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Using a gesture interactive game-based learning approach to improve preschool children's learning performance and motor skills

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A B S T R A C T

Children love to play games, and early childhood is a critical time for developing motor skills. This study combined gesture-based computing technology and a game-based learning model to develop a gesture interactive game-based learning (GIGL) approach that was suitable for preschool children. In this research, the ASUS Xtion PRO was used as a game-based device to build a virtual interactive learning environment for preschoolers. The aim of this study was to implement the GIGL approach to improve the learning performance and motor skills (namely, coordination and agility) of the participants. Based on a quasi-experiment involving 105 preschoolers (average age 5.5 years), the results showed that the participants who used the GIGL approach demonstrated better learning performance and motor skills than those who used the traditional activity game-based learning approach, and the statistics showed a significant deviation between the two approaches. Thus, this study provides additional evidence that using a GIGL approach is an effective learning method that improves both learning performance and motor skills to a greater extent compared with the traditional activity game-based learning approach.

1. Introduction

In gesture interactive game-based learning (GIGL), students use gesture-based interfaces (such as Microsoft Kinect, ASUS Xtion PRO, Nintendo Wii, etc.) to combine body movements with learning materials. This helps students to reinforce their memories, comprehend learning materials, improve their learning performance, and strengthen their motor skills in a student-centered context in which learners are actively engaged (Altanis, Boloudakis, Retalis, & Nikou, 2013; Chao, Huang, Fang, & Chen, 2013; Huang, Liu, Kao, & Huang, 2009; Lee, Huang, Wu, Huang, & Chen, 2012; Li, Wang, Wu, & Chen, 2014; Lu, Liu, Chuang, & Peng, 2012; Wu, Huang, & Chang, 2013). Early childhood is a critical period for developing motor skills (Chang, Huang, & Huang, 2010; Piao, 2010; Sun, Zhu, Shih, Lin, & Wu, 2010; Yang, Lin, & Tsai, 2014). Accompanied with positive reinforcement, sufficient instructional demonstration, and a suitable learning environment, exercise benefits the development of motor skills (Gallahue & Donnelly, 2003; Hsiao, Chen, & Hong, 2015; Piao, 2010). As an emerging technology, gesture-based devices have opened new opportunities for learning (Sheu & Chen, 2014). Teachers can observe students as they perform specific motions to solve learning tasks and obtain feedback directly from the playing screen. This entire process

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improves children's gross motor skills (Altanis et al., 2013; Hsiao et al., 2015; Huang et al., 2009; Li et al., 2014; Miller, Tsui, & Dearden, 2010).

As it is pivotal for children to learning from playing, it has found that game, especially those for children, play an important role in cognitive development (Mitchell & Savill-Smith, 2005) and reinforcing children's motor skills (Altanis et al., 2013; Huang et al., 2009; Li et al., 2014). Moreover, in Taiwan, according to the Educare Service Guidelines for Preschools, "every preschool should schedule gross-motor movement activity that involves perspiration for at least 30 min per day" (Ministry of Education, 2011). Combining motor movement activities and learning using a GIGL approach in preschools would meet this recommendation for daily physical activities. Between 2011 and 2014, New Media Consortium highlighted several times in the *Horizon Report* that both the game-based learning model and the gesture-based learning model provide preferable learning opportunities that allow students to interact in a multimedia learning environment. Motor skills development is crucial to children's learning because their cognitive learning is based on movement sensitivity (Gallahue & Donnelly, 2003; Sun et al., 2010). Therefore, numerous research has been devoted to creating a GIGL approach that is effective in enhancing children's learning performance and motor skills (Altanis et al., 2013; Huang et al., 2009; Li et al., 2014; Lu et al., 2012; Wu et al., 2013).

Preschool children (approximately 3–6 years old) are in the preoperational stage of cognitive development (ages 2 to 7), and they can recognize colors, shapes, and sizes and can use language to adapt to the world (Piaget & Inhelder, 1969). Pitchford and Mullen (2005) suggested that color preference, linguistic input, and developing color cognition may be linked. Moreover, according to the Educare Activity Curriculum Outline for the Preschool, "the six areas of curriculum guidelines for preschool include body movement, cognition, language, society, emotion and aesthetic feeling" (Ministry of Education, 2012). Thus, this study developed an interactive game using gestures called "The Goalkeeper" to teach the subject of "color recognition," which involved learning six different colors (namely, cognition) and their corresponding names in English (namely, language). This study hypothesized that the preschoolers' cognitive development and body movement would improve using the GIGL approach as posited by the research questions, which are presented in Section 3.

2. Related research

2.1. Gesture-based learning

The features of gesture-based devices allow the user as a controller to interact with the computer more directly through the use of motions and movements that are naturally performed in daily life (Johnson, Adams, & Cummins, 2012). People have used gesture-based devices to detect the location, direction, and activity records of an object in real-space (Hsiao et al., 2015). Low-cost and easily accessible gesture recognition technology that can accurately capture the natural movements of the human body has already been developed (Hsiao et al., 2015). The application of gesture-based computing technology in training and education is continually expanding (Sheu & Chen, 2014). Gesture-based learning involving body movements provides different learning channels for students, which helps them to understand learning materials more easily (Hostetter & Alibali, 2008; Tellier, 2008; Wilson, 2002).

Somatosensory interactive man-machine interfaces have been applied in the fields of entertainment, rehabilitation, and learning. Examples of technology in the learning field include the ASUS Xtion PRO somatosensory sensor and Kinect for Windows, which were released in 2011 and 2012, respectively (Wu et al., 2013). Microsoft Kinect and ASUS Xtion PRO are similar computing devices that are now becoming widely used, as they provide both range and video images at a reduced cost in comparison with previous generations of such devices (Farid & Sammut, 2014). Gesture-based computing devices such as Kinect, Xtion, and others are often used to improve learners' gross motor skills, memorization, aesthetic recognition, art learning ability, learning motivation, and learning performance in various disciplines (Altanis et al., 2013; Chao et al., 2013; Lee et al., 2012; Li et al., 2014; Lu et al., 2012; Wu et al., 2013). Additionally, the Nintendo Wii is one of the most utilized gesture-based devices in academic research (Sheu & Chen, 2014). The Wii console and interactive controller provide users with more interactive experiences than typical push-button controllers do (Lee, 2008; Miller et al., 2010). Moreover, the Wii console as a training simulator can improve users' fine motor control, visuospatial processing, hand-eye coordination, and two-dimensional depth perception (Hsiao et al., 2015).

Gesture-based computing devices are used to support teaching and learning within different sub-education domains, such as science and math education, general education, physical education, and other education-related fields (Sheu & Chen, 2014). For example, Altanis et al. (2013) used a Kinect learning game to help children with gross-motor skills problems and motor impairments improve skills that are required in their daily lives. Li et al. (2014) designed a motion-sensing curriculum for physical education using Microsoft Kinect. Additionally, Ochoa, Rooney, and Somers (2011) and Wheeler (2011) used the Wii remote as a device for their designed experiments and demonstration projects, which involved Newton's Third Law and simulations of weightlessness. Hsiao et al. (2015) used the Nintendo Wii remote to measure and train the hand motor skills of senior vocational school students. Chao et al. (2013) used the Microsoft Kinect sensor to build a learning system to improve university students' memorization of English vocabulary and phrases, while Lee et al. (2012) used the Microsoft Kinect sensor to build a near-authentic environment in which college students could be engaged in designated situations through their body movements. Moreover, Di Tore, Aiello, et al. (2012) and Di Tore, D'Elia, Aiello, Carlomagno, & Sibilio (2012) used Kinect to create a visual-motor game that improved fifth grade students' integration skills. Lu et al. (2012) used a webcam to design physically interactive games to teach the Minan dialect, focusing on third grade elementary school students. Furthermore, Wu et al. (2013) used the ASUS Xtion PRO as a somatosensory game device for third and fourth grade elementary school students that explored the children's aesthetic experiences. These studies have shown that gesture-based computing devices are popular in improving students' learning performance and motor skills.

Of the computing devices mentioned, the Nintendo Wii has been found to be a popular gesture-based computing device that is useful for training users' abilities in fine motor control, visuospatial processing, and hand-eye coordination. Moreover, Microsoft Kinect and the ASUS Xtion PRO are useful for building a near-authentic learning environment in which students can improve their gross motor skills through their body movements. While it has been shown that gesture-based computing devices support motor skills development and learning performance, past studies have usually focused on primary students, young people, or adults. There has been very little research concerning improving preschool children's learning performance and motor skills. In this study, we used gesture-based computing devices with preschool children to assess learning, cognitive, and gross motor skills development.

2.2. Motor skills

The fundamental movement skills of preschoolers are movements that involve at least two body parts (Gallahue, 1996). Motor skills involve the knowledge of how to complete a task and when to conduct the task in order to achieve its completion (Hsiao et al., 2015), as well as the processing of information via mental skills, which includes the reception of information, understanding the information, determining the appropriate response, and the execution of movement (Fleming, 1993). The classification of motor skills is based on “stability, locomotion, and manipulation,” and a gradual improvement in these three areas should produce a positive effect on children's growth and exercise capacity (Chang & Shih, 2003; Gallahue & Ozmun, 2002; Goshi, Demura, Kasuga, Sato, & Minami, 1999; Knight & Rizzuto, 1993).

Gabbard, LeBlanc, and Lowy (1987) identified the early childhood state (ages 2 to 7) as the fundamental movement phase of motor development. Moreover, it has been found that coordination and agility are fundamental abilities in developing body movement (Gallahue & Ozmun, 1998). Motor-skills learning involves a set of processes associated with practice or experience that leads to relatively permanent changes in movement capability (Schmidt & Lee, 1988) that can be improved through learning and repetitive practice. Gallahue and Ozmun (1998) divided the fundamental movement phase into three stages: the initial stage, the elementary stage, and the mature stage. In the initial stage (2–3 years old), children begin to engage in running-based action; however, their movements are slow and immature and lack coordination. In the elementary stage (4–5 years old), children's speed of movement becomes more agile and their physical coordination improves; for example, they can catch and throw ball but they still display clumsy body movements. In the mature stage (6–7 years old), children's body movement has matured to the point where they can coordinate their whole body to complete various actions; for instance, they can throw farther and more accurately, run faster, and move their body more quickly.

In considering how the preschoolers' muscle and body movements are trained during physical activities, it was decided that coordination and agility would be the focal point of this study. In this study, coordination is defined as the ability of the body to coordinate the neural and muscular systems to perform accurate, harmonious, and elegant movements. It is also a skill that is related to fitness and is present in people who exercise. In the physical activity session, the students were required to raise their arms, stand on their feet, balance their body, prepare to catch a ball, and eventually catch the ball, which all functioned as a means of enhancing coordination. Agility, on the other hand, is defined as the ability of the body to move and change direction swiftly and accurately without losing its balance. Changing direction involves either the entire body or parts of the body. In the physical activity session, the students have to move their body swiftly to the correct position in order to catch a ball, thereby enhancing their agility.

2.3. Game-based learning

Game-based learning, a recently emerged and highly exciting medium, actively engages students in learning through interactive entertainment (Prensky, 2007). Most research concerning gesture-based computing devices developed learning content in conjunction with game-based learning (Altanis et al., 2013; Di Tore, Aiello, et al., 2012; Di Tore, D'Elia et al., 2012; Lu et al., 2012; Wu et al., 2013). Sheu and Chen (2014) highlighted that body and mind are connected and, therefore, body movements assist learners in acquiring knowledge. Moreover, the “flow state,” pioneered by Csikszentmihalyi (1975) in a study of individuals involved in activities such as dancing, has also been found to improve children's learning performance. Characterized by the complete absorption or engagement in an activity, flow refers to an optimal experience (Csikszentmihalyi & Csikzentmihaly, 1991).

Garris, Ahlers, and Driskell (2002) proposed the Input-Process-Outcome (IPO) game-based learning model as an educational game design to improve children's learning performance (Ghergulescu & Muntean, 2014; Ibrahim, Yusoff, Omar, & Jaafar, 2011; Martens, Gulikers, & Bastiaens, 2004; Yang, Lin, Wu, & Chien, 2008), which is a tacit model that is inherent in most studies on instructional games (Ibrahim et al., 2011). For example, Yang et al. (2008) used the IPO model to improve the English learning achievement, motivation, and attitude of elementary school third graders. Ghergulescu and Muntean (2014) proposed a Motivation Assessment-oriented Input-Process-Outcome (MotIPO) game model to design an educational game. As shown in Fig. 1, the IPO game-based learning model includes three parts: (1) the Input, which is the design of the instructional content that incorporates the game's characteristics. Garris et al. (2002) suggested six different types of game characteristics, including Fantasy, Rule/Goal, Sensory Stimuli, Challenge, Mystery, and Control; (2) the Process, which

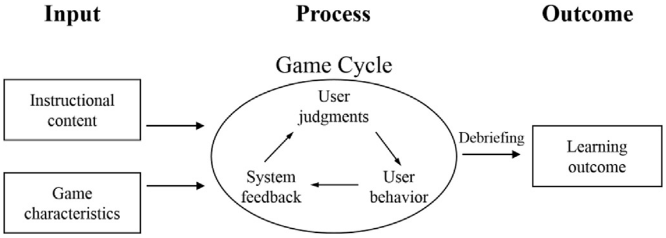


Fig. 1. The IPO game-based learning model (Garris et al., 2002).

represents a game cycle, including users' judgments (enjoyment or interest), users' behavior (greater persistence or time spent on a task), and system feedback (feedback pattern of the interaction between users and the system) (Yang et al., 2008); and (3) the Outcome, which analyzes the achievement of training objectives and specific learning outcomes (Ibrahim et al., 2011).

Considering the playful nature of children, the design of the physical activity session in the current study adopted the IPO game-based learning model to promote children's learning motivation and cognitive development and to reinforce their motor skills.

3. Method

This study developed a GIGL approach to help preschoolers improve their cognitive development and motor skills. A quasi-experiment design with a non-equivalent pretest-posttest control group design was conducted in a kindergarten in Taiwan to answer the following research questions:

(1) Did the preschoolers who learned using the GIGL approach acquire better learning performances than those who learned with the traditional activity game-based learning approach?
(2) Did the preschoolers who learned using the GIGL approach achieve better motor skills than those who learned using the traditional activity game-based learning approach?

The subject adopted in this study was “color recognition” and it was performed by children in kindergarten level 2. The teaching plan was designed based on game-based learning for all students. During the process, the students learned six different colors and their respective names in English while concurrently performing gross motor movements to enhance their motor skills (namely, coordination and agility).

3.1. Participants

This study adopted purposive sampling, selecting 105 kindergarten level 2 preschoolers (average age 5.5 years, 49 girls and 56 boys) from six classes in a kindergarten in Taoyuan, Taiwan. The kindergarten was located in the suburbs, and there were over 1000 preschoolers (3–6 years old) from urban and rural areas. In kindergarten level 1, children receive 40 min of computer coursework every week and each classroom is equipped with one whiteboard, one projector, two computers, and a large amount of e-learning content.

Three of the six classes comprised the experimental group (24 girls and 28 boys), which used the GIGL approach, and the other three classes comprised the control group (25 girls and 28 boys), which used the traditional activity game-based learning approach. All of the 105 participants had previous traditional activity game-based learning experience and no GIGL experience.

3.2. Procedure

The experiment was conducted in May 2014, and the procedure is shown in Fig. 2. First, all of the participants took a 20-min pretest, which included a 10-min learning performance test and a 10-min motor skills test. Then, a 40-min experiment followed. Using identical teaching materials, all of the students were instructed to learn the names of six colors in English (English was the students' second language). In addition, in the ball-catching game, the children moved their bodies to improve their coordination and agility. The students in the control group participated in the physical activity session using the traditional activity game-based learning approach with an instructor and a peer, while the students in the experimental group participated in the session using the GIGL approach with a game called “The Goalkeeper.” Finally, a 20-min posttest was given to all of the participants. The results of the experiments were not affected by external intrusive factors.

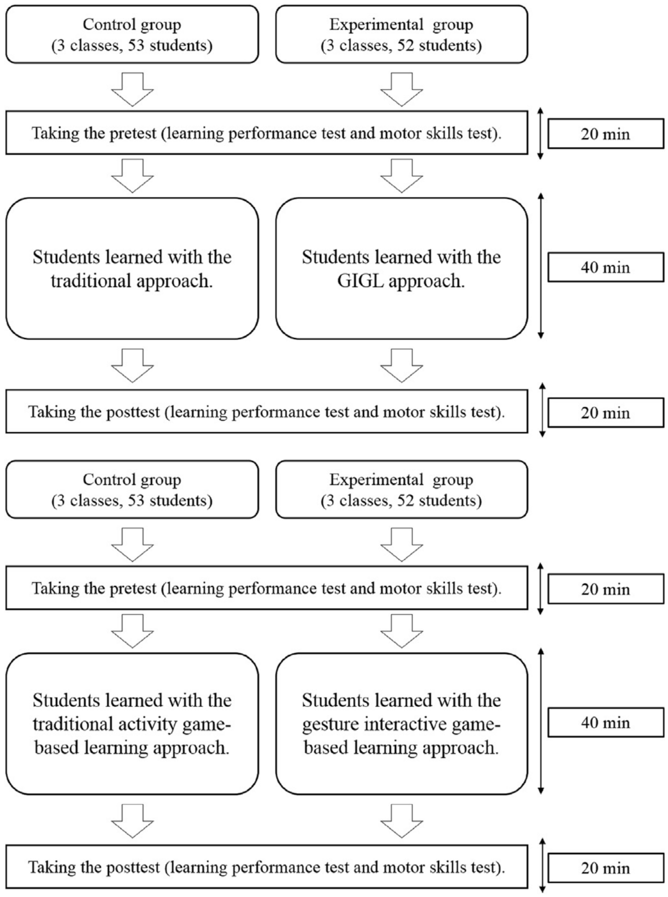


Fig. 2. The procedure of the experiment.

3.3. Technological platform

3.3.1. The gesture-based computing device: ASUS Xtion PRO

This study used the Xtion PRO produced by Taiwan's ASUS Corporation as the technological platform, which has the advantages of being small in size, self-powered, capable of supporting multiple operating systems, and compatible with USB drives. The interface of the Xtion PRO is Open Natural Interaction (OpenNI), which has the advantages of cross-platform and multi-operating system compatibility.

Moreover, the ASUS Xtion PRO has four implanted gesture detectors and six body posture detectors, making it widely applicable to different situations. As shown in Fig. 3, the Xtion PRO uses an infrared transmitter, an infrared receptor, and depth image detectors to measure the distance between an object in the room and the Xtion PRO. By sending and receiving infrared signals, the Xtion PRO builds a human skeleton with 15 joints and differentiates the skeleton from the background (as shown in Fig. 3). By observing and calculating the coordinating variables of these 15 joints, the Xtion PRO offers real-time motion-sensing controller technology that captures the body movements of users. The Xtion PRO was used because it has four implanted gesture detectors, six body posture detectors, and was chosen among the available ones.

3.3.2. Design of the gesture interactive game

This study aimed to use the ASUS Xtion PRO to develop a gesture interactive game called "The Goalkeeper." This game involved using a computer and a somatosensory device to simulate a ball-catching scenario. The operational details of the gesture interactive game are shown in Fig. 4: (a) a computer was used to run "The Goalkeeper" program; (b) the ASUS Xtion PRO received the participants' somatosensory data; (c) a human skeleton diagram demonstrated the participants' current body posture; (d) the gesture operation tool allowed the participants to interact with "The Goalkeeper"; and (e) the students used the control interface to manage the game.

The system framework of the gesture interactive game is shown in Fig. 5. In the client tier, a Flash player running on Windows 7 allowed the participants to browse, operate, and manage the game's functions. The system development technology consisted of three tiers. The bottom tier contained the somatosensory device control program written by Microsoft

Fig. 3. The ASUS Xtion PRO and human skeleton diagram.

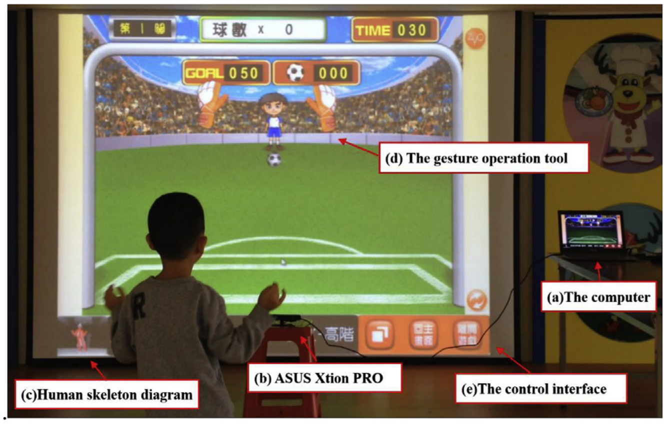


Fig. 4. The gesture interactive game “The Goalkeeper”.

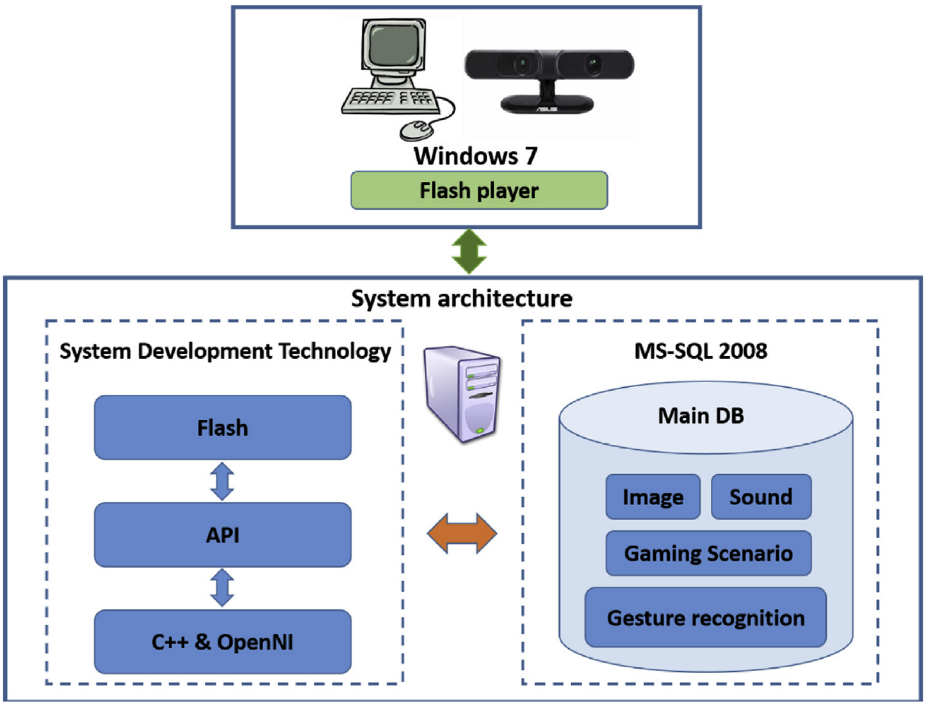


Fig. 5. System framework.

Visual C++ and OpenNI. The middle tier included the self-developed application programming interface (API), which was used to transfer the body movement data from the bottom tier. The upper tier used Flash to process the video and audio operations and the gesture interactive game. In the database tier, the MS-SQL 2008 database consisted of an image database, a sound database, a gaming scenario database, and a gesture recognition database.

3.4. Design of the learning activity

Considering the playful nature of children, who were participants in this study, the design of the physical activity session adopted a game-based learning approach, which was hypothesized to enhance the students' cognitive development and reinforce their motor skills. This study used the Input-Process-Outcome game-based learning model to design the learning activity. Tables 1–3 describe the applicability of the IPO game-based learning model in designing the physical activity session for the experimental group and the control group.

3.5. Research tools

3.5.1. Learning performance test

The learning performance test in this study was designed by two preschool teachers. Following the design of the test, the content was reviewed and edited by two professors with preschool education backgrounds in order to verify and modify the appropriateness of the items, as well as to provide expert validity. The test consisted of 14 questions, each worth one point. Specifically, this involved six multiple-choice questions and eight short-answer questions. The test was conducted via one-on-one interviews. The participants read the questions aloud and recorded the answers by either pointing them out or saying them in English. This learning performance test was taken by another 150 kindergarten level 3 preschoolers three months before the learning experiment commenced. The Cronbach's α value of the test was 0.763, which showed good reliability and internal consistency.

3.5.2. Motor skills test

The motor skills test was designed based on five types of motor skills assessment tools, namely, the Gross Motor Performance Measure, the Comprehensive Developmental Inventory for Infants and Toddlers, the Peabody Developmental Motor Scales II, the Preschooler Gross Motor Quality Scale, and the Fundamental Motor Ability Tool (Boyce et al., 1991; Folio & Fewell, 2000; Piao, 2010; Sun et al., 2010; Wang et al., 1998). Moreover, an expert conference was assembled to provide expert validity. This included two professors with preschool education backgrounds and two preschool teachers who had participated in the design of the motor skills test. The motor skills test focused on coordination and agility. The participants were required to perform harmonious movement, coordinating their eyes, hands, and feet, by tapping a balloon to keep it in the air. Each tap was worth one point, with 20 points being the maximum. The higher the score, the better the participants' coordination was. For agility, the participants were required to use their gross leg muscles to balance themselves as they completed three shuttle runs over a distance of 2 m. The time they spent on this task corresponded to their score for agility. The shorter the time, the better their agility was.

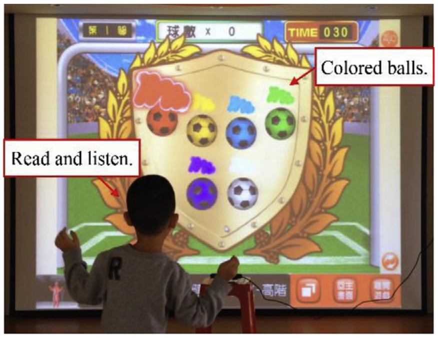
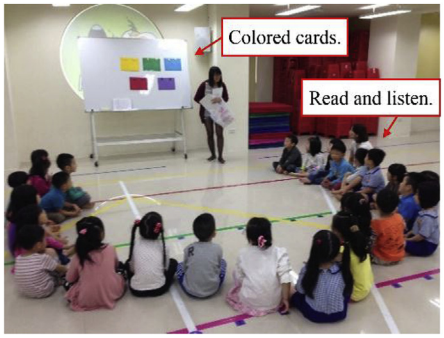
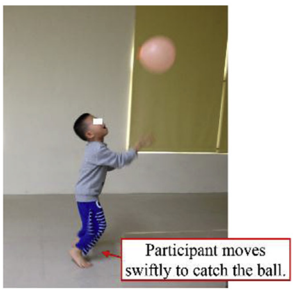
Table 1
The design of the physical activity session based on the IPO game-based learning model (Input).

Input	Experimental group	Control group
Instructional content	1. English is the participants' second language. They are shown six different colors (red, yellow, blue, green, purple, and white) and they must name them correctly in English. 2. The participants will raise their arms, stand on their feet, balance themselves, and be positioned to catch balls to train their coordination. 3. The participants must move swiftly to the correct location to be able to catch the ball, thereby enhancing their agility.	
Game characteristics	1. Fantasy: Simulate a goalkeeper in soccer; catch the ball or let it pass. 2. Rule/Goal: Judge the correct correspondence between the color of the ball (or the card) and the color's name in English; catch the ball if it is correct and let it pass if it is not. 3. Sensory stimuli: Visual, audio, and body movement. 4. Challenge: Time limits and scoring. 5. Mystery: Colors and their names are given randomly, the same as for the location of the ball. 6. Control: The participants should think, adjudicate, and use their body to play the game.	

Table 2
The design of the physical activity session based on the IPO game-based learning model (Process).

Process	Experimental group	Control group
User behavior	"The Goalkeeper" will throw a colored ball randomly and say the color's name in English 1. Judge the correct correspondence between the color and its name. 2. Stand still or move swiftly to catch the ball.	The instructor will hold a colored card and say the color's name in English. Then a peer will throw out a ball randomly. 1. Judge the correct correspondence between the color and its name. 2. Stand still or move swiftly to catch the ball.
System feedback	Each time the participant makes a correct judgment or performs a correct body movement, s/he will receive five points, recorded by the system or the instructor.	
User judgments		The participants are interested in the ball-catching game, so they are willing to accomplish the task and they enjoy the playfulness of the game. They will practice the game while simultaneously absorbing the instructional content.

Table 3
The design of the physical activity session based on the IPO game-based learning model (Outcome).

Outcome	Experimental group	Control group
Learning outcome	This activity was designed to enhance the participants' learning performance and motor skills.	
The physical activity session	 "The Goalkeeper" uses colored balls to teach different colors in English.	 The instructor uses colored cards to teach the names of different colors in English.
The Physical Activity Session	  "The Goalkeeper" throws balls, and the participant positions himself and moves swiftly to catch the ball. This movement trains coordination and agility.	  A peer throws balls, and the participant positions himself and moves swiftly to catch the ball. This movement trains coordination and agility.

4. Results

In this study, the data collected from the pretests and posttests were examined through descriptive statistics, a paired-samples *t*-test, analysis of covariance (ANCOVA), and pairwise comparison. The significance level was set at 0.05.

4.1. Differences in learning performance

Fig. 6 shows the comparison of the mean scores of the learning performance test between the experimental group and the control group. The posttest scores of the experimental group (M = 12.98, SD = 1.64) were higher than their pretest scores (M = 10.42, SD = 2.87). According to the *t*-test results, this demonstrated a significant difference ($t = -9.03$, $p < 0.001$). The posttest scores of the control group (M = 12.25, SD = 1.74) were also higher than their pretest scores (M = 11.19, SD = 2.48). According to the *t*-test results, this also demonstrated a significant difference ($t = -4.74$, $p < 0.001$).

Next, the learning effect difference between the experimental group and the control group was compared using ANCOVA to test the homogeneity of regression (F = 2.08, $p = 0.152$). The ANCOVA results showed that the experimental group achieved significantly better scores (F = 22.82, $p < 0.001$, $\eta^2 = 0.183$). The pretest score as the covariate was 10.81, and the adjusted mean scores were 13.16 for the experimental group and 12.07 for the control group. In addition, a partial η^2 value was provided as a substitute for effect size ($\eta^2 = 0.183$) ($\eta^2 > 0.138$ = large effect) (Pallant, 2007).

4.2. Differences in motor skills test (coordination)

Fig. 7 shows the comparison of the mean scores for coordination between the experimental group and the control group. The posttest scores of the experimental group (M = 13.73, SD = 4.31) were higher than their pretest scores (M = 7.15, SD = 4.13). According to the *t*-test results, this demonstrated a significant difference ($t = -11.25$, $p < 0.001$). The posttest scores of the control group (M = 11.40, SD = 5.63) were also higher than their pretest scores (M = 6.75, SD = 4.51). According to the *t*-test results, this also demonstrated a significant difference ($t = -7.50$, $p < 0.001$).

Next, the learning effect difference for coordination between the experimental group and the control group was compared using ANCOVA to test the homogeneity of regression ($F = 1.85$, $p = 0.177$). The ANCOVA results showed that the experimental group achieved significantly better scores ($F = 6.55$, $p = 0.012 < 0.05$, $\eta^2 = 0.060$). The pretest score as the covariate was 6.95, and the adjusted mean scores were 13.60 for the experimental group and 11.53 for the control group. In addition, a partial η^2 value was provided as a substitute for effect size ($\eta^2 = 0.060$) (η^2 between 0.06 and 0.138 = medium effect) (Pallant, 2007).

4.3. Differences in motor skills test (agility)

Agility was scored by the participants' finishing times in the shuttle run. The shorter the time, the better their agility was. Fig. 8 shows the comparison of the mean scores for agility between the experimental group and the control group. The posttest times of the experimental group (M = 10.22, SD = 1.18) were better than their pretest times (M = 11.53, SD = 1.83). According to the *t*-test results, this demonstrated a significant difference ($t = 6.34$, $p < 0.001$). The posttest times of the control group (M = 10.50, SD = 1.17) were also better than their pretest times (M = 11.05, SD = 1.45). According to the *t*-test results, this also demonstrates a significant difference ($t = 3.74$, $p < 0.001$).

Next, the learning effect difference for agility between the experimental group and the control group was compared using ANCOVA to test the homogeneity of regression ($F = 2.64$, $p = 0.107$). The ANCOVA results showed that the experimental group achieved significantly better times ($F = 7.62$, $p = 0.007 < 0.05$, $\eta^2 = 0.069$). The pretest time as the covariate was 11.29, and the

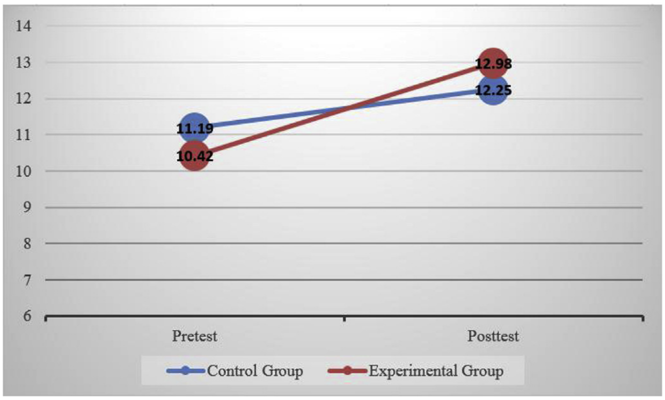


Fig. 6. Comparison of the mean scores of the learning performance test.

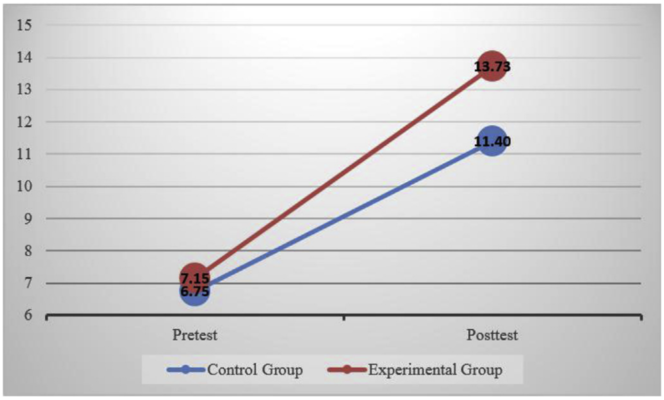


Fig. 7. Comparison of the mean scores for coordination.

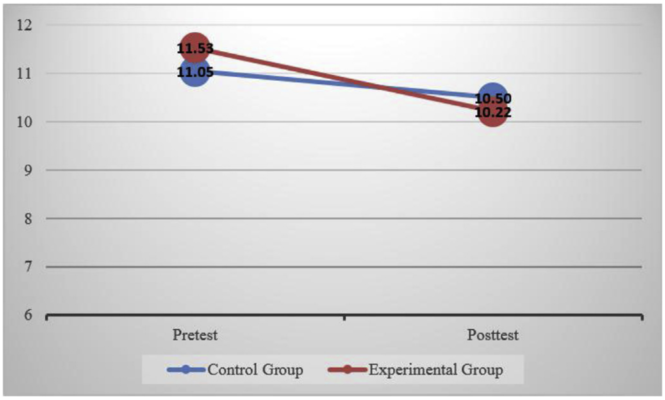


Fig. 8. Comparison of the mean seconds for agility.

adjusted mean times were 10.11 for the experimental group and 10.61 for the control group. In addition, a partial η^2 value was provided as a substitute for effect size ($\eta^2 = 0.069$) (η^2 between 0.06 and 0.138 was medium effect) (Pallant, 2007).

5. Discussion

This study adopted the ASUS Xtion PRO as its somatosensory device and utilized gesture recognition technology to create a favorable virtual interactive learning environment for preschoolers. Moreover, by combining the game-based learning model and the gesture-based learning model, the study developed a gesture interactive game-based learning approach that was suitable for preschoolers. A quasi-experiment was adopted to support the difference in learning performance and motor skills between the participants who learned using the GIGL approach and those who learned using the traditional activity game-based learning approach. It was found that the different learning approaches affected the participants' learning performance and motor skills.

The results showed an improvement in learning performance and motor skills for those who used the GIGL approach to complete the learning tasks. Referring to the IPO game-based learning model proposed by Garris et al. (2002), this study designed a gesture activity session. According to the results of the descriptive statistics and paired-samples *t*-test, the participants in both the experimental group and the control group scored higher in the posttest, demonstrating a significant difference, which is similar to the findings from other research (Ghergulescu & Muntean, 2014; Ibrahim et al., 2011; Martens et al., 2004; Yang et al., 2008). One plausible explanation for this may be that games, especially those for children, play an important role in cognitive development (Mitchell & Savill-Smith, 2005). The preschoolers were able to recognize the balance between the knowledge presented and their own capacity to learn it through the activities, achieving a flow state that improved their learning performance (Csikszentmihalyi, 1975).

As for motor skills, the participants in both the experimental group and the control group scored higher in the posttest, demonstrating a significant difference, which is similar to the findings from other research (Altanis et al., 2013; Huang et al., 2009; Li et al., 2014). One possible explanation for this may be that motor skills can foster relatively permanent changes in movement capability through learning experiences and practice (Schmidt & Lee, 1988). This suggests that with positive encouragement, sufficient instructional demonstrations, practice, and a suitable environment, children can achieve greater development of their motor skills (Gallahue & Donnelly, 2003; Hsiao et al., 2015; Piao, 2010).

From the results, it was found that the GIGL approach improved the participants' learning performance and motor skills to a greater extent compared with the improvement experienced by the participants using the traditional activity game-based learning approach. Judging from the ANCOVA statistical results, the participants in the experimental group performed better than those in the control group, demonstrating a significant difference. One possible explanation for this may be that the experimental group used gestured-based interfaces to combine body movements and learning materials to complete the learning tasks. This GIGL approach reinforced their memory and they were able to comprehend the learning materials more easily, which improved their learning performance and strengthened their motor skills. These results are similar to those from other research (Altanis et al., 2013; Chao et al., 2013; Huang et al., 2009; Lee et al., 2012; Li et al., 2014; Lu et al., 2012; Wu et al., 2013).

Regarding motor skills, the participants were required to make appropriate body movements to complete the learning tasks. During this process, the students in the experimental group adjusted their position and trained their gross muscles by referring to the Xtion PRO human skeleton diagram, and they obtained feedback directly from the playing screen. The results showed that, compared with the traditional instruction-giving method, the GIGL approach to learning led to greater achievements in terms of improved motor skills, which is similar to the findings from other research (Altanis et al., 2013; Hsiao et al., 2015; Huang et al., 2009; Li et al., 2014; Miller et al., 2010). This findings from the current study suggest that using low-cost and easily accessible gesture recognition technology to accurately capture the natural movements of the human body (Hsiao et al., 2015) and provide feedback helped the preschoolers to enhance their coordination and agility.

6. Conclusion

This research supported the effectiveness of the gesture interactive game-based learning approach. In the current study, a virtual interactive learning environment to improve preschoolers' coordination and agility was created. Moreover, by bridging the gap between game-based learning and gesture-based learning, this study provided evidence of engaging experiences that were created when using a gesture-based interface.

This study also created a physical activity session based on the IPO game-based learning model (with the characteristics of Fantasy, Rule/Goal, Sensory Stimuli, Challenge, Mystery, and Control) to promote learning motivation. During the learning process, the instructor gave suitable feedback depending on the participants' behavior in order to spur their interest in the learning content and encourage them to accomplish the task through the playfulness of the game. Finally, the learning performance, coordination, and agility of the students in the experimental group improved significantly, which was the goal of building the virtual interactive learning environment.

Based on the above conclusions, the recommendations for future research are as follows. First, the experimental scale should be extended to make the results more representative. There is much evidence suggesting that the GIGL approach is helpful in improving both learning performance and motor skills. However, the results of the current study are limited by the small scale of the experiment. The scale should cover different ages, regions, and races, and the time period should also be prolonged. Second, the GIGL approach should be applied to different subjects and motor skills. English learning, coordination, and agility were targeted in this study, but other subjects (e.g., Chinese, math, etc.) and motor skills (e.g., manipulative ability, balance, etc.) could be targeted for related teaching and learning.

Several limitations are important to note. First, the research was conducted over a relatively short timeframe. A longitudinal design would be useful in assessing the cumulative effects on the students' learning performance and motor skills. Second, the experimental activities were exploratory and on a small scale. Therefore, it is difficult to infer that all preschool children will improve their learning performance and motor skills when instructed using a GIGL approach.

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