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Abstract

The Effects of Young Children’s Knowledge Acquisition using Tangible Blocks

Playful learning through tangible interfaces is a powerful method to enhance children's attention and engagement with learning material from domains where critical reasoning and problem-solving skills are demanded. Also, physical affordances offer an implicit shared language that boosts collaboration among children. However, little is still known about the possible advantages of using tangible interfaces also for specific knowledge acquisition and memorization of new information.

This paper presents a study with children that investigate whether tangible and collaborative play could foster learning also in this area. For this purpose, we designed a longitudinal user study with 36 kindergarten children to assess differences in information learning when using two different platforms—a traditional illustrated book and its digital counterpart augmented by tangible toy-like interfaces. In order to measure interactional differences between the interface style, we recorded the number of absolute occurrences of behaviors (e.g., Questions engagement, Focus, Content engagement, Body feedback, Language feedback).

Our preliminary results show that the high degree of engagement provided by tangibles fosters attention and proactive attitude among children, resulting in better learning.
Moreover, tangible tools allow children to readily and autonomously deal with conflicts and to reduce the overall passive behavior.

**Keywords**: Tangible interaction, Learning, Collaboration, Engagement, Early childhood education
I. Introduction

1. Background

For children, playing is the passage leading them to access a variety of information around the world and provides educational opportunities to learn the concepts and techniques for the development of early childhood learning (Joe L. Frost 1992; Johnson, J et al., 1999). Also, it is possible to observe and evaluate the development of cognitive skills and social experiences of the infant through their playing by which, they will be enriched with the concept and techniques to adapt themselves to the world around them (Cheng, 2000).

In addition, the toys used in their playing tend to help the children to develop the sense of self-development and training to sharpen the senses is the foundation for intellectual growth and further expands the area of cognitive capability (Chung, hyun-sook, 2006). According to Sara Price (2003), Tangible learning using physical interface such as toys can be help build the environment where the child could be invoked positive imaginations making them to learn playing with more pleasurable and fun.

Playful learning (Sara Price et al., 2003) based on tangible interfaces has long being considered an effective method to foster concentration, critical thinking and the ability to work collaboratively among children (M. Montessori, 1964; Nesra Yanner et al., 2015). Researchers claim that tangible interaction and mixed-reality game interfaces, which blend digital and
physical elements (Nesra Yanner et al., 2015), are more engaging and therefore particularly effective for hands-on learning (Paul Marshall, 2007) because they encourage explorations supported by real-time feedback (Sara Price & Yvonne Rogers, 2004; Nesra Yanner et al., 2015) and expressive activities for the creation of new ideas (Paul Marshall, 2007; Raffle. H. S et al., 2004).

Moreover, physical affordances offer an implicit shared language that boost collaboration among children (Kori M. Inkpen et al., 1999; Izabel C. Olson et al., 2011; Lesley Xie et al., 2008). Successful examples of tangible learning platforms are in the domains of early reading (Nesra Yanner et al., 2015), language learning (Lucia Terrenghi et al., 2006), narratives (Zhen Bai et al., 2015), science and physics (Sara Price & Yvonne Rogers, 2004; Nesra Yanner et al, 2015), and problem solving (Lesley Xie et al., 2008; Oren Zuckerman et al, 2005).

2. Research Questions

In spite of many studies on positive impact of the children’s self-directed learning, still the majority of educational institutions and homes are being prevailed by cramming method of teaching that have been characterized by the one-sided teaching of teachers or parents. On the other hand, in the independent learning, students who are actively involved in tasks such as understanding, analyzing the material than those who are passively receiving information. Therefore, the proactive learning can bring about positive results in education through promoting the aggressive attitude of the children in their learning. In this regard, the teaching method of the tangible interface provides effective tools for the active and enjoyable learning
which promotes creating the atmosphere where children are learning with fun while playing involved in active interaction with the teaching tools.

However, while tangible interaction clearly promotes the development of analytical and reasoning abilities in children, it is arguably as much important and necessary to help children developing the necessary skillset used for rapidly acquiring and memorizing new knowledge (Michelene T.H. Chi, 1978). And not much empirical research has been proposed to explore whether tangible and immersive technologies can also enhance memorization and domain-specific knowledge acquisition.

The purpose of this study was whether children can better memorize and learn new information through spontaneous hands-on activities based on tangible interfaces as opposed to traditional learning imparted by parents or teachers through books. Furthermore, this paper explores the differences in knowledge acquisition when using tangibles individually or collaboratively.

We hypothesized that

H1 : Children will be able to memorize new knowledge better during tangible interface than a traditional learning.

H2 : Children will be more engaging with learning during tangible interface than traditional learning.

H3 : Tangible interfaces on learning will be influenced by the children’s collaboration skill.

We introduce the related work, a tangible learning platform that we developed, and the
quantitative and qualitative results from the longitudinal study.
II. Related Work

1. Playing Learning

The daily of life of children is playing itself. But playing of child causes not only the development of a variety of knowledge to be learning through new experiences but also the development of the physical body, sporting skills and the emotional, social, and intellectual behavior (Cho, Bok-hui et al., 1993). In addition, for the child, playing has the substantial property of leading them actively to participate in the learning in voluntary and joyful mind, and further the teaching-learning characteristics are inherent in playing, to help construct the knowledge by the initiative oriented internal motivation while enjoying the process rather than having the priority for the results (Sharon Whitton, 1998).

The previous researches have demonstrated that, as in the development theory of Piaget, in order to induce autonomous and active activities of child in the preoperational stage, they should be previously ensured of the education conducted through perceptual experience within the life experiences that are meaningful to children prior to the education in the acquisition of artificial concepts to be made. Therefore, in view of the aspect that the autonomous training method which helps children to develop the sense of self-development and sharpen their senses, makes the basis for their intellectual growth and expands the boundary of their perception, the playing is very important for the children (Chung, hyun-sook, 2006).
In particular, the science education of early childhood is the activity to induce the child to recognize and promote its attitude and ability to solve the problems arising from curiosity and interest in things and phenomena. Therefore, all natural phenomena, event, things, and information about children that occur in everyday life, belong to category of science education for children.

In the development process of inquiry capability of children, the toddlers when moving into five-year-old age, begin to show interest in the features such as the relationship between the day and the night, the sun and the moon, the characteristics of objects and animals, and are interested not only in the firsthand experience but also in indirect experience to be attained through the picture books and the TV. Children of this age period tend to raise a lot of questions about causality beginning with 'why' and 'how'. These exploration activities help children to solve the important problem arising from their experiences since they start to pay attention to their surroundings, and support them to enable to make decisions for themselves. Therefore, children acquire new information through their own experiences and they can learn how to validate their ideas by reorganizing the learned knowledge through the science education activities (Choi, Jeong-Ah, 2012).

This study aims to demonstrate how 5–6 years old children acquire and memorize new information about the 6 animals’ name, the appearances, their texture, and characteristics living Africa and show their enthusiasm over the interest and present the comparison of the outcome through two kinds of platform.
2. Tangible Learning

Montessori (1964) claim that, Physical Interaction in learning can lead to concentration on learning by wakening up children’s feeling and invoking considerable fascination in the teaching tools by children. The seminal theoretical works promoting the usage of tangible interfaces for playful learning (Paul Marshall 2007; Sara Price et al., 2003) are supported by a vast literature of empirical work demonstrating the benefits of this approach. Researchers seem to agree that the differences in learning when using a physical tangible environment (e.g., books, toys) or its digital counterpart (e.g., video, games) are not a direct product of the different affordances that these interfaces offer, but rather the result of the level of engagement and enjoyment that technologies provide (Kori M. Inkpen et al., 1999; Lesley Xie et al., 2008).

For example, Lauricella et al. (2014) show that children’s story and vocabulary comprehension of traditional and digital books do not directly depend on the physical properties of the interface used, but rather on the level of parents-children engagement when reading together – engagement which was higher when using digital storybooks. Similarly, Nersa Yannier et al. (2015) demonstrate that simply adding tangible elements to a game interface does not directly enhance children’s learning of basic physics principles. Instead, children engagement and understanding is correlated with how immersive, interactive and physical is the learning environment. Analogous results are reported for other augmented learning technologies, such as the FeelSleeve haptic interface for encouraging reading among children (Nersa Yannier at al., 2015), the FingAR puppet system for promoting reasoning on emotional states (Zhen Bai et al., 2015), the Hunting of the Snark physical exploration game (Sara Price at al., 2004; Sara price at al., 2003), and the cube quiz platforms introduced by Terrenghi et al. (2006).
The common findings of these work is that physical environments provide higher engagement and enjoyment for children, and consequently better learning (Kori M. Inkpen et al., 1999; Lesley Xie et al., 2008). A second factor in support of tangible immersive interfaces for learning is that they naturally lead to better collaborations, by promoting cooperation and discussion among children when faced with problem-solving tasks. The digital Montessori-inspired manipulatives by Zuckerman et al. (2005) are a clear example of how tangible representations of abstract concepts can sparkle discussions between small teams of children. Tangibles have also the advantage of solving conflicts between team-members, as children naturally learn to take turns and share control of physical interfaces more readily than when using digital ones (Izabel C. Olson et al., 2011).

The shapes and the structural complexity of the tangible teaching tools may affect the interests, learning attitude and safety of the children in a proportional manner depending on the age and experience of the learning children. The design, the structure, rigidity of the materials used and the easiness of manipulation of the teaching tools tend to affect the value and safety of the playing with them while the extent of the complexity and the structural form of toys will affect the interests and the content of learning for the children.

Therefore, in selecting or manufacturing the teaching tools, it has to consider children’s interest, motivation for the learning, cognitive development and so on. Lee, Yeung-suk (1986) proposed a desirable form of the tangible interfaces for children. First, children should be able to enjoy the game with interest. Interest is related to the attraction of the teaching tools. In other words, the color of the parish, shape, size and originality, should be associated to the infant's experience and capabilities in adequate proportion. Second, consider the safety. Not easily broken and no sharp corners with the teaching tools, and you have not to worry about the part of
the body caught between the teaching tools which should not pose a threat to other’s safety. Third, they must be solid and has a long durability. Fourth, the infant should be able to operate alone and they can foster imagination and creativity. Finally, with respect to understanding and memorization of the various concepts or ideas, they must fit the psychology of children. In accordance with the above guidelines, the teaching tools of the animal features were produced.

3. Engagement

Fun and engagement in learning is an essential element in children’s learning. Engagement can be seen as a process in an effort to understand the new information (Gavriel Salomon et al., 1987). Therefore, when learning, it is important that children are showing an active attitude while playing pleasantly.

According to Hanna et al (2004), Such behaviors of children as prawning the eye brow and yawning are called indicators showing that children are passive. Also, Read et al., (2004) proposed that engagement could be determined by observing the indicators of the following actions. : Smiles, laughing, concentration signs, excitable bouncing, positive vocalization. On the other hand, the observable behaviors in case of passive actions, are as follow : Frowns, signs of boredom, and negative verbalization.

In this study, when the children learn with books or tangible blocks and their behaviors were measured based on the frequency of passive / proactive ones by observing their actions through video taken (Read et al., 2004).
4. Collaboration

In playful and active learning, the indicators related to children’s interest are engagement and collaboration. Many researches found that collaboration learning of children has a positive impact on the child’s social development, personality development, language development, communication ability, problem solving ability, and cognitive development (Cartwright, 1981; Lyman & Foyle, 1990). Even the lower motivated child also may perceive a sense of their individual accomplishment for the success of their group in addition to the feeling of their own contribution to the group, while fulfilling the learning through a cooperative process with peers together. In addition, it increases the ability of children to understand the thinking of themselves by explaining themselves to the members of the group and thereby, acting as members of a team, lead them to make efforts to get along and achieve with other children (Hwang, Dong Sook. 2001).

<table>
<thead>
<tr>
<th>Action</th>
<th>Description</th>
<th>Type of behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach Over</td>
<td>Reaching over the workspace to try to use the control (Successfully or not).</td>
<td>Proactive (in this study, touching block &amp; thinking)</td>
</tr>
<tr>
<td>Blocking</td>
<td>Preventing another child from using the control using one’s body, arm, or a finger.</td>
<td>Passive</td>
</tr>
<tr>
<td>Verbal Complaint</td>
<td>Expressing dissatisfaction over how the control is being use or how another child is acting with respect to the control (e.g. “I want to use it now!”).</td>
<td>Passive</td>
</tr>
<tr>
<td>Passing Control</td>
<td>Passing the control to another child.</td>
<td>Proactive</td>
</tr>
<tr>
<td>Asking for Control</td>
<td>Asking to use or hold the control. (e.g. “Can I try it?”)</td>
<td>Proactive</td>
</tr>
</tbody>
</table>

Table 1. The measurement of collaboration behavior (Izbel C. Olson et al., 2011)
As above, I would modify the types of children’s behaviors to suit this study was referred to criteria for classifying the collaboration of children.

The impact of cooperative learning on the development of the children, was summarized as follows. (Lyman & Folye, 1990):

First, the ego-centric child can increase interaction with other children through cooperative learning as to understand the needs and perspectives of the other children.

Second, a collaborative learning can increase the interaction between the individuals as well as that of between the groups by enabling a positive social engagement.

Third, the early childhood develop pro-social behavior by sharing the use of learning materials with friends in the groups and then by working together.

Fourth, they develop the direct social techniques such as compromise, cooperation and tolerance, through direct interaction with other children.

Fifth, cooperative learning has a positive effect on language skills of child due to the active communication between sub-groups.

Sixth, the infant of low achievement levels, are able to perform tasks successfully together with other children and develop a sense of self-promotion for the goal.

Seventh, it develops the achievement motivation of the learning children because they help each other among infants who perform the same tasks.

As shown in the above, the collaboration through the cooperation is an essential element of early childhood education because it has a positive impact on children’s learning and development. In this study, I observed how the child collaborated and resolved the problem when the child made a team and learning with the tangible blocks.
### III. User Study

We designed a longitudinal user study with kindergarten children to assess differences in information learning when using two different platforms – a traditional illustrated book and its digital counterpart augmented by tangible toy-like interfaces.

We are interested in collecting and analyzing measures of the level of accuracy for newly acquired knowledge, and differences in the level of engagement with the content and the learning platform. Moreover, we are interested in comparing how children interact with tangibles when alone or in team with another child. Therefore, our experiment examined three different conditions: 1) Individual learning from a traditional book, 2) Individual learning from a digital book augmented by tangible interfaces, and 3) Collaborative learning from a digital book with tangible interfaces.

![Figure 1. Experiment examined 3 different conditions](image)

The next sections describe the content of the books and a platform based on tangibles. The Institutional Review Board approved the recruitment methods.
1. Learning Book Contents

For better control over the experiment conditions, we decided to design ourselves the content of the traditional and digital books. Both versions contain exactly the same type and amount of information, printed on paper for the traditional book and displayed on a touchscreen device as an interactive slideshow with sound for the digital version.

To choose the content topic, we surveyed several popular children books and consulted with a professor of early child education from Chung-Ang University. The material we finally designed is an illustrated description of six different animals living in Africa: a lion, a zebra, a giraffe, a leopard, a hippo and a crocodile.

Each animal features five knowledge units: 1) the written name of the animal in Korean and 2) in English, 3) the color/textures of the animal’s skin, 4) the animal’s living habits such as where/how the animal lives (e.g., ground vs. water / alone vs. in group) or what it eats (e.g., meat vs. plants) and 5) unique characteristics (e.g., lions are predators, zebras live with giraffes, giraffes are the tallest, leopards climb trees, hippos have webbed toes, crocodiles lay eggs).

All of the material in the books is presented using simplified language for children in 24 illustrated pages (6 pages introduction and 3 pages per animal).
Figure 3. The Learning contents in traditional / digital book
There are three differences in functional aspects between the book and digital content with the same contents of all. The digital one has the function that reads the name of the animal in selected specific language if you click one of the speaker shapes beside Korean / English and it makes animal features moving on each page by animation effects and there is the Home button in the upper-right corner of any page, which may move you to the menu that appears all 6 kinds of animals.

<table>
<thead>
<tr>
<th>Traditional Book</th>
<th>Digital Book</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Traditional Book" /></td>
<td><img src="image2" alt="Digital Book" /></td>
</tr>
</tbody>
</table>

Figure 4. The Differences in traditional and digital book

2. Pilot Study

In order to validate whether the information’s complexity and amount were novel and suitable for kindergarten children we ran an informal short pilot study with 8 participants aged between 4 and 10 years (μ: 6.6, σ: 2) in which we showed them the content material and asked them to answer some questions to prove their understanding. We found that the material was too
difficult for children aged 4 years (38% correct answers) but too easy for those aged 7 years or older (96% correct) due to pre-existing knowledge.

Through pilot study, we determined it was suitable that the age of participants of this study is 5 and 6 years old children. Also, we found out children couldn’t click PPT buttons precisely because they were far from precise manipulation. Thus, we modified PPT buttons larger.

3. Prototyping

In our tangible system, two types of blocks, representing different animal parts (bodies and heads), can be connected together. They provide feedback to users about the correctness of the match (Figure 6). Using several layers of machine-carved wood-sheets glued together, we built passive blocks representing the bodies of the six animals described in the illustrated book. On the neck there is a magnet for supporting connections with a head-block and a tiny RFID tag for unique identification.
The bodies are painted and their maximum dimensions are 16.5 x 8 x 3.6 cm thick. The head-blocks, on the other hand, are active components and consist of a micro-controller (Arduino Mini Pro), a 1.8” color TFT LCD display, an RFID reader (ID-12LA), a magnet and a Li-Po battery, all encased in a wood box measuring 33 x 70 x 47 mm. When a head-block is connected to an animal’s body-block, the RFID reader detects and deciphers the RFID tag to determine if both body parts belong to the same animal. Graphical feedback on the screen notifies users about the correctness of the match. In total, we built 6 body blocks and 3 head blocks, for a total cost of ~300 USD.
Figure 8. The body of animal blocks (A), The body and head (B), and Examples of connected blocks and a game challenge (C). In the background, a page from the digital book used in the study.

Figure 9. The six animals blocks

4. Tangible Learning Platform and Interaction

The blocks are meant to support playful learning through a simple puzzle-like interaction. At the beginning of the game, the blocks are not connected. Once started, the display located in the head-block shows a challenge, by means of an image picturing one of the animals’ properties described in the illustrated book (Figure 8 (C)).

To solve this challenge, children have to find and connect the head-block with the animal
body that best matches the question. If the question is answered correctly, the head of the animal appears on the LCD screen, completing the figure. If the match is not correct, then negative feedback is displayed on the screen and the children are encouraged to try a different head-body combination. Finally, using a special RFID card it is possible to pass on to the next question. In total, the game comprises by 30 challenge questions presented in random order (6 animals x 5 properties).

![Figure 10. The scenario of tangible interaction](image)

5. Participants

In line with the pilot results, we recruited 36 kindergarten children (19 female) aged 5 to 6 ($\mu$: 5.3, $\sigma$: 0.4). All ad received some type of public or private kindergarten education. On a scale from 1 to 3, the level of self-reported native language reading ability is 1.4 (0.7), and their familiarity with digital devices such as tablets was 2.8 (1.4). 28 children had been previously exposed to the English language (second language) but had a self-reported reading-ability of 0.2
Their parents were compensated with USD 10 and the children received a small gift for their time. The Institutional Review Board approved the recruitment methods.

<table>
<thead>
<tr>
<th>Traditional Book</th>
<th>Tangible blocks solo</th>
<th>Tangible blocks in team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Age</td>
<td>Ko</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>6</td>
<td>1</td>
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<tr>
<td>F</td>
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<td>1</td>
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<tr>
<td>F</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. The demographics of child participants

As Table 2, The Ko and Eng means child’s reading Korean / English ability on a scale from 1 to 3. And D.D means the familiarity of Digital Device on a scale from 1 to 5.

6. Evaluation Method

Following a between study design, twelve children were assigned to each of the three conditions: book, tangible, and tangible team. In the tangible team condition, the teams were generated by pairing children who already knew each other. Each condition consisted of a prologue, a learning session, - in which children were asked to memorize the information in the
book -, and an epilogue. Finally, a follow up investigation took place two weeks later. The experiment was conducted in a quiet and familiar facility inside the apartment complex where the children live (e.g., an apartment library), and took about 30 minutes. To ensure that the child’s felt comfortable, the parent remained in the room during the whole experiment. Each session was video-taped for later analysis and supervised by two adults, one being a trained and nationally certified school teacher in “electronic, information and communication” with previous experience in teaching young children.

The prologue and epilogue were the same across the conditions. In the prologue, the children - accompanied by a parent - were introduced to the experiment. We provided refreshment for the child along with an ice-breaking session. Meanwhile, the parent signed a consent form and provided basic demographics information about the child.

In the epilogue, children filled out a paper questionnaire with pictorial questions to assess the level of understanding and learning. And the teacher also did a brief interview with the child at end to see what they liked/disliked about the learnings. We asked children to fill up again the pictorial questionnaire two weeks later.

The learning sessions of the experiment differed the across conditions. In the book condition, the teacher sat next to the child and read the book aloud, - a typical and familiar learning environment (Lauricella, A. R. et al., 2014). To facilitate concentration and learning, the teacher used gestures, facial expressions and modulated voice. The teacher ensured that the child remained focused on the topic by asking and answering questions.

On the other side, when using tangibles, the role of the teacher changed from being the knowledge provider to being a mere facilitator and supervisor. For both the tangible and
tangible team conditions the teacher sat aside and, for each of the 30 challenges provided by
system, allowed the children freely to connect the blocks and attempt to match them correctly or
to navigate through the book content using the touchscreen. In these conditions, the children
were encouraged to explore blocks combinations and ask questions. If children made a mistake,
an animated page from the book with the explanation for the current challenge automatically
appeared on the PC touchscreen (remotely controlled by the assistant) and teachers read aloud
its content.

7. Measures

The learning performance is measured using a printed quiz with 30 pictorial questions, one
for each animal property, presented in randomized order. Each question was an image
describing a unique animal feature that has to be matched with one of the six animals (displayed
as icons).

After learning in traditional book or tangible blocks (solo or in team) children were also
given a survey to measure enjoyment. In this survey they were asked 3 questions as e measure
of how much they enjoyed the animals learning: “How much did you enjoy the animals
learning?”, “How much did you enjoy the learning materials?”, and “What did you like or
dislike about the class and learning materials?”
For engagement, we collected two types of measures: the first was a short self-assessment questionnaire that asked children to evaluate their level of interest on an iconic 3-points Likert scale (similar to Nesra Yannier et al., 2015) for both the content and the tools used in the experiment. Moreover, similar to previous work (Lesley Xie et al., 2008), we analyzed and transcribed the video recorded during the study and extracted occurrences for passive and proactive behavior. We classified the children’s actions in five groups: engagement with questions (e.g., children answering questions only when directly asked vs. children asking questions or speak without solicitation), focus (e.g., losing attention vs. making eye-contact with the teacher), content engagement (e.g., skipping ahead the pages/challenges vs. pointing or clicking the relevant material), body feedback (e.g., leaning one’s head on the table vs. maintaining an engaged posture) and language feedback (e.g., sighing or complaining vs. verbal expressions of interest) (Figure 12).
<table>
<thead>
<tr>
<th>Focus</th>
<th>Eye-contact with teacher</th>
</tr>
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<tbody>
<tr>
<td>Losing Attention</td>
<td></td>
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<table>
<thead>
<tr>
<th>Contents Engagement</th>
<th>Pointing or clicking relevant material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skipping ahead pages/challenges</td>
<td></td>
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<table>
<thead>
<tr>
<th>Body Feedback</th>
<th>Maintaining an engaged posture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaning head on the table</td>
<td></td>
</tr>
</tbody>
</table>
Moreover, in the tangible team condition, similarly to (Izabel C. Olson et al., 2011), we extracted actions indicating conflicts (e.g., blocking, complaining), collaborations, request for control, pointing and helping. (Figure 13)
<table>
<thead>
<tr>
<th><strong>Conflicts</strong></th>
<th><strong>Collaboration</strong></th>
</tr>
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<td>Blocking</td>
<td>Grabbing a single block together</td>
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<td>Complaining</td>
<td>Moving a block each to form a single match</td>
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<td><strong>Collaboration</strong></td>
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<td>Making a rule</td>
<td>Asking for control</td>
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<td>Asking for control</td>
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<td>Pointing and helping</td>
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Figure 13. Conflicts and Collaborations in *team* condition
IV. Results

The video recordings of all experiment of the children’s learning and interaction with the traditional book and tangible blocks (solo and in team) were taken. The video analysis focused on observations of the children’s interaction, focus, content engagements, spoken dialogue, body / language feedback, collaborations, and conflicts in learning. And the metrics of comparison were twofold: quantitative and qualitative. The quantitative metrics were measured memory quiz scores and occurrences of engagement and collaboration behaviors. As such the quantitative analysis was performed to provide descriptive statistics to accompany the qualitative findings.

1. Quantitative Analysis

A. Memory

In this analysis, one-way ANOVA tests followed by post-hoc analysis using by Bonferroni CI adjustments were performed using α=0.05. Firstly, we tested how children performed in both quizzes (short and long term) across the three learning environments (book, tangible, team). We found a main effect of learning environment (F (2,66)=11.6, p<0.01, ηp2=0.26) and post-hoc analysis indicated that the book condition performed worse (4.6 points lower on average) than the tangible and team conditions (p<0.01).
<table>
<thead>
<tr>
<th>Traditional Book</th>
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<th>Tangible Blocks in Team</th>
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<td>Long-term</td>
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<td>B12</td>
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Table 3. The results of memory quizzes (Short and Long term)

B. Engagement

The number of absolute occurrences of proactive and passive actions extracted from the video analysis were classified in five groups and are shown in Figure 14A. The average and normalized percentages for both actions (Figure 14B) revealed differences for learning environment (F(2,33)=23.2, p<0.01, ηp2=0.58), with the tangible and team conditions having significantly more proactive-actions (i.e. fewer passive-actions) than the book condition (p<0.01). Looking at the self-assessment questionnaires, teaching method received a median score of 2.8 of 3 (0.44) and material a score of 2.8 of 3 (0.57). A Kruskal-Wallis non-parametric test revealed no differences across conditions. Instead we found a substantial level of correlation with an interclass correlation coefficient of 0.68 (95% confidence interval between 0.38-0.84).
C. Collaboration

A second result stems from the different usage patterns with blocks in the solo versus collaborative modes. Collaborative learning does not increase the overall amount of proactive actions performed by children, but it definitely reduces the number of passive actions. These results can be explained by looking at the qualitative data from the team condition: when collaborating, children often chose a turn-taking approach, roughly dividing by two the total number of challenges (black/white areas in Figure 15).

Figure 14. Passive (light tint) and proactive (dark) actions groups for each learning environment in 5 categories and on average.

Figure 15. A diagram representing collaborative patterns for each team. White/black areas are individual children actions. Red/green areas show conflicts/collaborations. Sessions lengths are indicated on the right.
The white and the black in the above graph indicate the child 1 and child 2 respectively, and the length of the graph means that the corresponding child solved the question alone holding the box of the animal’s face. Red areas show the conflicts and green areas means the collaboration with child 1 and child 2 (in Figure 15).

2. Qualitative Analysis

The qualitative analysis was based on notes and video taken during children’s actions, interactions, gestures, and verbal discussion between teacher and children.

A. Engagement

During experiments, we found children’s engagement with their spoken dialogue and gestures. The children asked several questions related to animals to the teacher spontaneously. Especially, they used to compare with other animals’ appearance, power (the law of the jungle), and behavior characteristic. For example, a child asked questions such as “Isn’t a lion stronger than a leopard?”, “Can a lion eat a crocodile?”, and “How does a crocodile hunt other animals?” Also the other child said, “A crocodile lives in the water like a hippo”, “The crocodiles’ egg are similar to chick” (in Figure 16), “The frogs have webbed feet, too.”(She was learning about a hippo.)

And we could discover the children were interested in dinosaur. When they learned about powerful animals (e.g., a lion, a leopard, and a crocodile), they occasionally compared strong
animal to a dinosaur: “A brachiosaurus is the tallest in the dinosaur world.”, “A giraffe is the tallest animal in the world! But a tyrannosaurus is tall, too.”

Finally, we could observe that our learning book contents could be utilized. A child looked at a hippo’s Korean name and said “The letter of 하마 are very similar to one of 엄마”. The other child pointed a finger at the lion in digital book and said “One, Two, Three, Four! There are 4 lions.” These children’s actions and taking could be interpreted that the learning contents could be used in various ways (e.g., mathematics learning material, Korean text book).

Figure 16. Children engaged with learning contents.

B. Collaboration

There are two ways to solve the problem in team learning. One is children came into conflicts and ended up in collaborations. In case of team 1, child 1 and child 2 were close friend with aged 6. From the beginning, child 2 solved two questions consecutively by himself. When child 2 tried connecting animal’s body
and the head box to solve the 3rd questions, child 1 said “I want to get it”. (Figure 17A) and he deprived child 2 of the head box. Then the head box was in child 1 and child 2 did not have anything. Child 1 were looking for the answer, child 2 mixed the animal’s body and said “I’m mixing the bodies.” (Figure 17B)

At this time, teacher said “What is an answer?” Child 2 pointed his fingers at a block and said “this is!” And then when child 1 blocked child 2, he said “I’ll do it” and connected the answer. Consecutively, child 1 was solving the 4th answer, child 2 said “I’ll do, this is mine!” and tried to take way the head box. Then child 1 defended and said “You already did it twice, I’ll do twice, too!” (Figure 17C). Child 2 heard about that and conform to the child 1’s comment. After then, they were observed to connect the body and head box in turn. Sometimes they were conflicts with the block, but they did it alternatively under their rule. Afterward, child 2 said “I want it together” (Figure 17D) and grabbed the edge of the face box at the point of connecting the new question by child 1. They solve the problem touching together since then. When they got the right answer at a time, child 1 and 2 shouted for joy. Child 2 said “Wow, we correct the answer once again! We are the best!” (Figure 17E) and then child 1 said “We do good work do because of doing together!” In this tangible team learning, Children experienced conflicts to begin with but they made their rule and collaborate on solving the questions.
V. Conclusion

1. Discussion and Conclusion

Based on this study, we report three main findings. Firstly, it is clear from the results that learning through the usage of tangible blocks leads to higher quizzes scores than the traditional method based on top-down teaching with a book. Moreover, the ratio of proactive/passive actions when using tangibles is significantly higher than in the book condition. These combined results suggest that the higher level of engagement provided by tangibles is a powerful tool not only for critical thinking and problem solving activities, as already suggested in previous work (Paul Marshall, 2007; Izabel C. Olson et al., 2011; Nesra Yannier et al., 2015), but also when learning new content. Tangibles well support knowledge acquisition and memory development, two important skills to acquire in early education (Michelen T.H. Chi, 1978). Though in this study children did not experience both conditions (perhaps the reason why self-reported engagement scores did not differ), children who used tangible blocks expressed greater interest toward learning: “It is like a robot. I want to learn more with blocks”, said one child.

A second result stems from the different usage patterns with blocks in the solo or collaborative mode. Collaborative learning does not increase the overall amount of proactive actions performed by children, but it definitely reduces the number of passive actions. These results can be explained by looking at the qualitative data from the team condition: when collaborating, children often chose a turn-taking approach, roughly dividing by two the total number of challenges (black/white areas in Figure 15). It is therefore not surprising that the
individual number of proactive actions decreased, as only one child at a time was engaged with blocks. However, the fact that also the number of passive actions decreased showcases children, as in previous work (Kori M. Inkpen et al., 1999), remained attentive outside their turn: “I enjoy study with friends using blocks”, said a child.

Finally, the last result concerns collaborative learning and conflict resolutions. In the team condition, few conflicts arose and children were capable to autonomously deal with them. Most teams came up on their own with rules and turn-taking strategies for using tangibles. In Figure 18C, for example, a child indicates a two-turns-each policy using fingers. Otherwise, children spontaneously gave up control (in Figure 18D) or asked the teacher to mediate. In case of conflicts, children resolved them by collaborating together. For example, they grabbed and moved a single block together (in Figure 18A) or a block each to form a single match (in Figure 18B). Our results are aligned with previous work (Izabel C. Olson et al., 2011) and clearly indicate the potential of tangibles for collaborative learning.

Figure 18. Children using tangibles together. Establishing rules for turns (A) and sharing of control (B). Two children perform an action together on one (C) or two (D) blocks.

In conclusions, this paper presented a longitudinal study with kindergarten children investigating if a learning environment based on tangible blocks can lead to better knowledge
acquisition than traditional learning through books, and also explored the potential of tangibles in collaborative settings. We found that the high degree of engagement provided by tangibles fosters attention and proactive attitude among children, resulting in better learning. Moreover, tangible tools allow children to readily and autonomously deal with conflicts and to reduce the overall passive behavior. Future work will attempt to investigate alternative form-factors for tangible blocks and collaborations with teams larger than two individuals.

2. Future Work

There are several limitations in this paper. Firstly, we are planning to upgrade interactions between tangible blocks and digital learning contents. In this paper, they couldn’t know whether the answer is correct or not before they connected animal’s body and head box. Also, tangible blocks and digital book didn’t link with. So they couldn’t know whether the answer is correct or not before they connected. Therefore, we need to develop the prototype which can be linked with. For example, when children connect animal’s head box to body, they get the feedback on answer from not only the display in box, but computer.

Secondly, we will investigate alternative physical form such as animals living in water, various car (e.g., police car, ambulance, taxi), and diverse job (e.g., doctor and nurse, police, firefighter, bus driver). Also it can be used in learning materials (e.g., mathematics, English, Korean). Particularly, we believe that our tangible blocks can be beneficial for children to learn new information and engage in active learning.
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Appendix 2. Questionnaire
Appendix 3. Pictorial quiz
논문 요약

블록을 활용한 학습이 유아 학습에 미치는 영향

조 재 원

휴먼 ICT 융합학과
성균관대학교

Tangible interface를 활용한 유아 놀이 교육은 어린이의 집중력 향상을 도모하고 추론적 사고와 문제 해결 능력 향상과 함께 학습에 대한 어린이의 적극성을 향상시킴으로써 유용한 교육적 경험을 제공할 수 있다. 또한 Physical affordance는 유아는 규칙에 대해 논의하고 협상하는 과정을 통해 유아의 사회적 의사 소통 능력이 발달 된다. 그러나 아직 유아가 Tangible interface를 활용해 학습할 때, 새로운 정보를 어떻게 받아들이고 기억하는지에 대한 연구는 아직 부족한 실정이다.
따라서 본 연구는 유아가 어떻게 Tangible 교구를 통해 어떻게 학습하고 친구들과 협력하는지 알아보고자 한다. 이를 위해 36 명의 어린이들과 2 가지의 다른 학습 형태 – 1) 일반적인 그림책과 2) 장난감처럼 생긴 교구와 디지털 컨텐츠 – 로 동물에 대해 학습하여 비교하였다. 2 가지의 다른 학습형태에서 발생하는 유아의 상호작용 행동들을 측정하기 위해 어린이의 행동들을 5 가지 카테고리로 분류한 후, 소극적/적극적 행동들로 나누어 모두 기록하였다. (e.g., 질문의 적극성, 집중력, 학습 컨텐츠에 대한 적극성, 신체/언어적 피드백)

위 실험을 통해, 본 연구는 Tangible interface 를 활용한 유아 교육은 어린이들의 집중력을 강화시키고 긍정적인 학습 태도를 이끌어 학습의 효과적인 영향을 미치는 것을 확인하였다. 또한 Tangible 교구는 어린이들 스스로 친구들간의 갈등을 해결하여 또래간 협력을 증진시키고, 학습에 있어서 소극적 행동을 감소시키주는 것을 알 수 있었다.

주제어 : 실감형 인터랙션, 유아학습, 협력, 적극성, 유아교육