Wrapping Up LinguaBytes, For Now

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ABSTRACT
In this paper we present the final research prototype of LinguaBytes, a tangible interface aimed at stimulating the language development of non- or hardly speaking children between 1 and 4 years old. LinguaBytes was developed in a three-year Research through Design process in which five incremental prototypes were designed, built and evaluated in real-life settings. In this paper we present the original starting points of the project, describe our method and illustrate the resulting end-design using example scenarios of use. We give an overview of the most significant findings at the ten-month evaluation moment, after which we reflect on the original starting points and assess whether they hold up.

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Tangible interaction, learning, children, research through design, experienceable prototypes.

ACM Classification Keywords
H.5.2 User Interfaces

General Terms
Design, Experimentation, Theory.

INTRODUCTION
At the first TEI Conference in Baton Rouge we presented the starting points of the LinguaBytes project\cite{13}, a project aimed at developing a tangible play-and-learn system for stimulating the language development of non- or hardly speaking children between 1 and 4 years old, with multiple disabilities (i.e., motor and/or cognitive). We identified several key guidelines as pivotal for our design:

- **Playfulness** – Young children learn mostly through play. Play permits making mistakes and trying again.
- **Social Interaction** – Young children play and work in groups and not so much on their own. Our approach is to stimulate interpersonal interaction.

Although all guidelines were framed in theory (most prominently constructivist learning theory and Vygotsky’s notion of Scaffolding\cite{23}), many originated from our beliefs; or in other words, from the future situation we were trying to create for these children. Five years have passed since TEI’07. In this paper we describe how the guidelines mentioned above have led to a sequence of in total five incremental prototypes that not only demonstrated these guidelines, but also transformed them; or at the very least, provided nuance to them. We present the final prototype and reflect on (1) how the guidelines were put into practice and (2) whether they still hold up.

BACKGROUND
The LinguaBytes project is aimed at developing a tangible play-and-learn system aimed at stimulating the language development of non- or hardly speaking children between 1 and 4 years old, most prominently children with cerebral palsy (CP)\cite{3} in a speech therapy context. In comparison to their able-bodied peers these children often experience retardations in their linguistic development, caused either by the direct result of a brain injury or by the indirect repercussions thereof on parent-child communication (the...
most important factor in a child’s early language development) [11, 17]. Since the brain injury cannot be remedied much energy is spent on improving the repercussions, for example through so-called Alternative or Augmentative Communication (AAC). AAC is aimed at enhancing a person’s communication skills or at offering alternatives when a person’s communication is temporarily or permanently impaired and inadequate to meet a person’s communication needs [2]. AAC comes in many forms; from lo-tech graphic symbol sets to hi-tech speech output devices or interactive software. Many materials have been developed aimed at interactive story reading, for example from V-Tech® and LeapFrog®, all specifically developed for pre-school children. The HCI research community has gone even further, exploring the possibilities of tangible interaction (e.g., [12]) and augmented reality (e.g., [5]).

**Status quo of related research**

These examples notwithstanding we find it important to emphasize that LinguaBytes is aimed at, from the perspective of interaction design, very young children. Many researchers have already been investigating the ins and outs of interactive systems for children, but not so much related work can be found where the focus is on toddlers between 1 and 4 years old. There is compelling work on interactive technology designed for and/or with children by, e.g., [4, 6, 7, 8, 10]. Also, there are very comprehensive books by e.g., [5] or [20]. All of these provide valuable techniques and guidelines for researching interactive technologies for and with children. However, only very few studies include children from the LinguaBytes target group.

**Anticipated benefits of tangible interaction**

Despite the apparent (commercial) success of many AAC materials, there seems to be space for improvement [e.g., 19]. Many researchers believe in tangibility as a powerful drive for learning, as do we, although empirical evidence of this is scarce [21]. We ourselves anticipated that tangible interaction could hold benefits over existing assistive technologies, most prominently with regard to two factors:

- **Reductions in learning time**: because children with CP often require much physical care from a parent or caregiver, less time and attention is left for communication. As a result, a child receives less linguistic information and is less communicative;

- **Subordinate role for the child**: research has shown that, in parent-child communication with non- or hardly speaking children, the adults take on a too dominant and interpretive role [22]. This has negative effects on the child’s active communication participation.

We elaborate on these factors in the following section.

**Increasing time for learning**

For children with CP, physical care will always be necessary and time consuming. This puts a lot of pressure on speech therapy, as a session typically lasts only 30 minutes. We observed however that the time that remains is often even further reduced when interactive learning materials are involved, especially when setting up these materials—often through icon-clicking and plowing through menus. This reduces not only the time for communication, but also the child’s attention and motivation to participate. We expected that tangible interaction [16] could be beneficial here: we expected that, if we would make as much of the set-up process as possible tangible—and as such part of the speech session—the child’s involvement and engagement would increase. This could lead to a better motivation, concentration and participation and consequently to more opportunities for learning.

**Enhancing the child’s participation**

In addition, we expected tangible interaction to provide these very young children with more opportunities for participation; tangible materials can be grabbed, pointed at, shared, thrown away, or used in other inherently expressive ways, adapted to a child’s capabilities. A prominent component of this anticipated benefit is the quality of tangible interaction that it taps into our understanding of the physical world, for example in terms of the ability to reverse your actions. As such, we anticipated that tangible interaction would for these children be more intuitive and, as such, inclusive.

**METHOD**

LinguaBytes was developed in a multidisciplinary collaboration between Eindhoven University of Technology, Radboud University Nijmegen and Kentals Sint-Michielsgestel. This made that the project could benefit from rich scientific input from the fields of industrial design, child rehabilitation, speech pathology and special education, as well as from related connections and resources.

To develop LinguaBytes we adopted a Research through Design approach, which we associate with Archer’s “research through practice” [1]. Research through Design can be seen as an iterative process in which scientific knowledge is generated through, and fed back in consequent cycles of designing, building, and experimentally testing experiential prototypes in real-life settings. In our case we went through five research-through-design cycles. In this paper we will only focus on the final design here, as more about the first four iterations can be read in [15]. Of the final LinguaBytes design (on which we elaborate in the next section) we built three identical prototypes, which have been in use for almost two years to date, at four child rehabilitation centers. In this paper we consider our findings at the end of the 10-month evaluation moment, at which point 65 children and 19 caregivers had participated. During this period LinguaBytes was used most often in sessions of individual children with their regular speech therapist, but also in group-sessions with up to four
children under the supervision of therapeutic caregivers. The prototypes were used on a daily basis, up to multiple times a day.

**PROTOTYPE DESIGN**

**Overview**

The final LinguaBytes prototype (see Figure 1) is a modular system that offers language concepts to children in a physical and playful form. Using a large collection of playful materials, children can read interactive stories and do linguistic exercises together with a parent, caregiver, therapist or teacher. As these social partners play an essential role in not only the child’s linguistic development but also in its social and emotional development, LinguaBytes was specifically not developed to replace social interaction but to facilitate it by creating a shared space for interaction and communication. The LinguaBytes prototype consists of five modules for input, output and control, together with a wide range of tangible input materials—16 story booklets, 8 thematic backgrounds, 236 input figures, 31 word cards and several programmable RFID-labels—with which 16 stories and 220 games and exercises can be done.

To give an impression of how the elements making up the LinguaBytes prototype interact we describe a typical use scenario below.

**Scenario**

The first step in using LinguaBytes is to select a theme and gather play-and-learn materials. Whereas this is often left to a caregiver in current systems we see this step as a crucial opportunity for caregiver-child communication. LinguaBytes comes in a box holding six compartments for the input materials of six themes. The box can be closed with a lid using two strips of Velcro; a commonly used material in the context of speech therapy and AAC, which allows children to ‘help’ the therapist with opening the box. Caregiver and child can then choose a theme together (e.g., ‘animals’) and collect the accompanying materials from one of the compartments. The theme’s tangible thematic background is then inserted in the base module to preload its accompanying stories, games and exercises. The base module holds most of the technology and is always used in combination with other modules. Thematic backgrounds serve as tangible content filters, bypassing menu-trees. Additionally, they provide a thematic context to the child.

**Reading interactive stories**

It is recommended to start a session with interactive story reading, before moving to games or exercises. For this the story module should be placed on top of the base module. Also, a story booklet should be selected—again in a dialogue between child and caregiver—and retrieved from the box. To read the interactive story the booklet should be inserted into the right side the story module. The child can then move it through the story module using flippers on either side of the module’s viewing window. The right flipper can be pushed for going ahead through a story—mimicking flipping to the next page in a book—and the left for going back. The flippers switch on a transportation system within the story module that moves the booklet through the module. There are two types of stories: a linear one which is read from the first to the last scene; or a branched story, where a child chooses a new branch—a new three-scene page—at the end of the previous one. A child can choose the order of pages freely, or even repeat the same page.

**Exercises**

When the caregiver decides that story-reading time is over, the stop button on the control module is pushed. This closes the story application and shows the starting menu again. The control module is used in general to choose applications or to have control over content and timing.

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**Figure 1: Elements of the final LinguaBytes system.** Top row, left to right: the output module for displaying interactive content, the base module, the story module for reading interactive stories, the exercise module for doing linguistic exercises. Bottom row, left to right: the control module for choosing and controlling content, 16 story booklets, 236 input figures, 31 word cards. Not included: RFID-labels, storage box, manual.
Based on a story LinguaBytes can be used for linguistic exercises, focused on three language aspects:

- **Phonological awareness:** listening to songs, rhymes and natural sounds, finishing rhymes, practicing the coupling of sounds and letters, and stimulating auditory discrimination;
- **Semantics:** doing peek-a-boo guessing games, stimulating context-awareness (e.g., a cow can be found at the farm, an airplane usually not), relational classifications (e.g., fruit versus vegetable), word associations (e.g., airplane-pilot), and spatial relations (front, middle, back);
- **Syntax:** practicing one-word, two-word and three-word sentences, the use of adjectives and adverbs, and distinguishing shapes (square and round) and colors (red, yellow, blue and green).

Most of the exercises can be done in two modes, i.e., assignment-based or explorative. In the former setting a child gets assignments with right and wrong answers, in the latter a child can simply explore his options and learn from the provided feedback. In the following we go through a few exercise examples to illustrate how LinguaBytes is used.

**Example 1: listening to songs.**
One thing all young children enjoy is listening to songs. There are thirty-five songs included in the LinguaBytes prototype. To listen to songs the ‘song’ application has to be selected and the exercise module has to be placed on the base module. Let us assume that the thematic background ‘clothes’ is inserted in the base module. The opening screen of the ‘clothes’ song application is displayed on the output module: a room with clothes scattered around. A child can now place any of the available input materials—in this case wellington boots, a coat, a hat and shoes—in the middle tray of the exercise module. This will immediately start the song associated with that object. Removing the object from the tray immediately ceases the song and ends the animation. A caregiver can respond to a child’s actions by asking it questions like “Who do you see there?”, “What is he wearing?”, etcetera. This can stimulate the child’s communication skills and vocabulary. If a child loses attention or is not in the mood for clothes in the first place, it is easy to switch to another theme; simply replacing the thematic background with another suffices. At the end of the exercise, hitting the ‘stop’ button on the control module ceases the application and shows the LinguaBytes menu again.

**Example 2: creating personalized input materials**
LinguaBytes includes the option to create personalized input materials. To do this a caregiver can take an RFID-label from the box, place the appropriate thematic background in the base module—let’s stick with ‘clothes’—and place the label in the middle tray of the exercise module. Using the control module, the caregiver can assign any of LinguaBytes core words within that theme to the label, for example the word ‘shoe’. Now the RFID-label can be attached to a real shoe, a toy shoe, a photograph of a shoe, a drawing or any other representation of a shoe that a child understands. The label can be attached by using a clip or a piece of Velcro. Now, the newly created input material can be used as substitute material in the previously described example.

**Example 3: coupling sounds with letters**
Although learning to read is not part of the pre-school curriculum, introducing young children to the existence of letters is a good preparation for early literacy. Therefore, LinguaBytes includes exercises that stimulate the distinction of the sounds of letters. Let us assume we are in the theme ‘food and drinks’. On the output module a kitchen setting is displayed. A voice-over asks: “Which letter do you hear? Pan, the P of P-an, Pan”. The word ‘pan’ is displayed, with the first letter highlighted. A child can now grab his answer from the available letters; a caregiver can optionally suggest two alternatives: “Do you think it is this one or this one?” holding up the p and the k. The child places his selection in the middle tray of the exercise module. If the answer is correct, pear is displayed on the kitchen table and the voice-over congratulates the child, saying “Yes! Well done! The P of P-an, Pan”. If the answer was not correct, the table stays empty and the voice-over urges the child to try again.

**Example 4: constructing sentences**
For a 1-year-old, one word is a sentence. However, by the time a child is four years old it has learned to combine multiple words into meaningful three, or sometimes even four-word sentences. To practice this, LinguaBytes includes exercises to stimulate syntax. Let us assume we are still in the theme ‘Food and drinks’ and that a child can do two-word sentences in an explorative mode. The caregiver selects the two-word sentences application and removes one of the lids from the exercise module. Depending on whether a child is right-handed or left-handed, either one of the outer trays can remain closed. After collecting the available input materials—subject figures, verb cards and object figures—the child can freely explore them by placing combinations in the two open trays. Combining a subject with a verb card results in an animation on the output module that shows the subject executing the verb. The role of a caregiver here is to start communicating with the child, for example by asking questions or making up stories together: “Who’s hungry?”, “Who is thirsty?”, “What should the boy do when he is hungry?”, etcetera. When a child shows interest in using more words, a caregiver can try out if a child is also capable of making a three-word sentence. For this, it is necessary to remove the remaining tray lid. This is detected by the base module and automatically loads the three-word exercise. Now a child can combine a subject and verb with an object. For
example: ‘Girl’, ‘Drinking’ and ‘Lemonade’ results in an animated girl drinking a glass of cool lemonade, while a voice-over says “The girl...drinks...lemonade”.

Please note that these are only a few examples from a total of 16 stories and 220 exercises. Also note that we do not intend this paper to be a sales-pitch, we merely try to give an impression of the various possibilities of the system, the involvement of the child and the resulting social interaction with the caregiver based on the tangible interaction style.

**EVALUATION**

Two of the three identical LinguaBytes prototypes were tested over a period of ten months with the following objectives: (1) to research the usability of LinguaBytes. This research includes the effect of LinguaBytes on children’s language development, although this was not per se the focus as this is very, very difficult to ascertain with such a small and diverse user group; (2) to research whether the measure of adaptability of the LinguaBytes system was sufficient, as well as to identify opportunities for adaptivity. The two prototypes are still being used today and we are currently planning a follow-up study with a total set of ten prototypes. In this paper we limit ourselves to discussing the insights from the ten-month evaluation, with a focus on the role of tangibility and the starting points stated at the beginning of this paper. We will not dwell on generalities but try to focus as much as we can on relevant insights for the TEI community.

**Context**

LinguaBytes was tested at two rehabilitation centers at a total of four locations. Each center had one LinguaBytes prototype at their disposal, for the period of ten months. A third prototype was kept standby, as a back-up in case (parts of) the other two would cease functioning. In order to benefit from the wide offer of available in-house expertise, as well as from the variety of available children within the scope of LinguaBytes, any therapist, teacher or caregiver at the two rehabilitation centers was allowed to use LinguaBytes. At each center one speech therapist served as a liaison between local staff and the principal researcher. At the beginning of the evaluation period a demonstration of LinguaBytes was given at both centers to get the staff acquainted with its possibilities. The instruction was to use LinguaBytes as if ‘they had just got it from the store’. In other words, they were allowed to (ab)use the prototype, move it or modify it in any way they deemed appropriate in the context of their work. They were instructed to use all of LinguaBytes’ options and to keep track of malfunctions in software or hardware. Additionally, they were asked to keep an eye on striking results and positive or negative anecdotal evidence. At the end of the ten-month evaluation period therapists were asked to fill out a questionnaire, containing 5-point-scale rating questions and open questions. The answers were reviewed in an interview.

**Note**

As we have stated earlier in this paper LinguaBytes is aimed at very young children who are (1) illiterate and (2) often cannot speak. Often, related research is focused on older children and/or typical developing children. This makes that many of the evaluation techniques are difficult to adopt or adjust to our specific target group: pre-school children. As a consequence we had to rely on our own observations in relation to the expert opinion of people who know the children best, i.e., their parents and (educational/therapeutic) caregivers. For this reason we focused on investing in rich qualitative data. More about this can be read in [15].

**Results**

**General impression**

The participating therapists generally regarded LinguaBytes as a very valuable addition to the available body of speech therapy materials. It was their impression that LinguaBytes kept the children’s attention better in comparison with traditional materials such as picture books, and that LinguaBytes offered children more control and more opportunities for initiative taking compared with interactive computer programs. The most prominent critical remark pertained to the vulnerability of the prototypes compared to off-the-shelf commercial products. The participating therapists indicated that they found LinguaBytes suitable for any child between 1 and 4 years old, except for children with very severe motor disabilities, children who do not understand 2D representations, children who do not understand action-reaction relations, or children with severe vision limitations.

**Evaluation of the design and interaction**

The stories and exercises were regarded well chosen and designed in congruence with children’s perception of the world. The graphic design of the animated content as well as of the physical materials was generally regarded as ‘good’, some elements as ‘very good’. The physical design of LinguaBytes was generally rated as ‘good’, except for the design of the box, which was rated ‘neutral’ to ‘good’. The maneuverability of the modules was considered limited due to the cables. The interaction with LinguaBytes was considered suitable for non- or hardly speaking children between 1 and 4 years old. The materials are friendly and the interaction is playful and appropriate for the majority of the children (apart from those mentioned above). The physical nature of the interaction made that children can look around the room holding input materials for communication, can keep looking at the output module while interacting with the input materials, and can take more initiative. According to the participating therapists, the children appeared to like using LinguaBytes ‘very much’.

All therapists were very positive about the modular organization of LinguaBytes, as well as the ability to do exercises in two modes (assignment-based and explorative).
LinguaBytes offered more than enough opportunity and room for social interaction and communication with the child, as well as more than enough opportunities for learning (all were rated 5 on a 5-point scale).

**Evaluation of the effect of LinguaBytes on the children’s development.**

Although this evaluation was not a formal effect study, the participating therapists regarded it ‘probable’ to ‘certain’ that LinguaBytes stimulates the linguistic development of non- or hardly speaking children. They regarded it ‘probable’ that LinguaBytes actually contributed to the linguistic developments of the participating children, although they indicated that you can never be 100% certain. However, the child’s motivation, attention, concentration, initiative and engagement while using LinguaBytes were all unanimously rated as ‘better than normal’, which can be considered as indications of learning.

The child’s communication while using LinguaBytes was rated as ‘better than normal’ to ‘normal’. The participating therapists indicated that LinguaBytes has a positive effect on children’s cognitive development in terms of the stimulation of pre-lingual conditions such as action-reaction, attention, concentration, listening attitude and the ability to execute assignments. They indicated positive effects on children’s perceptual-motor development, attributed to: (1) the frequent manipulation of materials; (2) the fact that LinguaBytes stimulates careful perception of these materials, and; (3) the fact that LinguaBytes stimulates motor activity.

The effect of LinguaBytes on children’s socio-emotional development was regarded as positive, especially when two children use LinguaBytes together. This stimulates collaboration and turn-taking.

**Reflection on the initial guidelines**

In the introduction we brought our original starting points to memory, as we presented them at TEI’07 (although we changed the phrasing slightly over time). Here we look at them again and briefly reflect on whether they are still relevant.

**Playing**

*Young children learn mostly through play. Play permits making mistakes and trying again.* We have incorporated playfulness in LinguaBytes by allowing children to explore and take initiative, using an interaction style that fits how pre-school children interact with the world. In terms of dimensions and proportions all play materials are based on the ergonomic requirements for children between 1 and 4 years old, thus ensuring that these children are able to manipulate them as independently as they physically can. All of the available exercises can be done in an explorative, free play mode, some even contain funny ‘Easter-eggs’. For example, in some exercises children can create silly, unexpected situations or sentences.

All participating therapists identified the playfulness of LinguaBytes’ interaction style as one of the more powerful mechanisms for engagement and motivation. Much of this was attributed to the tangibility of the interaction as this involved children to ‘play with the rules set by the system’. For example, oftentimes it could be observed that children used the sentence-building exercises for creating stories of their own even though that was not the primary target of the exercise.

**Social Interaction**

*Young children play and work in groups and not so much on their own. Our approach is to stimulate interpersonal interaction.* LinguaBytes was fully designed to create opportunities for (social) interaction. From unpacking the box, to selecting the content and interacting with it: every action is aimed at setting up a space for participation and communication. As such LinguaBytes does not aim to replace a caregiver, but merely to provide topics for communication. Especially for the LinguaBytes target group—non- or hardly speaking children—the fact that they could use tangible materials meant that they were allowed an alternative channel for communication (through picking up, pointing at, or even throwing away materials).

**Tangibility**

*Especially for very young children, who naturally explore the world through play, interaction should be tangible.* From our earliest research-through-design iteration on, in which we compared various interaction styles, it was evident that a tangible, playful interaction style was far more appealing to children than less tangible ones. One strong indicator for this was the attention span of the children, which was evidently longer. Also their amount of initiatives was significantly higher than with related materials.

A prominent benefit seemed to be the quality that they allow for improvisation and exploration. One example of this is the aforementioned situation that children created stories using the sentence-building exercise but similar actions could be observed ‘outside the system’, i.e., in the social contact between child and caregiver: both interaction partners made opportunistic combinations of the functionalities of the digital system and the analogue world when singing songs, communicating through stories, and more.

**Challenge**

*Challenge is a key element of motivation. We wish to challenge children by designing interactions that are appealing, rewarding, engaging and fun.* As we have illustrated earlier, children found the interactions appealing fun and—based on the feedback from the therapists and our earlier iterations—engaging as well. On multiple occasions we experienced children who had to cry at the end of their session because they had to stop using LinguaBytes, and we collected ample anecdotal evidence of children specifically asking for LinguaBytes. To ensure sufficient challenge we
included games and exercises on the developmental levels of 1-year-olds to 4-year-olds. The participating therapists unanimously indicated that LinguaBytes offered more than enough flexibility to be used with diverse children (5 on a 5-point scale) and were of the opinion that LinguaBytes could ‘probably’ to ‘certainly’ grow along with, and remain interesting for children over several years (4’s and 5’s on a 5-point scale). Reflecting on LinguaBytes in its current form, the speech therapists indicated that the major forte of the system was that children could themselves have control over what happened on-screen, which they considered highly beneficial for their initiative and imagination.

Adaptivity
To optimize the learning setting for each individual child within a heterogeneous user group we see opportunities for automated adaptation: the product could learn along with the child. As indicated earlier LinguaBytes’ interaction was not considered suitable for the children with the most severe motor disabilities. These children could only use LinguaBytes with assistance. As part of the post-experiment interviews we discussed opportunities for making LinguaBytes adaptable to these children, or even adaptive (we consider these different strategies as they highly implicate the design process, see [14]). Generally, therapists were very interested in opportunities for adaptivity, but also skeptical: many pointed out that there will always be children who are so severely disabled that they may never be able to use LinguaBytes independently. However, they also indicated that for these children LinguaBytes already provided the most important thing: the feeling that they can actively participate.

Technology
Supporting such learning behaviour requires advanced technologies, which are not capitalized on in related available materials. Related to the previous reflection: while working on LinguaBytes, we experienced that designing adaptive systems is very difficult. When mimicking adaptive behaviour ourselves in earlier, Wizard of Oz sessions we experienced that it is probably more valuable to have an artifact understand part of you perfectly, rather than the entire you only so-so. We see this as a major challenge for future interactive products and systems, especially when they will be more embedded. We see a major challenge in creating adaptive tangible interfaces in the future. Not only will this require other prototyping methods, but probably also another design approach based on ascertaining the system’s social role in interaction.

Design
We wish to design products that are appealing to both challenged and able-bodied children by making products that resonate with all young children. Designs should be non-stigmatizing and can benefit from success formulas from the toy industry. Even though we developed LinguaBytes for children with multiple disabilities, we designed it to appeal to all children between 1 and 4 years old. We have spent an enormous effort on getting the design right so it would combine these mixed target groups. As such we believe this research has contributed to the awareness of the role of design aspects such as form and materiality within the tangible interaction community. These are elements that have a fundamental impact on not only the appeal of tangible interfaces but also the interaction with tangible interfaces. Throughout this research we have spent much attention to design details in order for LinguaBytes to be rootable in reality. We have made a serious attempt to advance the state of the art in the field from the perspective of design.

CONCLUSION
In this paper we have squeezed years of research into eight pages, trying to shed light on the assumed benefits of tangibility on learning, related to our original starting points presented at TEI’07. Concluding we can state that, based on our experience and articulated by a still increasing number of participants, one of the major benefits of tangibility for this particular very young user group is that tangible interaction offers an interaction style that almost all children can master. It allows for playful interaction, improvisation and alternative communication, which in our studies has led to an increased attention span and more initiative taking, which in turn leads to more opportunities for learning. In this respect the two anticipated benefits stated on the second page of this paper (increasing time for learning and enhancing the child’s participation) have unmistakably proven true.

Apart from the aforementioned insights we feel there are several other contributions this research has made to the field of tangible interaction. firstly, we believe LinguaBytes is one example of how tangible interaction can actually be implemented in a real-world situation and bring real value to real people: (1) it grants very young children with often limited motor skills room for initiative taking, as the interaction with LinguaBytes is not only limited to accessing digital content. Children can interact with all of LinguaBytes’ tangible materials at any given time. They can use the materials standing in front of them for immediate action, point at or grab other materials to indicate a change of theme or application, or even access the storage box for drastic initiative taking; (2) As a consequence, tangible interaction allows children more control over timing. This typically results in a slower interaction pace, which creates more moments for caregiver-child communication and thus opportunities for learning; (3) Additionally, tangible interaction can involve children in activities typically reserved for their caregivers, such as setting up the system. As such these activities become part of the communication process: children can help choose a thematic background, they can help place the story module or exercise module, even programming their cuddly toy’s RFID-label makes them part of the setup process since it becomes a communication topic; (4) Many existing materials are aimed at making interaction as easy
as possible, resulting in interfaces that often emphasize children’s limitations. LinguaBytes’ tangible interaction on the other hand offers an interaction based on low-threshold physical manipulation, allowing children with motor disabilities to prove to themselves that they are capable of the same things as ‘normal’ children. This helps raise their self-esteem and confidence. As a general consequence children show more engagement in the interaction, which can consequently lead to more opportunities for learning.

Secondly, at the time this research started there had been a scarcity of examples of tangible interaction in its or similar contexts. We hope that through this research the potential of tangible interaction has become apparent, as well as its viability.

REFERENCES