Sylla, C., Coutinho, C., & Branco, P. (2015). **Play Platforms for Children's Creativity**. In N. Zagalo & P. Branco (Eds.), Creativity in the Digital Age (pp. 223-243): Springer London.
doi: 10.1007/978-1-4471-6681-8_12

Play Platforms for Children's Creativity

1. Introduction

Children's imagination, their natural need for exploration and discovery can be stimulated when they are in contact with rich contexts and environments (Van Scoter et al., 2001; Van Scoter, 2008), this inherent tendency offers an enormous opportunity for researchers and designers to develop tools that unleash children's potential, involving them in creating meaningful projects (Papert, 1993). Research on this field has highlighted that well-design technological tools for children need to be compelling, support exploration, encourage creativity, develop curiosity, promote interaction, and collaboration with peers, while being simple and intuitive to use (Plowman et al., 2012; Resnick et al., 2005; Resnick & Silverman, 2005).

However, despite a move from virtual to physical as the focus of digital interaction (Ishy & Ullmer, 1997), which is leading to a diversification of interaction contexts, objects and applications, opening new possibilities for the creation of innovative interactive artifacts, discussions about the use of technology for young children have disclosed that technology often fails to exploit the affordances of the medium, by merely transposing traditional materials to the corresponding electronic format (Plowman et al., 2012).

Aiming at developing an authoring and sharing tool for children, which empowers them to collaboratively create interactive content and share it with others, this study describes the design and development of an interface for tangible narrative creation. The process, which extended for a period of three years, involved six classes of five years old pre-schoolers and six pre-school teachers. From the conception to the development of the final product, several design iterations were carried with the children, in which the research team tried to understand how to design an engaging and compelling tool, for children to play around and experimenting with story elements, creating their own narratives. The design of the digital tool 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).

2. Materials for Exploring the World

Using objects to promote exploration and spark imagination has a long tradition that can be traced back to Friedrich Fröbel - the creator of the world's first kindergarten in Germany, in 1840. Fröbel developed a curriculum for young children where they could engage in *self-activity* and *self-expression* through play (Fröbel, 1909:vi). Core to his approach were the *gifts*, a collection of 20 physical objects that included balls, strings, sticks and blocks, and were used as play materials to help children think about and express their ideas. 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).

Like Fröbel, Maria Montessori highlighted the importance of using objects and actively engaging in exploring the environment. Montessori's method, based on the *Didactic Materials*, addressed the stimulation of every sense (Montessori, 1912), and the design principle behind each of the objects from the *Didactic Materials* set, was to raise children's interest and curiosity.

2.1. Digital Manipulatives

Recent technological developments made it possible to embed computational technology in objects, creating a new interaction paradigm with digital technology. Digital manipulatives[1] (Resnick et al., 1998) also referred to as tangible interfaces - TUIs (Ishii & Ullmer, 1997; Ullmer & Ishii, 2001) or tangible systems provide a more natural interaction, stimulating sensory and whole body perception, giving users freedom of movements, while creating richer experiences. Research has shown that physical manipulation greatly improves comprehension (Glenberg, 2010; Glenberg et al., 2011), and that digital manipulatives have the potential to expand the range of concepts that children understand (O'Malley & Fraser, 2005; Zuckerman et al., 2005), promoting peer collaboration and negotiation (Hornecker, 2005; Hornecker & Buur 2006; Zuckerman et al., 2005), and particularly supporting exploratory and expressive learning activities (Marshall, 2007).

Zaman et al. (2012:368) summarize the affordances of digital manipulatives 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.

Resnick and colleagues (2005; Resnick & Silverman, 2005) suggest *Design Principles for Tools to Support Creative Thinking*, placing the emphasis on promoting exploration and creativity:

> Support Exploration
> Low Threshold, High Ceiling, and Wide Walls
> Support many paths, many styles
> Support Collaboration
> Support Open Interchange
> Make it as simple as possible – and maybe even simpler

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[1] The term digital manipulatives has been coined by Resnick and the lifelong kindergarten at the MIT, Media Laboratory, Cambridge, MA, referring to a new generation of computationally enhanced manipulative materials that enable children to interact with digital information (Resnick et al., 1998). In the scope of this work we will use the terms digital manipulatives, tangible interfaces (TUIs), or tangible systems as synonyms.

Choose black boxes carefully
Invent things that you would want to use yourself
Balance user suggestions, with observation and participatory processes
Iterate, iterate – then iterate again
Design for designers

3. Exploring the Design of Digital Manipulatives with Children

Previous research has shown that one of the most effective ways, of designing child centred technology, is to involve children in the design process. In fact, 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). Today this is a common practice, and 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).

3.1. Context of the Study

The study presented here took place in a Portuguese preschool, involving six classes of pre-schoolers, of five-years-olds and six preschool teachers, for a period of around three years (Sylla, 2013; Sylla et al., 2011; 2013b). Although the teachers were always the same, the team 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. During this period the research team carried several cycles of rapid prototyping, trying a variety of different approaches and materials, prototyping, testing, gathering information, and redesigning again. These various iterations led to the development of several prototypes, some of which evolved into more finished products, such as *t-words*, an interface that received the Golden Award for the Best Demo at ACE 2012 (Sylla et al., 2012) and the World Technology Award 2013[2] in the category Entertainment.

3.2. Initial Explorations

In the first design iterations the team wanted to assess how children create stories using tangible props. To gather information on this aspect the researchers used a low-fi prototype that consisted of a set of cards with drawings representing animals, objects, places and nature elements, (table 3-1) 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[3], using a small program developed in Processing[4], by pressing a certain key

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[2] http://www.prweb.com/releases/2013/11/prweb11342067.htm

[3] 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.

[4] Processing: http://www.processing.org/

on the computer, the researchers simulated audio feedback for each card that children placed on the prototype.

Table 3-1- 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. 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, and each session lasted about one hour (fig. 3-1).

Figure 1-1- Children creating and changing their stories.

The researchers 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”. The children could create variations of the narrative, according to the sequence of cards that they placed. 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, while trying to create stories. Children personalized and extended the narratives, adding their own ideas to the very simple stories they were hearing.

3.2.1 Reflexions on the First Design Iterations

The sessions with the children showed that the use of tangible picture cards generated ideas for the creation of narratives, promoting a very dynamic peer interaction. Relatively to using speech 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, the researchers decided to remove the speech in future versions of the prototype, giving children more freedom in the creation of the stories.

Further, 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 was generated 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, exchanging ideas about the cards they wanted to use. For instance, in one of the groups there was a conversation between the children about when they ought to use the card picturing a moon, as one child stated 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.

3.3. Follow-up

After the initial design explorations the team wanted to gather more detailed information about how children would use tangible cards to create a story. Therefore in the following iterations the researchers used a paper prototype that consisted of an A4 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, the team tested the prototype with four groups of three children each. The sessions took place in the preschool's painting room with the children and one researcher (fig. 3-2).

Figure 1-2 - Children interacting with the second paper prototype.

The children sat in groups of three around a table, where the picture cards were scattered, each child was given a cardboard, and the researcher proposed 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. 1-2 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. Very often the children spontaneously removed some cards from the "platform", replacing and adjusting them to the narrative that they were creating.

3.3.1. 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 entered 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.

3.4. Funcional Prototype

The next design stage was to explore the development of a prototype 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.

3.4.1. Physical Manipulation

The manipulation of the digital content 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), creating a direct mapping between input and output (Anderson & Shattuck, 2012; Antle et al., 2011). Outgoing from the idea of using picture cards, the team chose 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).

3.4.2. Detection of the Physical Content

Having defined the physical manipulation the researchers considered several methods for the detection of the blocks, ranging from optical recognition, radio identification, physical properties and embedded circuitry (fig. 1-3). 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 on the backside, created by different patterns of conductive aluminium. 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.

This prototype was tested with small groups of two children each, in the preschool's painting room. To assess how intuitive the system was for the children, the researcher briefly explained the functioning to the first group, and remained in the background, observing how children used it. Children immediately appropriated the prototype, placing the blocks on the platform and exploring the content, and when the following group came in the room the children were excited and eager to show the functioning to the new comers.

Figure 1-3 - Proof of concept (top left); first functional electronic prototype (bottom left); prototype with blocks (bottom centre) and backside of two blocks (bottom right).

3.4.3. 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 had to be easy, direct and quick. Also, there were some problems with the recognition of the block's IDs due to the oxidation of the contacts, therefore a different technical solution had to be implemented.

3.5. TOK – Touch, Organize, Create

After testing several solutions for the detection and considering different forms for the blocks, the final prototype recognizes the blocks through capacitive sensors. Each block has a sticker with a picture of what it represents on the upper side and a conductive pattern on its base, which is detected by capacitive sensors located on the platform base. The final system is composed by an electronic platform with six or eight slots, 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 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. 3-4).

Figure 1-4 - Children interacting with the system; block, front and backside (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 disappears from the screen.

Figure 1-5 – Some of the characters and objects.

Following suggestions from the teachers, the blocks represent classical scenarios and actants from narratives for children - basically, heroes and opponents (Greimas, 1973, Propp, 1928) - and are composed by characters, objects and nature elements (fig. 3-5).

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. 3-6).

Figure 1-6 - 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; Hunter et al., 2010). We will illustrate this with an example: when children place the combination of blocks as pictured on fig. 3-7 (left) (*witch*, *fairy*, *princess*), the witch attacks the princess and the fairy tries to help her.

Figure 1-7 - Children creating a narrative with the digital manipulative, setting the story at different times of the day (by placing the *moon* block).

As the fairy alone is not strong enough to defeat the witch, the princess dies. However children can use different strategies to change the plot, e.g. by 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.

The design of the interface placed a "high priority on tinkerability", stimulating children to explore different possibilities, encouraging them "to try out multiple alternatives, shift directions in the middle of the process, to take things apart and create new versions." Resnick et al. (2005). The system, which was named TOK -

Touch, Organize, Create – allows children to change the scene, mix and remix the characters, try out different solutions, shift direction and start all over again. Further, as 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 and share it with others, 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. 3-8), 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 1-8 - Automatically generated snapshots of a narrative.

3.6. Modelling the Story World

To define the relations between the story elements and to achieve a certain degree of unpredictability the story world was modelled through behaviour trees (BTs). 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 their level of health, there is a certain degree of unpredictability in the outcome of a given situation.

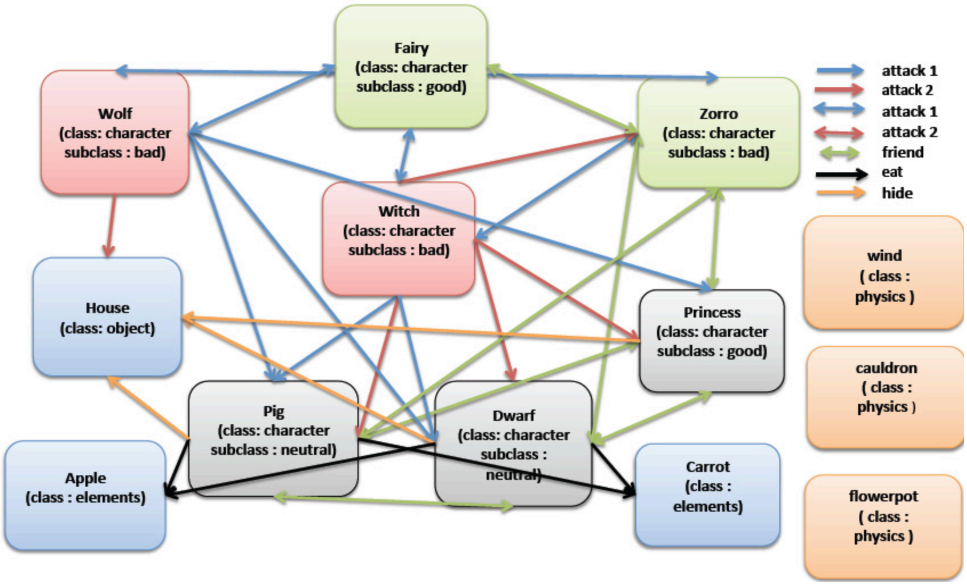
The principle followed in the design of the BTs was to model a world that would be understandable for young children, by creating a set of rules that they know from traditional story plots. As before mentioned there are four types of entities: scenarios, elements, objects and characters. Scenarios represent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

The objects and characters are classified in good, bad or neutral; bad characters attack the good ones, good characters defend the neutral and help each other. Both, good and bad characters can join forces to defend or attack their opponents. Specific objects like a caldron or a flowerpot can be used to knock down bad characters and defend the good ones. A bad object - 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 BT, which defines 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 to add 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 3-1.

Chart 1-1- Relations between the entities.



When users place the blocks on the platform, the BT gets the inputs of the entities that are present (we refer to the blocks 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.

4. Trying out Different Ways of Involvement

4.1. The t-words Interface - Tangible Words

A second interface that resulted from the various design sessions with the children is the *t-words* interface (Sylla et al., 2012; 2013a), which emerged out of the idea of exploring and experimenting with narratives, focusing on the audio aspect. Children no longer just use the content that they have at their disposal but are empowered to create their very personal audio materials. Inspired by other tangible systems like TellTale (Ananny, 2001), StoryMat (Cassel, 2004; Cassell, & Ryokai, 2001), or Jabberstamp (Raffle et al., 2007), t-words consists of a set of rectangular blocks that can record and play sounds, words or sentences, enabling users to record and store audio, as well as to play the recorded sounds (fig.4-1). Each block has an audio recorder with a 4GB storage card, an audio player with an embedded speaker and magnetic connectors on each side to connect to the other blocks.

Figure 1-1 - The t-words prototype.

Each block has a button to start and stop recording, and an LED that gives the user feedback about the action of recording and playing the sound. To play the recorded audio, users snap the blocks together, and the recorded audio sequence begins to play from left to right. The blocks can be arranged and rearranged creating different audio sequences. 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. Additionally, users can customize the blocks by drawing on top of their surface, the drawings can be wiped out and new ones can be drawn again.

5. Assessing how Children Use the Interfaces

5.1. The t-words interface

The researchers had the opportunity to carry two workshops with the t-words interface at the "Entertainment Kids Workshops", which were part of the ACE 2012[5] conference held in Kathmandu, Nepal. The theme of the conference was "Entertainment for the Whole World" (Cheok et al., 2014) and the Kids Workshop proposed to *engage with local young children with the aim of exploring concepts such as creativity, experience and "cool" ways of creating entertainment media and ways of expanding children's understanding of entertainment computing and its potential* (ACE, 2012). Additionally the workshops were hoped to act as seeds for further research.

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[5] 9th International Conference on Advances in Computer Entertainment Technology http://aceconference.tumblr.com

Figure 1-1 - Children in Kathmandu recording audio in the t-words blocks (top) and children drawing on their blocks (bottom).

The workshops were held in two schools - the Rudrayanee School and the Ullens School (fig. 5-1) children liked to record their own voices into the t-words boxes and to play around experimenting different audio sequences by just changing the order of the boxes. They used the boxes to record words, stories, messages, but also songs and a variety of sounds that they improvised with objects they found at hand. The workshops revealed that simple technology, which does not need a computer or any developed content, but instead gives users space to play around, explore with different audio recordings, creating their own content, is a powerful engaging tool, freeing users and developers of language constraints (Chisik et al., 2014).

5.2. The TOK Interface

Following the development of TOK, the researchers had the opportunity to carry two interventions at the preschool. The first intervention involved 24 pairs of five-years-old pre-schoolers, who interacted with the interface during free-play time for a period of four months; the second intervention involved 27 pairs of pre-schoolers who also interacted with TOK during free-play time for a period of six months. The first intervention investigated how children used the system after the novelty aspect had faded away, as well as the kind of activities in which they involved, the challenges they faced, and how they solved them. The second intervention investigated aspects of children's embodiment in the creation of narratives (Sylla et al. 2014). Both interventions disclosed that the sharing of the input devices (blocks and microphone) promoted children's embodiment of the stories they created, fostering their immersion in the story world. The microphone, initially used to capture children's verbalisations during their interaction with the interface for later analyses, turned out to be an important feature of the interface. Children immediately appropriated the device using it when they were speaking and creating their stories, and the microphone became a powerful motivating tool for children to verbalize their ideas.

Children used their voice as an expressive tool (Collins, 1999:82; White, 1954), changing the intonation and playing different voices for the various characters, sang songs or mimicked ambient sounds; they often spoke with the story elements addressing them with direct speech. 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), anxiety (e.g. when a character was in danger) standing up from their chairs, waving their arms, or jumping joyfully (fig. 5-2).

Figure 5-2 - Children gesturing and standing up, rejoicing and simulating movements of their characters.

The tangible blocks, with the different story elements stimulated children's imagination, triggering new ideas for the creation and development of narratives. Children created 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 collaboration with peers was a strong motivating factor.

6. Overall Reflexions on the Design Process

Having the possibility of carrying several design iterations and evaluating their use for an extended period of time gave the researchers an insight into children's world, allowing the team to understand some of their needs, preferences, likes and dislikes. Some ideas and prototypes created along this process slowly evolved into more developed products that underwent several optimisation cycles. Many of the initial ideas were left behind and several paths proved unpromising due to various reasons. However, they were part of the design process and helped to clear ideas towards what was important and not, which approach worked or not. Some important design solutions emerged just by chance, as for instance the use of a microphone.

The observations from the interventions at pre-school strongly support the *Design Principles for Tools to Support Creative Thinking* (see section 2.1) proposed by (Resnick et al. 2005; Resnick & Silverman, 2005). The very simple and intuitive setup of the interface, as well as its robustness, made it easy for children to start, supporting different approaches and different levels of interaction, promoting exploration and experimentation, while sparking children's creativity.

A certain degree of unpredictability of the stories (which depend from the sequence of blocks placed on the platform and the order they enter the system) generated by the integration of a plot- and character-based approach, nurtured children's motivation and engagement. They located their stories in different settings, combined 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.

The sharing of the input devices gave children equal control of their performance being another strong motivating factor. Children often verbalized that it was more fun to use the tools with their peers, and when creating stories together they built on each other's contribution. These joint activities generated fun, ideas, experimentation, experience change, and sometimes discussion, which in turn generated reflexion over their actions. "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). The importance of the social environment and the benefits of collaborative learning environments have long been acknowledged (Bruner, 1966; Eagle 2012; Lave & Wenger, 1991; Vygotsky, 1978).

Further, touching and manipulating the tangible objects, whether the TOK or t-words blocks, gave children a sense of ownership over their creations, acting as a motivational factor (Buur & Soendergaard, 2000).

7. Conclusions

While it is still difficult to measure creativity it seems consensual that longitudinal studies with active users in real world settings are a valid method to gain valuable insights about how the tools impact users in the long term (Yarosh et al.

2011:143) and which features are relevant for triggering creativity (Resnick et al. 2005). Research has emphasized the importance of developing tools that encourage authentic, creative, and meaningful opportunities (Plowman 2012, Yelland, 1999, Van Scoter, 2008). Indeed, although technology has the potential to create experiences that go beyond what is possible in the real world, nonetheless technology is useless if it does not meet children's needs (Van Scoter, 2008). It is by creating that people become creative (Resnick et al., 2005)

While t-words gives children absolute freedom to create their own personalized content, focusing on the audio component, TOK is like a stage where children take over multiple roles, becoming authors, directors, scripters, performers and narrators, thus creating multiple layers of interaction (Sylla et al., 2014, Wright, 2007). The versatility of tangible interfaces and their appropriateness for carrying child-centred activities, fostering exploratory and collaborative tasks, indeed show their potential for supporting a new paradigm, shifting from an instructional towards an exploratory model, where the use of well-designed technology can open up a space where active intrinsic learning may take place.

Acknowledgments

We would like to express our thankfulness to the Colégio Teresiano, Braga, and give a very special Thank You to all the pre-school children, their parents and pre-school teachers, who creatively helped us developing and testing this project in all its various development phases. This work is funded by FEDER through the Operational Competitiveness Factors Programme - COMPETE and by National Funds through the FCT - Portuguese Foundation for the Science and the Technology within the Projects: PTDC/CPE-CED/110417/2009, and the Doctoral Grant: SFRH / BD / 62531 / 2009.

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