Designing Tangible Multimedia for Preschoolers based on Constructivist and Cognitivist Learning Theories

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Abstract: Since its emergence more than 20 years ago, the digital form of presentation deprives multimedia of natural and tangible elements that allows children to learn in an intuitive way. Based on the idea of constructivist and cognitivist learning theories, tangible objects play a substantial role in learning and cognition growth of young children. Taking the strength of tangibility affordance of physical objects, a prototype of tangible multimedia that embraces the use of tangible objects named *TangiLearn* has been designed. In this paper, we revisit the idea of tangibility brought forward in the two compelling learning theories, followed by a brief discussion on how *Tangilearn* is designed. A relevant case study has been conducted and study finding revealed that *TangiLearn* provoked the preschoolers' learning outcomes.

Keywords: Tangible object, multimedia, tangible multimedia, preschoolers

Introduction

Since its emergence more than 20 years ago, multimedia has to date not accommodated patterns of learning that truly define the essential nature of childhood. This is because multimedia delivers knowledge only through digital visual and auditory formats. Young children are in a unique category, with unskilled motor acuity, limited vocabulary, and a preoperational level of cognitive development [1][2]. They require natural learning that suits their cognitive capacity and orientation. However, the digital form of presentation deprives multimedia of natural and tangible elements. In this respect, we observe a gap between multimedia learning systems and preschoolers. Constructivist and cognitivist learning theories posit that tangible objects serve as excellent candidates to bridge the gap in multimedia learning systems for preschoolers. We present this paper with the objective of discussing 1) the use of tangible objects in learning theories, 2) how these theories are applied in the multimedia realm, and 3) a case study.

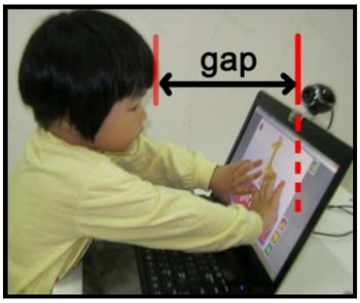

Fig. 1. The learning gap in multimedia

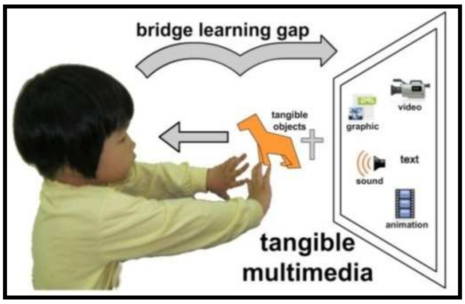

Fig. 2. Bridging gap in tangible multimedia

2. Tangible Objects as a Means of Learning

Cognitivists are passionate advocates of tangible objects in learning. McAnarney [4] stated that “Piaget's research clearly mandates that the learning environment should be rich in physical experiences … and for the elementary school child, this includes direct physical manipulation of objects” ([4], p. 33, as cited in [5]). Piaget’s theory of cognitive development explicitly rationalized the role of the learning process associated with activities using physical objects. Accordingly, human cognitive structure progresses linearly from stages of mental orientation dependent on external concrete stimuli (sensory-motor stage) and gradually moves on to abstract reasoning and thinking, not vice versa [2]. Children 7 years of age and younger are at the “preoperational” stage [1][2]. Hence, they require concrete materials for learning that they can grasp and feel.

Constructivists define learning as a cognitive construction of knowledge [6][7] and hold the belief that learning starts with active self-exploration. The use of tangible objects was popularized by constructivist practitioners over 100 years ago. Montessori’s learning approach, which is considered a constructivist approach, was exemplary [8][9]. Her method of “sense education” calls for teachers to be as non-disruptive as possible in class, and young children are allowed to freely choose any apparatuses for learning [10][11]. Tobin [7] stated the following: “Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning” ([7], p. 404–405, as cited in [5]). In other words, constructivists assert that learning takes place most effectively if the learning process moves from real action and direct experiencing of information to be learned rather than preceding it [8].

3. Case Study: Proposing *TangiLearn*

Cognitivist and constructivist theories shed light on the idea that multimedia should embrace tangible objects for learning [12][13]. Based on these theories, we conceived a multimedia learning system that embraces the sense of tangibility in preschoolers. We termed such multimedia a “tangibility-augmented multimedia learning system” or in short, tangible multimedia. We adopted the term “tangibility” from Ullmer and Ishii’s Tangible User Interface (TUI) research [14][15][19] because the term indicates that physical form is given to digital information. To gather preliminary evidence about the feasibility and pedagogical value of such multimedia, we developed a relevant prototype of tangible multimedia named *TangiLearn* [16][17][18].

3.1 Design of TangiLearn

TangiLearn was designed with the aim of implementing cognitivist and constructivist learning theories. Its learning sections contain a world that is "surrounded" by many virtual learning objects in virtual space and an array of corresponding tangible objects positioned irregularly in physical space.

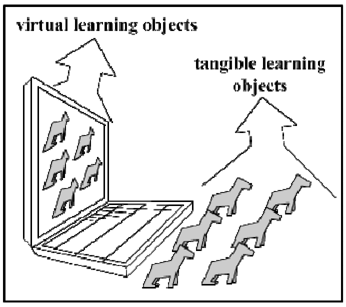

Fig. 3. The *TangiLearn* tangible and virtual world

The learning process in *TangiLearn* starts when a preschooler grabs a tangible object. During the course of direct manipulation of the object, relevant corresponding information is delivered on the computer screen. Unlike TUI and many other systems in which tangible objects are used for human-computer interaction purposes, tangible objects in *TangiLearn* are the target objects to learn. The learners are expected to acquire knowledge about the objects and master relevant English vocabulary (e.g., able to spell and read the name and key terms related to tangible objects).

Tangible and multimedia object binding is implemented through the adaptation of radio frequency identification (RFID) and sensor technology using Flash *ActionScript* 3.0. For the purpose of tangible object recognition, a RFID tag is inserted into a tangible object. When the object is moved towards the radio wave field generated by a compatible reader, the chip in the tag transmits the stored information to the reader, thereby establishing mutual communication that allows the computer to identify the object.

Fig. 4. Using RFID technology in *TangiLearn*

For a stronger tactile experience, representing constructivist and cognitivist theory in physical space, we used three types of sensors: electronic slider, force sensor, and spatial sensor. In the case of the electronic slider, a tangible object is attached to its knob (Fig. 5). When the preschooler grasps and moves the object from left to right, the digital learning object moves accordingly.

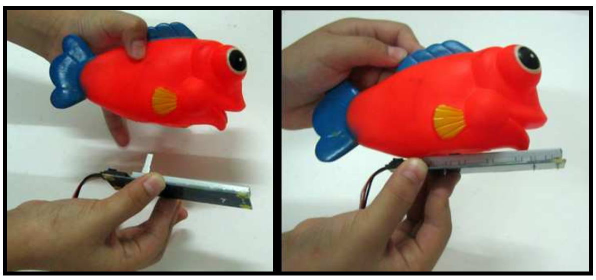

Fig. 5. Tangible object attached on electronic slider in *TangiLearn*

The force sensor is glued on the tangible object. During the learning process, preschoolers are requested to press the tangible object. The more they press the sensor via the object, the more the digital multimedia object reacts. For example, Flash's movie clip character moves further in the virtual scene. With the spatial sensor attached to tangible objects, simple hand motions and gestural operations can be performed for learning, and this greatly enhances the child's sense of spatiality.

Fig. 6. Force sensor and spatial sensor glued on tangible object in *TangiLearn*

3.2 Application of Constructivist theory in TangiLearn

According to Jonassen's constructivist paradigm, construction of knowledge take place most efficiently if learners are required to exert deliberate effort on information delivered to them [8]. In *TangiLearn*, irregular placement of tangible objects that requires preschoolers to perform an actual visual search for the object they are interested in greatly facilitates their performance of a deliberate task.

Constructivist theory states that learning objectives must not be pre-specified at the beginning of the lesson. Instead, they must be implicit and indirect throughout the learning process. In compliance with this approach, the learning objectives in *TangiLearn* are loosely defined and interspersed throughout the lesson through the arrangement of tangible objects displayed in front of the computer. With tangible objects, the preschoolers are continually reminded of what they are going to study in the whole learning lesson in *TangiLearn*.

The learning sections in the *TangiLearn* system are designed as complete virtual scenes that resemble a realistic environment representing the complexity of the real world (Fig. 7), consistent with authentic learning in Jonassen's constructivist learning environment (CLE) [20][21]. Tangible objects are real-world learning materials. As such, they are a logical choice for authentic content and activities. For example, children learn language well when learning materials are presented in meaningful contexts [22].

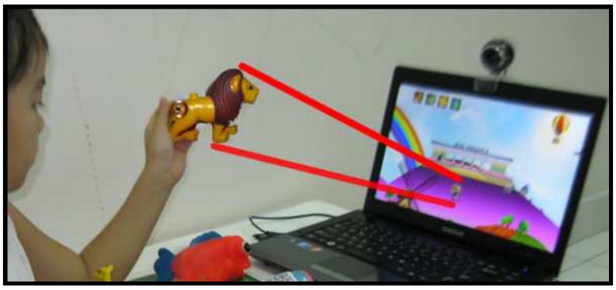

Fig. 7. An authentic learning scene in *TangiLearn*

CLE conceives problem-solving as the driving force in learning capable of moving learners to a higher level of cognitive reasoning. In view of this, problem-solving sessions covering "problem context", "problem representation" and "problem manipulation in space" are deployed in the *TangiLearn* system. The description of "problem context" is delivered using multimedia expression supported with tangible objects to assist learners in understanding the problem. "Problem representation" is accomplished using videos and animations coupled with tangible objects. For "problem manipulation in space", the realistic virtual scene and physical space of the display table are set to allow the learner to perform gestural operations and understand the effects of their manipulations. To answer the problem-solving questions, the preschooler has to respond by identifying the correct tangible object. For example, if a hammer is the subject of a question, the preschooler has to pick the real hammer as the answer. With concrete experience of the tangible hammer in hand, learners gain a better understanding of the use of a hammer. Their ability to solve the problem indicates that they fully comprehend the concept of a hammer that they learned.

3.3 Application of Cognitivist theory in TangiLearn

The *TangiLearn* system targets preschoolers 5 and 6 years old in the "pre-operational" stage [1][2] and is compatible with their level of cognitive development. The tangible objects chosen for learning are recognizable everyday objects from their surroundings. Symbolic objects are not chosen because preschoolers may have difficulty interpreting them as symbols [23][24]. In relation to virtual learning objects, tangible objects are designed so that they are directly mapped into the virtual world. For example, if a tangible apple is used, it is a virtual apple in *TangiLearn*. Such a design means physical instantiation is given to multimedia objects. For young children, this gives an illusion that the digital objects can be felt and grasped. This is unlike TUI systems in which many features of tangible manipulative materials are scrapped, made less realistic, and their properties simplified in order to represent other domains (such as shapes for coins and different colours for numbers).

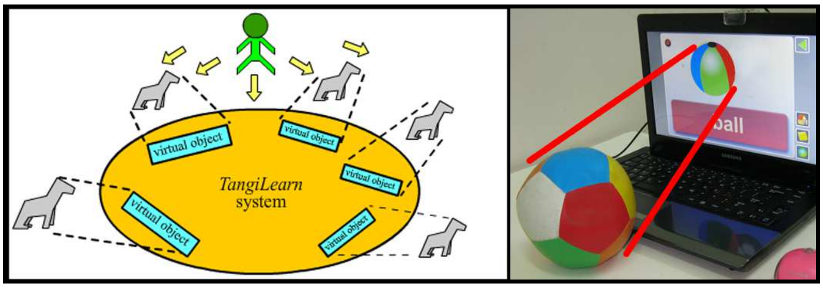

Fig. 8. Direct mapping of tangible and virtual worlds

The "open style" design in both tangible and virtual learning object arrangement greatly promotes autonomy in preschoolers. Figure 9 shows the main screen of the *TangiLearn* system that allows preschoolers to freely select where they want to begin, either starting with the Learning, Problem-Solving, or Quiz section, or tangible objects in front of them. There is no predetermined sequence of learning paths.

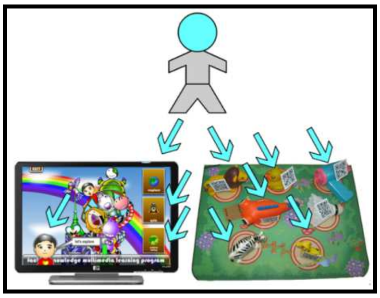
Fig. 9. "Open style" design in tangible and virtual objects in *TangiLearn*

In a cognitivist learning environment, learners are taught to associate their learning with prior knowledge. Adopting this approach, *TangiLearn* is designed to assist preschoolers in making connections between new knowledge and what they have learned previously. This is exemplified in the design of learning scenes that resemble familiar environments, and tangible objects that are organized meaningfully to become part of the overall environment. Familiar and real learning backgrounds help preschoolers recall existing knowledge more easily. With tangible objects connected to a known background, they are able to learn faster [25].

3.4 Findings of the case study

Six preschoolers 6 years of age from a kindergarten in Kuala Lumpur were selected as the participants in the case study [26]. We have planned a series of formal evaluation strategies to evaluate the working prototype prior to a full-scale comparative study. An on-going process of iterative cycles of drafting, evaluation, and revision will be conducted until the final *TangiLearn* is developed. This case study was our first evaluation aimed to gather preliminary evidence that *TangiLearn* can enhance preschoolers' learning outcomes. Thus, we did not include a control group.

In line with the National Preschool Curriculum (NPC) of Malaysia [31], the learning content of *TangiLearn* focuses on real-life objects and general knowledge in English. General knowledge in English was chosen because embedding literacy learning within knowledge-building activities is engaging for young children [22]. In addition, general knowledge nicely suits the use of tangible objects in *TangiLearn*. For the case study, topics of general knowledge were animals, fruits and household items. Abstract concepts were not introduced, consistent with the level of cognitive ability of young children [1].
Unstructured observation and questionnaires were used to elicit feedback pertaining to the use of the *TangiLearn* system from the participants. In this one-day case study, four participants rated their enjoyment in using *TangiLearn* with the highest score (enjoyed very much). They deliberately explored the tangible objects displayed in front of them, tinkered with them, and attempted different positions and alignments to the reader and sensor devices. The technologically simple configuration of the system allowed them to understand the tasks without much difficulty.

Although backed by two learning theories, the use of tangible objects exposed several limitations during the case study. For example, additional tangible objects introduced complexity and clutter to the multimedia. Therefore, there should be design considerations related to the use of such objects. The application of multimedia design theories such as Mayer's cognitive theory of multimedia learning as well as cognitive load and dual-coding theories might overcome the problem. However, one problem in applying these theories is that they only take into account visual and auditory sensory channels. Formal design guidelines that consider the tactile sensory channel in multimedia contexts is lacking. Thus, we look forward to further research aimed at designing guidelines covering both multimedia and tangible objects in multimedia.

4. Conclusion

Constructivist and cognitivist learning theories offer compelling rationales regarding the need for tangible objects in learning contexts. Duffy and Cunningham [28] contended that a digital mode of presentation is the most effective means to accommodate constructivist ideas [29][30]. We argue that tangible objects embedded in multimedia represent the best way to realize constructivistic self-exploration and cognitivistic concrete learning amongst preschoolers. The design of the *TangiLearn* system is rudimentary, but can be improved in full-scale comparative research in the future.

References

[1] Piaget, J. (1952). *The origins of intelligence in children*. New York, USA: University Press.

[2] Piaget, J. (1972). *The principles of genetic epistemology*. New York: Basic Books.

[3] Mohamad Jafre Zainol Abidin, Majid Pour-Mohammadi, Souriyavongsa, T., Chin Da, & Ong, L. K. (2011). Improving listening comprehension among Malay preschool children using digital stories. *International Journal of Humanities and Social Science, 1*(14), 159-164.

[4] McAnarney, H. (1978). What direction(s) elementary school science? *Science Education, 62*(1), 31-38.

[5] Haury, D. L. & Rillero, P. (1994). *What are the benefits of hands-on learning? How do I justify a hands-on approach? Perspectives of hands-on science teaching.* North Central Regional Educational Laboratory. Retrieved from http://www.ncrel.org/sdrs/areas/issues/content/cntareas/science/eric/eric-2.htm

[6] Merrill, M. D. (1991). Constructivism and instructional design. *Educational Technology, 31*(5), 45-53.

[7] Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics, 90*(5), 403-418.

[8] Cooperstein, S. E., & Kocevar-Weidinger, E. (2004). Beyond active learning: A constructivist approach to learning. *Reference Services Review, 32*(2), 141-148. DOI 10.1108/00907320410537658

[9] Anastasiu, I. (2008). Tangible E-Learning. In S. Streng, D. Baur, G. Broll, A. D. Luca, R. Wimmer, & A. Butz (Eds.) *Trends in E-Learning: An overview of current trends, developments, and research in E-Learning* [Technical Report]. German: Department of Computer Science Media Informatics Group, University of Munich.

[10] Montessori, M. (1917). *Spontaneous activity in education* (Translated by Florence Simmonds). New York, USA: Frederick A. Stokes Company. Retrieved from http://www.arvindguptatoys.com/arvindgupta/montessoriactivity.pdf

[11] Burnett, A. (1962). Montessori education today and yesterday. *The Elementary School Journal*, 63, 71-77.

[12] Chau, K. T., Toh, S. C., & Zarina Samsudin. (2012). Enriching multimedia expression with tangible objects: The learning benefits for preschoolers. *The Turkish Online Journal of Educational Technology.* (in press).

[13] Chau K. T., Toh S. C., Zarina Samsudin, Wan Ahmad Jaafar Wan Yahaya, & Lili Budiman. (2012) Tangible Objects: The missing attribute in multimedia learning systems for preschoolers. *The International Journal of Multimedia & Its Applications (IJMA), 4*(4), August issue, 17-33.

[14] Ullmer, B., & Ishii, H. (2001). Emerging frameworks for tangible user interfaces. In Carroll, J. M. (Ed.), *Human-Computer Interaction in the New Millenium*, 579-601. USA: Addison-Wesley.

[15] Ishii, H. & Ullmer, B. (1997). Tangible bits: Towards seamless interfaces between people, bits and atoms. *Proceedings from CHI'97: The ACM SIGCHI Conference on Human Factors in Computing Systems*, 234–241.

[16] Chau, K. T., Toh, S. C., & Zarina Samsudin. (2011). Tangible multimedia technology: A research proposal for bringing tangibility into multimedia learning amongst preschool children. *Proceedings of the 5th International Malaysian Educational Technology Convention (IMETC 2011)*, Kuantan, Malaysia.

[17] Chau K. T., Toh S. C., Zarina Samsudin, & Wan Ahmad Jaafar Wan Yahaya. (2012). Bringing tangibility into multimedia learning: Technology for tangible-multimedia objects binding. *Proceedings of the International Conference on Quality Of Teaching & Learning (ICQTL 2012).*

[18] Chau K. T., Toh S. C., Zarina Samsudin, Wan Ahmad Jaafar Wan Yahaya, & Lili Budiman. (2012) Visualizing a framework for tangibility in multimedia learning for preschoolers, *The International Journal of Multimedia & Its Applications (IJMA).* (in press)

[19] Chau K. T., Toh S. C., & Zarina Samsudin. (2012). Bringing tangibility into multimedia learning: From the past TUI researches to tangible multimedia for preschool children. *International Journal of Information Technology & Computer Science (IJITCS).* (in press).

[20] Jonassen, D. H. (1997). A model for designing constructivist learning environments. In Zaidah, R. et al. (Eds.), *Proceedings of the International Conference on Computers in Education,* 72-80. Sarawak: Universiti Malaysia Sarawak.

[21] Jonassen, D. H. (1999). Designing constructivist learning environments. In C.M. Reigeluth (Ed.), *Instructional-design Theories and Models: A New Paradigm of Instructional Theory*, *2,* 215-239. New Jersey: Lawrence Erlbaum Associates.

[22] Albert Shanker Institute. (2009). *Preschool curriculum: What's in it for children and teachers.* Washington, USA. Retrieved from http://www.shankerinstitute.org/Downloads/Early%20Childhood%2012-11-08.pdf
[23] Uttal, D. H., Scudder, K. V., & DeLoache, J. S. (1997). Manipulatives as symbols: A new perspective on the use of concrete objects to teach mathematics. *Journal of Applied Developmental Psychology, 18*(1), 37-54.
[24] Manches, A. (2010). *The effect of physical manipulation on children's numerical strategies: Evaluating the potential for tangible technology*. Unpublished doctoral dissertation. University of Nottingham, UK.
[25] Chau, K. T., Toh, S. C., & Zarina Samsudin. (2012). Designing tangible multimedia for preschool children based on multimedia design theories. *International Journal of Scientific & Engineering Research (3)*8.
[26] Chau, K. T., Toh, S. C., & Zarina Samsudin. (2012). Tangible multimedia: A case study for bringing tangibility into multimedia learning. *The Turkish Online Journal of Educational Technology*. (in press).
[27] O'Malley, C., & Fraser D. S. (2004). *Futurelab Series Report 12: Literature review in learning with tangible technologies*. Bristol, UK: NESTA Futurelab. [Online]. Available: http://www.futurelab.org.uk/download/pdfs/research/lit_reviews/futurelab_review_12.pdf
[28] Duffy, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology*, 170-198. New York: Simon & Schuster, Macmillan.
[29] Wilson, B. G. (1995). *Constructivist learning environments* [Special Issue]. Educational Technology, 35(6), 5-23.
[30] Wilson, B. G. (1996). *Constructivist learning environments: Case studies in instructional design*. Englewood Cliffs. NJ: Educational Technology Publications.
[31] Challenger Concept. (2009). *Schools of Malaysia directory: Your guide to children's schooling and upbringing*. Selangor: Challenger Concept (M) Sdn Bhd.