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Tangible Multimedia: A Case Study for Bringing Tangibility into Multimedia Learning

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Abstract

Multimedia augmented with tangible objects is an area that has not been explored. Current multimedia systems lack the natural elements that allow young children to learn tangibly and intuitively. In view of this, we propose a research to merge tangible objects with multimedia for preschoolers, and propose to term it as "tangible multimedia". To evaluate the feasibility of such multimedia prior to actual research, a prototype named *TangiLearn* has been developed for a case study. This paper is the report of what we discovered during the study. The study concluded that *TangiLearn* enhanced the preschoolers' enjoyment and learning performance.

multimedia; tangible multimedia; tangibility; tangible object.

1. Introduction

Tangible systems have been in existence across many computing domains nowadays, such as tangible user interface (TUI), augmented reality, and mixed reality, but there has not been any research on tangibility in multimedia learning for preschoolers. Even though some TUI researches have been observed to explore the coupling of tangible objects and multimedia objects, multimedia objects are not their main emphasis. The multimedia objects merely serve as testing elements for evaluating the usability of their physical user interfaces. The whole TUI research is on issues pertaining to tangible interaction, with the target to replace mouse, keyboard and computer screen (Marco, Cerezo, Baldassarri, Mazzone,

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&Read, 2009). In response to this, a "new genre" of multimedia learning system for preschoolers called "Tangible Multimedia Learning System" (or in short, tangible multimedia) that greatly capitalizes on "tangibility" of multimedia expression via tangible objects is conceived. We adopt the use of the term "tangible" from Ullmer and Ishii's researches (Ullmer & Ishii, 2001; Ishii & Ullmer, 1997) because the term carries the meaning that physical form is given to digital information. Unlike TUI system, tangible multimedia is designed based on real multimedia perspective. From its inception until prototyping, it was scratched up based on multimedia development model and the rule of multimedia design guidelines. A relevant comparative experimental research for the system has been planned in future. For formative evaluation purposes, we developed a low-fidelity prototype of tangible multimedia named *TangiLearn* for case study and this paper serves as a report for what we have found during the study.

2. Problem statement

A problem faced in current multimedia learning systems for preschoolers is the lack of natural elements and sense of tangibility that is truly adapted to their characteristics, learning capacities, and underlying cognitive developmental thinking abilities. For preschoolers whose learning abilities are highly dependent on the effective use of external stimuli, using the systems means chances to explore real-life objects and play educative toys does not exist (Jones, 2003). Logical reasoning and abstract thinking are beyond their level of thinking (preoperational stage) (Piaget, 1952, 1972). They need to grip something tangible in order to allow their cognition process to make sense of the concepts, especially ideas outside of their immediate context. In this respect, we observe a large learning gap between the preschoolers and multimedia environment, a phenomenon which could impair their overall motivation and learning performance.

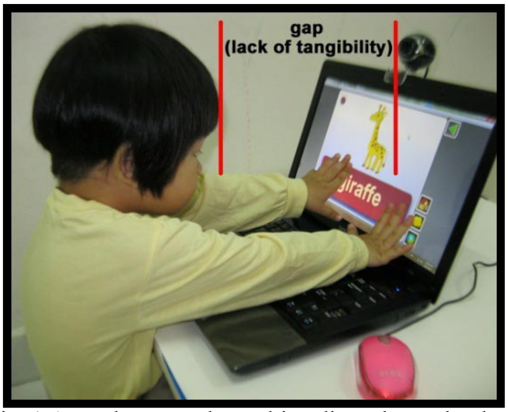

Fig. 1 A gap between the multimedia and preschoolers

3. Tangible objects as a means of tangibility in multimedia learning system

Tangible objects surrounding the preschoolers serve as the best means to bridge the learning gap. This is because they can be designed to realize the sense of tangibility in multimedia by providing simultaneous sensorial stimulation of visual, auditory and tactile of the children (Chau, Toh, & Zarina, 2012a). Tangible objects are physical objects that have been augmented with computational power (Manches, 2010)so that tangible objects can be bound to digital multimedia objects. With digital multimedia objects physically embodied in “tangible” form, preschoolers can hold, grasp, feel, move, and manipulate them from the physical environment.

4. The aim of the case study

The main purpose of the case study is threefold. First is to examine the feasibility and usability of the prototyped *TangiLearn* system, a manifestation of tangible multimedia, prior to actual experimental research (Chau, Toh, & Zarina, 2011). We look for preliminary evidence to support the assumption that tangible multimedia can enhance children’s learning performance. Second is to gather information required to fine-tune the design of the treatment in full-scale experiment. We seek to identify any necessary refinements to the overall design towards the final *TangiLearn* deployment in the typical preschool classroom setting. Third is to establish an appropriate experimental protocol, such as overall experimental flow, setting, and procedure for full-scale experimentalresearch.

5. Participants

Six preschoolers aged 6 were the participants in the case study. They were chosen because the age group is the primary user group for *TangiLearn* in the final experiment. As there were only a few participants in the case study, we administered the whole study ourselves.

6. Users’ information collection techniques

Quantitative and qualitative research methods, namely unstructured observation, unstructured interviewing, and questionnaires were employed in the case study.

Unstructured observation was conducted throughout the study. It is basically a method that is unplanned, informal, watching, and recording of behaviors in a natural environment (Cochen, Manion, & Morrison, 2002). Using observational notes, we recorded the children’s natural reaction to *TangiLearn*, the way the children collaborate, and whether the learning activities designed were appropriate. The technical performance of the system was also observed. In unstructured interview, 10 open questions were asked verbally to draw out ideas, impressions, and experiences pertaining to the prototype from the participants. They offered us key insights into issues not obvious in quantitative results obtained from questionnaires.

Quiz and *Smileyometer*(Read, MacFarlane, & Casey, 2002) were used to identify the participants’ learning performance and their level of enjoyment respectively. For measuring the level of enjoyment, we adopted the idea of Zaman and Abeele (2004), and referred the enjoyment to “joy-of-use” or “likeability” of using *TangiLearn*. *Smileyometer* was chosen because it has been proven easy to gauge the response from the children in many different situations (Xie, 2008). The self-report instrument was made child-friendly by the use of smiley, a pictorial representation of different kinds of happy faces to represent the different levels of enjoyment. We modified the *Smileyometer* to suit to the level of the participants.

7. Setting and implementation

TangiLearn, a manifestation of tangible multimedia, was developed for case study. This case study was an on-site evaluation took place in one of the kindergarten in Kuala Lumpur. It was conducted in a quiet classroom separated physically and acoustically from other classrooms to limit distractions. The case study was completed in one day. During the study, a laptop equipped with a camera, a set of tangible objects, and a normal display table suited to the participants’ anthropometric characteristics was set up.

The table was used as a space for participants to place and move the tangible objects (Figure 2). The tangible and multimedia objects binding were implemented through the adaptation of Quick Response (QR) code marker and Flash library. Implementation using open source library entails minimal monetary investments and times for development. QR code markers were attached on the tangible objects for binding purposes, and the children simply need to hold the tangible object and align to the camera mounted on the computer monitor.

Fig. 2 *TangiLearn* set up

8. Learning Contents

National Preschool Curriculum (NPC) of Malaysia emphasizes the mastery of language skills for preschoolers (Challenger Concept, 2009). In line with NPC, the learning content of *TangiLearn* focuses on real-life objects and general knowledge in English. General knowledge in English is chosen because first, embedding literacy learning within knowledge-building activities is engaging for young children (Albert Shanker Institute, 2009). English language curriculum set by the Ministry of Education of Malaysia (2001) stipulated that an enjoyment of the language learning should be developed through the use of interesting means. Second, general knowledge nicely suits the use of tangible objects in *TangiLearn*. For this case study, topics of general knowledge covered are animals, fruits and household items. Abstract concepts were not introduced, consistent with the level of cognitive ability of young children (Piaget, 1952).

9. Procedure

At the beginning of the case study, specific instructions on activities and features of the *TangiLearn* system were described to each participant in accordance with the experimental protocol. Subsequently, participants were arbitrarily grouped into pair because children prefer to work in groups (Africano et al., 2004), and would demonstrate a high level of engagement when learning alongside each other (Inkpen, Ho-Ching, Kuederle, Scott, & Shoemaker, 1999).

Each pair of participants was given 10 minutes for practice. After the practice, two consecutive experimental sessions began. The first session used *TangiLearn*, while the second session used conventional multimedia learning system. To avoid achievability differences, the two systems were made comparable in which both of them contained similar contents, breadth, and depth of the topics. With this, the issue of difference in extraneous cognitive load due to the differences in the contents would not arise. The only difference was that *TangiLearn* was augmented with tangible objects, whereas conventional multimedia learning system was not.

When the first session started, each pair was requested to explore *TangiLearn* freely for 30 minutes. *TangiLearn* consisted of two sections, the Learning section, and Quiz section. The Learning section was the section where the learning contents were delivered to the participants. Participants who entered Learning section in *TangiLearn* would find themselves entering a world consisted of many randomly-placed learning objects (both virtual and tangible), such as animals and household items (Figure 3). Learning object refers to the knowledge unit or concept that the system intended to deliver.

Fig. 3 Tangible and virtual learning objects in *TangiLearn*

To proceed, the participants were required to grip a tangible object on the display table in front of them, and point it to the computer camera to trigger the corresponding learning object in *TangiLearn*. If the participants grabbed a tangible lion and showed, the lion learning object would display corresponding animations and videos about the lion on the computer screen, and so the learning process started. Upon completion of learning session, the participants would need to answer the quiz by identifying and picking up the correct tangible object. There were 16 learning objects in total. Understanding these learning objects was the core objective of the prototyped *TangiLearn* system. Therefore, after the learning session, participants were expected to master the name, relevant key terms, and the description of the objects. The learner was free to explore any learning object, or to exit *TangiLearn*.

Right after the first session, the second session followed. Similarly, the pairs of children were asked to explore the conventional multimedia learning system for the same allocated time. After the two learning sessions were completed, pairs were asked to complete the quiz and*Smileyometer* questionnaire. The whole study was concluded with an unstructured interview.

10. Results from case study

Four participants rated their level of enjoyment of using the *TangiLearn* with the highest score (enjoyed very much) in *Smileyometer*. In our opinion, the use of some of the fascinating tangible objects contributed to this outcome. From their facial and emotional expression, *TangiLearn* seemed to be novel for them as they have not seen any computer system coupled with tangible objects before. They understood the tasks in *TangiLearn* without much problem. They were tinkering with the tangible objects and attempted different positions and alignments to the computer. They discussed most about how tangible objects could be bound to the computer. Discussion on the learning activities and concepts the *TangiLearn* aimed to deliver was relatively lesser, as such, the children were curious about the system more than the learning activities and concepts in *TangiLearn*. Even though towards the end of the learning session, two participants seemed to slightly lose patience in exploring many learning objects, overall, they still maintained a high level of alertness and engagement throughout the learning process. This was not easy as children normally have very short attention span, poor concentration and ease of distractibility (Blanchard & Moore, 2010; Alliance for Childhood, 2000). None of the children indicated that they wanted to stop prior to completion of the allocated amount of time. Based on this situation, we suggest that *TangiLearn* is an engaging multimedia learning system for preschoolers.

We discovered that the most attractive feature in *TangiLearn* to the children was not animations or videos, but the tangible objects. When we asked them whether they liked the animation, they shook their head, implying that animations were nothing for them. They said that the animated series in television were much better than what they saw in *TangiLearn*. Indeed, in today's world, animations and videos are no longer fun in the mind of the "new age" children. They are surrounded by opportunities to the exposure of the realm of digital media (Blanchard & Moore, 2010; Rideout, Vandewater & Wartella, 2003), such as high-end computer games and realistic animations. Therefore, some new paradigm shift in conventional multimedia learning has to be sorted out for the children in this technological age. Based on the result obtained from the case study, *TangiLearn* is able to attract the "new age" children with the tangible objects.

Besides, we observed that there was peer collaboration similar to "parallel play" aroused in *TangiLearn*. "Parallel play" is a classic study of Parten (1932) in social participation. Accordingly, "parallel play" describes activity where children play side by side on the same activity that provokes equal social involvement (Scarlett, 2004, as cited in Xie, 2008). *TangiLearn* was a low-fidelity tangible multimedia prototype, and the Game section in the prototype was not created for evaluation yet. As such, the term "parallel play" was not suitable. Instead, we suggested the term "parallel learning" to reflect the similar kind of collaboration. In this case study, it was obvious that "parallel learning" existed. With pairs of two children sitting side by side using similar tangible objects for similar tasks in *TangiLearn*, they had the opportunity to discuss together, interacted with each other, exchanged ideas, passed around the tangible objects, and worked cooperatively to answer the quiz. We did not observe "sequential turn taking," or other kinds of collaboration such as "directive learning," and "competitive learning" aroused.

Fig. 4 Parallel learning observed during the case study

Another important finding we observed was the successful use of direct representation level of tangible objects rather than the abstract or symbolic level. Since the inception of TUI researches in 1995, manipulative materials such as cubes and rods have been utilized in many researches, where many features are scrapped, made less realistic, and their simplified properties are always used to represent other domains, such as shapes for coins and different colours for numbers. They argued that this is the correct way of using manipulatives, otherwise, their effectiveness will be degraded (O'Malley & Fraser, 2004). There are also researches against this idea. They assert that children have problems in interpreting the symbolic representation of manipulatives (Uttal, Scudder, & DeLoache, 1997; Manches, 2010). In this case study, we did not make the tangible objects to represent other domain, instead, we directly map them into the virtual world. They represent themselves; for example, if tangible apple was used, it was apple in the virtual world in *TangiLearn*. The result evidenced that the use of direct mapping of tangible objects to the digital multimedia objects was as good as symbolic mapping in enhancing learning.

Quantitative results had helped support the qualitative results that *TangiLearn* was an educationally valuable system. The quiz results indicated that participants were successful in gaining knowledge from the system. In the *Smileyometer*, 3 participants reported that the quiz was easy, 2 moderate, and 1 difficult. We believed that the participants performed well in quiz due to the iterative hands-on experiences, which reinforced their understanding.

A number of technical problems arose during the case study. The most notable problem was related to difficulties in QR code execution. The QR code recognition engine in *TangiLearn* sometimes failed to response due to the low capacity computers used in the kindergarten. We also observed that the visual marker technology lacked of mobility due to the fact that the participants could not move the tangible objects too far from the camera. This problem must be addressed in the full-scale experimental research;otherwise, interest to use the full-scale *TangiLearn* among the children will be affected. Apart from that, some participants seemed to have difficulties in aligning the visual markers to the camera. However, the issue of physical alignment of visual markers was not totally a bad thing. According to Antle (2007a), orientating the visual marker to camera can also serve as a beneficial training to the preschoolers. It enhances their spatial experience as well as drilling their motor skills.

11. Considerations and refinements for the development of full-scale *TangiLearn*

After detailed analysis, we realized that there should be design considerations for tangible objects. If tangible objects are arbitrarily used, they may be disadvantaged by multimedia objects, or vice versa. The whole display could be cluttered in *TangiLearn*.

The choice of tangible objects for use in *TangiLearn* highly affected the children's rating of enjoyment level. The children tended to rate high level of enjoyment for toys. Level of enjoyment went lower for common objects such as books, plates, and erasers. Among all the common objects, animal objects captured more attention from the participants than those household utilities such as spoons and scissors. This may be because the children were more emotionally tied to animals. Famous branded commercial characters such as "Barbie doll," "Ben 10," and "Transformers" should not be used as these objects tended to attract children more than any other objects. They might divert their attention from actual learning, and ended up playing around with the toys.

The size of tangible objects chosen should be suitable to preschoolers. If tangible objects are too huge, they will not only block the view of the children to the computer screen, but will also take up a large portion of the space of the display table, and thus giving a very heavy "packed" feeling to the children. Besides, huge tangible objects will tend to be the frequent choice of the children. However, if tangible objects are too small, the sense of holding the tangible objects becomes weaker. From our observation, the best size of tangible objects are the size of slightly bigger than the hand palms of the preschoolers, and all tangible objects should be set around this size for consistency. Similarly, the size of the table for displaying tangible objects should not be too large to ensure reachability of points of contact amongst preschoolers. If not, visual search for the desired tangible objects will be affected.

Tangible objects used should be gender-free. In the case study, we intentionally placed a robotic model, "Transformer" as one of the tangible objects in *TangiLearn*. It ended up that the boys competed to play with it. Girls in turn argued why there was no "Barbie" doll available for them. A good multimedia learning system should be able to meet the learning preferences of both male and female learners. Apart from that, the participants were also found tended to choose tangible objects that have more striking color. The colour should be balanced among the tangible objects so that every object has equal chance to be chosen by the preschoolers for learning.

After the case study, we do agree with the guidelines suggested by Pederson, Sokoler, and Nelson (2000) and Antle (2007a, 2007b). According to Pederson and associates, the physical objects chosen for representing digital objects should be the "right" objects in a sense that human is able to grasp, to reason about, essence to the user's tasks, and meaningful in the use situation. According to Antle, three areas of cognition, namely symbolic reasoning, embodied and spatial cognition should be the criteria for choosing objects as physical instantiation to digital objects. To develop a truly usable tangible multimedia, we plan to apply these guidelines in the final version of *TangiLearn* system.

We were also informed of the change required for the research procedures and setting. We confirmed several alterations on the experimental protocol decisions. The first alteration is to limit the total number of learning objects (both virtual and tangible) to 7 objects in each learning scene, in compliance with Miller's (1956) idea that they are the limits that a person can remember at one time (Chau, Toh, & Zarina, 2012b). The second alteration is the number of topics covered. While reducing the number of learning objects in each scene, there should be more topics for learning. Such alteration could relieve their load in each learning session while maintaining the amount of learning contents. The third alteration is the elimination of the treatment using conventional multimedia system for participants using *TangiLearn*. As a controlled system, it should be conducted on different group of participants. This was because the result revealed a very large difference in the participants' level of enjoyment on *TangiLearn* and conventional multimedia learning systems. After lengthy duration of time for exploring *TangiLearn*, the participants seemed to feel bored navigating the conventional multimedia learning system due to similarity of learning contents.

On the technical side, due to the problem of execution of QR code flash library in *TangiLearn*, we plan to replace the QR code with other alternative technology. Among the technologies shortlisted for choice is RFID technology.

12. Conclusion

This case study sought to uncover the possible role that tangible objects in multimedia learning played in impacting preschoolers' learning performance and level of enjoyment. Despite the technical problems, the overall results of the study were highly positive in terms of the enjoyment, the feasibility and usability of *TangiLearn* system.On the whole, we have successfully elicited ideas from the preschoolers, and the results provided us insightful information about the areas that require refinements in the final full-scale research on tangible multimedia.

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