Graspable Multimedia: A Study of the Effect of a Multimedia System Embodied with Physical Artefacts on Working Memory Capacity of Preschoolers

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ABSTRACT
Insignificant consideration in multimedia research has been given to the features that are associated with cognitive functioning in general, and working memory (WM) in particular for preschoolers. As correlational research works discovered a close association between WM and learning achievement, multimedia research works that are tapping into preschoolers' WM not only has the potential to improve preschoolers' academic performance, but also to close the gap in multimedia research on cognitive functioning. Baddeley's WM and learning theories justifies the use of physical artefacts as an outstanding means to complete the set of sensory input for information processing in WM. Thus the researchers designed and developed a genre of multimedia that combined the physical artefacts. As physical artefacts graspable and manipulable for concrete experience, the researchers designated them as "graspable multimedia". The researchers had conducted a research that inquired the potential of the prototype of such multimedia system, *GraspLearn,* into the WM of preschoolers. In the research, learning mode, *GraspLearn* and conventional multimedia (*CLearn*) systems were set as independent variable, WM capacity (WMC) as the dependent variable cognitive style (field-dependent and field-independent) as the moderator variables. Analyses on 248 preschoolers reveal that the *GraspLearn* system did not improve preschoolers' WMC significantly more than *CLearn*. Interaction analyses by cognitive style with learning mode reports relationship between learning mode and did not differ by cognitive style. The culmination of such research drew a prognostic of the shortfall in capacity of the graspable multimedia in realm of cognitive functioning of preschoolers.

INTRODUCTION
There has been a multitude of commercial multimedia systems developed, but very few of them attuned to preschoolers' level of cognition, such as insignificant consideration towards the design of interface that considers the capacity of working memory (WMC) of preschoolers in knowledge acquisition (Barnes, 2010). Piagetian Theory (1972, 1976) postulates that the cognition of children age eight years and below who are in state of pre-operational stage requires concrete experiences (Semmar & Al-Thani, 2015). Meanwhile there exists substantial confirmation that visual-spatial structure improves human's ability to recall words (Çöltekin, Francelet, Richter, Thoresen, & Fabrikant, 2017). Thus, the researchers are of opinion that by embedding physical artefacts into the scope of multimedia learning for preschoolers, the researchers are not only attuning multimedia system to preschoolers' cognitive functioning level, but also defining a feature in multimedia context potentially playing a role in WM performance. The researchers designated this genre of multimedia "graspable multimedia". A prototype of such multimedia named *GraspLearn*, which structures real-life physical artefacts as a vital part of instructional medium was developed for research. The finding of the research presented adequately in the paper would render us the degree of capability of the graspable multimedia system in WM elevation with the relevant population.

PROBLEM STATEMENT
Preceding multimedia research works associated with cognitive functioning primarily concentrated on memory retention (Dooley, 2015; Pant, 2006), reflecting a dearth of attention given to the probability of multimedia playing a role in WM enhancement. The problem pertaining to WM among preschoolers nowadays are that children younger than eight years tend to be less proficient in tasks that access WM than those who are 10 or 19 years old (Hale, Bronik, & Fry, 1997). Substantial research works demonstrated that working memory capacity (WMC) is trainable and can be greatly improved (Harrison, Shipstead, Hicks, Hambrick, Redick, & Engle, 2013;

Shipstead, Redick, & Engle, 2010; Londe, 2008). Meanwhile, multimedia has been proven accounted for fun and playing role in children education (Heidig, Müller, & Reichelt, 2015). Hence, a research which takes into account WM in general, and a multimedia system that capable of enhancing WM in particular, is of great necessity to preschoolers whose attention span and WM are weak (Conejero & Rueda, 2017; Hale, Bronik, & Fry, 1997). In recent times, there have been growing literature and research works concerned with WM tasks attempting to alter the WMC (such as *Cogmed* Working Memory Training program (Ralph, 2013; Chacko, et al., 2013) and *JungleMemory* (Alloway, 2012)) (Shipstead, Redick, & Engle, 2010). The research works show that on average, a person, including five to six years old child, is typically able to recall three to four words or digits (Szmalec, Brysbaert, & Duyck, 2012; Londe, 2008; Xu & Chun, 2006). The maximum units of information of memory capacity reported are seven, plus or minus two at a time (Miller, 1956). In this respect, it is interesting to investigate; does the capacity limit of WM of a preschooler remain at three, attenuated to less than three, or strengthened beyond the maximum capacity of nine units (seven plus two) after extensive practice using *GraspLearn*? As correlational research works revealed a close relationship between WM and academic learning performance (Esteban, Vivas, Fuentes, & Estévez, 2015; Torres-Fernandez, 2008; Oberauer, 2005), a multimedia system conducted with the intent of enhancing WMC not only has the potential to improve preschoolers' short- and long-term academic achievements, but also to fill the gap in multimedia research on WM performance.

OBJECTIVES OF THE RESEARCH

The primary objective of the research was to design and develop a graspable multimedia learning system (*GraspLearn*) capable of maximising working memory capacity of preschoolers in the learning of real-life knowledge in English as Second Language (ESL). *GraspLearn* is a unified instructional multimedia system that unifies the strength of digital multimedia expressions and physical artefacts.

RESEARCH QUESTIONS (RQ)

RQ1. Do learners of the *GraspLearn* system demonstrate a significant difference in their working memory capacity (WMC) (as measured by "objects-span tri-tasks" test) compared to the learners engaged in *CLearn* system?

RQ2. Is there any interaction effect in the dependent variables (WMC) between learners in the *GraspLearn* group as compared to the *CLearn* group with different cognitive style (field-dependent and field-independent learners)?

RQ3. Is there any significant difference in the dependent variables (WMC) between learners in the *GraspLearn* group as compared to the *CLearn* group with different cognitive style?

RESEARCH HYPOTHESES

There was no prior similar research. Hence, the research has null effects on the learners. The level of significance of the research, $\alpha = 0.05$.

H_01: There is no significant difference in working memory capacity (WMC) between learners using *GraspLearn* and those using *CLearn* system.

H_02: There is no interaction effect between the learning modes (*GraspLearn* and *CLearn* systems) and cognitive style (field-dependent and field-independent learners) on WMC.

H_03: There is no significant difference in WMC between field-dependent and field-independent learners in the *GraspLearn* and *CLearn* groups.

RESEARCH FRAMEWORK

A quasi-experimental factorial design was deployed to assess the utility of *GraspLearn* system in enhancing the working memory capacity of preschoolers. The research framework was summarised as follows.

Table 1: Research Framework for the research

Independent variable (IV)	Moderator variables (MV)	Dependent variable (DV)
Learning mode: • *GraspLearn* (unified with physical artefacts) • *CLearn*(without physical artefacts)	Cognitive style (field-dependent / field-independent)	Working Memory Capacity (WMC) score

There was a potential moderator variable (MV) which might offer contingent effects upon the cognitive style (DV). Each individual perform differently (Snow & Cronbach, 1977). Thus there is high possibility that the experimental systems yield different findings for learners of distinct personal and psychological profiles after a new component was incorporated into multimedia. Inclusion of cognitive style as MV allowed the research to identify whether preschoolers' interactions with physical artefacts in multimedia context were sensitive to cognitive style differences. Cognitive style and functioning can be found in children as young as two years of age (Kogan, 2013). Apart from that, their relationship and interaction information with WMC have an important implication towards the design of the experimental system aimed to be adaptive and customisable to the psychological profile of preschoolers. In the context of the research, a quality experimental system should not only be able to reduce the cognitive style gap in terms of memory performance, but also be able to ensure that there is equity in learning for distinct learners. If it is not for full range of learners, at least it should be able to meet the needs of majority of the learners.

THE THEORETICAL FRAMEWORK

To develop a multimedia system that is adapted to preschoolers' level of cognitive structure yet capable of enhancing their WMC, one possible way is to design a system in accordance with the theoretical underpinnings prescribed by Baddeley's (2006, 2004) WM theories (BWM). The WM theories are the over-arching theory of the research. It was the major source or reference for the problem statement, research instrumentations, and variables used in the research. The theory shed light on the idea that typical multimedia nowadays should engage physical artefacts as part of instructional medium. It justifies the use of physical artefacts as a good means to realise the engagement of primary senses of the human, particularly hands, that stimulating the WM in multimedia learning (Figure 1). With physical artefacts, the children will have the opportunity to directly hold artefacts with one or both hands, grasp, manipulate, move, and release. On the similar ground, Hengeveld, Hummels, and Overbeeke (2009), Antle, Droumeva, and Ha (2009) elucidate physical artefacts can give rise to mental images in children mind, and making abstract concepts visible, accessible and learnable. Due to the natural relationship between physicality and touch, physical artefacts greatly convey additional meaningful information about its context such as the softness and weight of materials (Wimmer, 2011) not perceivable visually. Klemmer, Hartmann, and Takayama (2006) said "... they (hands) allow for complicated movement but their skin also has the highest tactile acuity of our extremities" (p. 143). If learning is merely done through visual and auditory channels as in conventional multimedia, the children's cognitive functioning process to remember and make sense of the learning outside of children's immediate context will be weaker.

Figure 1. Realisation of touch engagement via physical artefacts

SIGNIFICANCE OF THE RESEARCH

The nature of the graspable multimedia does not demand the mastery of language and physical monitor skills for interaction with the computer. Thus, the success of the research created the potentials to suggest an alternative to the conventional multimedia systems for use in kindergartens to facilitate learning as well as in primary schools in Malaysia. In the event that the research revealed that the experimental system failed to attain the positive performance, it could provide clues to the specific problems of the learning system.

Another pragmatic area of significance was that the research deepened into the scope of research on multimedia by looking into the aspect of WM of learners, which is rarely conducted in multimedia research. *GraspLearn* was unified with physical artefacts; in the meantime, researching the development of the ability to maintain object representations in WM was a core studied realm of Piaget (Zosh, 2009). Though research directions are different, the similarity of attribute in the research domain throws light to the researchers that multimedia research could cover investigation across other domain, such as the field of cognitive psychology at large, and WM in particular, as in the research.

Lastly, the "objects-span tri-tasks" memory test was designed by the researchers for measuring the WM of preschoolers in multimedia learning. The graspable multimedia and memory test have strong theoretical base because they were designed based upon the WM theory. If no relationship between multimedia learning and WM was found, practitioners and educators would be able to concentrate on other possible areas impacting

WMC for preschoolers. Findings would increase knowledge in the area of multimedia educational practices under the theoretical framework related to WM.

RESEARCH DESIGN

Design Of The *Grasplearn* System

In accordance with WM theory, a prototype of graspable multimedia named *GraspLearn* was designed. Research design discussed in the following section is applicable to both experimental systems, *GraspLearn* and *CLearn*.

Shematic view of Grasplearn

The schematic design of *GraspLearn* system is illustrated in Figure 2. *GraspLearn* was made up of two worlds, physical and virtual arenas.

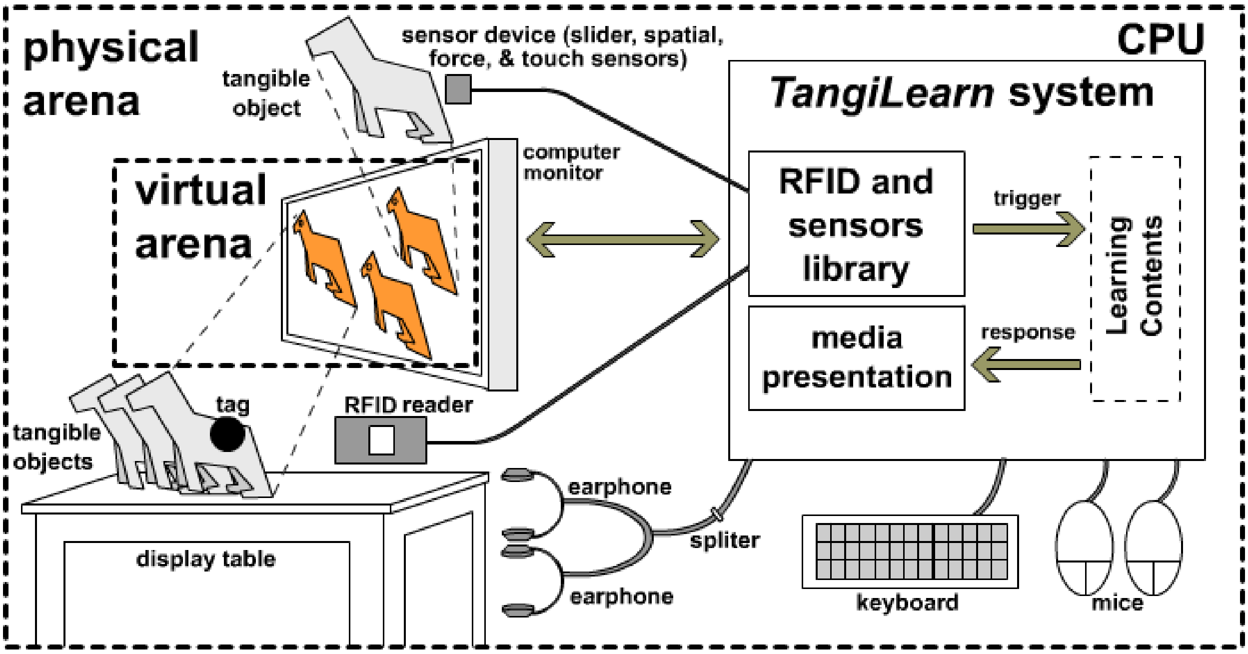

Figure 2. Schematic representation of *GraspLearn* system architecture

Physical arena consists of physical devices deployed to execute the "graspability" of multimedia expressions in the system (RFID tags and reader, sensor devices such as slider, spatial, force, and touch sensors), five physical artefacts, a display table, keyboard, monitor, CPU, two mice, two sets of earphones connected using a splitter. Virtual arena contained corresponding virtual learning artefacts designed to be "encircled" by many physical learning artefacts on table.

The implementation of graspable multimedia

Two sets of experimental systems were developed for the research, the *GraspLearn* and conventional multimedia (*CLearn*) learning systems, as demonstrated in Figure 3.

Figure 3. Graspable multimedia (*GraspLearn*) and conventional multimedia (*CLearn*)

GraspLearn system was delivered as a CD-ROM based standalone multimedia system in EXE format. It was developed to be universally portable in a way that it was only required to be copied onto computer, and not installed in computers. It can be copied right before the research started and deleted immediately after the research. It was able to run on either a low end Windows XP, Celeron laptop, or PC with Pentium I processor.
For *GraspLearn*, the hardest part to implement was the solid and accurate binding between physical artefacts and multimedia artefacts. Sensor devices, which comprises of Radio Frequency Identification (RFID), force sensor, electronic slider, touch and spatial sensors was chosen as a utilities for the development of the binding part in the *GraspLearn* (Figure 4). RFID reader and tags were deployed as a main device for object identification. RFID is a wireless object sensing technology using radio waves. Its components, RFID reader, were capable of sensing the presence of a tag when the tag-glued physical artefact was moved by the subjects towards the field of radio wave generated by RFID reader in front of the computer. The sole deployment of RFID reader was insufficient if *GraspLearn* was to deliver a robust capability of graspability to the subjects. Therefore, electronic slider, force and spatial sensors were deployed interchangeably.

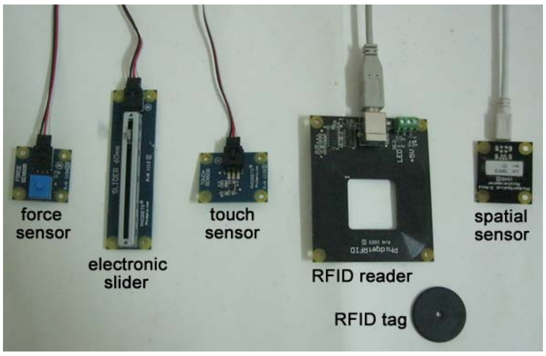

Figure 4. Sensor devices deployed in *GraspLearn*

The reason the sensor devices chosen are threefold. First, they are supported by *Adobe Flash Professional CC ActionScript* 3.0. *Phidget* Company of Canada has developed the *Flash* library for the devices and made available on the Internet for public use. Such library allowed the researchers to leave out the challenging and excessive programming part in physical-digital multimedia artefacts binding. Second, sensor devices have a multitude of characteristics that are more superior in performance, such as reducing the need of precise alignment to computer devices, greater detection speed than other technologies such as QR code marker to the web camera, which has occasional difficulty in detection and mobility for preschoolers. Third, different kinds of movements can be implemented because there were various devices catered for different operations. *Adobe Flash* and *PhotoShop CC* was utilised for developing and editing graphics and 2D animations because of its user-friendliness in graphical interface. *Adobe Priemere CC* was used for video editing and *Soundbooth* for sound editing, manipulation and recording. Correct deployment of implementing technology allows graspable experiences of multimedia environment translated efficiently in *GraspLearn*.

Learning procedure of grasplearn
Experimental system, *GraspLearn*, consisted of two sessions, learning session, of which learning contents were delivered, and quiz session. The learning artefacts, either virtual or physical artefacts, were the knowledge unit intended to be delivered. The multimedia expressions that tied to the learning artefacts offered rich definitional, contextual and featural information about the artefacts learned. The subjects were expected to learn and comprehend individual English words, contextual meaning of the key words, definitional information, and gain general knowledge of some of the features pertaining to the learning artefacts through the artefacts.

For *GraspLearn*, subjects who entered the learning session would find themselves entering a virtual arena, which was "surrounded" by many randomly-placed virtual artefacts such as office and gardening items. The pair of subjects was free to explore any learning artefact by grabbing any physical artefact, or to exit. In other words, subjects themselves paced the lessons, and subsequently pointed it to sensor devices or perform gestural movements to trigger corresponding virtual learning artefacts to display learning contents on the computer screen. If subject grasped a RFID embedded physical calculator to the RFID reader, the virtual calculator would display its key word in written text and supplementary facts about the artefacts. With this, the learning process started. To probe the subjects' progress, relevant quiz sections of the topic studied followed. For quiz session in *GraspLearn*, the subject would have to answer by identifying the correct physical artefact. They also could click the quiz session anytime they like. For example, in the case of question related to fire extinguisher, the subject would have to pick up a physical extinguisher from an array of physical artefacts on the table. With concrete experience of the physical extinguisher in hand, they gained better the concept of extinguisher. There were a total of 27 learning artefacts in six learning scenes. As there were only seven days of lessons, some artefacts were used repeatedly, and some were mixed with common artefacts familiar to subjects.

One week prior to the implementation of the experimental classes, the researchers sought formal permission to conduct the research from the principals of the kindergartens and subjects' parents. They were given general information on what the research was about without informing them about *GraspLearn* and *CLearn*. To ensure full cooperation from them, they were told about their contribution, that was, they were contributing to new knowledge in multimedia education as well as providing opportunity for their students and children to learn computer and ESL. After permissions were granted, each principal and parent was then requested to fill up a consent form. Thereafter, all subjects were required to sit for CEFT and baseline "object-span tri-tasks" tests.
Day 1 of the experimental classes was a day for orientation and demonstration. At the beginning of the class, the subjects proceeded to classroom or computer laboratory arranged by the kindergarten management. The subjects were then given a briefing on the learning activities. They were also told that they could stop at any time for any reason. Specific instructions on the features of the experimental system, like how to operate the system were described to each subject. Subsequently, subjects were arbitrarily grouped into pair. Each pair was provided with one PC. After the system demonstration, each pair of subjects was given 20 minutes of practice for them to familiar with the system, thereby eliminating potential effects of novelty.

Day 2 was the day that learning lessons started. Throughout learning lessons, the subjects were left to explore by themselves for 20 minutes. They were required to grasp, point, and perform gestural movements on the physical artefacts to sensors (for *GraspLearn*), or navigated around (clicked here and there) (for *CLearn*) by themselves. The whole learning process was designed to be self-directed. This was done because first, as prescribed in cognition theories, exploration is regularly followed by the engagement of cognitive efforts, particularly when developing and applying domain concepts or knowledge (Chen, 2005; Kamouri, Kamouri, & Smith, 1986). Second, self-exploratory learning is of particularly conducive for Malaysian students who are generally passive and shy to be inquisitive (Nik Ahmad & Sulaiman, 2013). The whole learning process is essentially allowing the students proceed themselves. Adopting this approach, all topics were set in prior to the commencement of classes each day, but explicit direction specifying which and when the learning artefacts was explored during the learning process was not provided. The experimental classes ended with closing post-assessments where the subjects were asked to complete "objects-span tri-tasks" test. The whole learning process in *GraspLearn* system was designed in such cyclical sequential format that the subject started from physical artefact exploration, followed by presentation of multimedia contents.

The subjects were randomly assigned to use different treatments where the experimental classes were administered with the *GraspLearn* whereas the control classes with the *CLearn* system. All kindergartens were not informed of the differences. The subjects, teachers, and parents did not know about the nature of the research. Under this circumstance, there would be no way for them to discuss, compare and interact with each other, thus avoiding a situation which could affect the reliability of the research outcomes.

Choice of common and affordable physical artefacts
There were a total of 27 individual physical artefacts deployed in the research. Office, food, fire, vehicles, and gardening items were chosen because first, they are common artefacts within school compound, consistent with the idea of Tredway (1982) that items that can be observed in a site within a 15-minute walk from school should be considered as learning materials for young children. Second, they are outdoor and surrounding materials, which are important source for teaching (Tredway, 1982). Third, they are real concrete artefacts that can be well representative of virtual artefacts presented in digital multimedia. No abstract materials or concepts like "melt", "minus", and "think" were introduced, consistent with the level of cognitive development of children. Individual artefacts rather than collection of related artefacts were chosen because they are easier to be recognised, as stated by Zosh (2009), "… both adults and infants can store representations of individual objects, rather than unbound collections of perceptual features". (Zosh, 2009, p. 36)

Common physical artefacts were chosen because first, the more basic the idea the students learned, the greater their ability to apply it to new problems (Cooperstein & Kocevar-Weidinger, 2004). Second, learning should begin with observable action words and not vague terms (Felder, 2002), considering the cognitive level of the subjects. Patsalides (2012, p.1) has asserted that the tasks for learning, particular in the learning of problem-solving, should be simple and one-dimensional rather than setting too difficult. The researcher stated, "preschoolers certainly have the ability to problem solve ... They are at the pre-operational stage of human development, meaning that they can only think of one dimension of a problem at a time". (Patsalides, 2012, p.1)

Why was featural knowledge about the objects chosen?
In the research, knowledge-building was integrated into ESL learning activities. This means the subjects were not only required to learn the name and key words of the learning artefacts, but also the featural knowledge about the artefacts. This was done because first, the researchers followed the semantic learning approach adopted in Weill's (2011) research in the research. Weill (2011, p. 42) said, "… the more knowledge a toddler has about an object, the easier it will be for him or her to retrieve the word from memory and recognise and name the object". Knowledge and background meaning of words form a vocabulary base for children and help them with the learning of other (Weill, 2011) and to make sense of what they read (Loraine, 2008). For instance, a child who reads about an essay of war requires a basic vocabulary such as soldier, war, and guns. Second, engaging knowledge-building experiences in word learning suggests children's natural desire to discover new knowledge about their world. Generally, young children are eager to understand more about the world and their knowledge and understanding of the real world helps them explain phenomena and solve problems. The surrounding is also a part for young children to learn second language (Albert Shanker Institute, 2009). Albert Shanker Institute (2009, p. 20) stated, "young children are naturally curious about the world, and they regularly ask 'why' and 'how' questions that logically leads to scientific inquiry".

Third, the learning outcomes are much less satisfactory if learning process merely focuses on drilling young children in isolated skills (Albert Shanker Institute, 2009). ESL learning tied to knowledge-building activities not only cogently provides the base for enjoyable and exciting learning experiences for young preschoolers, but also makes reading and writing a meaningful and purposeful activity (Albert Shanker Institute, 2009). The research followed the English language curriculum stipulated by the Ministry of Education of Malaysia (2001) that an enjoyment of the language learning should be developed through the use of interesting means.

Fourth, there is a need for the development of a computer-aided courseware that teaches both real-life knowledge and ESL at the same time. Multimedia markets in Malaysia nowadays are overwhelmed by multimedia courseware in genuine language domain (such as Malay, English, Mandarin), and thematic domain (such as Mathematics and Science) (Osman & Lee, 2014; Han, Abd Halim, Shariffuddin, Abdullah, 2013; Norhayati & Siew, 2004). Multimedia systems on real-life knowledge building in second language learning setting, particularly ESL learning for preschoolers are very scarce.

Experimental Design
The 2 by 2 quasi-experimental factorial design, a variation of an experimental design, was employed in the research. Each group was given a pre- and post-assessments, which would be performed and analysed separately.

Table 2: Multiple-group pre- and post-assessments quasi-experimental design

GraspLearn (experimental group)	CEFT Baseline "objects-span tri-tasks" test	"Objects-span tri-tasks" test
CLearn system (controlled group)	CEFT Baseline "objects-span tri-tasks" test	"Objects-span tri-tasks" test

The quasi-experimental factorial design was chosen in the research because it allows the researchers to determine whether the effects of an experimental variable are generalisable across all levels of a control variable, or are specific to certain level of the control variable (Gay, 1996). Besides, it also allows the researchers to manipulate independent variable (IV) in order to investigate the interaction of the IV with other variables, such as moderator variables and dependent variables (Fraenkel & Wallen, 1996).

Sampling of kindergarten
There were seven private registered kindergartens in Malaysia participated in the research. The criteria used for the selection of kindergartens were that majorities of their students were non-English-speaking (NES) or limited-English-speaking (LES) students. The researchers used students' demographic data and discussion with the teachers to determine the eligibility of kindergartens. The researchers scoped the areas for the selection of kindergartens to three town areas in the Kajang, Selangor, Malaysia with the exception of one chosen from another town area, Subang, Selangor because it is one of the branches of the participating kindergartens from the towns the researchers scoped. These three towns were selected because of its close proximity to the residential area of the researchers. Using stratified sampling procedure, all kindergartens in the scoped areas were randomly assigned a number. This procedure ensures that each kindergarten in the defined areas has an equal chance of being selected to take part in the research (Gall, Borg, & Gall, 1996).

The population
A total of 248 preschoolers between five and six years of age from the seven kindergartens were utilised in the analyses. The subjects chosen were Malaysians who were homogeneous in terms of education condition, societal background, and English level. All of them were non-English-speaking (NES) or limited-English-speaking (LES) children, meaning that they had very limited vocabulary of the English language, in the mid of learning English as second language (ESL), did not speak, or rarely spoke English at home. The subjects also came from a population of preschoolers who had not undergone any lesson on the topics covered by the research, for the researchers to attribute their knowledge and vocabulary in ESL to the efficacy of the experimental systems they used. Other than that, they were healthy without any major physical deficiencies.

Table 3: Demographic profile of the participating subjects

Characteristics		Frequency (N=248)	Percentage (%)
Nationality	Malaysian	248	100
Age	5	107	43.1
	6	141	56.9

Table 3 shows that male subjects made up 48.8% (121) of the sample whereas females made up the balance of 51.2% (127). They took part in the research voluntarily. In fact, there were 269 preschoolers recruited as the subjects in the research. However, only 248 were utilised in the analyses because of attrition. In other words, despite efforts had been taken to reduce attrition rate by promising them candy and ice cream as token of appreciations at the end of the experiment, there were still 21 students excluded from the analysis. After consulting with the teachers and research facilitators, among the reasons identified for those who did not make the cut for answering the assessment were sickness, fatigue, absenteeism, and subjects found scribbling the assessment instruments. Apart from that, many of the subjects nervous and anxious when answering questions to the researchers in one-to-one setting in a specific room arranged by the kindergarten management. Many of them were lost in the contemplation of word recitation which took relatively lengthy duration compared to other assessments during the “objects-span tri-tasks” test.

The experimental classes for the research were conducted on-site in the classrooms of the participating kindergartens. Each lesson lasted one hour per day, for seven days consecutively in each kindergarten (Figure 5(a) and 5(b)).

Figure 5(a). Scenario of participating subjects in the experimental *GraspLearn* classes

Figure 5(b). Scenario of participating subjects in the experimental *CLearn* classes

Two participating kindergartens used their own PCs in computer laboratory and five others used the PCs brought in by the researchers because they were not equipped with computers. As the researchers only had 5 PCs to cater for ten students per session, they would take turn to attend the researchers' experimental classes. Out of seven participating kindergartens, four were randomly allocated as the experimental kindergartens and the balance as the control kindergartens. With this, a total of 128 subjects were allotted to the experimental group and the rest into the control group, as shown in Table 4.

Table 4: Subjects distribution across the learning modes (N=248)

GraspLearn (experimental group)	*CLearn* (control group)	Total
128 (51.6%)	120 (48.4%)	248 (100%)

Five and six years old preschoolers were selected on ground that first, the subjects were preschoolers within the targeted population in the stage of "pre-operational" cognitive development. There are strong theoretical cognitive-developmental viewpoints agreed that the manipulation of physical artefacts is relevant with their level of cognitive structure. Second, preschoolers of five to six years old are relatively easier to be studied. They have mastered the conventions of oral language, understand meanings of common talking, and converse using sentence correctly (Smith, 2009). Children of three to four years old were not chosen because they tend to have too short attention span (Blanchard & Moore, 2010). Children of seven years old were not chosen because this is the age they enter primary school in Malaysia, thus dropout the condition of the targeted population that must be in the "pre-operational" stage.

The reason the researchers restricted the range of age of subjects narrowly to only two age groups, five and six years old was to reduce the children differences in characters (Gelderblom & Kotze, 2009). Children of different ages have varied needs, preferences, attitudes, and ability pertaining to literacy (Son, 2006; Neuman & Dickinson, 2003). They arrive at kindergartens with huge degree of differences. Their behaviour on using computers is also too difficult to expect (Nur Sukinah, Mohd Nizam, Abdul Hadi, Azman Yasinc, 2010). Those aged five to eight years, for example, can be in two extreme distinct situations where some are entertained by the same events over and over, but some care little about the event (Gelderblom & Kotze, 2009).

Research Instruments

Two testing instruments, namely CEFT and "objects-span tri-tasks" were deployed to measure the cognitive style and WMC of preschoolers respectively.

All testing instruments were paper-based rather than computer-based because the young subjects generally had problems in using computer mouse, especially when they were required to click on small checkboxes on computer screen (Barnes, 2010). The researchers were present at all time at the kindergartens during the experimental classes. However, the researchers only acted as a "helper" to facilitate learning process. When problems arose, or they were stuck, then only the researchers highlighted to them what they could do. Aiming to focus on the pedagogical affordance of the experimental systems, formative feedbacks would not be provided to the subjects at any time in fear that the results of the research would be interfered. Only inquiries related to understanding the questions, instructions, and tasks were answered. To ensure standard explanation to inquiry, tri-language versions (English with Bahasa Malaysia and Mandarin translation) of all instruments were prepared for research facilitators for consistency in answering inquiries raised by the subjects (Figure 6). If at all there were effects, the use of mother tongue based on a standard version would have equally affected all the subjects. Due to time constraints, the Malay language and Mandarin translation of all instruments were quickly reviewed and checked for readability by the researchers' Malay and Chinese friends and corrections were made based on their comments. With this, variances would not be affected due to the extent of formative feedbacks.

Figure 6. Mother tongue were allowed for explanation in the experimental classes

Objects-span tri-tasks

"Objects-span tri-tasks" test was a memory test designed by the researchers to measure the preschooler's WMC. The WMC was the size of the largest sequence of words correctly spelled in correct sequence able to be recalled by a subject. Developing new cognitive tests based on Baddley's WM ideas is not uncommon in cognitive psychology (Lee, Pe, Ang & Stankov, 2009). One of the first such tests was "mental counting" by Massaro (1975). Although countless more WM tests have been developed since, many of them are frequently pitted against common tests (Lee, Pe, Ang & Stankov, 2009).

The procedure of "Objects-span tri-tasks" test was that a subject was started with sequentially presented with words, one at a time, with which each was printed on different cards. Two letters in each word were removed and replaced with lines (Figure 7). When presenting to the subject, the researcher read the word aloud. Each word on the card was remained for viewing for 30 seconds, followed by a one-second inter-stimulus-interval (ISI) before a new word was presented. This continued until a blank card, signifying the end of a set was presented.

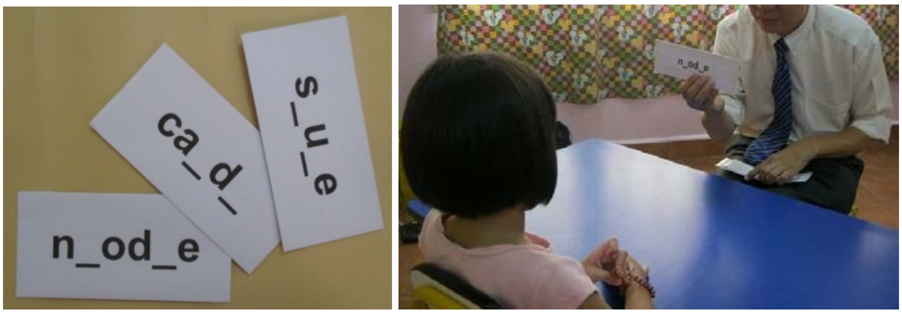

Figure 7. Two letters in a word were left blank in "objects-span tri-tasks" test and the words were read aloud and presented to subjects

After the words presentation, the subject was requested to repeat the presented words to the researcher by choosing the answer options shown on cards on table in the exact order of presentation (Figure 8). For example, if "bottle", "toothpaste" and "pepper" were shown on the cards, the correct response from the subject should be "bottle, toothpaste, pepper".

Figure 8. Subject chose the answer option

In the first level, two words were presented. If the subject recalled one out of the total words, its sequence, and spelling correctly, a second level with three different words was given. If one of these were recalled correctly, they would then proceed to the third level with four different words, and so on. The researcher continued presenting words with increasing number of words until the subject was no longer able to reproduce them. The sequence length (number of words) was progressively increased by one in each subsequent level. Testing was discontinued if the subject committed three full consecutive incorrect sequence, incorrect words, or missing letters recall in any one level (Figure 9). Two rounds with two and three words of test were conducted as practice trials. Administration time required for the whole testing process was 30 minutes, including practice trial.

Figure 9. Subject recalled the words in serial order

Words recitation were chosen as task for measuring WMC in the "objects-span tri-tasks" test because first, the researchers followed the idea of a number of research works that the tasks designed in a WM test should focus on simple solitary item or task (such as word, digit, letter, or things) so that WMC can be measured effectively. The task that demand knowledge and strategies should be kept to a minimum (Oberauer, S¨uß, Schulze, Wilhelm, & Wittmann, 2000). Second, word learning is the targeted research domain in the research. Third, word is highly relevant as it has practical implication that a preschooler has learned from physical artefacts inspected in the research. The overall Cronbach's alpha reliability coefficient of the "objects-span tri-tasks" test in Pilot study 2 (small group evaluation) is 0.72, a value which is considered high and acceptable as good internal consistency (Lay & Khoo, 2009), proving that the selection of words recitation as measuring task for WMC a right selection in the research.

Cards were used for words presentation rather than computer display because uncertainty by subjects regarding computer operation may impact the baseline measure, as Flad (2002, p. 84) stated, "the dual-task procedure utilised … combined with the technological aspects (such as computer, internet) produced a very complex exercise for the researcher and subjects".

The researchers began the memory test with a series of two words (the number of words in Level 1). Two words were chosen because first, the finding from the Pilot Study showed that the number was appropriate for young preschoolers. Second, it helped to reduce the stress already arisen amongst the young subjects who attended the experimental classes conducted by a stranger (the researcher). Past research works also implicated that memory task starting from two words was more than easy for the young subjects. They documented that a person is typically able to recall a list of up to four digits with near perfect accuracy (Cowan, 2005; Miller, 1956), or plus or minus one (Cowan, 1999, as cited in Londe, 2008). For four to six years old children, there was research works acknowledged their capability to repeat sequences of digits from three to four digits (Binet & Simon, 1905; Szmalec, Brysbaert, & Duyck, 2012). Short lists are remembered better than long lists (Broadbent, 1975;

Cowan, 2005; Stiles, 2010). Thus starting a memory test with a lesser number of words could help the subjects to have a better feel of their performance and this helped to ease their stress.

"Objects-span tri-tasks" test were conducted twice, one pre-treatment measure of prior WMC of subjects conducted a week before the commencement of the experimental classes as a baseline measurement and another immediately after the entire system treatments as a post-measurement. The gap between the baseline and post-measurements was fourteen days, sufficient to minimise the threat to internal validity due to maturation or history of the subjects. The words tested in the baseline "objects-span tri-tasks" test were entirely different from the post "objects-span tri-tasks" test because first, to avoid the "set response effect" or any possible interactions between them. Second, similar words could have been tested in pretest conducted at the same time with baseline "objects-span tri-tasks" test. Third, WMC test are different from other tests in nature. It is independent of general background factors such as education and socio-economic status, and does not reflect what subjects have or have not learned prior to the tests (Gathercole & Alloway, 2004). No subject will benefit from knowledge acquired in learning lesson in performing the tests. Because of this, baseline "objects-span tri-tasks" test could be designed to be equally unfamiliar to all subjects.

Three types of scores were obtained from the instruments, namely number of correctly arranged sequence, number of words correctly recalled, and number of missing letters correctly recalled by each subject in each level. A score of zero was given to an incorrect recall, and one for a correct recall. The subjects' total score, the measures of WMC, was the total number of these three recalls that the subjects performed correctly, converted to a percentage (100%) for analysis. This way of calculation has the advantage of obtaining individual score from single item.

The tasks in "objects-span tri-tasks" was designed by reference to the "backward digit" (Ackerman, Beier, & Boyle, 2002; Oberauer, S¨uß, Schulze, Wilhelm, & Wittmann, 2000), "backward word" (Rosen & Engle, 1997; Yuan, Steedle, Shavelson, Alonzo, & Oppezzo, 2006), "reading-span dual-tasks" span (Daneman & Carpenter, 1980; Fedorenko, Gibson, & Rohde, 2007), and "operation span task" (Ospan) (Turner & Engle, 1989) tests. The difference of these instruments lies in the contents of the tasks and the way the tasks are processed. For "backward digit" and "backward word" span tests, the researchers picked the idea of the recitation of the order of numbers and words as the processing task. For "reading-span dual-tasks", the researchers adopted the idea of simultaneous processing task of reading aloud a set of sentences and the memory task of recitation of the last word in the sentences. For Ospan, the researchers followed the idea of adding another degree of challenge to the memory task, that is the idea of engagement of long-term memory. The Ospan task interleaves the presentation of each to-be-recalled item with a simple mathematical equation that must be solved. The mathematical task in between the presentation of each to-be-remembered item causes the to-be-remembered item to be removed from the focus of attention. Each time such a task occurs, a process of search and recovery is needed to retrieve the to-be-remembered items from long-term memory. It has been argued that the efficacy of this process is what differentiates high and low WMC of a learner (Shipstead, Redick, & Engle, 2010; Unsworth & Engle, 2007a, 2007b). There have been unskilled motor acuity and limited vocabulary mastery among preschoolers (Barnes, 2010), let alone mathematical skills, hence the mathematical tasks in Ospan was replaced with the recall of 2 missing letter in the "objects-span tri-tasks" test, which is more age-appropriate for the preschoolers. Shipstead, Redick, and Engle (2010) states, "many different tasks can be utilised to measure WMC, the critical component is that the task challenges the limits of immediate awareness. It is at this boundary that accurate recall requires controlled, effortful cognition" (2010, p. 248). In light of these, "objects-span tri-tasks" represents a valid test for measuring WMC.

CEFT (Children'S Embedded Figure Test)
CEFT was a paper-and-pencil test designed to determine cognitive style of a subject in the dimension of field-dependence or field-independence (Karp & Konstadt, 1963, 1971; Witkin, Oltman, Raskin, & Karp, 1971). It was normed for five to twelve years old children from Embedded Figures Test (EFT). The subjects were given 30 minutes to search, identify, and locate the equilateral triangle and house shapes embedded within 25 pictures of greater size (Figure 10). Ten minutes of practice trial, where the subjects were required to locate seven simple items out of bigger pictures in the CEFT test.

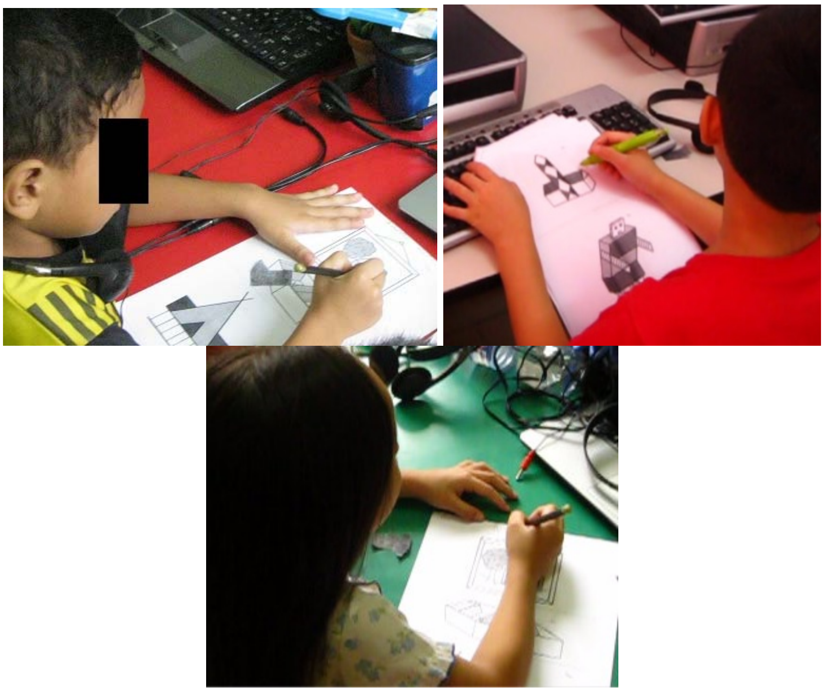

Figure 10. CEFT test in progress

CEFT score is based on the subject's success in locating the shapes correctly. CEFT yields quantitative scoring ranging from 0 to 25. The subjects, who have low level of perceptual competence, are those modes of perception highly affected by surrounding fields, and hence are categorised as field-dependent. Quantitative scoring of field-dependency is represented by a score in the range of 0-11 points whereas field-independency is in the range of 12-25 points (Davis, 2004). The CEFT was chosen because it is a standard instrument (Tinajero & Paramo, 1997) that had been verified and tested for construct validity in numerous lines of research works for WM. The reliability of the CEFT ranges from 0.72 to 0.90 (Kusuma, 2005; Saracho, 1997). For children from the ages of 5 to 12 years, it had reliability ratios of 0.84 to 0.90. For 9 to 10 years, validity coefficients was 0.70 (Witkin, Oltman, Raskin, & Karp, 1971). In Malaysia, a high reliability of 0.87 in Sabrina's (1997) research was reported.

Data Analysis Methods Chosen

Quantitative data analysis was the primary data analysis method employed in the research. Statistical analysis of the instruments was conducted using SPSS, and presented using descriptive and inferential statistics.

Overview of dataset

The results of the data collected, which were analysed using the MANCOVA, are presented in adequate detail in the paper. Table 5 shows the categories and the number of subjects in each cell. A total of 248 preschoolers' data were taken into analysis, of which 128 (51.6%) were in the *GraspLearn* group and 120 (48.4%) in control group.

Table 5: Statistics for IVs and MVs for each cell in the research

Variable		Frequency (N=248)	Percentage (%)
Learning Mode	*GraspLearn*	128	51.6
	CLearn	120	48.4
Cognitive Style	Field-dependent	127	51.2
	Field-independent	121	48.8

A total of 127 (51.2%) were field-dependent and 121 (48.8%) field-independent subjects.
Table 6 reports different combinations of cells and sizes for each cell based on the learning modes. A total of 59 field-dependent and 69 field-independent subjects utilised the *GraspLearn* while 68 field-dependent and 52 field-independent subjects utilised the *CLearn*.

Table 6: Statistics for cognitive style by learning mode (IV)

Learning mode	Cognitive style	
	Field-dependent	Field-independent
GraspLearn (n_T = 128)	59 (46.1%)	69 (53.9%)
CLearn (n_{CLearn} =120)	68 (56.7%)	52 (43.3%)

Total	127	121

Testing Assumptions for Mancova

MANCOVA enables the researchers to examine which group, if any, came out best in terms of learning performance (Dancey & Reidy, 2011). However, MANCOVA analyses, which at the overall pattern of DVs in combination, carry with them a number of assumptions that needs to be satisfied, which, if violated, can result in incorrect conclusions. As such, this analysis begins with the priori screening of dataset of the research. Numerical and graphical inspections will be conducted to ensure that the assumptions for MANCOVA are not violated.

Appropriateness of cell combinations and sizes

The cells of the dataset are appropriate for MANCOVA analyses because first, the cells were derived from the research which was a complete between-participants research. The two comparing learning modes consisted of different subjects, hence ensuring each cell is not influenced by other cells. Second, independence of cells was maintained. As each subject was appeared under only one mode, unnecessary interaction between cells was not only avoided, the scores obtained from the subjects were also independent of each other. Third, there were sufficient dataset for each cell (n>30). Fourth, a balanced number of subjects was acquired, compliant with the rule of thumb of balanced dataset that ratio of the smallest sample variance to the largest should not exceed the ratio of 1:1.5 on the range of variables tested (Coakes, Steed, & Ong, 2010). The aforesaid ratio of the dataset of the research was 52:70, indicating a ratio lesser than 1:1.5. Lastly, the ratio of the largest group variance was not more than three times the smallest group variance, thereby forming a robust dataset for testing.

Normality of DV

Using Skewness and Kurtosis statistical measures as numerical means of assessing normality, the normality of distributions for each DVs is satisfied. As shown in Table 7, Skewness and Kurtosis values for each DV were between -1.0 and +1.0, indicating the existence of reasonable normality of dataset.

Table 7: Statistical analyses of Skewness and Kurtosis measures of distributions

	Mean ($\bar{X}$)	SD	Skewness	Kurtosis
WMC	59.60	4.08	-0.387	-0.449

Though the Shapiro-Wilk and Kolmogorov-Smirnov statistical measures for each variable indicated otherwise with the *Sig.* values of less than 0.05 that suggesting violation of the normality distribution, the dataset was acceptable for MANCOVA analyses (Dancey & Reidy, 2011). This is because first, the sample sizes for the DV were over 30, thus yielded reasonable accurate results even if the assumption is violated (Gravetter & Wallnau, 2000; Stevens, 2001). Dancey and Reidy (2011, p. 497) stated, "MANOVA is still a valid test even with modest violations of the assumption of multivariate normality, particularly when the researchers have equal sample sizes and a reasonable number of participants in each group. By "reasonable", the researchers mean that for a completely between-participants design you have at least 12 participipnats per group". (Dancey & Reidy, 2011, p. 497). Pallant (2001) stated that non-significant results in statistical measures are quite common in large samples. Second, the dataset has fairly equal numbers of subjects in each cell (Dancey & Reidy, 2011). With this, the researchers were able to continue with MANCOVA with reasonable confidence.

Homogeneity of variance-covariance matrices

The assumption of equality of homogeneity of the variance-covariance matrices of the DVs across all cells has not been violated in the dataset. This is based upon the statistical supports that first, the standard deviation (SD) of subjects shows a samples of population with highly equivalent variances. There exists a balanced ratio of subjects of not exceeding 1.15 on the smallest to the largest cell size in the range of variables tested. This suggests a fairly similar variability of scores for each group, and thus can be reasonably confident that the homogeneity of variance was not violated (Dancey & Reidy, 2011).

TESTING OF HYPOTHESES

In view of the absence of violation of the assumptions of MANCOVA, the researchers can continue with MANCOVA to examine the possible main effects and interaction effects of using the *GraspLearn* and *CLearn* across the groups with high degree of confidence. The main effects are tested at an alpha level of 0.05. Each simple effect, if any, are tested at an α level of 0.017 (0.5 divided by three univariate tests), making use of the Bonferoni adjustments (Field, 2009) to take into account the family-wise error so as to guard against inflating Type I error (Dancey & Reidy, 2011)

The Main Effect of Learning Mode

The main effect of the two learning modes, *GraspLearn* and *CLearn* on the three DVs are analysed and presented based on the following hypotheses:

H_o1.3 There is no significant difference in WMC between learners using the *GraspLearn* and those using *CLearn* mode.

Descriptive statistics analysis of the effects of learning mode on the dependent variables (DVs)

Table 8 provides preliminary view of the assessment results of both *GraspLearn* and *CLearn* treatments in descriptive statistics.

Table 8: Mean scores ($\bar{X}$) and Standard Deviations (SD) of DV by learning mode

	Mode	$\bar{X}$	SD	difference of $\bar{X}$
WMC	*GraspLearn*	59.76	4.09	0.01
	CLearn	59.44	4.08	

For WMC scores, *GraspLearn* and *CLearn* modes were 59.76 (SD=4.09) and 59.44 (SD=4.08) respectively. Low difference of average of 0.01 signals the absence of expansion of the WMC. Inferential statistics is performed for analyses in the following section.

The Interaction Effects for Cognitive Style and Learning Mode

The analysis of interaction effects between the two learning modes and cognitive style on the three DVs is discussed in this section. Descriptive statistics of the analysis are presented first, followed by multivariate analyses. The hypotheses tested are:

H_o2.3 There is no interaction effect between the learning modes (*GraspLearn* and *CLearn*) and cognitive style (field-dependent and field-independent) on WMC.

The interaction effects between cognitive style and learning mode on the wmc score

Table 9 demonstrates descriptive statistics of WMC score achieved by field-dependent and field-independent subjects after treatment using *GraspLearn* and *CLearn*.

Table 9: Descriptive statistics (mean scores ($\bar{X}$) and standard deviations (SD)) of WMC score by learning mode and cognitive style

	Learning Mode		
Cognitive style	*CLearn* ($\bar{X}$)	*GraspLearn* ($\bar{X}$)	Average
Field-dependent	59.14	59.64	59.39
Field-independent	59.83	59.86	59.85
Average	59.49	59.75	

Table 9 reveals that the $\bar{X}$ WMC scores of field-dependent and field-independent subjects in both *GraspLearn* and *CLearn* differ by 0.46 (59.85-59.39), with field-independent subjects doing slightly better and differ by only 0.26 (59.75-59.49) for learning mode, with *GraspLearn* did better. *GraspLearn*. Figure 11 shows a visual description of it.

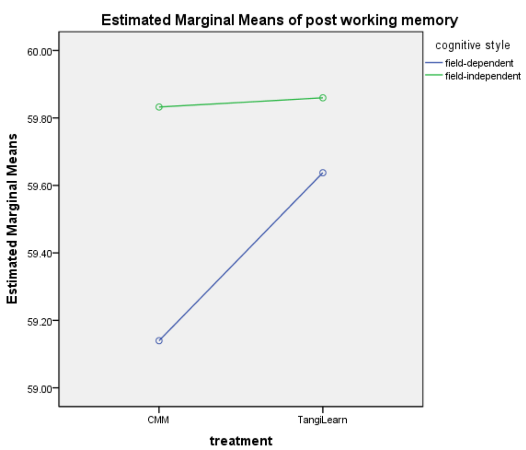

Figure 11. Plot of effects on WMC between learning mode and cognitive style

The line for field-independent subjects in Figure 11 is almost a horizontal line, carrying the meaning of absence of difference between any levels of learning mode and cognitive style. The line for field-independent subjects is a steeper upward slope, indicating that the *GraspLearn* led field-independent subjects to slightly higher WMC scores. The nearly crossing lines in the graph are indicative of interaction effect. Table 10 is the inferential statistics of it.

Table 10: Analysis of main and interaction effects of cognitive style and learning mode on WMC scores
Tests of Between-Subjects Effects

Dependent Variable: Working Memory

source	type III sum of squares	*df*	mean square	*F*	*Sig.*
Corrected Model	21.948[a]	3	7.316	0.436	0.727
Intercept	869820.829	1	869820.829	51841.587	0.000
CEFT	12.797	1	12.797	0.763	0.383
learningmode	4.221	1	4.221	0.252	0.616
CEFT x learningmode	3.386	1	3.386	0.202	0.654
Error	4093.939	244	16.778		
Total	885161.234	248			
Corrected Total	4115.886	247			

a. R Squared=0.005 (Adjusted R Squared=-0.007) b. Computed using alpha=0.05

The main effects of cognitive style ($F(1,244)=0.763$, $p=0.383$) and learning mode ($F(1,244)=0.252$, $p=0.616$), and interaction interaction effect between cognitive style and learning mode ($F(1,244)=0.202$, $p=0.654$) on WMC score were all not significant. A conclusion can thus be drawn that the $H_o2.3$ hypothesis was accepted.

The Difference of Dependent Variables by Cognitive Style

This section analyses the difference of the three DVs by cognitive style at each level of learning mode. The hypotheses tested are as follows:

$H_o4.3$ There is no significant difference in WMC between field-dependent and field-independent learners in the *GraspLearn* and *CLearn* groups.

Analysis of the difference of dependent variables by cognitive style in learning mode

Table 11 reports that mean differences of -0.498 for field-dependent subjects in *GraspLearn* and *CLearn*, and -0.027 for field-independent subjects *GraspLearn* and *CLearn*.

Table 11: Pairwise comparisons analysis of the difference of the WMC score between subjects of different cognitive style in learning mode

Dependent Variable: WMC

Cognitive style	(I) treatment	(J) treatment	mean difference (I-J)	etd. error	*Sig.*
field-dependent	*CLearn*	*GraspLearn*	-0.498*	0.729	0.495
field-independent	*CLearn*	*GraspLearn*	-0.027*	0.752	0.971

* The mean difference is significance at the 0.05 level.
a. Adjustment for multiple comparisons: Bonferroni.

Table 12 reports *GraspLearn* had insignificant differences of WMC score for field-dependent subjects in *GraspLearn* and *CLearn* ($F(1,244)=0.467$, $p=0.495$), and for field-independent subjects in *GraspLearn* and *CLearn* ($F(1,244)=0.001$, $p=0.971$), thus it is concluded that $H_o4.3$ was accepted.

Table 12: Univariate analysis of the difference of the WMC score between subjects of different cognitive style in learning mode

Dependent Variable: WMC

Cognitive style		sum of squares	*df*	mean square	*F*	*Sig.*[a]
Field-dependent	Contrast	7.832	1	7.832	0.467	0.495
	Error	4093.939	244	16.778		
Field-independent	Contrast	0.022	1	0.022	0.001	0.971
	Error	4093.939	244	16.778		

Summary of the Testing Results of Hypotheses

The results of the hypotheses tested are summarised in Table 13:

Table 13: Summary of the testing results of hypotheses

	Hypotheses	Decision	General implications
$H_0$1	There is no significant difference in WMC between *GraspLearn* learners and *CLearn* learners.	fail to reject	*GraspLearn* is no better in enhancing WMC than *CLearn*. Educators should look for other features that could enhance WMC.
$H_0$2	There is no interaction effect between the learning modes (*GraspLearn* and *CLearn* systems) and cognitive style on the WMC.	fail to reject	*GraspLearn* is not able to enhance WMC of field-dependent and field-independent preschoolers' WMC. Educators should look for other features that could enhance WMC.
H_o3	There is no significant difference in WMC between field-dependent and field-independent learners in the *GraspLearn* and *CLearn* groups.	fail to reject	*GraspLearn* is same as *CLearn*, incapable of enhancing WMC of field-dependent and field-independent preschoolers.

DISCUSSIONS, IMPLICATIONS AND CONCLUSION

The results of the research were presented according to the dependent variables by main effects and interaction effects of each level of variable. In discussion of the results, the researchers attempts to infer underlying reasons in the light of theoretical framework adopted.

The Main Effect and Interaction Effect in relation to WMC

GraspLearn did not enhance subjects' WMC. The WMC was entirely similar to subjects in *CLearn*, irrespective of subjects' cognitive style. There is neither main effect, nor interaction effect for cognitive style in terms of WMC scores. By average, *GraspLearn* subject's WMC were in the range of three to four words, similar to *CLearn* groups. This signifies *GraspLearn* subjects, irrespective of any differences, recited as much words as the subjects in the *CLearn*. Such results led to no discernable sign of elevation of WMC of learners after treatment using *GraspLearn*.

The absence of effects denote neither any relationship exists between learning mode and WMC in terms of cognitive style, nor had had any factors that could impact and alter the relationship between learning mode and WMC scores in *GraspLearn* and *CLearn*. Though there is non-existence of any effects on WMC, some subtle patterns can be observed. In respect of cognitive style, field-independent subjects in both *GraspLearn* and *CLearn* modes performed slightly better than field-dependent subjects in *GraspLearn* and *CLearn*.

The research findings of where equal levels of words recitation demonstrated in *GraspLearn* and *CLearn* contradict with general consensus of theoretical viewpoints that the additional engagement of tactile sensory channel could enhance the WM of a learner (Manches, 2010). The findings were not uncommon because carrying out cognitive operations in WMC test, as in "objects-span tri-tasks" test, was error-prone and effortful (Gathercole & Alloway, 2004). It was prone to loss because it requires full attention.

Although the WMC score is low, the subjects, either field-dependent or field-independent, gravitated towards physical artefacts in multimedia context somewhat shows the appropriate pedagogical strategy deployed in *GraspLearn*. At least, it helps to lower cognition processing load for coping with learning situations, particularly for young children with relatively lower WM. Otherwise, learning is slower, more difficult, and exposed to higher chance of failure. A common instance is learning by reading off a sentence on white board written by teachers. For low WM students, such strategy was observed to be a source of error or difficulty. Whilst having insufficient capacity to store and manipulate information, they are exposed to various difficulties in processing such as distraction and locating key information in the distant white board. Gathercole and Alloway (2004) suggest a way of improvement, which is making the key words to be available on the students' own desk rather than a distant white board. This is exactly comparable to *GraspLearn* setting in which learning artefacts were placed in front of subjects. With such reduction of opportunity for error and difficulty in learning, learning knowledge are much more likely to hold in their WM (Gathercole & Alloway, 2004). This explains why while having poor WMC, the subjects were still perform in quiz questions.

The research results contradict with some of the research works conducted on subject of distinct cognitive style. The research works that report the improvement of WM after certain treatments as well as the positive impact of WM are Patten and Ishii (2000), Kelly, Singer, Hicks, and Goldin-Meadow (2002), Alibali and DiRusso (1999) and Hatano and Osawa's (1983) research works. Gathercole and his associates (Gathercole, Pickering, Knight, & Stegmann, 2004) reported 83 children aged 6 and 7 years old that have better WMC had higher abilities in both English and Mathematics than children of low WMC ability. Service's (1992) research reported Finnish children with good immediate verbal memory performed better at ESL vocabulary learning than those with short spans.

LIMITATIONS OF THE RESEARCH

One of the notable limitations of the research was that the scope of the learning contents was limited to 27 concrete artefacts. In the research, the researchers chose to concentrate on learning real-life artefacts from surrounding. For this reason, the results were not readily generalised to learning contents that encompass abstract topic such as Mathematics learning. Besides, the range of age of subjects for the research was restricted to preschoolers aged five and six years old. Due to narrow setting of age range, probability of generalisation to younger or older learners is restricted. This also conveys implication that the usability of the graspable multimedia only took into account the cognitive style and WM of this category of population. On the same note, as the research was only conducted in seven urban private kindergartens, thus generalisation of the findings to rural and government kindergartens or kindergartens from western countries are less tenable. Pertaining to "objects-span tri-tasks" test, its limitation was that only words recitation was utilised as indicators of WM. Although the words chosen were highly relevant to preschoolers and the learning context of the research, it can be argued that visual elements can be included to form a more comprehensive measure of WM.

IMPLICATIONS OF THE RESEARCH

Concern over whether multimedia systems allow preschoolers to learn in accordance with their cognitive level have been now assuaged had the development of the *GraspLearn* that attuned to their cognition with the deployment of physical artefacts. The concrete nature of physical artefacts prompts graspable multimedia as the developmentally appropriately way for preschoolers in which the multimedia and ICT are used. Consistent with Haugland's (1999) contention that ICT should be used in developmentally appropriate ways with young children, physical artefacts in multimedia context provide a ground to close the gap between preoperational state of mentality of preschoolers and digital multimedia.

Due to absence of capability in elevating WMC using *GraspLearn,* it is now difficult for the diffusion of this innovation for use as an aid to enhance WMC of preschoolers. Multimedia researchers should now consider researching other features or components that can be satisfactorily incorporated to enhance their WMC. For practitioners and educators, they should now attempt other possible means impacting ESL learning among preschoolers in multimedia context. Despite negative findings, there is still a lot to be learned about the cognition ramifications of *GraspLearn* treatment. It suggests several implications, both theoretical and methodological. Amongst others, first, the embodiment of tactile and spatial sensory channels that are being overlooked in multimedia learning for preschoolers. Second, the bonding of physical artefacts in multimedia learning environment which allows preschoolers' cognition to stay oriented to concepts not easily visualised or grasped can be manifested by the unique affordances of the technological implementation. Third, the role of the long-term memory in WM operations, manifested by the tasks designed in accordance with the fundamental cognition theories in the "objects-span tri-tasks" instruments.

The successful development of the *GraspLearn* provides empirical evidence that its physical artefacts mediated constructivist-cognitivist environment is highly appropriate for exploratory learning purposes, and of particularly conducive for Malaysian students who are generally passive and non-participative (Nik Ahmad & Sulaiman, 2013; Halimah & Ng, 2002, Kong, 2006), to inculcate collaborative and interpersonal learning skills. The Malaysian national education system has been reformed towards constructivist based since 2001 (Kong, 2006; Vickneasvari, 2006). The finding not only implies that the graspable multimedia appears to be a right system to implement the constructivist-oriented "5E learning" classroom (Engage, Explore, Explain, Elaborate, and Evaluate) (Pusat Perkembangan Kurikulum, 2001), but also viable as institutionalised learning mechanism for preschoolers, like the set of manipulative apparatus in Montessori's "education of the senses".

Lastly, inclusion of preschoolers' cognitive style in the research has an imperative implication on the design of the graspable multimedia aimed to be customisable and adaptive to the psychological profile of preschoolers of distinct characteristics in learning styles and abilities. The interaction results on cognitive style by learning mode imply that *GraspLearn* offers a promising medium to accommodate individual differences: Irrespective of cognitive style, preschoolers were equally benefited from the *GraspLearn* system.

RECOMMENDATIONS FOR FUTURE RESEARCH

The research opens up several potential areas, directions and foci that warrant future investigation. Areas that appear worthwhile to be laid out for further investigation are research works that could bring about improvements to overcome the limitations of the research. A potential research is the questions on whether the same findings are to be observed when it is extended to National Language (Bahasa Malaysia), or replication studies to other languages (such as Korean or Mandarin language) in similar context. It is worth revamping the experimental systems using other languages to find out how system in other languages could have impacts on the learning. They enable us to ensure that the *GraspLearn* system benefits students from various fields of language learning.

Other plausible research works addressing the limitations of the research are examining the applicability of the *GraspLearn* to a wider population covering kindergartens from suburban and rural areas, or replicated to a larger scale in kindergartens covering different socio-economic background. The students from urban and rural areas might differ because the socio-economic status is perceived to have influence over their academic performance as well as preferences towards computer-assisted instruction (Attewell & Battle, 1997). The efficacy of the *GraspLearn* system might also be different due to the age differences, thus it would be worthwhile to investigate the efficacy of similar systems among the primary school students. Besides, to determine whether *GraspLearn* is applicable for other personality traits or psychology domain, target users could also be extended to extroversion, introversion, anxiety, and specific aptitudes, or to include disabled persons, dyslexia and autism patients. Research may also be extended to examining incidental word learning and listening comprehension. Apart from that, research works that lasted for a longer duration, or conducted in compliance with the number of hours allocated for ESL learning stipulated in NPC are also recommended in future. This is because the research that was held seven days consecutively may be too packed and heavy for a preschooler. Lastly, it is also essential to replicate the findings of the research using a wider variety of WM testing instruments and tasks.

The research could also be improved by looking into the application of the graspable multimedia in different situations. For example, it can aim to find out in which settings does graspable multimedia work best, what kind of task in multimedia environment is best suited for using physical artefacts, and which kind of physical artefacts is best suited for which task in multimedia environment. In this respect, research can be formulated as to like "what are the suitable learning domains for graspable multimedia environment?". All these highly enlighten us on how a task or learning factor interact with the graspable multimedia to either aid or inhibit learning.

Future researches may focus on systems that encompass more abstract subjects such as Mathematics and science. These subjects are perceived as amongst the difficult subjects to teach and to learn because various numerical concepts are abstract to young children. Graspable multimedia potentially overcomes the difficulty because physical manipulation assists the formulation of concrete ways of thinking about abstract phenomena. For this, the research questions can be formulated as to "what is the role of graspable multimedia in Mathematics and sciences?".

Lastly, it is therefore interesting to compare *iPad* with graspable multimedia. The young generation of students is very facile in using *iPad* and gamepad. It is possible that graspable multimedia could be better than *iPad* since graspable multimedia possesses tactile and spatial characteristics required by the young children.

CONCLUSION

The research aimed to produce a solution that could overcome the problem of the lack of the design of interface that considers the capacity of working memory (WMC) for preschoolers in digital multimedia context. One may curious about whether multimedia systems that had incorporated graspable physical artefacts yielded different finding for different category of subjects. Hence, cognitive style was constituted as moderator variable in the research. Different from the past research on multimedia, the research was one of very few research works which had tapped the research scope into the cognitive structure of a preschooler. Analyses reveal that the *GraspLearn* system did not improve preschoolers' WMC significantly more than *CLearn*. There is no discernable sign of WMC elevation across all conditions. Interaction analyses by cognitive style with learning mode reports relationship between learning mode and did not differ by cognitive style, suggesting that *GraspLearn* equally accommodates preschoolers of different field-dependency. The culmination of such research drew a prognostic of the shortfall in capacity of the graspable multimedia in realm of cognitive functioning of preschoolers.

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