

USER-DEFINED MULTIMODAL INTERACTION TO ENHANCE CHILDREN'S  
NUMBER LEARNING

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## DEDICATION

*To  
all my family members, friends and my supervisor  
who support me spiritually throughout my life*

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## **ABSTRACT**

Children today are already exposed to the new technology and have experienced excellent number learning applications at an early age. Despite that, most of the children's application softwares either fail to establish the interaction design or are not child-friendly. Involving children in the design phase of any children application is therefore essential as adults or developers do not know the children's needs and requirements. In other words, designing children's computer applications adapted to the capabilities of children is an important part of today's software development methodology. The goal of this research is to propose a new interaction technique and usability that evaluates children learning performance of numbers. The new interaction technique is designed by participatory design in which children are involved in the design process. A VisionMath interface was implemented with the user-defined multimodal interaction dialogues which was proposed to evaluate the children's learning ability and subjective satisfaction. An evaluation with 20 participants was conducted using usability testing methods. The result shows that there is a significant difference in the number learning performance between tactile interaction and multimodal interaction. This study reveals the proposed user-defined multimodal interaction dialogue was successful in providing a new interaction technique for children's number learning by offering alternative input modality and potentially providing a rich field of research in the future.

## ABSTRAK

Kanak-kanak hari ini sudah terdedah kepada teknologi baru dan mempunyai banyak aplikasi pembelajaran matematik pada usia muda. Namun, sebahagian besar perisian aplikasi kanak-kanak gagal untuk mewujudkan reka bentuk interaksi atau tidak mesra kanak-kanak. Oleh itu ia sangat penting kerana orang dewasa tidak mengetahui keperluan dan kehendak kanak-kanak. Dengan kata lain, mereka bentuk aplikasi komputer kanak-kanak yang disesuaikan dengan keupayaan kanak-kanak merupakan bahagian penting dalam metodologi pembangunan perisian masa kini. Matlamat kajian ini adalah untuk mencadangkan teknik interaksi dan kebolehgunaan baru yang menilai pretasi pembelajaran matematik kanak-kanak. Teknik interaksi baru direka oleh reka bentuk partisipatif di mana kanak-kanak melibatkan diri dalam proses reka bentuk. Antaramuka VisionMath dilaksanakan dengan dialog interaksi multimodal yang ditentukan pengguna yang dicadangkan untuk menilai kemampuan belajar anak dan kepuasan subjektif. Penilaian dengan 20 peserta dijalankan dengan menggunakan kaedah ujian kebolehgunaan. Keputusan menunjukkan bahawa terdapat perbezaan yang signifikan dalam prestasi pembelajaran matematik antara interaksi sentuhan dan interaksi multimodal. Kajian ini mendedahkan bahawa dialog interaksi multimodal yang dicadangkan oleh pengguna berjaya menyediakan teknik interaksi baru untuk pembelajaran nombor kanak-kanak dengan menawarkan modaliti input alternatif dan berpotensi dalam pelbagai bidang penyelidikan pada masa akan datang.

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## LIST OF ABBREVIATIONS

BEACHES	-	Behaviors of Eating and Activity for Children's Health
BMI	-	Body Mass Index
CCI	-	Child Computer Interaction
CSCW	-	Computer-supported cooperative work
HCI	-	Human Computer Interaction
HFS	-	High Fidelity Simulation
IDC	-	Interaction Design and Children
I/O	-	Input/Output
OSRAC-H	-	Observation System for Recording Physical Activity in Children home version
SUS	-	System Usability Scale
TV	-	Television
WIC	-	Women, Infants and Children
WOZ	-	Wizard of Oz

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Overview

Learning number remains extremely important around the world (Cipani, 1988). Many researchers and educators assert that number knowledge should be developed as early as prekindergarten or latest in kindergarten before entry to school where formal learning occurs (Levin, 2006). Recently with the emergent of multimodal interaction technology in children-computer interaction has been getting researchers and educators' attention as an interesting alternative and exciting ways of creating teaching and learning tools. Despite this, very few have explored its use in the number learning. Unlike the traditional method of interaction using mouse and keyboard, the multimodal metaphor to interact with application or system in natural way (Forceville, 2009). Being different from the traditional interface method, this will naturally grab the student attention (Turk, 2014). To educate young child is a challenging endeavor by enhance interaction performance thus engagement and motivation children in learning education technology. Children's requirements are different from adults. Therefore, children may play a significant role in the technology design process. Hence, this research will proposed a suitable interaction style of input modality or combination of more than one input modality by involving children in designing phase to enhance children learning performance and usability for number learning interface.

## **1.2 Background of the Problem**

From the year 2010, the Malaysian Education Ministry had introduced KSPK (Kurikulum Standard Prasekolah Kebangsaan) in preschools. Based on National Preschool Curriculum Standard, learning involves 4M (Membaca, Menulis, Mengira and Menaakul) which is reading, writing and counting and reasoning. However, there are no standard textbook and an examination which had been standardized using in all preschool in Malaysia. This is due to Malaysian preschool being developed and operated by different agencies such as KEMAS, PERMATA, JPNIN and private institution (MCA, PAS, ABIM, SC etc.), which are actually operated by political parties (Putri et al, 2005). In this context, standardize learning material and syllabus is very important for Malaysia Preschool. In order to learn number, children need to know how to read, write, count and reason.

Researchers have proposed various learning pedagogy frameworks founded on holistic values and reflecting on math learning among children in terms of physical, cognitive and emotional features (Leonard and Moor, 2014; Aguirre and Zavala, 2013). Various cognitive practices, emphasizing on extensive activity and multisensory learning, worry for self-esteem among children as well as their learning agency, varied home practices and supportive group conditions are known as key aspects. It is imperative for teaching methods to consider the above aspects, such as through evading direct questioning.

Previous researchers show that about 5% to 8% of student having learning disability in using and mastering the number concept and skill (Geary, 2004). A study by Fischer (2011) and Fischer (2013) showed that almost all of 4 to 6 year-old children have tended to reverse letter writing. For instance, children write number four as number 3. There are several factors causing the ineffectiveness number learning among the children. These several factors may be as a result of the development of textbooks and education materials fail to design a complete critical concept of number understanding (Stood and Jitendra, 2007). However, learning through flashcards may help overcome this challenge. This is because this technique

is effective in memory-aid tool that can help in learning new knowledge quickly no matter what age.

According to Nakata (2011) and considering an ELT poll, the results indicated that 93% of teachers agreed that flashcard technique could help student in learning. Studies have proven flashcard technique was effective and beneficial in educational domains and suggested to be employed by many researchers (Van and Rolider, 1989; Glover *et al*, 2010; Mann *et al*, 2012; Li and Tong, 2018;). In this age, although the touch screens technology and handheld device had been rapidly grow, input modality such as computer mouse and keyboard are still extensively employed. Child Trends Databank had reported the percentage of children ages 3 to 17 in using computers had steadily increasing (Child Trends DataBank, 2015). This is due to extensive use of computer as one of the education tools in the schools. Computer technologies are beneficial for those users who are well known in the application of those tools and hardware.

Previous researchers had determined that computer mouse is the most suitable indirect input modality for children in controlling the computer (Donker and Reitsma, 2007, Wood *et al*, 2004). Nevertheless, there is still a lot of error and problem interrupt in existence when children interact with computer, hence cannot be ignored. Additionally, Kino and Read (2009) show that a vast majority (average of 84%) for both young student (aged 6 to 10 years old) and undergraduate computing student issue with Zero Time keystrokes problem. This is due to miss aim of the finger or one finger pressing two keys at the same time. Therefore, several researchers have focused on designing a suitable task in using computer mouse to overcome the limited motor skill of children. However, computer mouse only have three buttons and can only perform simple tasks. Due to the increment in development of technology, multimodal interaction has become popular used and employ in our daily activity in this decade. But people are not aware of this technology (Hegedus and Moreno-Armella, 2011).

As stated by Jaimes and Sebe (2007), Multimodal interaction is a combination of more than one input modality to interact with technology in order to

perform the task. Many developers and researchers have engaged a discussion concerning the use and integration of multimodal interaction into the education technology (Hegedus and Roschelle, 2013). A new interaction method, the tabletop interaction, has been proposed by Marco et al (2009) suit for kindergarten children to interact in tangible game. However, tabletop interaction are less common fix for kindergarten children, since children less than 6 years old are required to find hand control for interaction and this has not been achieved, while also education materials remain an expressive tool (Mansor et al., 2008). In other study, Danli et al (2008) combined pen-gesture and speech as multimodal interaction pattern for children in 3D storytelling system and evaluation on usability of the system are satisfying. Also, Jennifer et al. (2011) show that combination of speech, pen-touch in AmbiLearning could enhance the learning environment with interest, fun and their language ability. Multimodal learning is not only a usefully tool to be carried out as an alternative input modality for traditional interface, but it also assists in improving the efficiency, accessibility and usability of the system (Jacobson and Sam, 2006). Each of these researchers had introduced and proposed different interaction techniques in their system.

Besides that, previous researches had proven that multimodal interaction is useful in improving the efficiency, accessibility and usability of the system. Unfortunately, most of the application either fail to establish the interaction design or are not child-friendly. This is due to involve children in design stage are excluded and children's requirements are different from adults. Therefore, child's requirements and needs should be taken into consideration for number learning interface to overcome this issue and adapt new input technique that suitable to children interaction.

### 1.3 Problem Statement

Number had been used and important in our daily life. However, some children have shown difficulties in mastering the concept, skill and writing (Geary, 2004; Fischer, 2010; Fischer, 2011; Fischer, 2013). Furthermore, Malaysian Preschools do not have standardized learning material and syllabus for children and are operate by different political parties. Therefore, there is a challenge to identify and design the learning content that is suitable for children towards the improvement of children number learning.

Traditional input such as keyboard and computer mouse are not child friendly, children tend to concentrate in interact (move and control) with the input devices more than learning. From the previous literature suggestion and contribution in determining the issue although the development of touchscreen and handheld device technology has rapidly grown, there is scarcity in the use of computer-aided tools at schools and home as a teaching and learning environment (Donker and Reitsma, 2007, Akiya and Janet, 2009, Wood *et al*, 2014). But the study on multimodal interaction in number learning is limited. Therefore, there is a key challenge in the design of a new interaction technique which is easy to use and natural and significant in enhancing their ability to learn with computer technology.

Current technology was design based on adult or developer. There is no perfect design and do not fulfil children's requirement and need. Yet by involving the children in design and develop is challenge due adult or designer do not really know what children needs. Appropriate interaction for each activity in learning number is one of the concerns. Therefore, the third challenge is to identify children-defined dialogue for learning number activities by classification of hand gesture and speech to optimize the solution for maximizing the usability and children experience.

Based on the study, the research questions relating to this study include the following:

- i. What are the suitable relevant contexts for children numbers used for teaching and learning number that have been proposed to date?
- ii. What are the technological problems and limitations facing on children, when they learn with or without education technology?
- iii. Can a new multimodal interaction technique be proposed to enhance children number learning performance and subjective satisfaction?

#### **1.4 Research Objectives**

The main research objective is to propose a new interaction technique and increase the usability of children learning performance of numbers. In order to achieve this goal, a set of specific objective are listed below

- i. To identify the children study behavior on learning number using current interaction mode with computer.
- ii. To derive a children-defined dialogue multimodal interaction for children learning of number.
- iii. To design and evaluate a new multimodal interaction technique for children learning of numbers on their learning performance and subjective satisfaction.



## 1.5 Research Scopes

The scope of this research focuses on the following:

- i. The curriculum of learning number by focusing on Malaysia.
- ii. The study sample comprised of children aged 5 to 6 years, since it's during this age that children start to learn read, write, count, and reason academic wise in preschool. We constrained our participants in this specific age group so as to ensure the formation of a relatively homogenous group, thus minimizing some of the effects of age difference and validating the generalizations. By making the differences between the youngest and oldest children in the research smaller, the researcher was able to come up with an age group with children of very similar capabilities, therefore it was decided to narrow the age group down to 5-6 years old to the sampled children. This means that the youngest children have just turned five years old while the oldest children have not yet turned six years old. In the remaining sections of this thesis the phrase "between five and six years old" will be used to indicate this chosen age group. Children between five and six years old form a very interesting group for this thesis because according to Hanna *et al* (1997) they may require extensive adaptations of traditional usability testing. Furthermore, many children in this age group already play computer games quite often, making it important to include them in the evaluation of games. From one hand, the children in this age group cannot read very well, they are impulsive and reactive in their approach to the world, rather than logical, reasonable, or reflective, and they may have difficulties verbalizing their thoughts when talking about computer learning. On the other hand they are suitable participants for participatory Design practice because they can concentrate long enough to perform an evaluation in a usability lab or at school.

## **1.6 Significance of Research**

The research is integrating multimodal interaction into children number learning tool. The proposed of the multimodal interaction technique contribute in child-computer interaction and educational technology domain. Moreover, learning number is very important and we use it in our daily life around the world. Learning writing through technology expected could solving children handwriting issue such as mirror writing and reverser direction writing.

A literature review and small-scale children study on children issue and needs in learning number with and without technology to determine children needs in number learning interface. Multimodal interface is also important employ in education system to improve the interaction performance between children and technology. Hence, expect the proposed technique can increase the usability of the system and reduce the interaction problem between children and computer. Furthermore, this technique can be applied and use in any related fields such as argument reality, virtual reality and so on.

Based on this study, the outcome of this research contributes in current multimodal interaction technology and education domain. The significance of this study not only enriches the learning knowledge but also help in their daily life in the society,

## 1.7 Organisation of Thesis

There are seven chapter had structured in this thesis as follow:

- i. **Chapter 1** present overview the children number learning with and without technology, research background and problem of this research. In this chapter it also discuss research aims, objective, scope, contribution and outline for each chapter.
- ii. **Chapter 2** provides the literature review on the previous and existing work. The Malaysia preschool curriculum, flashcard learning, multimodal interaction and usability will present and discuss in this chapter.
- iii. **Chapter 3** describe step-by-step phase of research design in research methodology. This includes task description, activities, method, content delivery and evaluation measurement of the study.
- iv. **Chapter 4** presents the preliminary investigation result and the detail of designing a number learning context. In this chapter the proposed techniques suit for each number learning tasks had design.
- v. **Chapter 5** details of development of VisionMath prototype. This includes the task description and process of the model.
- vi. **Chapter 6** provides the result of the proposed technique used in children number learning interface and analysis are carried out based on their learning performance, usability and subjective satisfaction level on proposed input modality.
- vii. **Chapter 7** summarizes the thesis by enumerating the overall achievement, implication of the research. The discussion on the limitation of the study and suggestion for future work in education domain had presented.

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