: Can I tell you something? - She takes the blocks with the houses in her hands – Look, this straw house is easy to blow away, this wooden house is more difficult, but this brick house is impossible to be blown away!

Eva [who was curious and joined them: My house wouldn’t also fly away if a wolf came, and would try to blow it away, neither yours. [She laughs and looks with complicity at the researcher].

Interaction 2: Ana and Samuel begin by sharing the blocks among them: each one gets a pig and the corresponding house (they say that each pig has his own specific house and do not want to separate the pigs from their houses). They personalize the pigs, decide which one is the oldest, the middle one, and the youngest, assigning them character traits, e.g. one is more courageous than the others, and another one is very diligent. Then taking turns each child places a block and tells a part of the story.

Ana: I want to be the yellow piggy

Samuel: I want to be the diligent piggy.

Samuel: Oh, that’s my house, good, good [his *house* displays on the screen, he claps hands].

[As the platform only comprises six slots for placing the blocks and as all six are occupied, they discuss which block to remove, in order to place the wolf].

Samuel: let’s take one piggy!

Ana: We just take one of the houses!

Samuel: No, if we do that we lose!

Eva, joining them: It’s better you take the wooden house away; it is not strong enough!

Samuel: You can hide in my house [*brick house*]. They clap hands when they defeat the wolf.

Let’s start again

Ana: I have the forest, so it’s me who starts. [They place the *pigs* and a *house*, but she also wants to place the *wind*].

Samuel: No, please, please don’t do that. My piggy will be blown away! If you want to place the wind, we have to place this house [*brick*

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house], so that it doesn't fly away!
Ana: Run, run, piggy, run", quick, quick piggy, hide inside the house! [She bounces in her chair, anxious] Oh my piggy hides inside your house! [She claps hands delighted].

Interaction 3: Joana and Maria start by dividing the blocks; Joana begins to speak (fig. 10-2):

Joana: Once upon a time there was a castle and there lived a princess, and it was a castle from a princess' kingdom, and in the forest lived witches; there lived a fairy that protected the entire kingdom. And the fairy protected the princess day and night; she walked back and forth, back and forth and never got tired [when there is no danger, the fairy always walk from one side to the other].
Maria: But suddenly a witch appeared [the intonation of her voice raises creating suspense], and then a knight appeared and a caldron.
[Platform is full] Maria: But then the witch disappeared and she promised to never come again [Joana removes the *witch*]
Joana: and the princess died [removes the *princess*], everyone was very sad, but another beautiful princess appeared.
Maria: She was the most elegant in the palace
Joana: And the princess was sad, because there was nobody to play, the fairy always had to work, always went back and forth, and then by that time a piggy that had a straw house lived there [she tries to place one of the *pigs*].
Maria: No not that one that one is for the beach, he has a towel.
[Joana agrees and places another pig. The platform is full].
Joana: but suddenly in that town everything disappeared [removes all the blocks, places the *forest*]
Maria: and a forest appeared and there lived a little fairy, the fairy from the woods, that little fairy was in all the places, because she was the only

one, who protected the things, and everyone wanted one like that, therefore she walked always from here to there, from there to here [she bounces her head to the right and to the left, as many times as she repeats that sentence] and then she went to another place and did the same, she went from here to there [she begins to sing] ...

Joana: And in that forest appeared a flower [places block with *flower*], but at that time... [Maria holds the block with the *witch* looking at, Joana, but Joana shakes her head and places the *princess*]

Joana: But in that forest there was a princess, it was the forest protected by the fairy and from the princess Motabuela. And at that time, but only at that time a knight lived there...

Maria: it’s me now; he protected the princess together with the fairy, because there were many witches there, and wolfs and many wicked faces....

Maria: And there everything was very quite [lowers her voice giving it a slowly intonation, extending the sound of each word], so the little fairy went to another place, she took the princess with her and the knight.

Joana: you have to place another place [a block with a scenario].

Maria: because they were all friends. And after they had gone from one place to another, one place to another [she bounces her head to the right and to the left, as many times as she repeats that sentence] a forest appeared [places the *woods*], it was very frightening, with noises [she whispers] suddenly the witch of that forest appeared, she was the strongest, but the fairy was trying to kill the witch. Who is going to win? [Whispers, and makes a voice of suspense].

[Joana lets the *caldron* fall over the *witch*]

Joana: and the caldron felt on the witch [both look at the screen and watch what is happening].

Maria: You have won, little fairy from the woods! [Raises her voice, happily] That’s why you walk from place to place, because you are the strongest.

They go on already telling a new story

56 Joana: a princess appeared, but then all them disappeared and at
57 that time the prince appeared and all died [removes all the blocks],
58 [Maria whispers to her: No, everybody disappeared]
59 Joana: But at that time a kingdom, kingdom, kingdom appeared,
60 there lived a wolf, a caldron and a witch...

They go on for more 25 minutes telling stories, one following the previous, and so on.

Figure 10-2 Children talking about how to continue the narrative.

10.4 Analyses of the Data

These three examples reveal different aspects of children's embodiment of their narratives. This section is dedicated to the statistical analyses of the collected data, we start by comparing the relation between the levels of embodiment and the time children interacted with the interface; further, we investigated the extent to which the different group dynamics influenced children's interaction, examining whether there were group combinations that worked better, an information that might be of interest for teachers and educators.

As before mentioned, the children interacted with TOK in groups of two, the sample was composed by eight groups of boys, seven groups of girls and twelve mixed groups, in a total of 27 groups (table 10-1). The mean interaction time of each group was 19 minutes.

Table 10-1 Embodiment scores of all groups.

		Embodiment			
Group	Interaction Time (min)	Speak with characters	Incorporate songs	Embody the characters	Total
BG	17	1			1
GG	45	1	2	3	6
BB	14	1		3	4
GB	12				0
BB	17	1			1
GG	6				0
GB	12				0
GB	11	1			1
GB	9		2		2
BB	21				0
GB	17			3	3
GB	37				0
GG	33	1	2	3	6
BB	12				0
BB	9				0
GG	9				0
GB	40	1	2	3	6
BB	25	1			1
GB	10				
GG	17			3	3
GB	21			3	3
GG	5			3	3
GB	4				
GB	25	1	2	3	6
BB	30	1		3	4
GG	35	1	2	3	6
BB	26				0

The groups of girls interacted the longest time with TOK, with a mean value of 21 minutes; the group of boys with a mean of 19 minutes, and the mixed groups with a mean value of 18 minutes. Aspects of embodiment were present in four groups of boys five groups of girls and seven mixed groups, in a total of 16 groups. The analysis of the values for each of the three coded categories revealed that the first category (*Speak with characters*) was present in four groups of boys, three groups of girls and four mixed groups, in a total of eleven groups. Relatively to the second category (*Sing songs*), the results showed that it was not present in any of the boys' groups, and that three of the groups of girls as well as three of the mixed groups incorporated songs in their narratives, in a total of six groups. The third category (*Embody the characters*) was present in one group of boys; five groups of girls and in four mixed groups, in a total of 10 groups (table 10-2).

Table 10-2 embodiment and type of group.

Type of group	Speak with characters	Sings songs	Embody the character
BB	4	0	1
GG	3	3	5
BG	4	3	4
Total	11	6	10

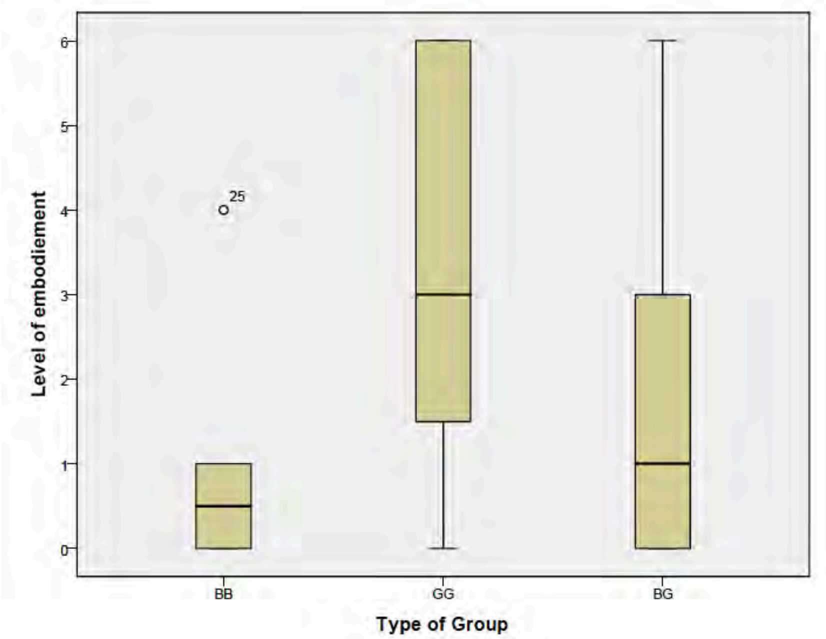
Pursuing the analysis and considering that the level of embodiment was in interval scale, we obtained following values of children's levels of embodiment through the descriptive statistical analyses (table 10-3).

Table 10-3 Level of embodiment per group.

Type of group	Minimum	Maximum	Mean	Median	Std. Deviation
BB	0	4	,88	,50	1,356
GG	0	6	3,43	3,00	2,699
BG	0	6	1,083	1,00	2,250

As the results presented on table 10-3 show the mean embodiment value for the groups of girls was the highest with 3.43 followed by the mixed groups with 1.083, whereas the groups of boys scored 0.88. Indeed, the results show that the groups of girls had a higher level of embodiment followed by the mixed groups, while the groups of boys scored the lowest value.

Chart 10-1 Children's level of embodiment.



The application of the Anova test on the data to access the significance of the differences on the level of embodiment between the different type of groups showed a p= 0.092 (table 10-4). Although this value is not significant at the level of less than 5% value – the standard value of reference to reject the null hypothesis in educational sciences – nonetheless it is a value that is significant at the level of less than 10%, which somehow confirms the differences that arise in the visualization of the boxplot graph (chart 10-1).

Table 10-4 relation between the type of group and the level of embodiment.

ANOVA

Level of embodiement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	24,707	2	12,354	2,641	,092
Within Groups	112,256	24	4,677		
Total	136,963	26			

In order to access the relation between the interaction time of all the groups, and the level of embodiment, a Pearson correlation was applied to the data. The obtained value (0.665) showed a significant correlation between the interaction time and the level of embodiment, even for the level of less than 0.001 (table 10-5).

Table 10-5 correlation between time of interaction and level of embodiment.

Correlations

		Time of Interaction	Level of embodiement
Time of Interaction	Pearson Correlation	1	,665**
	Sig. (2-tailed)		,000
	N	27	27
Level of embodiement	Pearson Correlation	,665**	1
	Sig. (2-tailed)	,000	
	N	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

In summary we can say that according to our analyses a great part of the groups integrated aspects of embodiment in their narratives, and it seems that the interaction time is positively related with the level of embodiment, as the correlation between these two dimensions have shown. Further, the groups of girls obtained the highest level of embodiment and the groups of boys the lowest, the mixed groups seem to bee a good combination for carrying this kind of activities.

10.4.1Reflections on the Interaction

The results showed that embodiment was an important factor in the creation of children's narratives, contributing to their involvement and immersion in the flow of the narrative. Indeed, as illustrated in the transcribed examples, children's interaction with the digital manipulative took place in two distinct levels, in one level children acted as the directors of a play, orchestrating the action (Hermans, 1997; Wright, 2007), like in a theatre play, on the other level children embodied the characters and become the actors of their own play. Definitely, as directors of the "stage-narrative" children planned their story in advance preparing the stage for the performance, which they clearly preferred to do with their peers, saying that it was more fun (Interaction 1: lines 6,21). Children ascribed attributes to their characters and houses. As directors of the play children guided the actors, speaking with them (category *Speak with characters*: interaction 1: 11-14, 21-22, 26: interaction 2: 17; interaction 3: lines 53,54) urging them to hide from the wolf, or telling the wolf they were going to give him a lesson. Together they discussed the best strategy to orchestrate their play when the slots on the platform were full.

As actors, children embodied the characters; clearly stating which character they were (category *Embody the characters* interaction 1: line 25; interaction 2: lines 1-3) and offering their actor friends refuge in their homes (interaction 2: line 9). They sang songs (category *Sing songs*: Interaction 3: line 28). Moreover, through their body movements and expression children conveyed their emotions, such as anxiety (interaction 1: lines 10,15; Interaction 2: 18), happiness (interaction 2: lines 3,9,19), or they illustrated and reinforced what they wanted to say (interaction 1: line 19,20). The performing of the story generated a sense of unity and belonging among the children; in fact, when embodying their pig characters children faced a common peril, and they hold together offering each others house as shelter. Collaboration and peer interaction was a strong motivational factor, driving the children to engage in creative narrative construction. Interaction 1 is a good example of peer tutoring, where one of the boys, helped the other to understand what was happening on the screen. Or as shown in interaction 3 one of the girls instructed the other that it was necessary to place a new scenery when that was mentioned in the story plot (line 42), or instructs her that the pig the other girl wanted to place was not the correct one (lines 18,19) - as we have referred before, the children had very precise conceptions about each of the characters. Also Maria suggests her friend to say that the characters had disappeared, instead of saying that they all had died (lines 58).

The variety of narrative approaches was also visible in the presented examples, indeed while in interaction one and two children created different variations of the story of the “Three Little Pigs” concentrating in trying to escape the wolf and saving the little pigs; the girls that performed interaction three preferred to mix characters from different traditional stories, creating different narratives. Like the two other groups the two girls embodied and dramatized the story, creating moments of tension, which they emphasised through the intonation of their voices raising (lines 7,8,53), lowering (lines 38,39), or whispering (lines 47,49,58) indeed, creating moments of tension, expectation and happiness according to the development of the plot.

The girls directed their stage-narrative in a very collaborative and tuned way, always building on each other's narrative and extending it further. Sometimes they made suggestions explicitly, or merely implicitly, communicating through their bodies without needing to use words (lines 30,31), just by simply gesturing, gazing or nodding.

10.5 Discussion

At the end of the interaction Maria turned to the researcher, saying: "TOK, tells stories very well"! That may give a clue on how children view and understood the digital manipulative. As a space where imagination could flew, which was reflected in the fluidity of their narratives. Indeed, we can refer to TOK, as a digital environment that supports what we call embodied stage-narratives, integrating visuals, voice, emotions, and sensory modalities. The creation of the stories was definitely an embodied performance, which involved sorting the elements, ordering, rearranging them, looking for specific blocks, and placing and removing the blocks from the digital manipulative platform. The physical actions on the blocks seem to support the structuring and organizing of the story. As suggested by Antle et al. (2009:87) the direct handling of objects supports children to mentally solve the task through exploratory iterations. We can refer to the digital manipulative as a virtual stage where children create and act out their narratives. The interaction occurs in two levels, as children share the stage, (controlling the characters, the location, the props, and the nature elements) and simultaneously perform on this stage. The sharing of the input devices (blocks) gives children equal control of the performance and *orchestration* of the story. Simultaneously freeing them to embody their stories, externalizing feelings of apprehension, anxiety, enthusiasm or joy. As Wright points out "embodiment seems to be deeply imbedded in the children's act of meaning-making itself" (Wright, 2007:17).

Like in a theatre play (Burke, 1945; Goffman, 1959; Rifkin, 2009), children perform the narrative acting out different roles, embodying the characters.

Moreover, children's identification with their narratives was also visible in the parallels that they created between the story and their personal lives (interaction 1: lines 28-33). We subscribe Wright, when she says: "Such open-ended, personal forms of knowing, expressing and communicating unleash and reveal children's deep meaning, multiple perspective-taking and fluidity of thought." (Wright, 2007:24).

Further, by acting as directors of the play, children may develop metanarrative awareness, planning and discussing the course of the narrative, and taking decisions. Peer collaboration was strongly promoted through the handling of the physical devices, which empowered each child to have an active role in the creation of the narrative. Relatively to this, we subscribe Fischer & Shipman when they say: "Environments that support the interaction of different skilled participants, encouraging "all voices to be heard" and combining different perspectives are a potential source for learning" (Fischer & Shipman, 2011, cited in Eagle, 2012:48). Eagle adds to this, that the extent to which the artefact is capable of promoting social interactions, and an active, engaged, participation with the learning subject is decisive (Eagle, 2012).

Additionally, as a suggestion for educational practitioners, and according to the results of our intervention, we were able to conclude that mixed groups seem to work very well in collaborative narrative construction.

10.6 Limitations of the Study

As every work, our study also has its limitations, although we have worked with various groups of children, the study was carried in a single school with predominantly middle class children, which clearly is not representative of children's population. However, we are convinced that the results also apply to a wide range of children, as they targeted skills and subjects, which are inherent to children. Also, and as the teachers pointed out, the content needs to be broadened, encompassing different themes, which indeed represents a chance for improving the tool, and develop different kits of picture-blocks, covering other areas targeted in preschool education. Future work will contemplate these issues.

Concerning the investigation of the development of language and literacy further research is needed to fully understand the potential of digital manipulatives, but we hope that the design approach proposed by TOK may contribute to incentivise further research and development of other digital manipulatives, bringing scientific knowledge forward.

CHAPTER 11 - Overall Conclusions

This work was motivated by the need expressed by educators and researchers for technological materials that meet children's needs, as well as the lack of educational research involving technology, specially concerning children under nine years of age. Read and Markopoulos summarize the research landscape as follows, " Whatever motivates the design of interactive technology for children, it is clear that there is an urgent and present need for research in the design of interactive products for children, related methodology, as well as a scientific account of the interaction between children and technology." (Read & Markopoulos, 2013:2).

Given the characteristics of our study, which encompassed two investigation lines - a theoretical one that informed, supported and later validated the development of TOK, and a practical one, which resulted in the development of the tool itself - Design Based Research provided the ideal framework for the study, allowing the articulation between theory and practice, between knowledge and practical intervention, so that it was possible to create a sustainable and effective intervention. In accordance with Design Based Research the study resulted in the development of a technological tool, at the same time the study was also able to contribute to bring research and theory forward. The engineering component was addressed by a cyclical and iterative approach, in which several prototypes were developed, which were tested with the children and the teachers in a cyclical iterative process, of designing, testing, incorporating the feedback and the suggestions provided by the children and the teachers, and redesigning again until the final prototype was assembled. The various iterations requested a long development period, spanning over a period of three years. As reported by recent research the length of such a development process is precisely what hinders much investigation to successfully get over preliminary findings. Moreover, iterative design with children is even more difficult to achieve, due to the difficulties in working with such a young public. As a result, except for very few exceptions, most research involving young children and technology has been limited to small groups and has not been set in real school environments.

Yet, before we proceed with the final discussion of the research presented in this work we considered it useful to give an overview of the different phases of the study and their articulation with the research questions (table 11-1).

Table 11-1 Articulation of the different phases of the study.

RESEARCH PHASE 1 – DESIGN AND IMPLEMENTATION OF TOK

RQ 1 How should a digital manipulative be designed in order to support a child-centred approach, fulfilling children and teachers' needs, while bringing an added value to pre-school curriculum?

LITERATURE REVIEW
DESIGN BASED RESEARCH
DESIGNING AND EVALUATING TECHNOLOGY WITH CHILDREN
INTERVENTION CHAPTER -7

↓

RESEARCH PHASE 2 – EVALUATION OF TOK

RQ 2 - How to integrate digital manipulatives in the preschool curriculum, which support free activities?

INTERVENTION CHAPTER - 8

RQ 3 - How to integrate digital manipulatives in the preschool curriculum, which support guided activities? Can digital manipulatives stimulate the development of relevant language dimensions, namely language and phonological awareness?

INTERVENTION CHAPTER - 9	INTERVENTION CHAPTER -10

RQ 4 - Can digital manipulatives contribute to the development of early literacy, promoting creative thinking and the construction of narratives?

INTERVENTION CHAPTER – 8	INTERVENTION CHAPTER - 9	INTERVENTION CHAPTER -10

RQ 5 - What are the constraints associated with the integration in the classroom context of such technological developments?

INTERVENTION CHAPTER – 8	INTERVENTION CHAPTER - 9	INTERVENTION CHAPTER -10

BRIEF GUIDELINES FOR CONDUCTING CHILDREN STUDIES

The difficulties concerning the investigation of young children's use of technology in preschool is very complex due to the limited use of technology within the preschool context. Despite the growing awareness of the importance of using ICT at school the integration of computers in schools is still limited and confined, which is partially explained by curriculum related issues, as the implications of integrating technology in school imply revision of the curriculum content and goals, as well as the revision of examination programs, which clearly is beyond the scope of the teachers. And obviously, technology needs to fit teacher's practices and be easily adapted to the needs of the teachers and the children. Regarding this aspect, our inquiry revealed that the teachers were very willingly to work with innovative pedagogical materials welcoming the new possibilities offered by the tangible technology. Moreover, the children were also very enthusiastic about the tool, and their enthusiasm did not diminished after several months of use.

This interest was undoubtedly the result from a technology that was able to meet children's needs. As the results of our study have shown, TOK was able to support and promote following aspects:

- Exploratory learning, promoting children's need to explore their surrounding environment in order to construct knowledge, as highlighted by Constructivists and Constructionists;

- Enclosing learning within the social environment, as defended by Vygotsky, Bruner, Papert, and Social Cognitivists.

- Collaboration and scaffolding from more skilled peers or teachers, an important aspect for learning, which has been pointed out by Bruner, Vygotsky, and Social Cognitivists;

- Stimulating different learning approaches as highlighted by Gardner, and addressing different channels, in accordance with results from the Dual Coding theory, while supporting different interaction levels as stressed by Papert and research in multimodal environments.

- The manipulation of objects and symbols, which is particularly important during this period, as the link between body and mind is still very strong, as highlighted by Constructivists, Constructionists as well as theories from Embodied Cognition.

Based on the results of our research, we can conclude that the intervention described on chapter seven, together with the empirical findings described in chapters eight to ten, positively answer our first research question (RQ 1) relatively to the design of a child-centred technology. As described on chapter seven the design and development of the digital manipulative was carried with six different classes of preschool children and six preschool teachers for a period of around three years, in which multiple iterations with different low-tech prototypes were carried, incorporating the feedback provided by the children and the teachers in the development of new prototypes, always following a cyclical process of developing, testing and redesigning.

TOK showed to be adequate for being used by the teachers to carry guided activities, as well as for being used by the children during their free-play time, a topic that we addressed with (RQ 2 and RQ 3).

Actually, outgoing from the potential offered by the digital manipulative, one of the preschool teachers used TOK targeting the development of phonological awareness, and lexical skills. In fact, the stimulation and development of the two language dimensions addressed in chapter nine, are considered of major importance for the development of early literacy skills, influencing the later acquisition of reading and writing, indeed positively answering (RQ 3). Children's construction of multiple fictional worlds, which was motivated by their continuous verbal interactions a propos and with TOK, contextualized the learning of an extensive collection of vocabulary and the playing of language games. Indeed, the results of pre and post-tests applied to the children showed significant improvements in terms of lexical knowledge and phonological awareness skills.

Recent research on emergent literacy has highlighted the fundamental importance of exposing children to literacy rich and stimulating environments. TOK has definitely showed that it has the potential to be used to create such an environment, as the results of the interventions presented in chapter eight, nine, and ten have shown, thus positively answering (RQ 4).

Further, the results of the interventions presented in chapter eight and ten, disclosed how the physicality of the input devices promoted children's embodiment of their stories, and the creation of structured narratives where the placing of the blocks was not merely random, but the result of peer collaboration. In fact, the tangible blocks, with the different story elements stimulated children's imagination, triggering new ideas for the creation and development of narratives.

The data obtained during children's free interaction (chapter eight), confirmed that the combination of tangible elements, and the integration of a plot- and character-based approach to storytelling, promoted the creation of a great variety of different narratives, allowing children to locate the stories in different scenarios, combining the characters and the objects in numerous ways, always creating original stories. Children explored the digital manipulative and created their stories autonomously. Definitely, the great majority of the groups involved in activities, which promote language development and emergent literacy, such as telling stories or playing language games. The collaboration with peers was a strong motivating factor, which was visible in the groups that collaborate together.

Finally the results of the intervention presented on chapter ten, disclosed how the physical blocks, created a context, similar to the staging of a theatre play, in which children are both directors, who concentrate in creating the drama, define the characters, the scenario and the plot, orchestrating the play together, while at the same time embodying the characters and role playing the narrative. The performance of what we call embodied stage-narratives opened up a space, in which children could free their imagination, promoting creative thinking, as well as fostering early literacy skills and metalinguistic awareness.

The results allow us to reinforce our statement that well-designed digital manipulatives do have an important role to play in the development of competencies targeted in preschool education, as powerful scaffolds for fundamental language developments.

Relatively to the constraints of the implementation of digital manipulatives in the preschool context, (RQ 5) there are a number of factors from which the success of pedagogical interventions depends.

11.1 Brief Guidelines for Conducting Children Studies

Outgoing from our experience and concerning this subject, we would like to make following suggestions for future researchers to successfully carrying research and eventually develop new technology within the school context:

- It is fundamental to have a formal agreement with a school, where the study can take place. Given the tight school schedule, interventions, which take place within the classroom need to be planned in advance and agreed on with the teachers (depending on the school policy, the school board may also be informed about the research plan).

- Researchers need to be flexible and ready to change their calendar whenever it is necessary, as there often are unforeseen changes that may arise, indeed researchers need to adapt their research plan to meet the needs of both educators and children.

- Further, it is necessary to inform the parents and the children in advance of the activities that will be carried with the children in the scope of the study, asking for their agreement. Additionally, in case there is a need for filming and photographing the children, besides of course asking the school board and the teachers for their agreement, it is necessary to have an undersigned document from the children's parents stating their formal agreement and permission, highlighting that any filming will be done only for scientific purposes, safeguarding the child's identity.

- Children should enjoy participating in the research activities, and never ever be forced to participate when they do not want to do it, always respecting their will. We consider that is important to have a good and informal relation both with the children and the teachers, and enjoy the work together. Moreover, children should be treated with the same respect as adults.

- Further, the study has reinforced our awareness of the importance of collaborative, multidisciplinary design and research teams, whose competencies in the various areas of knowledge make the development of well-designed educational materials able to meet the needs of not only the children but also the ones from their teachers. Indeed, this work has shown 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.

- Obviously, funding is needed to sustain development costs and the dissemination of the study results.

To conclude, we can say that we successfully closed this iterative research cycle, and we hope that the design approach proposed in this study may contribute to incentivise further research and development of other digital manipulatives, thus bringing scientific knowledge forward. And above all creating engaging technology that can be used in the preschool context, contributing to a change of a learning paradigm, which is more in line with the world we live in.

11.2 Future Work

Future work will continue to address the question of how to integrate innovative learning approaches in the school curriculum, allowing students to develop competencies that enhance learning, preparing them to successfully meet the demands of the future Information Society. In the scope of future work the researcher proposes to gather information on how to best integrate tangible technology in the preschool curriculum, trying to access advantages and drawbacks of such integration, creating a set of guidelines for future interventions. The study will be carried within the classroom with different schools and classes for an extended period of time, involving a team of experts, from the field of education and engineering as well as teachers from different schools and classes. The work will also encompass a strong collaboration with the children, who will be involved in the design of educational content, ranging from problem solving to mathematical contents.

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.

Additionally the team will create strategies to involve the community in the exploration of these systems, extending its use behind the school context by creating clubhouses and after school centers where students can gather together to explore new technology, and design their own projects with the support of a team of volunteers that provide guidance and support if needed. We are convinced that only by involving the community it will be possible to achieve a lasting change.

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Attachments

Sub-teste de Definição Verbal

Nome Data observação:____ Idade (em meses): ______________

Cotação Máxima: **70 pontos**

Categorias de respostas	**Pontuação**	**Exemplos**
Definição categorial particularizada	**2**	É um animal que dá leite
Definição categorial	**1,5**	É um animal
Definição perceptual e/ou funcional/sinónimo	**1**	Dá leite
Exemplificação	**0,5**	Cornélia
Exemplificação genérica / não resposta / ou resposta errada	**0**	É uma coisa

Instruções e exemplo:

Quero que me digas o que é aquilo que te vou perguntar:
O que é a banana? / - O que é a vaca? / - O que é regar?

Items e respostas

Items	Resposta	Observações	Cotação
Açúcar			
Águia			
Ave			
Baleia			
Canguru			
Cara			
Cenoura			
Círculo			
Cotovelo			
Dentista			
Floresta			
Globo			
Golfinho			
Hortaliça			
Ilha			
Joelho			
Lagarto			
Maça			
Ombro			
Pescador			
Pescoço			
Pinguim			
Praia			
Professor			
Pulso			
Rio			
Vinho			
Colorir			
Descansar			
Descascar			
Despejar			
Empurrar			
Medir			
Mergulhar			
Pegar			

TOTAL

Sub-teste de Nomeação

Nome da criança:____
Data da observação:____
Idade (em meses): ________________

Cotação Máxima: 70 pontos

Instruções e exemplos:

Vou-te mostrar uns desenhos e tu vais dizer-me o que vês.

-O que é isto? (do *açúcar* até *vinho*) / - O que está (o/a menino/a) a fazer? (de *colorir* até *pegar*)

Categorias de respostas	**Pontuação**	**Exemplos**
Atribuição do rótulo correto	**2**	Vaca
Designação do atributo classificativo	**1**	Dá leite
Não resposta ou reposta errada	**0**	

Itens e respostas

Itens	Resposta	Observações	Cotação
Açúcar			
Águia			
Ave			
Baleia			
Canguru			
Cara			
Cenoura			
Círculo			
Cotovelo			
Dentista			
Floresta			
Globo			
Golfinho			
Hortaliça			
Ilha			
Joelho			
Lagarto			
Maça			
Ombro			
Pescador			
Pescoço			
Pinguim			
Praia			
Professor			
Pulso			
Rio			
Vinho			
Colorir			
Descansar			
Descascar			
Despejar			
Empurrar			
Medir			
Mergulhar			
Pegar			

TOTAL:

Sub-teste de Estrutura Fonológica

Nome da criança:____
Data da observação:____
Idade (em meses): ________________

1. Discriminação de pares de palavras

Cotação Máxima: **<u>10 pontos</u>**
Atribuição de 1 ponto a cada resposta certa e 0 a cada errada

Instruções e exemplo:
Eu vou dizer duas palavras que às vezes são iguais e outras vezes não. Por exemplo: Bola – bola são iguais.
As palavras que e vou dizer agora são iguais ou não?

Itens e respostas

Itens	Resposta	Cotação
Doce – Doze	S / N	
Gato – Gato	S / N	
Dente – Dente	S / N	
Trinta - Tinta	S / N	
Vento – Vendo	S / N	
Faca – Vaca	S / N	
Bate – Bate	S / N	
Dado – Nado	S / N	
Frasco – Fraco	S / N	
Roupa - Rouba	S / N	

TOTAL:

2. Discriminação de pseudo-palavras

Cotação Máxima: 10 pontos
Atribuição de 1 ponto a cada resposta certa e 0 a cada errada

Instruções e exemplo:
Eu vou dizer duas palavras inventadas que às vezes são iguais e outras vezes não. Por exemplo: Bofa – bofa são iguais.
As palavras que e vou dizer agora são iguais ou não?

Itens e respostas

Itens	Resposta	Cotação
Caqui – Gaqui	S / N	
Pul – Pul	S / N	
Duzu – Duzu	S / N	
Trico – Tico	S / N	
Dodi – Todi	S / N	
Volo - Folo	S / N	
Tal - tal	S / N	
Deda - Neda	S / N	
Drasque - Draque	S / N	
Guido - Guipo	S / N	

3. Identificação de palavras que rimam

Cotação Máxima: **10 pontos**
Atribuição de 1 ponto a cada resposta certa e 0 a cada errada

Instruções e exemplo:
Diz-me se as palavras rimam ou não. Por exemplo: Mão – Pão são duas palavras que rimam.
E as que te vou dizer agora rimam ou não?

Itens e respostas

Itens	Resposta	Cotação
Fita – Guita	S / N	
Saco – Saia	S / N	
Tia – Mia	S / N	
Jogo – Fogo	S / N	
Bota – Mota	S / N	
Feira – Beira	S / N	
Mel – Pão	S / N	
Comilão - Castelão	S / N	
Pincel – Batel	S / N	
Copo - Leite	S / N	

TOTAL

4. Segmentação silábica

Cotação Máxima: **10 pontos**
Atribuição de 1 ponto a cada resposta certa e 0 a cada errada

Instruções e exemplo:
Divide as palavras que eu disser em bocadinhos. Por exemplo: Bola dividida em bocadinhos fica BO – LA.
E estas palavras que vou dizer como ficam?

Itens e respostas

Itens	**Resposta**	**Cotação**
Cama	S / N	
Bolo	S / N	
Batata	S / N	
Cadeira	S / N	
Mão	S / N	
Sol	S / N	
Colchão	S / N	
Camisola	S / N	
Erva	S / N	
Flor	S / N	

TOTAL:

Sua Kay, E.; Santos, M.E.; Ferreira, A.L.; Duarte, G.M. & Calado, A.M. (2003). Grelha de avaliação da linguagem- nível escolar (GOL-E). Ecola Superior de Saúde de Alcoitão

Requested Permission to Film /Photograph

TOK – [Tocar, Organizar, Criar] uma plataforma para contar histórias

Caros Pais/Mães desenvolvemos na Universidade do Minho em colaboração com o Colégio Teresiano uma plataforma para contar histórias direcionada para o ensino pré-escolar. A plataforma está ligada ao computador; ao posicionar um conjunto de blocos que representam elementos como personagens, cenários e objetos na plataforma, as crianças criam as suas próprias histórias, que visualizam no ecrã. O objectivo deste projeto é promover o desenvolvimento da linguagem, competências narrativas, aquisição de novo vocabulário assim como a colaboração entre as crianças. A educadora Andreia Oliveira está a dinamizar este projeto com as crianças da sua sala, no contexto da sua dissertação de mestrado.

Para avaliar os benefícios da interação das crianças com este material pedagógico, gostávamos de obter a vossa autorização para poder filmar algumas das sessões onde as crianças utilizam este material.

O *uso de fotografias / filmagens destina-se unicamente à avaliação dos resultados e eventuais publicações científicas na área, sendo o anonimato do seu/sua educando/a salvaguardado.*

Agradecendo desde já a colaboração, Com os melhores cumprimentos

Nome do/a aluno/a ....

Sim autorizo que o meu educando/a seja filmado/fotografado ☐

Não autorizo que o meu educando/a seja filmado/fotografado ☐