Enhancing Collaboration and Facilitating Children's Learning Using TUIs: A Human-Centered Design Approach

Wafa Almukadi[1,2(✉)] and Guy A. Boy[1]

[1] School of Human-Centered Design, Innovation and Art, Florida Institute of Technology, 150 West University Boulevard, Melbourne, FL 32901, USA
Walmukadi2013@my.fit.edu, gboy@fit.edu
[2] Computing and Information Technology College, Information System Department, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract. Human-Computer Interaction (HCI) literature already suggests that Tangible User Interfaces (TUIs) can support children learning. This paper presents a human-centered design approach of TUIs applied for reading tasks in the classroom for children aged 5 to 8 years. This approach is also supported by agile software and hardware development. We focused on language learning by building 3-letter words. We also discover the remarkable advantage of TUIs to support collaboration with teachers and the others children in the achievement of such tasks. We discuss related human-system integration issues, and more specifically tangibility and emerging collaboration factors elicited from formative evaluation results.

Keywords: Author keywords tangible user interface · Learning · Children · Engagement · Collaboration · Fun · Human-centered design

1 Introduction

The Human-Computer Interaction (HCI) community works on TUIs for around two decades [20]. More recently, TUI in children learning's environments started to have an impact showing interesting possibilities from various viewpoints such as usability, learning, collaboration, and fun [10, 20]. Several research efforts have been carried out and provided empirical evidence and theoretical validations of the benefits of TUIs on learning outcomes [10, 19]. Many applications [15–18] developed for children in a large variety of domains and tasks. However, results show potential influence processes related to learning, while still no conclusive evidence of measuring learning outcomes [20]. This paper will discuss how TUIs can enhance children's learning environment that facilitates learning overall. It presents an interactive tangible learning system for children age 5 to 8, designed to facilitate language learning with 3-letter words. An empirical experiment was performed with 9 children to evaluate the affect of TUIs in children's learning environment.

P. Zaphiris and A. Ioannou (Eds.): LCT 2016, LNCS 9753, pp. 105–114, 2016.
DOI: 10.1007/978-3-319-39483-1_10

1.1 What Do Children Like and Do Not Like in the Classroom?

A discussion session involving 17 children aged 5 to 8 (11 girls and 6 boys) and 4 teachers were conducted in a local school to explore what children like in their classroom and what they don't like. Findings are summarized as follows:

- Children don't like sitting at a desk, they prefer booths or round tables that can fit groups of children and provide more freedom to move;
- Children don't like to be tested;
- Children like to be rewarded;
- Children like to use interactive tool to learn, such as tablet and iPad;
- Children like to have fun while learning supported by games and stories;
- Children like working together.

In addition, teachers involved endorsed the benefit of serious games designed for learning and problem-solving purposes, which can replace traditional exercises and entertain children. Children like to play, and playing facilitates learning. Based on these findings we claimed that using TUIs in children classroom could enhance children's learning by supporting interactivity, collaboration, embodiment, and pleasure [20]. At the same time, TUIs support what children and teachers prefer.

2 Why Tangible User Interface?

Human-Centered Design (HCD) [4] promotes involving potential future users into the design process. It typically consists in iterative loops that include ideation, prototype development, formative evaluation and validation. At a higher level of abstraction, HCD dictates looking for emerging properties of technology being developed, as well as organizational and human factors [4, 12]. Children are involved in affective exploration by creating imaginary and rich artificial life through play. TUIs in the classroom provide children with useful support for such exploration and knowledge acquisition. This tangible reading and writing environment enables children to acquire knowledge by acting (i.e., moving letter cubes among each other to form words).

TUIs provide a playful environment that facilitates children's overall development and learning [9, 10]. Providing such playful environments in classrooms increases children's engagement [16], offers freedom, motivation, and also learning through natural activities that fit into children's everyday contexts [5, 19]. Moreover, TUIs support collaboration of several users interacting with their environment as well as among each other [10, 16, 19]. Collaborative learning increases productivity levels [5], boosting confidence and self-esteem of children. Furthermore, TUIs require little cognitive effort to learn how to use systems, enabling students to focus exclusively on objects and tasks [19].

We claim that use of TUIs in the classroom, more specifically for language-learning purposes, improves learning outcomes. Demonstration of this claim led us to develop a TUI prototype that supports language learning by "building" and spelling 3-letters words, for children age 4 to 8. We tested the prototype in local school, involving 9 children (4 girls and 5 boys).

3 The Proposed TUI System

The proposed prototype designed as a portable lightweight and low-cost TUI based on open source framework reacTIVision[1]. The system's design support children's familiarity with letter-cubes manipulation. This result is corroborated by [19] results telling that children better grasp an abstract concept when its concrete representation can be grasped physically [18]. We considered Antle's five TUIs properties for children's [3]. The components of our prototype are (Fig. 1):

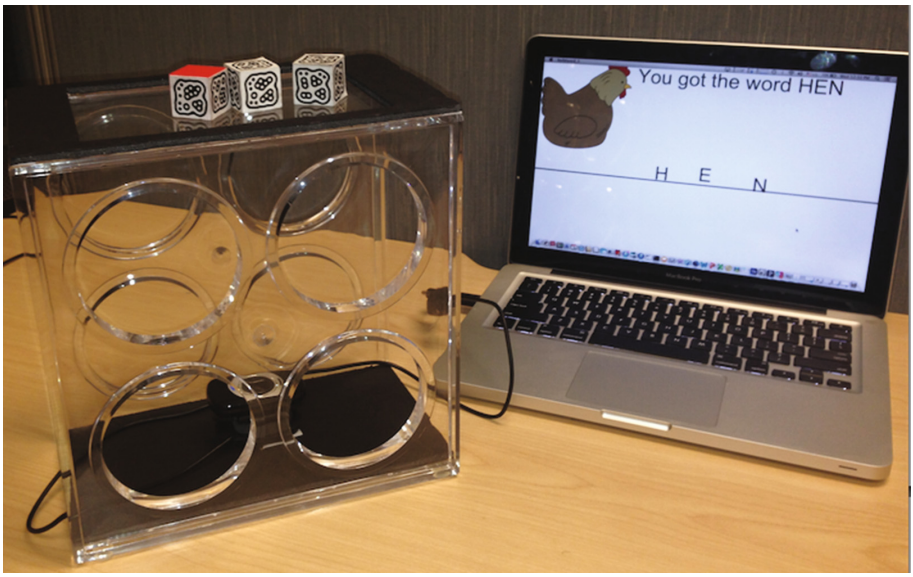

Fig. 1. The proposed TUI system components with a running example of 3-letter words "HEN"

A medium-size transparent box, which has a useful table-top surface that enables children to manipulate letter-cubes on it. A black foam board has been added around the playing surface to define the playing area.

- Three blocks represent the system objects; we call them blocks. Blocks are input objects. They afford gesture-based interaction, flexibility, reliability [16] and children familiarity acquisition. Four sides of each block have fiducial markers (Fig. 2) providing each of them with a unique ID representing a letter (note that two sides are left for future work). The resulting 3-block system enables the manipulation of 12 letters. Letters C, F, H, and B belong to Block1. Letters A, U, O, and E belong to Block2. Letters T, G, N, and X belong to Block3. The system enables 23 different

[1] http://reactivision.sourceforge.net/.

meaningful 3-letter words: cat, fat, hat, bat, act, hug, hut, hot, cut, tab, fun, hen, fan, can, tub, bag, bug, hog, bog, cot, fox, fog, and box. These words were recommended by teachers that we interviewed as the most common learning words for children 5–8 years old.

- A web-camera (Logitech HD webcam C615) enabling optical marker recognition is placed at the bottom of the box.
- A laptop is used to run the system framework, application, and display output. The application is coded by Processing[2].

3.1 How Does the System Work?

We chose an easy topic of 3-letter words that is familiar with our audience age because we wanted to focus on activity (i.e., what children effectively do) and not only the task (i.e., what children are requested to do), as well as TUI impact in the classroom. Children have the task to discover meaningful words. Children have to manipulate blocks on all four sides, which have optical markers, to "build" a meaningful word. Letters are not attached to the blocks. The idea behind that is to boost children curiosity and challenge them by providing game atmosphere. Whenever children obtain a meaningful 3-letter word, such as "HEN", an image corresponding to the word is immediately displayed together with the text message, "You got the word HEN", as well as clapping sounds is played. Conversely, if children build a non-meaningful word (e.g., "BFG"), nothing happens, (i.e. no negative feedback is provided). The overall principle is to encourage children to explore at their own pace further possibilities and thus motivate them to improve their vocabulary and spelling.

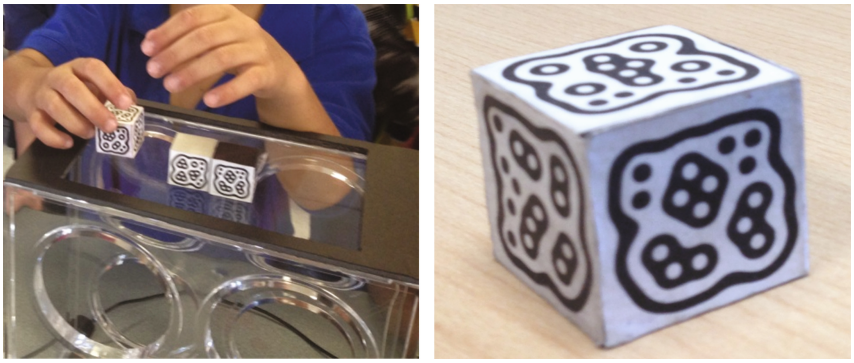

Fig. 2. On the left, three tangible objects with fiducial makers. On the right, close look to the fiducial markers that are attached to objects

[2] https://processing.org/.

4 Evaluation Study

A pilot study conducted at a local school. A group of 9 children aged 5 to 8 (4 girls and 5 boys) participated in the study. The experiment took place in a classroom after school day. We observed children's interactions with the system (i.e., activity), and learning outcomes.

4.1 Methods

We adapted Hanna's guidelines for usability testing with children [7]. Furthermore, we choose the co-discovery evaluation approach for the observation of children's activities. This approach consists in letting children collaborate with each other to learn how to interact with the proposed system [11]. We also used the Peer Tutoring method [8] where children who used the system can teach their friends what to do. After completing requested tasks, children were requested to complete a questionnaire using smiley ometer [13].

4.2 The Study Scenario

Children were brought into the classroom and asked to individually write 3-letter words that they know (Fig. 3). They had 20 min to complete the task. Our main goal was to observe children's behavior and interactivity, and build a basis for comparison with equivalent behavior using the TUI system. Another goal of this first task was to know children's knowledge level. After that, they asked to play together using the TUI system for 20 min (Fig. 4). Following the session, they were asked to fill in an evaluation sheet consisting of questionnaire with a smiley ometer for 10 min.

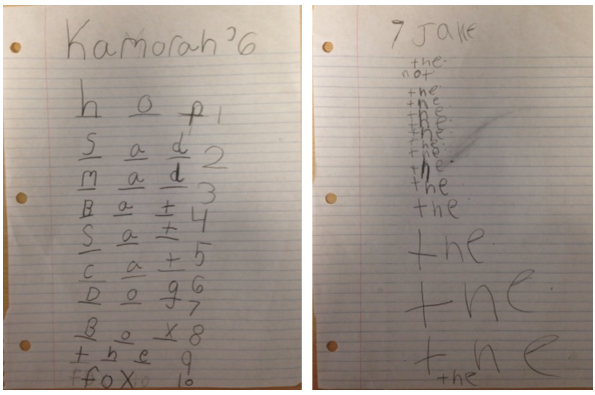

Fig. 3. An example of children hand writing, on the left six years old got 10 words, on the right 7 years old got 2words.

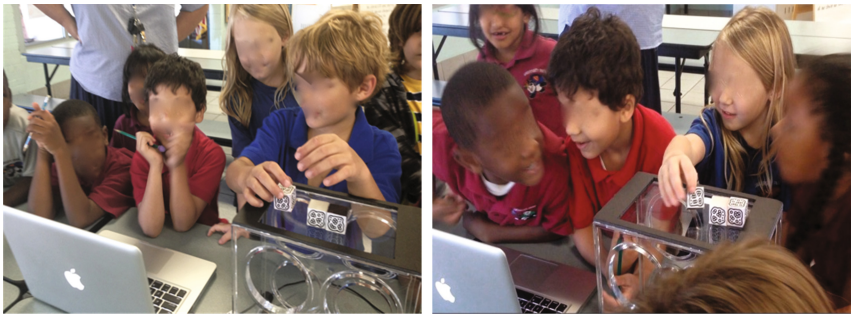

Fig. 4. Children play with the TUI system in classroom

Children were introduced to the system as a new game consisting in learning 3-letter words. They had to explore various ways of combining blocks. In practice, children stood around the TUI system and tried to play with it. A six years old child began to align the blocks and turned them on different sides until he achieved a meaningful word. With no request, this child, who tried the system first, started to guide other children and taught them how to build successful words, using a Peer Tutoring approach implicitly. After a while, three children were leading the group and showed them how to use the TUI system. They expressed their thoughts loudly and discussed about various possibilities of building words. After the session, children sat at a table to complete a paper evaluation sheet (Fig. 5).

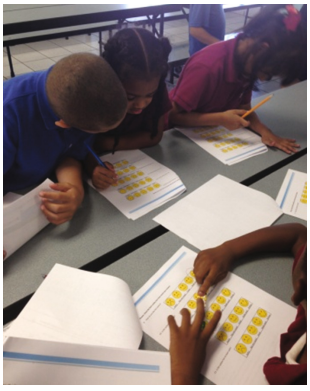

Fig. 5. Children completing evaluation sheet

5 Results and Discussion

The researcher who conducted the study mainly focused on observing children's activities, taking notes, taking pictures, and video recording the "playground". A volunteer teacher provided help with children interaction and organizing the sessions.

During the first session, children were first very quiet, staring at each other and at the ceiling. Some children put their heads on the table pretending they were tired and needed to sleep. Others complained that they didn't know any words. Then the volunteer teacher provided some examples orally. Consequently, children started to fill in their sheets. A few children tried to talk with others silently, asking about some words. Two children exchange their sheets to help each other.

When children started using the TUI system, they were very active and curious about how the system worked and how could these objects represent letters. They started by grasping the blocks and examined them by looking at and touching them. Children interacted with the system smoothly by discovering how to use it without asking for help. Children collaborated very well while they thought aloud about 3-letter words, continuously spelling. They explained meaning of some words to their peers such as "cot and bog" pointed to the pictures displayed on the screen. The room was full of children giggling and laughing, which proved their happiness and fun. After completing the evaluation form, children asked us when they could use the system again. They also asked if it was possible to leave the system and suggested visiting them in their classroom at least once a week.

Regarding performance results, since we could not guaranty task completeness, we counted the number of words that children were able to "build" in 20 min. During the first session, children were able to successfully build 14 words. During the second session, they were able to build, 20 words. In addition, during the first session none of them learned new vocabulary, while during the second session 3 children, ages 5, 6, and 7, learned two new words "cot" and "bog". Learning happened when other children built these words, so they started asking about their meaning and pointed to the image displayed in the screen to show the meaning (i.e., using a connotation cognitive process). Some children used the words "cot" and "bog" in a sentence to explain their meaning.

Since this paper focuses on children activity and collaboration, we need to evaluate children engagement as an important factor of children's playful learning experiences. Engagement defined as a kind of mindfulness and awareness requiring cognitive effort and deep processing of new information [1]. Some researches evaluate engagement by the amount of time spent on and off a particular task [1]. In our case it was difficult to count the time spent for building words. However, it was suggested that observing children behaviors such as smiles, laughing, frowns, and yawns are more reliable indicators of engagement or lack of engagement [6, 14]. Based on previous suggested principles on measuring engagement [6, 14], we deduced that children in the first session showed lack of engagement clearly appearing in their behaviors, such as staring at the ceiling, putting their heads down on the desks, verbalizing negative expressions, such as, "I feel tired, I want to sleep, I don't know any 3-letter words". In the second session, we observed that children were very much engaged, based on their face expressions, laughs and giggling sounds, letters and words screaming, and positive expressions such as "yes, yeah, easy, cool, and nice". Children like feedback whether audio, text, or image, which keeps them more engaged representing their success.

An important factor that emerged during the experiment is collaboration. Not only the TUI system supports collaboration among children, but it also affords collaboration (i.e., it naturally suggests collaboration). Children collaborated also by giving turns to

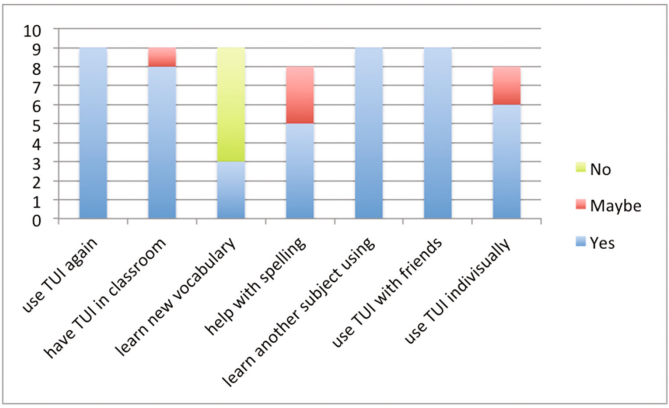

Fig. 6. Results of evaluation sheet

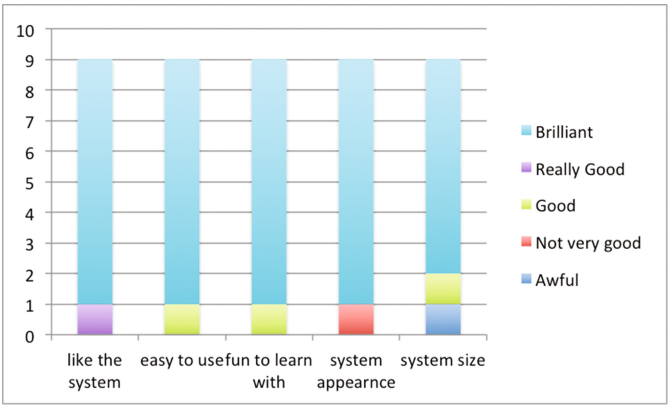

Fig. 7. Results of smiley ometer

their peers and taught each other how to use the system. Observational analysis revealed that children were much more active in terms of moving their bodies, guessing and expressing themselves. Figures 6 and 7 show the results of children questionnaire.

6 Summary

Human-centered design of using a TUI system in the classroom greatly contributes to facilitate children's learning and enhance collaboration. Our language-learning experimental results show that a TUI system used in a classroom with children 5–8 years old supports exploratory learning, collaboration, engagement, and enjoyment. Tangibility is crucial for the manipulation of abstract concepts and learning through the manipulation of equivalent physical objects. TUIs enable children to express themselves

through natural body movements, interactivity, collaboration and having fun. Consequently, providing behaviors of exploration, social interaction, manipulation of objects, movement, and enjoyment while learning.

7 Future Work

Regarding the small sample size (9 children); we could not perform a significant quantitative analysis. Planned studies are in progress that involves more children. We already started to extend the approach to numbers and basic math [2]. Future work includes comparison experiments between abstract objects that are presented in this paper (objects with no letters) and objects with letters to explore the effect of physical correspondence on learning and engagement.

Acknowledgements. We thank all the teachers, children, and participants. Thanks to the University Park elementary school and district of Brevard public school. Special thanks to Sally Sabawi, Jeri Moore, Karen Strauss, and Theresa Nicolette. Thanks to Dr. Kolski, Dr. Stephane, and Dr. Read for their feedback and comments.

References

1. Africano, D., Berg, S., Lindbergh, K., Lundholm, P., Nilbrink, F., Persson, A.: Designing tangible interfaces for children's collaboration. In: CHI 2004 Extended Abstracts on Human Factors in Computing Systems, ACM Press, pp. 853–868 (2004)
2. Almukadi, W., Stephane, A.L.: BlackBlocks: tangible interactive system for children to learn 3-letter words and basic math. In: Proceedings of the 2015 ACM International Conference on Interactive Tabletops & Surfaces, pp. 421–424 (2015)
3. Antle, A.: Tangibles: five properties to consider for children. In: CHI 2007 Workshop on Tangibles, pp. 1–10 (2007)
4. Boy, G.A. (ed.): The Handbook of Human-Machine Interaction: A Human-Centered Design Approach. Ashgate Publishing Ltd., Farnham (2012)
5. Fails, J.A., Druin, A., Guha, M.L., Chipman, G., Simms, S., Churaman, W.: Child's play: a comparison of desktop and physical interactive environments. In: ACM Proceedings of the 2005 Conference on IDC, pp. 48–55 (2005)
6. Hanna, L., Neapolitan, D., Risden, K.: Evaluating computer game concepts with children. In: Proceeding of the 2004 Conference on IDC: Building A Community, pp. 49–56. ACM Press IDC (2004)
7. Hanna, L., Risden, K., Alexander, K.: Guidelines for usability testing with children. Interactions **4**(5), 9–14 (1997)
8. Hoysniemi, J., Hamalainen, P., Turkki, L.: Using peer tutoring in evaluating the usability of a physically interactive computer game with children. Interact. Comput. **15**(2), 203–225 (2003)
9. Inhelder, B., Piaget, J., Iverson, J.M., Goldin-Meadow, S.: The Early Growth of Logic in the Child; Gesture Paves the Way for Language Development. Norton, New York (1964)
10. Marshall, P.: Do tangible interfaces enhance learning? In: ACM Proceedings of the 1st International Conference on TEI, pp. 163–170 (2007)

11. Mazzone, E., Xu, D., Read, J.C.: Design in evaluation: reflections on designing for children's technology. In: Proceedings 21st British HCI Group Annual Conference on People and Computers: HCI But Not as We Know It, vol. 2, pp. 153–156. BCS (2007)
12. Norman, D.A.: Things That Make Us Smart: Defending Human Attributes in the Age of the Machine. Basic Books, New York (1993)
13. Read, J.C.: Validating the Fun Toolkit: an instrument for measuring children's opinions of technology. Cogn. Technol. Work **10**(2), 119–128 (2008)
14. Read, J.C., MacFarlane, S.J., Casey, C.: Endurability, engagement and expectations: measuring children's fun. In: Proceedings of the IDC, pp. 189–198. Shaker Publishing, Germany (2002)
15. Ryokai, K., Marti, S., Ishii, H.: I/O brush: drawing with everyday objects as ink. In: Proceedings of CHI 2004, pp. 303–310 (2004)
16. Sheridan, J.G., Short, B.W., Van Laerhoven, K., Villar, N., Kortuem, G.: Exploring cube affordance: towards a classification of non-verbal dynamics of physical interfaces for wearable computing. In: IET Eurowearable, 2003, pp. 113–118. IEEE (2003)
17. Sylla, C.: Designing a tangible interface for collaborative storytelling to access' embodiment and meaning making. In: Proceedings of the 12th ACM International Conference on IDC, pp. 651–654 (2013)
18. Wang, D., et al.: E-Block: a tangible programming tool for children. In: Adjunct Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology (2012)
19. Xu, D.: Design and evaluation of tangible interfaces for primary school children. In: Proceedings of the 6th ACM International Conference on IDC, pp. 209–212 (2007)
20. Zaman, B., Vanden Abeele, V., Markopoulos, P., Marshall, P.: Editorial: the evolving field of tangible interaction for children: the challenge of empirical validation. Pers. Ubiquit. Comput. **16**(4), 367–378 (2012)