Learning through intuitive interface: A case study on preschool learning

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ABSTRACT

For a child, playing is not only an act of fun, but also a way of learning. Long hours of study in a classroom without playing only serve to make the children detest learning. A current interest of research is to integrate the learning process with the latest technology to engage children with learning and playing. Game-based learning (GBL) is one of the approaches that utilises the gaming environment to attract the student's attention and increase participation throughout the process of learning. We proposed an intervention program that used voice and gesture-based interactive virtual learning environment (VGVLE) based on GBL framework to teach colour and shape to preschool children. The program with quasi-experimental design (N = 84) was conducted to evaluate the effectiveness of the proposed approach in promoting preschool learning when compared with the traditional classroom teaching approach. Our findings show that preschoolers who learnt with the proposed approach surpassed those who learnt with the classroom approach. Besides that, the gap in learning performance was also reduced.

1. Introduction

Long hours of study in a classroom without playing only serve to make the children detest learning. For a child, playing is not only an act of fun, but also a way of learning. There exist various researches that focused on creating effective teaching and learning environments to enhance the traditional approach. Game-based learning (GBL) is one of the recommended approaches to enhance children's learning interest and motivation (Chen & Law, 2016; Erhel & Jamet, 2013; Sun, 2013). GBL engages the children in a game world, allowing them to interact with the learning material while motivating them to improve their knowledge and skills via competitive activities with rules, goals, feedbacks, interactions, and outcomes (Kim, Park, & Baek, 2009).

Many GBL studies have produced positive gains in achieving desired learning goals for cognitive development such as knowledge acquisition (Hwang, Chu, Lin, & Tsai, 2011; Ward, Finley, Keil, & Clay, 2013), literacy (Beschorner & Hutchison, 2013; Couse & Chen, 2010; Neumann & Neumann, 2014), and problem solving (Chang, Chen, & Hsu, 2011; Sánchez & Olivares, 2011). Thousands of educational games and apps spring up like mushrooms when GBL emerges as new learning approach. Teachers and parents start questioning on the content, relevancy and suitability that those software claimed to be (Papadakis, Kalogiannakis, & Zarantis, 2018). In addition, they also concern about the effect of playing such games on children physical and cognitive developments (Hirsh-Pasek et al., 2015; Johnson, Ridgers, Hulteen, Mellecker, & Barnett, 2015). The recent review on educational apps discovered that most of them are not developmentally appropriate to the children. Some of the apps failed to meet the frameworks' guidelines and not even focused on a single learning goal (Papadakis et al., 2018). On other words, these apps were not designed to promote learning and...
development but for other purposes like entertainment or filling children's spare time. In addition, the achievement gap in the learning performance is another issue to be handled (Hung, Young, & Lin, 2015). Those children with poor learning performance are those who are at risk of being left behind in the classroom (Bradbury, Corak, Waldfogel, & Washbrook, 2015).

Cognitive development is one of the general goal of Early Childhood Care and Education (ECCE) (Mishra, 2009). Cognitive development involves the development of higher order thinking skills such as reasoning, problem solving, and decision-making skills (Bjorklund, 2013). These cognitive skills assist a child in exploring the world to which he belongs to, and include the understanding of object properties (colour and shape), forming own strategies for solving problems, and making selections among alternative choices. Language skills are said to set the foundation for cognitive development (Barac, Bialystok, Castro, & Sanchez, 2014; Marchman & Fernald, 2008; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Learning and master a language gives a child the ability to acquire knowledge and communicate with people.

1.1. Game-based learning and its platform

The advancement in technology allows GBL to be implemented in various platforms such as desktops, mobiles, and gaming consoles. In general, each platform has its own strengths and weaknesses in promoting children’s learning and development. Although computers have a high penetration rate in the household market for the last two decades, the use of a computer mouse may trouble young children with learning activities that require accuracy in clicking and aiming at target objects (Donker & Reitsma, 2007). Moreover, they may suffer from other computer-related physical discomforts (Jacobs & Baker, 2002).

The cellular and tablet platforms are similar in many ways. These two platforms provide multi-touch interaction, simplifying the input commands (i.e. typing and clicking) and reducing the difficulty and frustration in learning caused by the inaccurate aiming action. Besides, reviews of these platforms also indicate that the use of multi-touch interaction enhances the learning experience of pre-schoolers and facilitates collaboration among peers, as well as engagement with the learning environment (Nacher, Garcia-Sanjuan, & Jaen, 2016). The only limitation for these platforms is that it is not suitable for group learning, physical exercise, and gross motor skill development.

Recently, researchers are beginning to study the potential of a gesture and voice recognition feature in promoting early childhood learning. The current gaming console system such as Kinect utilises voice and gesture recognition technology to detect the players' voice and body movement in real time (Tashev, 2013; Yi, 2012). With the use of cameras and microphones, the players are no longer sitting on the floor and using a game controller to play a game but moving the body, hands, and legs in order to play a game. As the gaming system promotes more bodily movement, it may lead to a more active lifestyle and help prevent obesity.

Homer et al. (2014) conducted a study by embedding games that incorporated gesture-based interaction into the story reading process to engage preschool children in literacy activities. The use of in-game activities engaged the children in literacy activities and supported the acquisition of language and literacy skills. Hsiao and Chen (2016) used a gesture interactive GBL approach to improve the preschoolers' performance in learning word-related colours and enhance their coordination and agility with regards to their motor skills. The children who participated in the game intervention program demonstrated better learning performance and motor skills when compared to those who learnt through the traditional approach. To effectively attract the children’s interest of learning and improve their learning performance, the effort of integrating GBL with classroom learning has to be continued and should be connected to the latest and most innovative technology at hand.

1.2. Children's cognitive development

The foundation of language and communication plays an important role in the cognitive development of a child. Reading is an essential skill for building a foundation for language development and knowledge acquisition. Language has a positive effect on the developmental outcomes of a child (Zauche, Thul, Mahoney, & Stapel-Wax, 2016). The learning and use of a language may begin with vocabularies of familiar objects or the surrounding environment such colours (Carey, 1978) and shapes (Rieben & Perfetti, 2013).

Curiosity with one's surroundings encourages a child to start exploring the world around him. The process of learning may begin with familiar objects that are encountered every day. Usually, the visual contact with an object informs us about its colour and shapes. Colour and shape can provide useful information, such as being able to justify the freshness of food by the aforementioned features. In fact, many areas involve the sense and use of colour and shape such as aesthetics, art and design. The learning of colours and shapes can be affected by social interactions and culture (Althouse, Johnson, & Mitchell, 2003; Clemens & Sarama, 2014).

At the preoperational stage of cognitive development, young children (ages 2 to 7) can recognise colours, shapes, and sizes as well as use language to adapt to the world (Hsiao & Chen, 2016). According to a study investigated the children's brain growth for children from age 1 to 18 on (Vargas-Barón, 2005), a child's brain started to grow rapidly at aged 1 and reached an optimal level of growth at aged 4 but does not reach saturation till aged 13. In other words, the perfect timing for a child to learn may begin at age 4.

1.3. Game-based learning framework

Game-based learning framework is effective in designing, selecting, facilitating, and evaluating the educational game for learning purposes (Van Staaldhuizen & de Freitas, 2011). It incorporated both the instructional and cognitive approaches in four-dimensional framework (De Freitas & Oliver, 2006) and serious-games design framework (De Freitas & Jarvis, 2009) into the design process. This framework covers three important areas of the learning process, which are learning, instruction, and assessment (see Fig. 1). Learning objectives, player goals, and learning content are defined in learning column. For the instruction, learner, pedagogy, representation,
and context are integrated into the instructional approach to enhance the individual or group learning. Two types of assessment are recommended which are debriefing (informal assessment) and system feedback (in-game assessment) for evaluation purposes.

This framework offers a good model for educators and researchers to design or adopt educational games for learning purpose. In current study, it is modified for preschool children learning to enhance their learning. A game-based virtual learning environment (VGVLE) approach was proposed to foster the cognitive development of preschool children. A learning game, Fun to learn, was developed to teach colour and shape to preschool children. It operates on a game console that can recognise human voice and gesture signals. The preschool children will learn to pronounce the name of colours and shapes of an object and recognise its properties.

This study aimed to investigate the effectiveness of proposed game-based virtual learning environment (VGVLE) approach on aged 4 preschool children's learning performance and answer the following research questions:

1. Does the VGVLE approach improve preschool children's learning in terms of language and communication development?
2. Does the VGVLE approach improve the learning performance of preschool children at different categories of performance?

2. Game design and content mapping

The Game-based learning framework provides a complete guideline for aligning learning, instruction, and assessment (Van Staalduinen & de Freitas, 2011). The existing activities (learning, instruction, and assessment) are enhanced to give focus on preschool learning (see Fig. 1). Preschool children use voice and gesture interactions to communicate, interact and manipulate virtual objects in the game. Two types of assessment: Physical Game Assessment and Virtual Game Assessment were proposed to evaluate the knowledge transfer of preschool children in two different contexts: virtual reality and reality.

2.1. Learning

In the perspective of an educational setting, learning has objectives and each academic subject consists of specific content or skills to be learned. This framework aims to improve preschool children's learning in term of language and communication. Pronunciation skills and the ability to learn new vocabulary in a language play an essential role in the language and communication development (Buckley, 2012). The player goal is then defined as to learn the vocabulary.

A survey, which consisted of multiple choices and open-ended questions, was used to gather the information and suggestion of the participants on the scope of learning content. The choices of word were based on the published Early Childhood Care and Education (ECCE) syllabus (Cecille Maye-Hemmings & Wint, 2010; Damovska, Janeva, Palcevska, Panova, & Shaehu, 2006; GoB & Unicef, 2008). 32 participants from 16 preschools located in the Klang Valley, Malaysia volunteered to participate in this survey. The survey was conducted individually for confidentiality purposes. Majority have experience and are familiar with preschool education (see Appendix A1). They were advised to select those words that were appropriate to 4 years-old children. All the words that rated above 80% were selected for Fun to learn (see Appendix A2 & A3) and summarized in Table 1. The learning objective and player goal were
identified as well after the discussion with all the participants (see Table 2).

2.2. Instruction

“Educational games do not automatically facilitate a wished-for educational outcome, as this is seldom part of either the game universe or the game culture” (Van Staalduinen & de Freitas, 2011). The integration of educational instruction with game elements can ensure the delivering of learning objectives and desired learning outcomes (Garris, Ahlers, & Driskell, 2002).

Learning context, learner specifics, representation, and pedagogy are identified and used for designing educational game (see Table 3). Context refers to the setting of a game and the way it is played. Garris et al. (2002) listed the following elements to define a learning context: fantasy, rules/goals, sensory stimuli, challenge, mystery, and control. Although a fantastical context can easily immerse a player into a game, the effort on integrating educational content with fantastical context to promote learning is still questionable (Asgari & Kaufman, 2004; Gunter, Kenny, & Vick, 2008; Malone & Lepper, 1987). Using realistic context (use of real characters) to teach real world information to preschool children may be more easier than fantastical context (use of fantasy characters) (Richert & Smith, 2011; Richert, Shawber, Hoffman, & Taylor, 2009). As preschool children are the target learner, therefore a virtual learning environment (VLE) with real world objects and characters (realistic context) is designed to ease transfer of knowledge.

In brief, representation refers to interactivity and level of fidelity whereas pedagogy is the instructional approaches. Preschool children use voice to learn and practice word pronunciation whereas gesture-based interaction is for manipulating virtual objects in the game. Voice- and gesture-based interaction reduces the dependent on mouse, keyboard, and joystick and offers young children a natural form of human-computer interaction. To link the game with learning, scaffolding and trial-and-error are incorporated for Fun to learn to facilitate preschool children’s learning. The preschool children are assisted by hints, visual aids and demonstration to enhance learning and improve understanding of the learning materials. The trial-and-error approach allows them to continue practicing their learning on words. They may improve and strengthen their memory on words through this approach. Feedback is important to preschool children about their progress of learning (Nicol & Macfarlane Dick, 2006). Two types of feedback messages are provided: compliment message and repeat learning instruction. If correct response is received, a compliment message is shown else if the system receives an incorrect response or no response from the preschool children, the learning process will start again by repeating the learning instruction for the same word. The preschool children will repeat their learning and practice for the same topic until the correct response is given (trial-and-error). After the compliment feedback is received, the preschool children can proceed to next word.

2.2.1. Fun to learn

Fun to learn focuses on the development of language and communication skills of preschool children. There are total 13 words and divided into two categories: colour and shape (see Table 1). The teacher can select any word for the preschool children to practice via a drop down menu. Fig. 2 (a) and (b) are the examples for colour and shape learning respectively. A virtual avatar will teach the children to pronounce the selected word. The detected speech will be processed and verified by a speech recognition algorithm. For a correct response, a compliment will be given; else the avatar will repeat the teaching of that particular word. Colour Brush and Sticker Game are exercises that designed to strengthen their understanding and memory of the words they have learnt through gesture interaction, where the selection and movement of an object is done by hand gesture. Colour Brush allows the children to paint with a palette that consists of seven colours and labelled with their respective names (see Fig. 2(c)). There are six objects available for

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Categories of word.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Shape</td>
</tr>
<tr>
<td>Black</td>
<td>Circle</td>
</tr>
<tr>
<td>Red</td>
<td>Square</td>
</tr>
<tr>
<td>Orange</td>
<td>Rectangle</td>
</tr>
<tr>
<td>Yellow</td>
<td>Triangle</td>
</tr>
<tr>
<td>Green</td>
<td>Oval</td>
</tr>
<tr>
<td>Blue</td>
<td>Star</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>The learning objective and goal for Fun to learn.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning objective</td>
<td>Clear player goal</td>
</tr>
<tr>
<td>Language and communication</td>
<td>1 To learn and practice the vocabulary related with colours and shapes.</td>
</tr>
<tr>
<td></td>
<td>2 To recognise the colours and shapes.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
selection and each is designed based on the shapes selected for *Fun to learn* (see Table 1). *Sticker Game* is used to fortify the recognition of shapes (see Fig. 2(d)).

### 2.3. Assessment

"Assessment is a broad, comprehensive process, not any specific activity or technique" (Lidz, 2002). Assessment can be paper test, experiment, or evaluation. To effectively evaluate a child in various aspects, use of multiple forms of assessment is required. To examine the transfer of knowledge of preschool children as well as to compare their learning performance based on the different

#### Table 3

**Instructional design of Fun to learn.**

<table>
<thead>
<tr>
<th>Learner specific</th>
<th>Pedagogy</th>
<th>Representation</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preschool children</td>
<td>Demonstration, scaffolding, trial-and-error</td>
<td>Voice interaction</td>
<td>Realistic</td>
</tr>
<tr>
<td>User behaviour</td>
<td>• Recognise the correct correspondence between the word and its representation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pronounce the word correctly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Player feedback</td>
<td>• Compliment for correct response</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Repeat pronunciation for wrong response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td>• Participation in learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Willingness to continue and accomplish the learning task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>• Pronounce the word correctly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Recognise the word and its representation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting</td>
<td>Individual and/or group learning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Table 4

**Assessments for Fun to learn.**

<table>
<thead>
<tr>
<th>Type of assessment</th>
<th>Language and communication</th>
<th>Cognitive development</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speech</td>
<td>Vocabulary</td>
<td>Recognition skill</td>
</tr>
<tr>
<td>Physical Game Assessment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Virtual Game Assessment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

![Fig. 2. Screenshot of Fun to learn.](image-url)
learning approaches (i.e. classroom and VGVLE), two assessments: *Physical Game Assessment* (post-test (I)) and *Virtual Game Assessment* (post-test (II)) were developed (see Table 4).

Both the assessments are designed based on the scope of *Fun to learn*. A survey was conducted to collect the feedback from 32 preschool teachers for the proposed assessments. They were the same participants who took the survey on defining the scope of learning for *Fun to learn*. The validity (scope and marking scheme) of all tests were approved and accepted by all the participants. The assessments were revised based on their review and suggestion.

2.3.1. Post-test (I)

Post-test (I) consists of two tests, which are *Card Game* and *Q & A*. The purpose of this test is twofold. First, it examines the transfer of knowledge in a different context (i.e. game). Then, the effectiveness of the learning approach (classroom and VGVLE) in enhancing the learning performance of preschool children is evaluated. *Card Game* examines word recognition of various colours and shapes whereas *Q & A* evaluates the recognition and names of colours and shapes.

*Card Game* consists of two tests which are *Colour* and *Shape*. The *Colour* game uses seven toys and seven cards (each written with the name of one colour) (see Fig. 3 (a)) whereas the *Shape* assessment utilises six building blocks and six cards (see Fig. 3 (b)). *Q & A* is executed together with *Card Game* in the same session. The teacher will randomly select five objects for the use of the test. The child needs to tell the name (i.e. colour or shape) of the object and match the correct card with the given object. For example, a red scissor is given to a child. If the child can tell the colour of the scissor, he/she earns 1 mark for object recognition else 0 mark is given. Total mark for object recognition is 5 marks. If the child can find the card written with red and place it next to the scissors, he/she earns 1 mark for word recognition else 0 mark is given. Total mark for word recognition is 5 marks. The *Shape* test works in a similar fashion.

2.3.2. Post-test (II)

*Virtual Game Assessment* is used to evaluate the learning performance of the preschool children in VLE. The preschool children will be evaluated through games. The choices that they made reflect their knowledge and learning progress (recognition of colour/shape and decision making). They are assessed individually in all the assessments.

Post-test (II) runs on a game console and utilises voice and gesture inputs for interaction purposes. It consists of four tests, namely, *Colour Quiz*, *Shape Quiz*, *Ball Game* and *Keep the Toys*. The *Colour Quiz* and *Shape Quiz* are designed to evaluate the recognition of colours and shapes respectively. A uniform randomisation algorithm was used to randomly select five objects for the evaluation purposes. Let’s assume a child is taking the *Colour Quiz*. The child is required to tell the name of the colour for the shown object (see Fig. 4 (a)). 1 mark is awarded for each correct answer whereas 0 is given for an incorrect or absent answer. Similarly, the child has to tell the name of the shape for the displayed object in the *Shape Quiz* (see Fig. 4 (b)).

On the other hand, both the *Ball Game* and *Keep the Toys* assessment are designed to examine the decision making skills of preschool children in the areas of colour and shape recognition. For the *Ball Game*, a child is required to select five balls based on the given instruction and put it into a basket (see Fig. 4 (c)). A uniform randomisation algorithm was used to randomly select five objects for the evaluation purposes. 1 mark is awarded for each correct answer whereas 0 is given for an incorrect or absent answer. *Keep the Toys* works in a similar way (see Fig. 4 (d)). The teacher is allowed to remind the child to give responses for all the aforementioned tests but not to hint or tell the answer.

2.4. System architecture and design

The system architecture consists of *Fun to learn*, Application Manager, and Storage Manager (see Fig. 5). *Fun to learn* was developed using .NET C# running on Visual Studio 2015. It is a standalone system that runs on Xbox Kinect console (somatosensory platform), a device that used to process visual, voice and gesture signals. The Xbox console requires a monitor or a projector screen for visual display. The Application Manager responsible to launch a game (*Fun to learn*) and manage communication between game.
and the Storage Manager, which is used to handle the data query, accessing and storing. The preschool children can learn, practice, and take assessment using gesture or speech. Their assessment result will be saved in the Storage Manager individually. The teacher can launch Fun to learn using voice/gesture command via Xbox 360 and view the children’s assessment results via a web browser.

2.5. Testing

Fun to learn had gone through three testing, which were speech recognition, gesture recognition and system integration testing. Speech recognition testing aimed at finding the best acceptance level of speech recognition without losing the clarity whereas the testing of gesture recognition focused on skeletal tracking function. The system integration testing mainly tested on system function (e.g. data storing and retrieving, loading of game, command), picture quality, and system compatibility.

Children have a shorter vocal tract and vocal folds (Benzeghiba et al., 2007). Therefore, they have higher pitch when compared with adult’s speech (Gerosa, Giuliani, & Brugnara, 2007). A preliminary test was conducted for sixteen (16) 4-year-old children (8 boys and 8 girls) to examine the level of acceptance (the confidence level (CL)) for the speech recognition function. CL is not the indicator for speech accuracy but works as a mechanism for deciding the best acceptance level of speech recognition without losing clarity. Its value ranging from 0 to 1, where 0 represents the lowest confidence, and 1, the highest. They were taught to read all the words in Fun to learn. The detected speech was translated into text. If the translated text is the same as the spoken speech, the speech recognition is correct otherwise, the speech recognition is incorrect. The testing result showed that the correct recognition rate is between 75% (12/16) and 81% (13/16) when CL = 0.55. Therefore, the best CL value for the group of 4 years old children is 0.55.

After the testing on gesture recognition, the skeletal tracking function was adjusted to be flexible in tracking the movement of 4
year old children. The system integration testing also showed that *Fun to learn* met all the specified requirements.

3. Method

3.1. Participants

This study includes 84 preschool children (44 boys and 40 girls, average age 4.3 years) from 16 kindergartens in Klang Valley, Malaysia. The participants is comprised of 61.9% (52) Chinese, 28.6% (24) Malay, 4.8% (4) Indian, and 4.8% (4) other races (i.e. Arab and Iban). Their family is at middle socioeconomic class and the native language is not English. This study was approved by the authorities of participated preschool and parents via written informed consent.

3.2. Procedure

An intervention program was conducted in sixteen selected preschools (kindergartens) using the proposed system- *Fun to learn*. Fig. 6 illustrates the execution procedure of the intervention program. A pre-test, which consists of ten questions (5 questions on colour and 5 questions on shape recognition), was given to all the participating children (see Appendix B). The pre-test was reviewed and approved by two kindergarten teachers with master in preschool education and have at least 10 years of preschool's teaching experience. This test aimed to examine their prior knowledge on colour and shape. One (1) mark for each correct answer (total marks = 10). The final score will then be converted to a percentage. The children were divided into three categories of performance: *Excellent* (80% and above), *Average* (between 50% and 79%), and *Low Performance* (below 50%) based on their final score. This test was given to 20 preschool children (10 girls and 10 boys) at age 5 one month before the execution of intervention program. The test was acceptable and reliable (Cronbach’s $\alpha = 0.712$).

After that, the children in each category were randomly assigned into two groups, the control group (24 boys and 19 girls, total = 43) and the experimental group (20 boys and 21 girls, total = 41). The control group followed the existing classroom lesson on shape and colour lessons whereas the experimental group learnt with VGVLE approach. This grouping allowed the examination on the effectiveness of the VGVLE approach for children at different categories of learning performance and the comparison of their learning performance before and after participating in the intervention program. The intervention program was conducted for 4 weeks, 1 day a week, with each daily session lasting up to 10 min (4 min for group learning and 6 min for individual practice). There are two post-tests: Post-test (I) and Post-test (II). After the intervention program had ran its course, all children sat for the Post-test (I). Additionally, the experimental group was also required to take the Post-test (II) that ran on game console. The final score of Post-test (I) (20 marks) and Post-test (II) (20 marks) will then be converted to a percentage for comparison purposes.

4. Results

A total of 84 preschool children had taken the pre-test ($N = 84$, $M = 53.33$, $SD = 19.53$). A normality test (Shapiro-Wilk Test) was conducted to ensure the sample is normally distributed. As the Sig. (significant) value of the Shapiro-Wilk Test was greater than 0.05, the collected data was normal. The children were divided into three categories (*Excellent*, *Average* and *Low Performance*) and
randomly assigned into two groups (control group and experimental group). A paired-samples t-test was used to compare the learning performance of these two groups before and after the intervention program. The significant level was set at 0.05. A factorial ANOVA (Analysis of variance) was conducted to examine the main effects of group (control, experimental) and category (Excellent, Average and Low Performance) and the interaction effect between group and category on 84 preschool children’s overall learning performance (Post-test I). Analysis of covariance (ANCOVA) was used to examine the effect of group and category and the interaction effect between group and category on learning performance of colour and shape. All effects were statistically significant at the .05 significance level and a partial eta square, $\eta^2_p$ was provided as a substitute for effect size.

4.1. Analysis of post-test (I)

Overall, the experimental group outperformed the control group in Post-test (I) (see Fig. 7). According to the t-test analysis, experimental group demonstrated a significant difference ($t = -11.47, p < 0.001$) in Post-test (I) ($N = 41, M = 74.15, SD = 15.28$) when compared with their pre-test ($N = 41, M = 55.12, SD = 18.32$). The control group had higher score for Post-test (I) ($N = 43, M = 66.05, SD = 17.75$) when compared with their pre-test ($N = 43, M = 50.93, SD = 19.37$) and this also showed a significant difference ($t = -4.98, p < 0.001$).

According to the ANOVA analysis, the main effect for group yielded an F ratio of $F(1,83) = 5.93$, $p < 0.05$, $\eta^2_p = 0.07$ indicating a significant different between control group ($N = 43, M = 66.05, SD = 17.75$) and experimental group ($N = 41, M = 74.15, SD = 15.28$). The main effect for category yielded an F ratio of $F(2,82) = 18.62$, $p < 0.001$, $\eta^2_p = 0.32$ indicating a significant different between Low performance ($N = 23, M = 58.04, SD = 15.28$), Average performance ($N = 49, M = 71.33, SD = 13.22$), and Excellent performance ($N = 12, M = 87.50, SD = 17.52$). The interaction effect between group and category on preschool children’s learning performance was also significant ($F(2,82) = 3.20$, $p < 0.05$, $\eta^2_p = 0.08$).

Fig. 8 illustrates the comparison of mean score between control group and experimental group by category of performance. In the category of Excellent performance, the experimental group ($N = 6, M = 98.33, SD = 2.58$) scored better than the control group ($N = 6, M = 76.67, SD = 19.66$). For the category of Average performance, experimental group's children ($N = 26, M = 74.81, SD = 10.34$) also achieved better results than the control group's children ($N = 23, M = 67.39, SD = 15.14$). However, in the category of Low performance, the control group ($N = 14, M = 59.29, SD = 19.40$) scored better than the experimental group ($N = 9, M = 56.11, SD = 4.86$).
4.1.1. Analysis of children performance by test

Further analysis was conducted on word recognition (Card Game) and object recognition (Q & A). According to the ANOVA analysis, the effect of group was not significant \((F(1,83) = 3.71, p = 0.06, \eta^2 = 0.05)\). The main effect for category yielded an \(F\) ratio of \(F(1,83) = 17.17, p < 0.001, \eta^2 = 0.31\) indicating a significant different between Low performance \((N = 23, M = 5.74, SD = 0.30)\), Average performance \((N = 49, M = 6.70, SD = 0.20)\), and Excellent performance \((N = 12, M = 8.67, SD = 0.4)\). The interaction effect between group and category on preschool children's learning performance was not significant \((F(2,82) = 2.80, p = 0.07, \eta^2 = 0.07)\).

Fig. 9 shows the comparison of performance in word recognition between the control group and the experimental group by category of performance. In the category of Excellent performance, the experimental group \((N = 6, M = 9.67, SD = 0.57)\) scored better than the control group \((N = 6, M = 7.67, SD = 0.57)\). For the category of Average performance, the experimental group's children \((N = 26, M = 7.19, SD = 0.27)\) also achieved better results than the control group's children \((N = 23, M = 6.74, SD = 0.29)\). However, in the category of Low performance, the control group \((N = 14, M = 5.93, SD = 0.37)\) scored better than the experimental group \((N = 9, M = 5.56, SD = 0.47)\).

According to the ANOVA analysis, the main effect for group on object recognition yielded an \(F\) ratio of \(F(1,83) = 8.08, p < 0.01, \eta^2 = 0.09\) indicating a significant different between experimental group \((N = 41, M = 7.81, SD = 0.27)\) and control group \((N = 43, M = 6.78, SD = 0.25)\). The main effect for category yielded an \(F\) ratio of \(F(1,83) = 18.68, p < 0.001, \eta^2 = 0.32\) indicating a significant different between Low performance \((N = 23, M = 5.74, SD = 0.30)\), Average performance \((N = 49, M = 6.70, SD = 0.20)\), and Excellent performance \((N = 12, M = 8.67, SD = 0.4)\). The interaction effect between group and category on preschool children's learning performance was also significant \((F(2,82) = 3.45, p < 0.05, \eta^2 = 0.08)\).

Fig. 10 shows the comparison of performance in object recognition between the control group and the experimental group by category of performance. In the category of Excellent performance, the experimental group \((N = 6, M = 10.0, SD = 0.58)\) scored better than the control group \((N = 6, M = 7.67, SD = 0.58)\). For the category of Average performance, the experimental group's children \((N = 26, M = 7.77, SD = 0.28)\) also achieved better results than the control group's children \((N = 23, M = 6.74, SD = 0.29)\). However, in the category of Low performance, the control group \((N = 14, M = 5.93, SD = 0.38)\) scored better than the
experimental group ($N = 9, M = 5.67, SD = 0.47$).

### 4.2. Comparison of children’s learning performance

The learning performance in pre-test and Post-test (I) was compared by group and category of performance. The pre-test did not include the Q & A test, therefore only the score of Card Game was used to compare with the pre-test’s score.

#### 4.2.1. Difference in learning colour’s word

Overall, the experimental group outperformed the control group in colour recognition (see Fig. 11). According to the $t$-test analysis, experimental group demonstrated a significant difference ($t = -4.83, p < 0.001$) in Card Game ($N = 41, M = 3.56, SD = 0.87$) when compared with their pre-test ($N = 41, M = 3.02, SD = 0.99$). In contrast, the control group also had higher score in colour recognition ($N = 43, M = 3.33, SD = 0.92$) when compared with their pre-test ($N = 43, M = 2.81, SD = 1.16$) and this also showed a significant difference ($t = -2.79, p < 0.01$).

For ANCOVA analysis, the pre-test score as the covariate was 2.92. The adjusted mean scores for group: experimental group ($3.65$ and control group ($3.37$) and category: Excellent ($3.84$), Average ($3.41$), and Low ($3.28$). Although the effect of group ($F(1,82) = 2.11, p = 0.15, \eta^2 = 0.03$) and category ($F(2,82) = 1.20, p = 0.31, \eta^2 = 0.03$) were not significantly related to colour’s learning performance, the interaction effect between group and category on colour’s learning performance was significant ($F(2,82) = 4.15, p < 0.05, \eta^2 = 0.10$).

Fig. 12 shows the comparison of performance in colour’s word between the control group and the experimental group by category of performance. In the category of Excellent performance, the experimental group ($N = 6, M = 4.36, SD = 0.34$) scored better than the control group ($N = 6, M = 3.52, SD = 0.24$). For the category of Average performance, the experimental group’s children ($N = 26, M = 3.54, SD = 0.15$) also achieved better results than the control group’s children ($N = 23, M = 3.31, SD = 0.16$). However, in the category of Low performance, the control group ($N = 14, M = 3.28, SD = 0.35$) scored better than the experimental group ($N = 9, M = 3.04, SD = 0.27$).

#### 4.2.2. Difference in learning shape’s word

Overall, the experimental group outperformed the control group in shape recognition (see Fig. 13). According to the $t$-test analysis, experimental group demonstrated a significant difference ($t = -6.28, p < 0.001$) in Card Game ($N = 41, M = 3.61, SD = 0.89$) when compared with their pre-test ($N = 41, M = 2.49, SD = 1.38$). The control group also had higher score in colour recognition ($N = 43, M = 3.28, SD = 1.08$) when compared with their pre-test ($N = 43, M = 2.28, SD = 1.22$) and this also showed a significant difference ($t = -5.49, p < 0.001$).

For ANCOVA analysis, the pre-test score as the covariate was 2.38. The following are the adjusted mean scores for group: experimental group ($3.67$) and control group ($3.29$) and category: Excellent ($3.87$), Average ($3.51$), and Low ($3.05$). There were no significant effect of group ($F(1,82) = 2.97, p = 0.09, \eta^2 = 0.04$), category ($F(2,82) = 2.21, p = 0.12, \eta^2 = 0.05$) as well as the interaction effect between group and category ($F(2,82) = 1.34, p = 0.27, \eta^2 = 0.03$) on shape’s learning performance.

Fig. 14 illustrates the comparison of mean score between control group and experimental group by category of performance. In the category of Excellent performance, the experimental group ($N = 6, M = 4.35, SD = 0.40$) scored better than the control group ($N = 6, M = 3.44, SD = 0.39$). For the category of Average performance, the experimental group’s children ($N = 26, M = 3.59, SD = 0.17$) also achieved better results than the control group’s children ($N = 23, M = 3.39, SD = 0.18$). However, in the category of Low performance, the control group ($N = 14, M = 3.04, SD = 0.25$) scored better than the experimental group ($N = 9, M = 3.07, SD = 0.18$).
4.3. Analysis of post-test (II)

The analysis of post-test (II) was decided upon to only investigate the difference by category. Fig. 15 illustrates the comparison of performance in the Colour Quiz, Shape Quiz, Ball Game, and Keep the Toys test. The children showed good performance in all the tests especially for Keep the Toys (ceiling performance). This suggested that the gap of performance was reduced among the children in experimental group.

5. Discussion

This study was conducted to investigate the effectiveness of the game-based virtual learning environment (VGVLE) approach on preschool children's learning performance. In addition to that, we were also interested in evaluating the effects of VGVLE in assisting the preschool children with different category performance (Excellent, Average & Low). A quasi-experimental approach with randomised, non-equivalent pretest-posttest control group design was adopted for this study. Overall, both groups showed better performance in the Post-test (I) than the pre-test. The children in the experimental group surpassed those who were in the control group, demonstrating a significant difference after attending the intervention program. The findings also reveal that VGVLE was equally
beneficial to both boys and girls and reduced the gap in performance among the children in experimental group. Throughout the observation, almost all participating children enjoyed the assessment activities (post-test I & II) as a form of play and were willing to complete and repeat the activities.

5.1. Analysis of post-test (I)

Post-test (I) examined the children’s word recognition (language) skill via Card Game and evaluated their communication skill through Q & A. The Card Game tests the children on word recognition whereas Q & A challenges the children on object recognition skill (colour and shape). For Q & A, the children needed to recall the name of the shown object (i.e. colour and shape) and tell it correctly. Through the observation, most of the children can easily identify the colour and shape of shown object. On the other hands, Card Game examines their memorizing skill in looking for a right card. Some of the children encountered difficulty to match the right word (name) to the shown object. The findings are in line with current research that human can recognise and process pictures more easily than words (Dewan, 2015). However, more practice can strengthen their memory on word and improve the learning performance.

Overall, the word recognition performance of the experimental group was better than the control group. The gap in performance for children at the Excellent, Average and Low performance was reduced compared with the results garnered from the pre-test. The results reveal that an effective GBL approach can also minimise the gap in achievement (Hung et al., 2015).

The children’s word learning performance can be influenced by their familiarity with the objects they need to learn and name (Gray & Brinkley, 2011; Sera, Cole, Oromendia, & Koenig, 2014). This is essential as learning words through categorisation can enhance the ability to retain words and their conceptual properties (Neuman, Newman, & Dwyer, 2011). The Excellent performance of the experimental group in Card Game is consistent with the aforementioned studies and suggests that the selection and categorisation of words are suitable for preschool-aged children and that the design of the learning system can produce a sense of familiarity with the learning subject. Moreover, the findings also confirm the appropriateness and level of challenge of the learning activities in
delivering content knowledge to preschool-age children. Besides, sufficient practice and engaging learning activities (VLE with voice interaction versus whiteboard and objects) may also be contributing factors of the good performance.

Early word learning is linked with the ability to recognise and differentiate an object (Jones & Smith, 2005; Smith, 2013). Word learning is a process to translate visual codes (vocabulary) into meaningful language (Whitehurst & Lonigan, 1998). Linking vocabulary with semantic representation could be one of the many effective ways to learn a word. Let's take the word “ant” as an example. The logical connection between word and object can be formed easily if a child knows what an ant is or how it looks. Otherwise, “ant” is meaningless to the child and increases the difficulty of remembering and recognising the word. The correlation between shape and word recognition performance establishes a link between object recognition (shape) skill and word learning. This study also indicates that careful design of learning activities (object used and interaction method) can trigger the children’s interest of learning, while simultaneously enhance their learning performance as well as the recall of a particular word and image.

5.2. Analysis of post-test (II)

The post-test (II) assessed the children’s ability in applying the learnt knowledge in a virtual context. Through observation, all the children in the experimental group demonstrated great motivation in learning during the intervention program. Different approaches such as a question and answer (Q & A) session and various games were used to evaluate the children’s learning performance. The tremendous performance shown by the experimental group provides evidence for transfer of knowledge across modalities (different assessment method) (Barnett & Ceci, 2002). In addition to that, the analysis of three categories of performance (Excellent, Average, and Low) showed that the gap in learning performance was reduced especially in Keep the Toys. According to Aunola, Leskinnen, Lerkkonen, and Nurmi (2004), children with different category performance can also benefit from a different curriculum and methods of instruction. Besides, Hung et al. (2015) also reported that learning with effective GBL approach can help diminish the gap in achievement.

Mitchell and Savill-Smith (2004) stated that games can enhance children’s cognitive development and this can be seen through the performance in Ball Game and Keep the Toys, which examine the children’s problem solving skills. Many studies have reported that learning with games can improve the children’s learning performance (Chuang, 2007; Muis, Ranellucci, Trevors, & Duffy, 2015; Shute, Ventura, & Ke, 2015) and thus lead to further changes in knowledge, attitudes, behaviour, and skills (Iftentaler, Eseryel, & Ge, 2012). The children absorb the knowledge presented to them through game activities while subsequent practice serve to reinforce their memory on the content knowledge, thereby improving their learning performance (Hsiao & Chen, 2016). This explains the improvement shown by the experimental group in post-test (I) and (II). This finding suggests that with sufficient practice, VGVLE approach could assist children at different category performance to improve and achieve for a more profitable learning experience.

6. Limitation

This study compared the effects of VGVLE with the conventional classroom approach on the learning performance of preschool children. However, the studied subjects focused only on learning colours and shapes. Therefore, a future direction of study might consider expanding the subjects to include other languages such as Chinese or Malay, academic subjects (i.e. music, mathematics, and science), and even psychomotor skills for preschool children. Another limitation of this study is that it evaluates only the short term effects of VGVLE on learning. A longitudinal design with a broader scope would be useful in evaluating the effectiveness of the proposed approach in promoting the learning of preschool children. Also worth noting is that this study did not investigate the factors of age group, socioeconomic status (SES), race, religion, subject, and language due to time and resource constraints. Consequently, future studies should consider including these factors to comprehensively investigate the usefulness of the proposed approach in improving the learning experience of preschool children and minimising the learning gap.

7. Conclusion

This study proposed a VGVLE approach to enhance the preschool children’s. The proposed approach allows preschool children to explore and learn in a realistic context that is closely represented by real life objects and environments. The embedded voice and gesture interaction is capable of attracting the interest of preschool children and promoting learning. Moreover, this natural form of control and object manipulation enhances the children’s learning experience and deepens their understanding and memory of learning materials. The evaluation via games was accepted by the teachers and enjoyed by the children. This suggests that games can be used as one of the formal assessment approaches especially for preschool children.

The proposed approach improved the learning performance of preschool children in term of language and communication. Besides, it also helped to reduce the gap in performance for children at different categories of learning performance (Excellent, Average and Low categories). Furthermore, it encouraged the use of multiple evaluation approaches to evaluate the preschool children's learning performance such as Q & A, card games and computer games.

In conclusion, preschool education requires continuous research and effort in improving the quality of learning, use of variety assessment methods (modalities) as well as the interest to learn. In this context, the researchers, educators, and developers should work together in developing good quality educational games and software without sacrifice the element of fun to enhance the preschool’s learning process and children’s learning experience.
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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.cpepedu.2018.08.015.

References


