



## A Kinect- and Game-Based Interactive Learning System

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### ABSTRACT

This study combined the attention–relevance–confidence–satisfaction (ARCS) motivation model with a game design model to develop a Kinect- and game-based interactive learning system to enhance learning motivation and effect. In this system, game characteristics incorporated into the learning procedure through a game model allowed the learner to have fun while learning, and it stimulated their interest in the learning activities. A Kinect-based somatosensory interface was adopted to enable the learner to control virtual characters by using their physical movements. The learning objective investigated in this study was to learn about various zoo animals. Sixty adults aged 20–25 years were recruited as experiment participants, divided equally between the experimental and control groups. Learning effect was analyzed by using a t test to compare the participants' performance in tests administered before and after one hour of learning. Learning motivation was investigated using a questionnaire in which the four elements of the ARCS model were adopted as four dimensions of inquiry. Compared with the control group, the experimental group achieved a larger test score improvement. Analyzing the questionnaire results confirmed that the learners had significantly increased motivation across all four ARCS dimensions. Finally, learners gave positive evaluations of the developed learning system.

**Keywords:** game/toy-based learning, somatosensory learning, Kinect, game design model, attention–relevance–confidence–satisfaction model

### INTRODUCTION

In somatosensory interactive learning, learners use gesture-based interfaces such as Microsoft Kinect, Nintendo Wii, etc., to combine body movements with learning materials. The launch of Microsoft Kinect and Nintendo Wii products has altered how learners interact with video games. Such products are somatosensory video games that can be played indoors. Moreover, they can be used to increase learners' motivation in learning or exercising through providing a fun gaming experience (Chang, Lin, Fang, & Lu, 2017; Chao, Huang, Fang, & Chen, 2013; Hsiao & Chen, 2016; Lee, Huang, Wu, & Chen, 2012; Li, Wang, Wu, & Chen, 2014; Lu, Liu, Chuang, & Peng, 2012). Tsai, Kuo, Chu, and Yen (2015) reported that interactive games designed for use with Microsoft Kinect could be employed as learning tools to improve students' activity levels during learning and efficiency at learning using

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### State of the literature

- Interactive games designed for use with Microsoft Kinect could be employed as learning tools to improve students' activity levels during learning and efficiency at learning using multimedia.
- Game/toy-based learning is an educational approach that employs games and recreational activities to teach students.
- This motivation model based on attention, relevance, confidence, and satisfaction facilitated motivational design and improved teaching effect.
- Interaction the zoo's website typically contains learning content, such as educational text, pictures, and videos, but interactive web designs, which increase learning motivation, are rare

### Contribution of this paper to the literature

- This study firstly combined the attention-relevance-confidence-satisfaction (ARCS) motivation model with the Input-Process-Output (IPO) game-based model to develop a Kinect- and game-based interactive learning system to enhance learning motivation and effect.
- The present study incorporated the characteristics of game-based learning into an educational game model, to improve learning motivation and effect.
- An animated avatar is controlled using the Kinect's somatosensory functions. The learner assumes the guise of the avatar and walks around the feature zones, thereby assisting them with attaining learning objectives.
- According to the experiment, the system significantly increased students' learning motivation across all four ARCS dimensions and learning outcomes. Finally, learners gave positive evaluations of the developed learning system.

multimedia. Papastergiou (2009) and Hoysniemi et al. (2005) revealed that kinetic video games designed for game-based learning successfully combined gaming with smart technology, and that incorporating these games in course designs improved learning motivation.

Game/toy-based learning is an educational approach that employs games and recreational activities to teach students. Game-based learning is also an effective method for increasing the learning motivation and learning outcome for learners. (Tsai, Tsai, & Lin, 2015; Tsai, & Yen, 2016; Sheu, & Chen, 2014; Wu et al., 2013). Prensky (2001) and Garris, Ahlers, and Driskell (2002) noted that learning using educational games was relatively easy. Activities within games lead to better understanding of the content and improve problem-solving and active-learning skills. Additionally, attention, confidence, and learning effect are elevated during learning-based games. Cheung et al. (2008) found that learning materials which incorporated digital games enhanced the learning effect and helped to achieve the learning objectives. Therefore, through a combination of learning objectives and recreational games, game/toy-based learning provides an interesting and challenging learning environment for students, enhances motivation to learn, and prompts students to be active in their education, thereby improving learning effect.

To obtain the large effect sizes for both motivation and outcome in game-based learning, some authors gave their suggestions. Vos, Meijden, and Denessen (2011) suggested that constructing a game might be a better way to enhance student motivation and deep learning than paying an existing game. Tsai and Yen (2016) offers the following two suggestions: In practice, digital game-based learning must be linked to the meaning of teaching subject; and game software design must provide immediate and accurate feedback that aids in thinking. These suggestions will be considered into the design of the proposed system in this paper.

Zoos are popular tourist attractions and recreational sites, but they are also educational institutes within which research is performed and endangered animals are protected. Taipei Zoo (2015) is one of the most popular in Taiwan. However, because of limitations in visitor capacity and opening hours of the zoo, prospect visitors sometimes cannot visit the zoo in person; instead, they can only browse the zoo's website. Such websites typically contain learning content, such as educational text, pictures, and videos, but interactive web designs, which increase

learning motivation, are rare. To enable the public to learn about zoo animals more easily, the present study developed a Kinect- and game-based learning system that adopted somatosensory human-computer interaction technology to enhance learning motivation and thereby improve learning effect. The research questions of this study were as follows:

- (1) Can the Kinect- and game-based interactive learning system enhance learning motivation?
- (2) Can the Kinect- and game-based interactive learning system improve learning effect?

## LITERATURE DISCUSSION

### Game/Toy-Based Learning

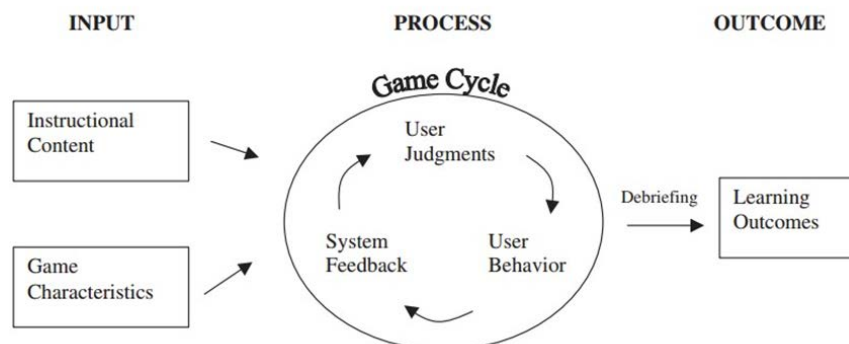
Game/toy-based learning attracts learners and encourages active participation in learning, which ultimately enhances learning effect. Prensky (2001) reported that digital game-based learning is appealing to learners because it incorporates the following: fun, play, rules, goals, interactive, outcomes and feedback, adaptive, win states, conflict/competition/challenge/opposition, problem solving, interaction, representation, and story. Designing learning games requires the setting of the game styles and forms, followed by the combination of suitable elements from the aforementioned list with learning content.

Game/toy-based learning is currently one of the most popular topics within the digital learning field. Most research concerning somatosensory-based equipments developed learning materials in conjunction with game-based learning (Lu, et al., 2012; Wu, et al., 2013; Sheu, & Chen 2014). For example, Giannakas, Kambourakis, and Gritzalis (2015) adopted the concept of game/toy-based learning to develop a mobile digital game-based learning smartphone game, in which players are asked to complete multiple game levels to enhance their awareness of cybersecurity.

During the design of learning games, the theory of modularity is generally adopted as the framework to ensure smooth game operation. Garris et al. (2002) proposed an Input-Process-Outcome (IPO) game-based learning model as an educational game design to improve children's learning performance. For example, Hsiao and Chen (2016) combined gesture-based computing technology and IPO model to develop a gesture interactive game-based learning approach that was suitable for preschool children. Ghergulescu and Muntean (2014) proposed a motivation assessment-oriented Input-Process-Outcome game model to design an educational game. Yang, Lin, and Tsai (2008) used the IPO model to enhance the English learning motivation, outcome, and attitude of elementary school third graders.

The IPO game-based learning model divides the game into three stages (**Figure 1**). During the input stage, instructional content is combined with game characteristics, and together they comprise the teaching material of the game. During the process stage, a user-oriented game cycle is created to involve user judgments, user behavior, and system feedback. The game cycle incorporates the teaching content and game characteristics processed during the input stage. After the game cycle is completed, debriefing is performed, during which the learning outcomes of the game cycle are produced. This game model incorporates game characteristics into learning procedures, which leads to learners enjoying the game and thus becoming interested in learning. Through system feedback, learners repeat the game cycle until they achieve the learning objectives.

The present study first incorporated the characteristics of game-based learning proposed by Prensky and combined the attention-relevance-confidence-satisfaction model (ARCS model) with IPO game-based model to developing the proposed Kinect- and game-based interactive learning system to improve learners' learning motivation and outcome.



**Figure 1.** Game model (Garris et al. 2002)

### Kinect

Kinect is a motion sensing input device used in the Xbox 360 console consisting of four major components: an RGB camera, 3D depth sensors, a multi-array microphone, and built-in processing cores (Kinect for Windows, 2014). Users can employ gestures or voice commands to operate the Xbox system interface without having to use a handheld remote or pedal controllers.

In recent years, Kinect has been applied in numerous fields such as elderly care (Ejupi, et al., 2015; Erdoan, & Ekenel, 2015; Doyle, Caprani, & Bond, 2015; Ofli, et al., 2016; Zhang, Conly, & Athitsos, 2015; Zhao, Lun, Espy, & Reinthal, 2014; Zhao, & Lun, 2016), digital learning (Chye, & Nakajima, 2012; Lee, et al., 2012; Yang, et al., 2014), etc. By applying Kinect to digital learning, Too, et al. (2016) proposed an alternative learning method via Microsoft Kinect. The framework proposed by them included new alternative method of delivering subjects to physically disabled students rather than the current method. Tsai, Kuo, Chu, and Yen (2015) focus on developing the Kinect sensor-assisted game-based learning system with ARCS model to provide kinesthetic pedagogical practices for learning spatial skills, motivating students, and enhancing students' effectiveness. They conclude that the Kinect sensor-assisted learning system promotes the development of students' spatial visualization skills and encourages them to become active learners. Cheong, Yap, Logeswaran, and Chai (2012) designed a cost-effective technology (including a multi-touch interactive whiteboard and a teaching station) to enhance the learning environment of a classroom. Their innovative use of a Kinect camera was based on Kinect's ability to send a fixed speckle pattern to a plane, track the reflected infrared light sources, and carry out the necessary processing to achieve an interactive multi-touch surface. Preliminary test results of the system indicated superior operability and interactivity compared with those of traditional computers.

### ARCS Model

After analyzing the concepts and characteristics of learning motivation, Keller (2000) proposed a motivation model based on attention, relevance, confidence, and satisfaction. This model facilitated motivational design and improved teaching effect. Keller considered that personality and learning environment directly affect how much is learnt. Garris et al. (2002) defined motivation as the engagement in certain events out of willingness or yearning—a person's engagement in certain activities out of their own free will, as opposed to their participation being required.

In recent years, the ARCS model has been variously applied to investigate whether it enhances learning motivation, and the results have generally been positive (Alhazbi, 2015; Hamzah et al, 2015; Kaneko et al., 2015; Qian, 2014; Yurdaarmagan et al., 2015; Peng, Liu, & Liu, 2016). For example, Zhang (2017) designed a micro-lecture teaching platform based on ARCS model theory. The platform could carry out teaching practice on intelligent mobile devices, and had some features like mobility, seamlessness and strong advancement. The research found that the ARCS motivation model based micro-lecture platform paid attention to the stimulation and maintenance

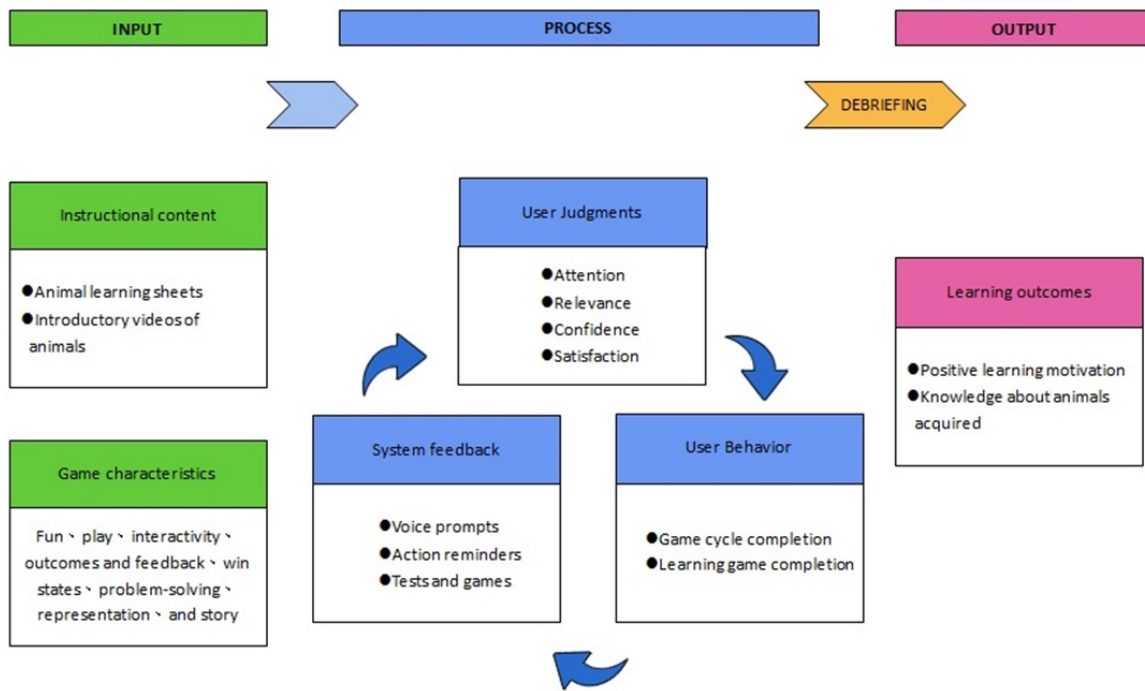


Figure 2. Game model design

of learners’ motive, focuses on the interest in learning, and strengthens and kept the interest of learners through a series of strategies to achieve the purpose of learning. Giannakas, Kambourakis, and Gritzalis (2015) adopted the ARCS model in the development of a mobile phone application that promoted cybersecurity awareness. They concluded that using the ARCS model as the design framework did enhance learning motivation and increase learning performance. Lee and Hao (2015) combined the ARCS motivation model, and humor to design a set of multimedia applications to develop a Cat’s Cradle Multimedia Learning System (CCMLS). Significance was also found in ARCS learning motivation and perceived fun of teaching materials. Moreover, there is a significant positive correlation between the perceived fun related to the teaching materials and learning motivation.

Based on the aforementioned studies, ARCS model can really promote the learners’ learning motivation.

### GAME MODEL DESIGN

The present study combined the Input–Process–Outcome Game model proposed by Garris et al. (2002) with the ARCS model and the properties of learning games proposed by Prensky (2011) to create the proposed game model (Figure 2).

#### Teaching Content

The learning objectives of this study were to teach the English names of various animals. The learning material was based on three feature zones of the Taipei Zoo – Animals of Taiwan, Children’s Ranch, and Animals of the Temperate Zone – which were inhabited by 14, 13, and 13 species, respectively (Figure 3).

- (1) Animals of Taiwan, Children’s Ranch, and Animals of the Temperate Zone

In each of the feature zones of the learning game, an animated avatar is controlled using the Kinect’s somatosensory functions. The learner assumes the guise of the avatar and walks around the feature zones, selecting animals they wish to learn more about along the way. Once a learner has completed the learning tour of one zone, the system asks five random questions to test and record the learning

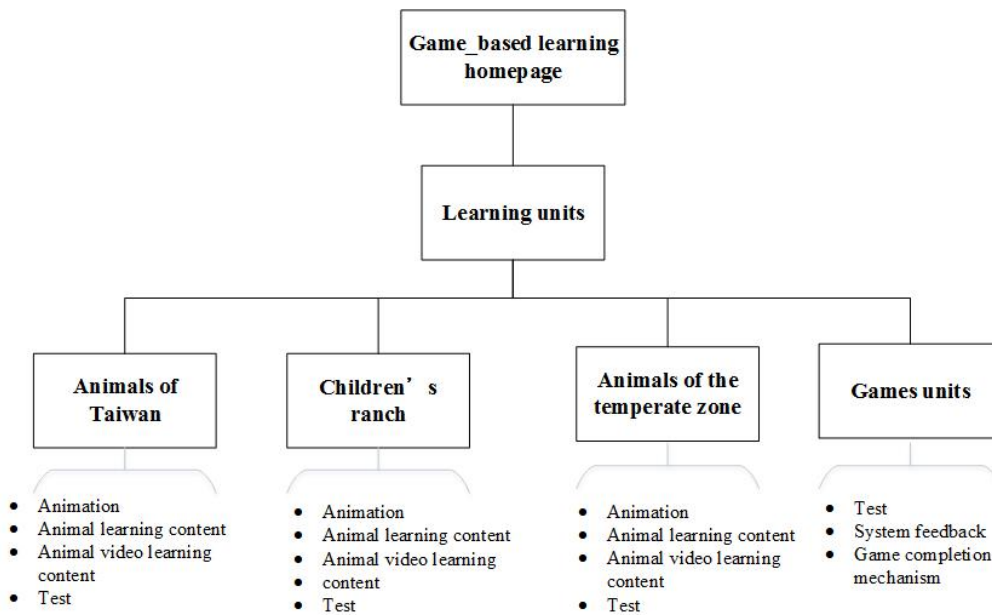


Figure 3. Conceptual diagram of learning topics



Figure 4. Animated avatar facing different directions

effect. Each zone includes an animation, some animal facts, a video, and some test questions, which are detailed as follows:

- a. Animation
  - i. Design of game avatar
 

When a learner activates the Kinect device and begins the game, the learner walks on the spot to control the avatar to move forward. When the learner wishes to move left or right (to learn or review related information), he or she raises the left or right arm so that it is horizontal to prompt the avatar to turn in the corresponding direction.
  - ii. Design of the learning scenes
 

Figure 5 displays the starting screen of the feature zone learning units, which consist of Animals of Taiwan, Children's Ranch, and Animals of the Temperate Zone. The game zone entitled Guess who does not appear until the learning tours of the other three zones have been completed.
  - iii. Design of specific learning zones
 

The learning scenes are presented as two-dimensional illustration scrolls, on which the corresponding pictures, textual information, and animal videos are arranged. Learners are



Figure 5. Learning scene



Figure 6. Learning unit

guided by textual or verbal instructions during the learning activities. After reading or listening to the instructions, learners move their left or right hand to touch the animal buttons and learn information (Figure 6).

- iv. Design of the learning unit completion mechanism  
When a learner completes a learning unit tour, they walk to the far right side of the scene where a door (Exit) icon appears. Learners leave the learning unit tour by touching the door icon (Figure 7).



Figure 7. Icon to complete a learning tour



Figure 8. Vocabulary learning

b. Animal learning content

The learning content for each animal contains its Chinese and English names, classification, conservation status, and habitat. When the learner touches the button of a specific animal and holds it for three seconds, a screen containing the corresponding vocabulary and learning content appears. By clicking on the play button, the learner hears a recitation of the teaching content, whereas by clicking on the close button, they close the learning content window. Animals can be selected repeatedly.

c. Animal video learning content

The researchers personally visited Taipei Zoo to film videos of the animals used, and subtitles and audio were subsequently added to teach some facts about them. These videos are accessed by clicking on the Video button embedded in the learning content window for a specific animal. **Figure 9** shows the learning video content screens for the Formosan black bear, Formosan Sika deer, and Formosan wild boar.





Figure 9. Animal video screen



Figure 10. Test screen

d. Test

During the test for each unit, five random questions relating to the current feature zone appear. The questions appear at the top of the window, and the choices right below the question. The learner chooses their answer by using the hand to touch the answer choice, and hears a sound that indicates whether their answer is correct or incorrect. Learners proceed to other learning units if they choose three or more correct answers; otherwise, they remain in that unit for further practice and a second test. Figure 10 illustrates one test question, Which animal does Formosan black bear refer to?, beneath which the picture and Chinese name of the Formosan serow and Formosan black bear are presented as choices.

(2) Game unit

This unit comprises animated test questions. Learners can proceed to the *Guess who* game unit for a final review after completion of the three learning units. To enhance satisfaction, the test was designed as a game to be passed using the somatosensory operations of the Kinect device.

a. Test

The system selects 12 random questions. Learners are guided by textual or audio instructions before the test begins. During the test, questions appear on top of the screen, and animals falling from both sides the screen. Learners choose their answer by navigating the cursor to the correct animal icon using their hands. For example, Figure 11 presents the screen of the



Figure 11. Guess who game screen



Figure 12. System feedback from the game

question South American coati, and an option is given or either an alpaca icon or a South American coati icon.

- b. System feedback  
The system plays one of two sounds that correspond to correct and incorrect answers. The animated avatar also performs a corresponding action (Figure 12).
- c. Game completion mechanism  
Upon the completion of the 12-question test in the *Guess who* game zone, the system generates a message indicating the number of correctly answered questions, and this marks the completion of the whole learning process. Learners then click on the home button to return to the system entry screen. Figure 13 displays the screen when the learner answered 10 questions correctly.

### Game Design Combining Game Characteristics and the ARCS Model

Of the 12 game characteristics proposed by Prensky, the games in this system incorporated seven of them: fun, play, interactivity, outcomes and feedback, win states, problem-solving, representation, and story. The four motivational aspects addressed in the ARCS model were also employed. To enhance motivation and learning effect, games used in the process stage of the game cycle were designed by combining the game characteristics with the ARCS model (Table 1).



Figure 13. Final screen of the *Guess who* game

Table 1. Game design combining game characteristics with the ARCS model

Characteristic	Game design	ARCS
Fun and play	Using entertaining and relevant games to stimulate motivation and interest, and prompt active learning.	Attention
Interactivity	Situational learning realized using the Kinect device, which enables human-computer interaction.	Attention
Outcomes and feedback	The system generates feedback to test results.	Satisfaction
Win states	After the completion of all learning units, the <i>Guess who</i> final challenge is designed to enhance the learner's sense of victory.	Satisfaction
Problem-solving	Tests within each learning units in addition to the final challenge to improve problem-solving skills.	Confidence
Representation and story	Cute visual style adopted, with games designed on two-dimensional scrolls and zoo-related situations and graphics.	Relevance

## LEARNING SYSTEM

### Interface Design

The home screen of the zoo-themed learning system has four sections: learning activities, graphics and explanations, textual explanations, and the sensing section (Figure 14).

- (1) Learning activities: The top left section of the screen is the learning activity area in which the learner initiates activity events and interacts with virtual items.
- (2) Graphics and explanations: The bottom section of the screen explains visually what the learner should do at various moments.
- (3) Textual explanations: The right section of the screen presents a textual explanation of the activities or movements the learner should perform at various moments.
- (4) Sensing section: The top right section of the screen displays the real-time silhouette of the learner as detected by the Kinect device. When a learner enters a learning zone, their body is identified as a white object in the sensing zone.



Figure 14. Main screen of the learning system

### Learning Process

The somatosensory function of the Kinect device enables learning on a human-computer interaction platform. The learning process is as follows:

Step 1: Enter system homepage.

Step 2: Select activity unit.

Step 3: Enter the selected unit to start learning.

Step 3.1: Begin somatosensory learning.

Step 3.2: Take the unit test and document the learning outcome.

Step 3.3: Return to Step 3.1 if test is not passed.

Step 4: Return to Step 2 if all learning units have not been completed.

Step 5: Enter the game unit to take the final test and record the learning outcome.

Step 6: End of the learning process.

### Development Tools

Hardware for developing the proposed system included a desktop computer as well as a laptop computer connected to the Kinect sensor.

The following software was used to develop the system: Microsoft Windows 10 Home Edition, Visual Studio 2012 C#, Kinect for Windows SDK 1.8, Adobe Photoshop CC, Moo0 Voice Recorder, and SPSS 20 (Traditional Chinese Edition).

### EXPERIMENTAL DESIGN

To evaluate the developed system, 60 university students aged 20–25 years were randomly selected as experimental participants, of whom 30 were assigned to the experimental group and 30 to the control group. The evaluation took place from June 8, 2016 to June 22, 2016.

**Table 2.** Paired-samples *t* test results for the experimental group

Experimental group	NO.	Mean	SD	t
Pre-test	30	54.833	14.056	-11.740
Post-test	30	74.167	9.105	

\*\*p &lt; .001

**Table 3.** Paired-samples *t* test results for the control group

Control group	NO.	Mean	SD	t
Pre-test	30	52.500	13.880	-12.042
Post-test	30	63.333	11.841	

\*\*p &lt; .001

### Experiment Procedure

The experiment proceeded in five steps:

Step 1: Explaining the motivation and objectives of the study to both groups (10 min).

Step 2: Pretesting (their animal knowledge) both groups (20 min).

Step 3: Explaining to the experimental group how to use the developed system, while the control group browsed and learnt on the Taipei Zoo website (<http://www.zoo.gov.tw/>, 20 min).

Step 4: Learning with the developed system for the experimental group, and continued learning by the control group on the Taipei Zoo website (60 min).

Step 5: Posttesting each group (20 min).

Step 6: Administering a questionnaire survey to the experimental group (15 min).

### Tools of Measurement

A *t* test was used to evaluate the participants' knowledge at the pretest and posttest stages. The pretest and posttest contained 20 multiple choice questions each, with a perfect score of 100. A 5-point Likert scale was adopted in the questionnaire, which addressed the four dimensions of the ARCS model. Each dimension had six items.

### RESULTS

#### (1) Analysis of learning achievements

**Table 2** shows that, for the experimental group, the *t* value of the pre- and posttest results was -11.74, with the *p* value being .000 (< .0001), which indicates that their test scores were significantly improved after using the developed system.

The learning achievements of the control group were also assessed using a paired-samples *t* test. The *t* value of the pre- and posttest results was -12.042, with the *p* value being .000 (< .0001), and thus the control group also attained significantly improved scores in the posttest (**Table 3**).

To measure the difference between the two groups, in terms of the posttest results of the learning outcome, an independent-sample *t*-test was also analyzed. **Table 4** shows the result of the analysis, in which the *t*-value is 9.616 and the *p*-value is .000 (< .0001). This shows that the two groups both made significant progress, but the improvement made by the learners in the experimental group was much more significant than that of the control group. Therefore, the developed system has the significant influence on the learning outcomes of learners.

**Table 4.** The difference between the two groups, in terms of the results of the learning effectiveness posttest

Post-test	NO.	Mean	SD	t
Experimental group	30	74.167	14.056	9.616
Control group	30	63.333	11.842	

\*\*p<0.001

**Table 5.** Reliability analysis of the questionnaire

Subscale	Number of questions	Cronbach $\alpha$
ARCS-A (attention )	6	0.921
ARCS-R (relevance )	6	0.910
ARCS-C (confidence )	6	0.918
ARCS-S (satisfaction )	6	0.934
Entire scale	24	0.957

**Table 6.** Statistical results for the ARCS-A (Attention) items

NO	Item content	Mean	SD
A-1	I became more attentive during learning with the Kinect learning system.	4.774	0.425
A-2	The design and animation of the system captured my attention.	4.581	0.672
A-3	I could stay focused on the learning system.	4.516	0.570
A-4	I fully understood the system instructions and explanations.	4.548	0.723
A-5	I fully understood the learning process of this system.	4.387	0.803
A-6	I already knew much of what was taught by the system before the experiment (reverse-coding item).	4.065	0.964
Total average		4.478	0.736

(2) Reliability analysis

Cronbach’s  $\alpha$  was employed to test the internal consistency of the questionnaire. Any Cronbach’s  $\alpha$  value >0.7 indicated high reliability. **Table 5** presents the reliability analysis results by ARCS dimension, and shows that all  $\alpha$  values were >0.7, with the  $\alpha$  value of the entire scale determined to be 0.957. Therefore, this questionnaire exhibited adequate reliability.

(3) Descriptive statistical analysis

Thirty questionnaires were distributed to the experimental group, of which 30 were returned, yielding a return rate of 100%. The mean and standard deviation (SD) of the questionnaire responses were then calculated. In accordance with a previous study (Chen, Chiu, Huang, and Chang, 2011), the present study used the SD value of 1 as the cutoff. An SD  $\geq 1$  indicated a relatively large difference in the levels of agreement for the item; an SD < 1 indicated a relatively small difference in the levels of agreement regarding the item.

(a) ARCS-A (Attention )

The results of the analysis of attention dimension are shown in **Table 6**, where the total average of the mean and the SD are 4.478 and 0.736, respectively. Item A-1 attained the highest mean (4.774) and smallest SD (0.425), showing that when the participants engaged in learning, using the developed Kinect system enabled them to concentrate. Item A-6 had the lowest mean and highest SD, demonstrating that most participants were not knowledgeable about the educational topics covered in the system.

(b) ARCS-R (Relevance)

**Table 7** details the analysis of the subscale ARCS-R. The mean and SD were 4.419 and 0.768, respectively. Item R-4 attained the highest mean score of 4.581, indicating that the participants

**Table 7.** Statistics results for the ARCS-R (Relevance) items

NO	Item content	Mean	SD
R-1	Kinect enabled me to feel more absorbed in the situations of the system.	4.258	0.729
R-2	What I learnt from the Kinect-based learning system can be linked to real experiences.	4.452	0.961
R-3	I quickly grasped the system content and interacted easily with the system during tests and games.	4.484	0.570
R-4	I could learn more about animals through the system.	4.581	0.672
R-5	I fully understood the teaching materials in the system.	4.452	0.768
R-6	I could recall relevant animal knowledge when using this system.	4.290	0.864
Total average		4.419	0.768

**Table 8.** Statistical results for the ARCS-C (Confidence) items

NO	Item content	Mean	SD
C-1	I can learn more easily and efficiently using a Kinect-based system.	4.355	0.709
C-2	Compared with books or webpages, I prefer Kinect-based interactive learning.	4.677	0.748
C-3	The operations of this system were highly learner friendly.	4.226	0.956
C-4	The system layout was easy to understand.	4.613	0.803
C-5	I completed the course of learning with a favorable performance.	4.323	0.871
C-6	I am confident I can learn well using the system.	4.290	0.902
Total average		4.410	0.842

felt they could learn about animals using this system, and that they might not have frequently been exposed to related knowledge.

(c) ARCS-C (Confidence)

**Table 8** lists the analysis results of the subscale ARCS-C (Confidence). The overall mean and SD were 4.410 and 0.842, respectively. Item C-2 had the highest mean 4.677, from which we can conclude that the participants preferred extracurricular learning through an interactive system rather than through conventional books or webpages.

(d) ARCS-S (Satisfaction)

**Table 9** presents the analysis results of ARCS-S (satisfaction), which had a mean of 4.410 and SD of 0.628. Item S-5 had the highest mean and smallest SD, and it can be concluded that the participants were satisfied with what they learnt using the system.

(4) Discussion

Analysis of learning effect demonstrated that the experimental group achieved more satisfactory learning outcomes than did the control group, verifying that the developed system provided an appropriate environment for learning about various animals. Specifically, learners acquired in-depth knowledge on animals through interactive game-based learning activities, video feedback, and learning tests and games. Analysis of questionnaire results discovered that the SD and mean of all items were  $<1$  and  $>4$ , respectively. Therefore, learners agreed that the ARCS model facilitated attention, relevance, confidence, and satisfaction enhancement during the learning process.

The experiment participants made three suggestions to improve the system: adding more animal introduction videos, enhancing system stability, and enriching game diversity. Only 40 species introduction videos were filmed because of the limited system development time available. The number of videos could be increased in the future to expand the content of the system. Regarding system stability, learners reported that they sometimes activated a button unintentionally before they

**Table 9.** Statistical results for the ARCS-S (Satisfaction) items

NO	Item content	Mean	SD
S-1	The Kinect-based system is a convenient method of learning.	4.419	0.564
S-2	I was satisfied with the Kinect-based learning system.	4.452	0.624
S-3	I had a sense of achievement when passing tests or games.	4.452	0.723
S-4	I found the various levels of learning challenges within the system interesting.	4.387	0.715
S-5	I was satisfied with what I learnt using this system.	4.516	0.508
S-6	I wish to learn using this system again.	4.258	0.631
Total average		4.410	0.628

had made the decision of their next move; also, the system animation occasionally lagged. Therefore, future interface designers should ensure buttons are sufficiently far away from one another, and ensure that the system is quick enough to avoid display lag. In terms of game diversity, the current design had only one test in each learning unit and a single-level final test in the game zone. More games could easily be added to the system to increase the fun component.

### CONCLUSIONS AND FUTURE PROSPECTS

This study combined the ARCS model and game characteristics to propose a Kinect-and game- based learning system designed to teach learners about zoo animals. The results showed that, compared with the control group, learners demonstrated enhanced learning outcomes and efficiency by using this system. Analyzing the posttest questionnaire responses confirmed that the learners had increased motivation during the learning activities and that all the four dimensions of the ARCS model were successfully addressed by the system. Taken together, the results verified that combining the ARCS model with a game-based learning system increases active learning motivation.

In response to the suggestions proposed by the experiment participants, various system improvements are planned. Because of time and manpower constraints, the evaluated system only taught about a limited number of animals and had a few test questions. Therefore, unit test questions and the final test questions were likely to overlap when they were both randomly generated. Future work can enrich the content of the system by adding more questions. To improve system efficacy, Kinect for Windows SDK 2.0 (or the latest version) should be employed, which has more comprehensive functions and better presentation for content design and system operations than the versions used in the present study (Kinect for Windows SDK 1.8). The latest versions of the Xbox include virtual reality technology, which could be applied to education in the future, thus creating more vivid learning situations.

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