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Designing Tangible Multimedia for Preschoolers based on Multimedia Design Theories

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Abstract— Coupling of tangible objects and multimedia expression for preschool children has not taken place yet. The reasons could be the concern over possible physical clutter and confusion in display. The problem can be overcome by applying relevant multimedia design theories on the system. However, we have problem to find a design theory specifically used for leveraging tangible objects and multimedia objects. For the purpose of demonstrating the need of such design theory in a newly explored area, we divert our focus on the application of the well-established Cognitive Theory of Multimedia Learning, Dual-Coding and Cognitive Load theory. Such discussion serves as a grounding reference for other similar research in future. A relevant prototype named "*TangiLearn*" has been developed for a case study and the finding revealed that there is a need for specific full-fledged design guidelines in tangible multimedia.

Index Terms— Dual-coding theory, cognitive theory, Mayer's cognitive theory of multimedia learning, Tangible multimedia, Tangible object, Preschooler.

1 INTRODUCTION

IN multimedia research realm, the coupling of tangible objects and multimedia expression for preschool children has not been explored yet. As tangible objects are characterized by providing real visual-spatial imagery and full sensorial stimulation (visual, auditory, and tactile) which potentially enhance the learning capability of a preschool child, we thus take an important step forward by proposing a research on multimedia system augmented with tangible objects. We name such multimedia as "tangible multimedia". However, as a newly explored area, we have problem to find one design guidelines and theories specifically used to ensure that tangible objects and multimedia expression are leveraged. Such design theories are crucial because adding tangible objects means adding complexity to the system. If tangible objects are arbitrarily used, multimedia expression may be disadvantaged, or vice versa, and physical clutter leading to display confusion may be surfaced. To overcome this problem, we divert our focus on the application of the well-established Mayer's Cognitive Theory of Multimedia Learning [1], [2], and two of its associated theories, the Dual-Coding Theory [3], [4], [5] and Cognitive Load theory [6], [7], [8] for the design of tangible multimedia. Despite these theories cover only visual and auditory sensory channel, majority of the principles are relevant due to the fact that tangible multimedia is still a normal multimedia system with just additional tangible objects for learning. In this paper, we discuss how the theories can be applied in a prototype of tangible multimedia, *TangiLearn*. A brief report of the case study is provided at the end of the paper. Such discussion serves as a grounding reference for other similar research in future.

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2 DESIGN OF THE *TANGILEARN* MULTIMEDIA SYSTEM

TangiLearn is a manifestation of tangible multimedia. Its Learning, Quiz and Problem-Solving sections are designed to accommodate the use of tangible objects.

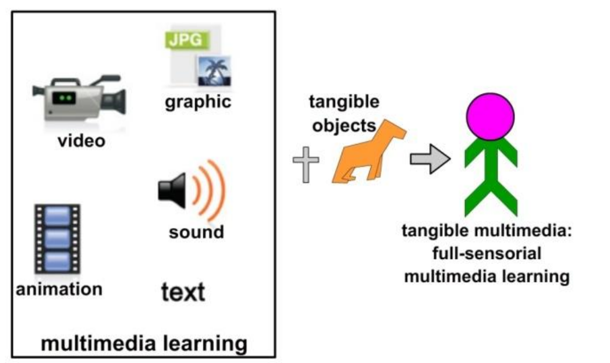

Fig. 1. *TangiLearn*: Adding tangible objects to conventional multimedia system.

When a learner clicks the Learning section in the main menu, the learner "enters" a virtual world "surrounded" by many irregularly-placed virtual and tangible learning objects (e.g. animals and household utilities) arranged in front of the computer (Fig. 2 and Fig. 9).

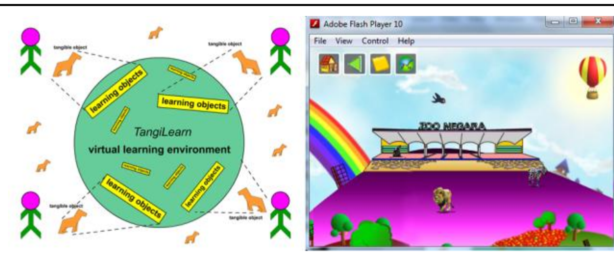

Fig. 2. *TangiLearn* tangible and virtual world

Understanding of these learning objects is the core objective of the *TangiLearn* system.The tangible and virtual learning objects binding is done through the adaptation of QR code library to the Adobe Flash Professional CS5 *ActionScripts* 3.0. QR code markers are attached on the tangible objects. To proceed, a preschool child will need to identify and grab a tangible object, and align it to computer camera to trigger the corresponding virtual learning object to display relevant multimedia based learning contents. With this, the learning process begins.

Fig. 3. QR code marker and its implementation in *TangiLearn*.

The whole learning flow in *TangiLearn* system is designed in cyclical sequential format that the preschool children start from tangible object exploration, followed by conceptualization, reinforcement and application of the concepts through problem-solving activities and quizzes to ensure lasting acquisition of knowledge (Fig. 4).

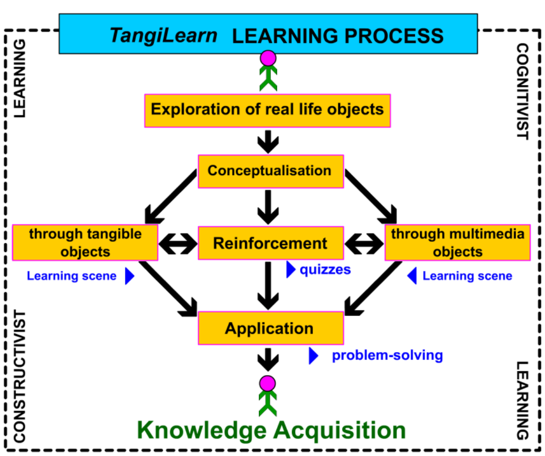

Fig. 4. Learning process in *TangiLearn* system.

3 APPLICATION OF COGNITIVE LOAD THEORY IN *TANGILEARN* SYSTEM

Extraneous cognitive load [6], [7] is overcome by the use of tangible objects in *TangiLearn* (Fig. 5). Most of the conventional multimedia systems nowadays deliver contents using visual and auditory formats. Hence, load is only shared by visual and auditory sensory channels. *TangiLearn* offers the engagement of visual, auditory and tactile channels, and based on the idea of load sharing in cognitive load theory, it will further free up more space in each channel for learning process.

Fig. 5. Tangible objects for overcoming extraneous load.

In line with the idea of Miller [9] that human has 7 units of information of memory capacity, the use of tangible objects in *TangiLearn* is limited to 7 tangible objects in each scene (Fig. 5). In *TangiLearn*, the number of virtual learning objects is corresponding to the number of tangible objects used, as such, it leads to a plain and clean screen design shown in Fig. 6.

Fig. 6. Plain and clean screen layout.

Humans start to forget once they stop learning. According to Ebbinghaus [10], there is a forgetting curve for humans. The largest forgetting period takes place within 24 hours, and then gradually, they forget 80% of the knowledge they have learned. To reduce the forgetting curve, three ways of repetition [11] has been employed in *TangiLearn*. First, repetition of activities involving the identification of learned tangible objects. Second, tangible objects displayed in front of the preschool children provide all-time exposure to them. Third, repeated practice in quiz and problem-solving associated with tangible objects are allowed. The ways employed to increase the likelihood of retention of knowledge learned in long-term memory in *TangiLearn* are different from the behaviourist way. Behaviourist way of repetition is teach, test and then teach, and test again, whereas the *TangiLearn* system takes a more lively approach where real life objects are used extensively.

4 Application of Dual-Coding Theory in *TangiLearn* System

In compliance with dual-coding theory [3],[4],[5], the multimedia content is delivered using visual and auditory format for different sensory channels. As shown in Figure 7, the learning object is shown using graphic and spoken text. Considering the limited information that each channel can hold, only short phrases of sound files and simple picture are used. In fact, due to the inclusion of tangible objects, *TangiLearn* deals with more than two types of sensory channels [12].

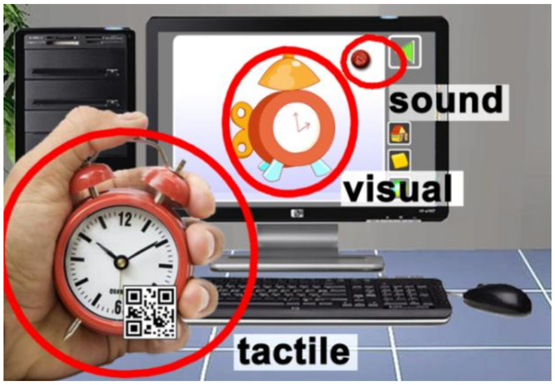

Fig. 7. Application of dual-coding theory in *TangiLearn*.

5 Application of Mayer's Cognitive Theory of Multimedia Learning

Mayer [1], [2] derives a set of design principles in cognitive theory of multimedia learning that serves as a guideline for designing an effective multimedia system. His first principle, multimedia design principle is applied in a way that *TangiLearn* engages more than one sensory channel. Information overloaded on a single sensory channel will impede the learning process of a child [13]. In *TangiLearn*, learning is guided through the use of sound played together with visual text, rather than single visual text, to avoid visual channel overloaded (Fig. 8).

Fig. 8. Multimedia Design Principle: Separated sound and visual text

Spatial contiguity principle is applied in a way that all relevant materials are arranged closely adjacent to one another to get rid of split attention effect that will forcibly divide a learner's attention. For example, instructional supporting tools are grouped virtually on screen whereas tangible objects are grouped physically in front of computer. This assists the preschool children to form the connection between the relevant materials mentally, and lead to a sharp diminishment in split-attention effect.

Fig. 9. Spatial Contiguity Principle: Relevant items adjacent to one another.

Coherence principle is applied in a way that irrelevant material is avoided in the system. All fancy words and meaningless images are removed, thereby giving a "clean" layout design in Fig. 10. The children absorb knowledge better when extraneous information is excluded. In line with the redundancy principle, redundant complete information (e.g. cross-reference, repeated information, similar written text and images) does not exist in *TangiLearn* system. For example, in the "Related Cases" screen shown in Fig. 11, only images are presented, similar information in sound and animation format are removed to ensure that the children will be able to concentrate on relevant information for solving problem. Similarly, no redundant tangible objects will be used.

Fig. 10. Unnecessary items avoided.

Fig. 11. Redundant items avoided.

6 Results from Case Study

Six preschoolers aged 6 were the evaluators in the case study. Unstructured interviewing, observation, and questionnaires were employed [14]. The study, which took place in a kindergarten in Kuala Lumpur, showed that 4 evaluators rated their level of enjoyment of using the *TangiLearn* with the highest score (enjoyed very much). The quiz results indicated that the evaluators were successful in acquiring knowledge from the system. 3 evaluators reported that the quiz was easy, 2 moderate, and 1 difficult. In our opinion, the application of tangible objects as well as multimedia design theories contributed to this outcome. We believed both of them had reduced the children's extraneous cognitive load for learning. This was evidenced from the situation where they picked up the learning process very quickly, and understood the tasks without much problem. From their facial expression, it was obvious that the tangible objects demanded less deliberate interpretation. They grasped the objects firmly, implicated the need of tactile information for learning. They moved around the objects, signifying the contribution of spatial information and iterative hands-on learning experience. In *TangiLearn*, tangible objects and multimedia objects are designed to complement each other meaningfully. For example, in parts of problem-solving section, multimedia objects are designed to provide versatile clue to the evaluators the kind of action or interaction expected for the tangible objects, and this made them enjoyed tinkering with the tangible objects. Even toward the end of the learning session, they still maintained a high level of engagement in learning.

Case study indicated that there should be design considerations on the use of tangible objects. The type of tangible objects chosen for use in *TangiLearn* highly affected the children rating of enjoyment level. The children tended to rate higher level of enjoyment for toys. Level of enjoyment went lower for common objects (e.g. books and erasers). Among all the common objects, animal objects captured more attention from the children than those household utilities (spoons and scissors). This may be due to the reason that children are more emotionally tied to animals. Children are sensitive, and they tend to choose those attractive to them, or capture their attention, like those more colorful, or larger in size. In the case study, we intentionally placed a "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 absence of "Barbie" doll. This implied that famous branded commercial characters, or gender-based figurines should be avoided in the choice of tangible objects for tangible multimedia. The size and color of tangible objects should be balanced among the tangible objects. If an object attracts children more than any other objects, it may result in diverting their attention from actual learning, and ended up playing around with it. In our opinion, every object should have equal chance to be chosen for learning.

7 Conclusion

The application of multimedia design theories on tangible multimedia is discussed in this paper. One problem in applying these theories is that they only take account of visual and auditory information channel. Case study revealed that a formal design guideline for tangible objects in multimedia context is lacking. To take full advantages of the contrasting strengths of different media, we look forward research efforts on deriving full-fledged design guidelines, covering both multimedia and tangible objects, for tangible multimedia [15].

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