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TANGIBLE INTERFACE GAME FOR STIMULATING CHILD LANGUAGE COGNITIVE SKILL

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ABSTRACT

The intervention for cognitive language development is required to be conducted at a young age. As children usually gain the skill through their play, this study proposed a physical interactive game to help children improve their language skill in both Thai and English language for pre-schoolers. The motivation of this research is to create a game that has characteristics of a toy where children require bodily engagement with the objects to enhance their cognitive processes to effectively develop language skills. The research proposed and developed a novel game system underpinned by the interactive technologies. The game is evaluated by three methods: paired t-test is used to determine the overall performance of the proposed game; the 90/90 standard evaluation is also applied to see whether if the game is used for formal education the majority of the group (>90%) will achieve the objective of learning. Also, the feedbacks from expert validation are collected. All three evaluation methods indicate the primary success of the game is to assist Thai pre-schoolers in improving their skill at a young age.

KEYWORDS

Tangible User Interface, Interactive game, E-learning, Child development, Receptive language

1. BACKGROUND

Child development testing is a measurement conducted to evaluate development of children at a certain age covering several aspects including language, fine motor, adaptation, gross motor, personal and social aspects. Several studies conducted over many years indicate that the most frequently occurring development delays in Thai children involve language development (Voramongkol and Wongdejakul, 2011, Jintana, 2015, Pongpol, 2014).

Developmental problems of children can associate with many problems in their future such as risk of academic failures, behavioural and psychiatric problems, unemployment and economic and social impairment (Bishop, 2014). However, a golden period of language development exists as brain research indicates that children would gain biological advantage to learn foreign languages in pre-primary or primary school (Hinton et al., 2008).

A child's development is usually progressed from their activities and parenting. Play is a primary activity of children contributing several aspects to child development such as the cognitive, physical, social, and emotional well-being of children and young people (Goldstein, 2012). Also, many studies have reported that knowledge can be created when children play (Plowman et al., 2010). In addition, play is a means to improve language in fun and supportive ways (Oddo et al., 2013).

Nowadays, children grow up with the new era of Information Technology (IT) and new kinds of media and toys. This is inevitably affecting the way children are fostered and play. There are several studies showing evidence that interactive digital media can enhance language development skills such as boosting children's vocabulary skills and their acquisition of spelling and reading/writing skills as well as improving word recognition and word creation (Lieberman et al., 2009). The digital media presented as digital toys can provide catalysts for new forms of child play and augment the content of traditional play to bring challenges as well as opportunities to early childhood education (Meyer, 2012). With a bodily engagement, abstraction learning of children can be improved (Resnick et al., 1998). This has an association with the Piagetian developmental theory on the manipulation of concrete physical objects in supporting and developing thinking, particularly in young children.

Currently, computer games are widespread play things for children. Education games are a genre of games that has a purpose of offering benefits of child learning and development rather than just fun. This type of game is considered as one of the effective channels that can enhance language learning as they can increase intrinsic motivation, and provide meaningful exposure to the target language (Meyer, 2012). This study is motivated by the study of Hengeveld et al. (2008) where physical interfaces are integrated into the computer game to amplify the advantages to intervene in the development of toddlers with multiple disabilities. The major benefits of this system compared to the familiar PC interface were that it was closer to the usual style of exploration of children and enhancing their concentration (Hengeveld et al., 2008). This system also offered the practical benefit of slowing down the interaction of children with computer interface and creating the human-to-human interventional environment between children and caregivers (Hengeveld et al., 2008).

Jamil et al. (2012) identified that the majority of the current literature on the study of using digital objects for child-development intervention is based only on cases in Western countries; there is little understanding on how children in other parts of the world who are living in different cultural settings interact with digital objects.

The motivation of this study is to implement and investigate the solution of a physical and interactive game that can improve language recognition skill in both Thai and English for Thai pre-schoolers at the same time they enjoy play without being forced to learn. The rest of the paper is outlined as follow: Section 2 provides the background of child development; Section 3 reviews the current research in this area; Section 4 explains the design and implementation details; Section 5 discusses the method to verify and validate the proposed system and finally, Section 6 is conclusion and future work.

2. CHILD LANGUAGE DEVELOPMENT

Normal development of language is predicated on the infant's ability to hear, see, comprehend, remember and socially interact with others. Language processing requires defined and precise neuronal networks. Language skills are divided into receptive and expressive language (Kliegman et al., 2016). While the receptive language (auditory comprehension/ understanding) is the ability to comprehend complex constructions, function words, nuances of speech, and extended blocks of language, the expressive language (speech and language production and/ or communication) is the ability to recall required words effortlessly, control meanings by varying position and word endings, and construct meaningful paragraph and stories.

Nonverbal communication of children such as emotional expression starts from 7 months old. At the age of between 8 -10 months, they start babbling. At 12 months children can express the first true word (a sound refers to specific object or person) at the same time they can respond to several simple statements such as "No", "Give me". At 18 months they can speak around 10-15 words then 50-100 words in the 2nd year. From 2-5 years old, children will have rapid development in their words increasing from 50-100 to more than 2,000 words. After acquiring a vocabulary of about 50 words, they begin to combine them to make simple sentences, the beginning of grammar. Finally, at around 4-5 years old, they can use sentences that include details and communicate easily with most sounds made correctly and use proper grammar(Kliegman et al., 2016).

Language disorder can be defined as an impairment in comprehension and/or use of a spoken, written, and/or other symbol system (ASHA, 1993). Language problems not only affect communication with other people but also the ability to learn such as reading, writing and mathematics. Common speech and language disorders include developmental dysphasia, autism and pervasive development disorders, also Asperger syndrome and isolated expressive language disorder (Kliegman et al., 2016). Children with language impairment are prone to have not only poor academic achievement and social problems but also parental anxiety. Then it is very important to detect the language problems early and provide the most effective intervention.

There are many accurate screening and surveillance tools. Developmental Surveillance and Promotion Manual (DSPM) is one of the most recognized medical batteries for monitoring growth and development for Thai children (MOPH, 2016). DSPM guidebook contains the content of normal standard development for age and provides a recommendation for parents to stimulate their children for better development. It is also notably recognized that children's motor skill is associated with language skill. Ross et al. (2018) indicated that in 18 month old premature children with normal motor development have a higher score of expressive language.

3. RELATED WORKS

Computer games are common play things of children in this digital age. There are some games especially dedicated for language skill development of pre-schoolers. For instance, "My name is Haas" is a game that creates a playful learning environment for children aged 3 to 7 having the purpose to increase young children's vocabulary as well as story comprehension and

problem solving skills (Schuurs, 2012). "weMakeWords" is a game that has an aim to make children learn to read through motivating stories (Demmel et al., 2011). For example, in the mission to save the animal in the game, they are asked to combine alphabetical words or Chinese ideographs out of individual letters (Demmel et al., 2011). Agudo et al. (2007) developed a Web-based adaptive hypermedia system called SHAIEx focusing on the adaptive mechanism of the game that fit user background such as educational level and the psychomotor skills captured from mouse interaction.

Alongside the progress of computer game development, several researchers focus on investigating the new use-cases of emerging embedded and immersive technologies. The outcome produced from this research direction usually turns out as physical learning aid products. For example, Movellan et al. (2009) developed a low-cost sociable robot which operate autonomously to be used at an Early Childhood Education Centre for a period of 2 weeks to assist children gaining vocabulary; the results showed children learn more than 27 % of the target words taught by the robot. A similar approach was conducted to support children to learn a new language (i.e. Spanish) while the robot can be controlled via a tablet (Westlund et al., 2015), The reversed approach of using robot was used in (Tanaka and Matsuzoe, 2012) where Japanese children are motivated to practice using English to commute with robot .

Augmented Reality (AR) is another tool that can enhance learning experiences of children. Rambli et al. (2013) designed an application of AR to teach the alphabet to pre-school children such that they can view the alphabet in a funnier and interactive manner. Tekkesinoglu et al. (2013) implemented web-based AR leading children through a virtual zoo by viewing 3D animal models to let them learn the names of animals.

Local identification technologies such as Radio Frequency Identification (RFID) and Near Field Communication (NFC) are deployed to support building up vocabulary cognition of real life objects in the living environment (Jeong et al., 2015, Lee and Doh, 2013). NFC application was also implemented to assist pre-schoolers starting to read starting from recognition of letter and names (Riekki et al., 2013).

There are a few efforts evidenced from the literature indicating the employment of physical controllers, other than typical peripheral devices, to games. Sensors and actuators are utilized to generate tangible game interfaces to create toy-like feelings with the aim to immerse users into the game. Wang et al. (2014) proposed a Story Cube which is children's storytelling tool in a 3D environment. The tool has a controller integrated several tangible inputs and sensors including button, joystick, RFID, and accelerometer. Another story telling tool called Story Tech offers children a mixed reality environment in which to tell imaginative stories using RFID tags attached to plush dolls (Kara et al., 2014). Hengeveld et al. (2008) explored a language development system for toddlers with multiple disabilities aged between 1–4 years. The study demonstrates the evolution of developing three different tangible interfaces.

This study integrates the tailor-made controller to associate with the game for a unique experience to improve language cognitive skill of pre-schoolers. The implementation details are outlined in the Section 4.

4. DESIGN AND IMPLEMENTATION

The important challenge of this research involved designing and implementing a game system for the specific type of users. To be precise, young children have limited ability and experience interacting with the computer system. Another challenge is that the game will lead the user to achieve the aim of improving language recognition skills. The design of the system is intended to meet these two requirements. In general, the User eXperience/User Interface (UX/UI) design for children follows the guideline of Hourcade (2008) as shown in Table 1.

Table 1. General principle of interactive design for children (Hourcade, 2008)

Interactive design principle
1. Minimize using Text and using Icon instead in particular for children who are pre-literate.
2. Minimize visual complexity of the user interfaces
3. Deploy direct manipulation which is: visibility of objects and actions of interest; rapid, reversible, incremental actions
4. Providing menu for actions
5. Avoid using text-based interaction i.e. typing
6. Choose the most appropriate pointing input device for children
7. If a mouse is used as a pointing device, consider the following guidelines a. be aware of inaccurate click; b. expect an unexpected click such as "machine gun style" click; c. compound action such as drag-and-drop can be a challenge, d. the speed of the curser shall be slowed down e. Use only one button or enabling only one button to control the system (the experiment left button outperformed the right button)

The game developed for this research is entitled "Kid Society". It is functionally designed based on the Developmental Surveillance and Promotion Manual (DSPM). The battery covers five areas of developmental monitoring including Gross Motor (GM), Fine Motor (FM), Receptive Language (RL), Expressive Language (EL), Personal and Social (PS) (MOPH, 2016). This research investigates the solution focusing on RL improvement for pre-schoolers (children aged from 3-5 years old). DSPM suggests the protocol to practice to gain certain skill together with guideline to operate them. The training activities for selected skill (RL) for 3-5 year children are indicated in Table 2. They are used to map to the game for the game's mechanical design of the system.

Table 2. DSPM guideline for receptive language skill evaluation (MOPH, 2016)

RL Skills	**DSPM**
Continuously perform 2 actions with 2 objects	1. Put 4 items in front of the children at a reachable distance then ask the children to perform 2 actions. 2. Shuffle the items. 3. If children cannot perform the action, change the command **Pass criteria**: child can perform successfully at least 1 out of 3 attempts
Able to differentiate between large and small items	1. Prepare set of items by making sure that all items are not located in the order of size 2. Select the item that has a middle size among the group, then asking a question "which item is larger/smaller than this one?" **Pass criteria**: children can perform successfully at least 2 out of 3 attempts
Able to differentiate between day-time and night-time	1. Prepare one picture to indicate day-time, and one picture to indicate night-time, and then ask a question "which one is a day-time picture?", and "which one is a night-time picture?" 2. Ask a child to choose 3 times, each time swap the pictures **Pass criteria**: child can perform successfully at least 2 out of 3 attempts
Able to differentiate 8 different colours	1. Prepare 10 coloured blocks, and ask a child to choose each colour of block. When each selection is finished, return that block to its position **Pass criteria**: child can select all colour of block correctly

Regarding Table 2, there are four objectives to achieve, and this research introduces four computer games mapped to each learning objectives of RL skills.

The user interface design is one of the most challenging processes of this research. Not only because the system is to be designed for a specific user group, but the system also has the key and extra requirement to attract users to use the system with enjoyment. There are 2 parts of the interface to consider which are the game software interfaces and the physical interface which is also known as a game controller. The interfaces design was conducted iteratively as follows:

Iteration 1: The design process was started from drafting a game sequence through a wireframe to show the coherence of the idea. A rough UI for each screen was sketched as shown in Figure 1.

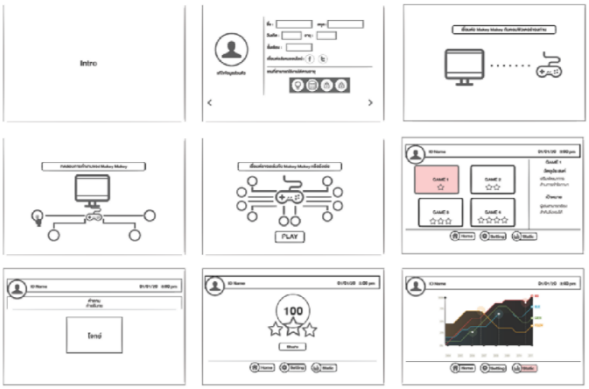

Figure 1. Wireframe sketch of the system

Phase 2

As it was indicated that the game for small children should immerse children in play with this toy, the strategy of the research is to build a game interface encouraging children to have look and feel as they are interacting with toys. During the brainstorm process, several commercial peripheral technologies were raised, but eventually it ended up with the strategy of proposing a tailor-made controller to maximise the learning outcome of the children. The expected layout of the controller was sketched as indicating in Figure 2. Then, the sensory devices to operate the controllers were considered. This study selected the Makey Makey that has the key feature of turning everyday-life objects into touchpads.

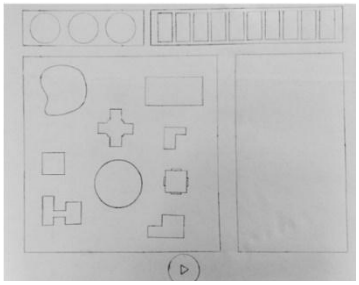

Figure 2. Sketch of the controller

Phase 3

The sketch of the controller and games was implemented and they were integrated into the computer game. The developed controller was tailored to operate the four mini games that are designed based on the DSPM guidelines discussed in Table 1. There are four types of buttons which are 1) a group of buttons that are embedded to operate as switches to trigger the action when the shapes are located to the correct position, 2) a confirm/forward button, 3) a group of buttons to represent the direction (i.e. Left, Centre and Right), and 4) a group of buttons for

colour section. All buttons have extended their functions from the Makey Makey. The proposed controller is identical; to make sure that a player can play the game. The tutorial on how to use the controller to play the game is also provided at the beginning of the game. The developed controller of the game is depicted as Figure 3.

Figure 3. Controller of the game system

The game system contains four mini-games designed to associate with the developed controller. In general, the story of the game is progressed through a girl intentionally designed to have a similar age to players. The girl will challenge a player to perform certain tasks indicated in DSPM using the voice instructions. During the play, when a player answers a question/performs the correct action; applause is given as a small reward to a player. Otherwise, an encouraging sound will respond back to encourage a player to try again. When players can achieve the mission of that mini-game, the game will lead the player to the new game. The interfaces of the four mini-games which are associated with the proposed controller are illustrated in Figure 4.

Figure 4. Game interfaces

The details of four mini-game games are:

Game 1: A player is encouraged to build a town using jigsaw-like 3D-items representing basic objects and places in everyday life such as car, tree, house, market and zoo. A player will ask for one vocabulary item at a time, and he/she is required to pick the items (by pinching) to locate in a block. Only correct items can be used to fill in the block. If a play selects the correct item, a switch located underneath the item will be activated to give a response back to the players. The system will teach vocabulary and the pronunciation of the word in both English and Thai. The tangible interface of this game is demonstrated in Figure 5 when a user is asked to locate a bus to a block.

Figure 5. Demonstration of using physical interface in game 1

The design of the game also takes into account the updateability of a new set of vocabulary. The surface of the board is designed to be replaceable. When children have already leant the vocabulary of particular domain, the new sets of vocabulary in other domains can be used as replacement as shown in Figure 6.

Figure 6. The new set of vocabulary

Game 2: This game has an objective to encourage children to achieve the identified goal of DSPM in which he/she shall be able to differentiate between the item that has larger and smaller sizes. Three choices of items are provided on the screen and a player is asked which item is larger/smaller than the other. The selection will be made by the controller type 3.

Game 3: This game has an objective to encourage children to achieve the identified goal of DSPM in which he/shall be able to differentiate between day-time and night-time. The game will randomly show the picture indicating a night-time or day-time, and asking children to use type 3 controllers to answer the questions.

Game 4: This game has an objective to encourage children to achieve the identified goal of DSPM in which he/shall be able to differentiate 8 colours. Three pictures of things having different colour is shown, a player is asked what colour of the specific item has. A player uses a controller type 4 to answer this kind of question.

Another game component includes a scoring system to evaluate the performance of players and to test that a child can pass the DSPM test. The score can be viewed per mini-games, record a statistic to analyse the progress of learning, and can also share the results to Facebook to motivate other children/parents and to build up society. The scoring interface is shown in Figure 7.

Figure 7. The scoring interface

The game also has administration menu for flexibility to expand and adjust the content of the game. The software is designed to allow new vocabulary and can be updated to associate with the new tangible items (i.e. in game 1). New pronunciations can also be re-recorded together with new graphics to be added as well.

5. VERIFICATION AND VALIDATION

The implementation of this project is under the supervision of two experts who have strong experience about child development. The background of the experts is listed in Table 3.

Table 3. Issue detection and action conducted to improve the system

Qualification	Expert I	Expert II
Position	Registered Nurse (Experienced level)	Registered Nurse (Operational level)
Academic degree	M.N.S. (Psychiatric and Mental Health Nursing)	B.N.S
Working experience	1) Working at an Institute of Child Development 2) 20-years' experience 3) Child development trainer in the use of several Thailand guidelines including TDSI DSPM TEDA 4I	1)Working at an Institute of Child Development 2) Child development trainer in the use of several Thailand guidelines including TDSI DSPM TEDA 4I

When the first version of the system was developed, it was then first evaluated by the experts. The comments received from the experts who were used to improve the implementation are:

- The icons in the games should be larger.
- The pictures indicated night-time and day-time in the game should have more variation and indicate common activities or atmosphere of the famous festival.
- The result page, it should not indicate that the result is either pass or fail. If the score is lower than the standard it should indicate a message to encourage children to practice by playing more instead.

- The system should provide more guidelines on which controller should be used for specific game i.e. showing the picture of the controller to use on the screen.

The verification was also conducted by trying the drafted prototype with representative of three to five year's old pre-schoolers (1 representing each age). Then, the field observation was conducted to capture the User experience to detect the problems from the design to improve them. The results from the field investigation and the improvement actions are provided in Table 4.

Table 4. Issue detections and actions proceeded to improve the system

Issues	**Actions**
1. For the game 1, a player can select the item correctly, but be confused to locate the block where the selected item is fitted as the boundary is unclear	1. Make a boundary of each block more obvious using space and colour
2. A child may be over-enthusiastic about the game kit when he first sees it, he/she is distracted by the game items before the game can start	2. Modify the game package to have a cover sheet such that a caregiver controls opening the box when a child is ready.
3. Sometimes a child cannot pick up words and cannot manage to repeat the word in time	3. Slow down the speed of the game especially the speech
4. A child has a difficulty to reach a far-end of the controller	4. Adjust position of buttons so that small children can reach them all

After the modification was made from the verification procedure, the evaluation was conducted at the kindergarten in Chiang Mai, Thailand. There are fifteen participants broken down into five of kindergarten level 1 (3 year's old), five of kindergarten level 2 (4 years old), and five of kindergarten 3 (5 years old). They were invited to play the game then; the results were recorded for analysis by 3 evaluation methods.

First, a paired-t-test was used to examine whether a child who plays with the game gains better receptive language skill. The Pre-test was conducted to measure the skill of the group before the intervention by playing the proposed game. The Mean of the Pre-test is 28.87 and the SD. is 3.29. Children are then asked to play the game and after the Post-test is conducted and the mean has risen to 31.60 with the SD =3.29. Both Pre-test and Post-test were tested for normality and they are normally distributed. The analysis results in Table 5 show that the P value < 0.01 which indicates the effectiveness of the intervention by the proposed game.

Table 5. Paired t-test result

Score	**Mean**	**SD**	**T**	**P value**
Pre-test	28.87	3.29	3.030	0.009
Post-test	31.60	2.06		

The second evaluation was analysed having a purpose to explore the feasibility to apply the proposed system for formal education in a school. One of the most recognized evaluation methods for instructional material and media in Thai academic society is the 90/90 Standard (Kumut, 1976).The main principle was underpinned by the Mastery Learning theory stating that everyone can learn if appropriate learning environment is arranged and adequate time is supplied (Yamkasikorn, 2007). The first 90 indicates the average score in the percentage of the group. The second 90 indicates the percentage of the learners who can achieve every objective of the lesson (Yamkasikorn, 2007) cited (Kumut, 1976).

The evaluation was conducted by allocating the game to each player adequately (approximately 15-20 minutes). Players can explore the system freely under the observation of the research team who provided the guidance and assisted the players in using the developed game system. Then, the players are evaluated in their learning outcome again. The evaluation result found that the average score of the participant is 95.75%. Also, the number of the players who can pass the receptive language test is 14 out of 15 equivalent to 93.33% (to pass the test, the DSPM requires children achieve at least 3 out of 4 activities). The score 95.75% and 93.33% are both higher than 90/90. Therefore, it can be concluded that the developed game achieves 90/90 standard.

The final evaluation investigates the effectiveness from the experts' point-of-view. The two experts who are the consultants of this project invited their colleagues to join the evaluation. The evaluation measures the satisfaction of the system in several aspects using a Likert scale (1-5). The summary of the evaluation result is shown in Table 6.

Table 6. Result of expert satisfaction evaluation

Satisfactory criteria	Average score
Game mechanics and interactivity	3.52
Game administration system	3.83
The Proposed game controller	3.22
Look and feel	3.55
Total	**3.53**

The game achieved relatively high satisfaction from the experts using the Likert scale evaluation. The experts judge that the best part of the proposed game is the system administration part where the new set vocabulary can be added to provide flexibility for tweaking or amending the game content in the future. However, the evaluation result indicated the lowest score in the physical interactive controller which will require further research to improve it.

Additionally, this game apparently contributes extra benefit to the child development apart from the primary goal to improve language skill as in the game 1 children are required to have a tangible interaction of grasping the objects and locating objects to the blocks, and this encourages children to practice and develop their fine-motor during the play.

6. CONCLUSION AND FUTURE WORK

The research proposes a physical interactive game having the primary aim to enhance receptive language skills of Thai pre-schoolers. The game has the purpose to teach series of vocabulary in everyday life through play following DSPM guideline. The game consists of three components. The proposed controller is identically tailored from Makey Makey. The 4 mini-computer games that can share the results to Facebook and finally the administration component allows vocabulary to be added and parameters that can be modified.

The game development is under the supervision of experts and the game is evaluated with 15 children in kindergarten school of northern Thailand. The evaluation results indicated that the game can be used to enhance the receptive language skill of children .Plus, it is possibly used for formal education as the proposed game system can support the majority of the group (>90%) to achieve the ultimate aim of language learning. Moreover, the evaluation by the experts showed that the proposed system achieve overall satisfaction.

The additional contribution of the system to child development apart from the language skill has apparently occurred as well. In game 1 children are required to have a tangible interaction of grasping objects and locating objects to the blocks, this encourages children to practice and develop their fine-motor skill during the play.

However, the results from the evaluation also indicated that further research will be conducted to improve the system. For example, although the result of the expert evaluation indicated that the satisfaction with the system is high; the satisfaction with the proposed controller is relatively lower compared to the other aspects. Further research will be focused on the improvement of the design and functionalities of the interface of the controller to be more effective for learning of pre-schoolers. This opens up new focuses for future work. Research on the Natural User Interface (NUI) will be conducted to enhance the user experience of this system. Similar research direction regarding the NUI is the study of (Martin-SanJose et al., 2017) where comparative research of the 2 NUIs for education games are tested with 7-11 year ‘s old. Ultimately, this research project is aimed at contributing an effective DSPM digital game system to substitute the manual guideline where children enjoy play and to provide high effectiveness to improve language recognition skills.

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