A Study of the Relationship among Self-efficacy, Cognitive Load, Failure Attribution and Intention of Continue Participation in the "Insect Garden VR Game"

Chin-Chieh Juh, Chow-Chin Lu, and Jon-Chao Hong

***Abstract*—Education reform is ongoing in Taiwan, the 12-year compulsory education has been implemented since 2019. The science curriculum emphasizes the importance of students' self-learning and problem-solving skills. This study applied the "Insect Garden VR Game" to understand the relationship among students' self-efficacy, cognitive load, failure attribution, and intention of continuous participation in the game. In this study, 172 4th-grade students participated. This study adopted the method of questionnaire survey, which was valid and reliable (Cronbach's α =0.934). Path analysis of data from 160 effective responses was performed using SPSS (version 20) and structural equation modeling-AMOS (version 20). The conclusions were: 1). the game's self-efficacy of student was significantly positively correlated with cognitive load. 2). Self-efficacy of student was significantly negatively correlated with failure attribution. 3). Cognitive load of student was significantly positively correlated with failure attribution. 4). Failure attribution of student was significantly negatively correlated with intention of continuous participation. 5). Cognitive load of student was significantly positively correlated with the intention of continuous participation. The suggestions of this study were: 1). Focus on improving the self-efficacy of students' in VR-game-based-eLearning that could enhance students to challenge the tasks in the game. 2). Many tasks can be designed in the game. Although it will increase the cognitive load of the students, it can increase the intention to continue with the participation. 3). The game operation is simple, the equipment can be used normally, the experience of failure is reduced, and the intention of continuous participation can be improved.**

***Index Terms*—Cognitive load, failure attribution, intention of continue participation, self-efficacy, VR.**

I. Introduction

The 12-year compulsory education was implemented in 2019, and education reform is still ongoing in Taiwan. The science curriculum emphasized exploration and practice. The development of students' real-life skills was emphasized such as students' self-learning and problem-solving skills [1]. It was difficult to provide students with a favorable learning environment, and some students' learning activities were limited by time and space. Perhaps the development and assistance of technology could help improve teaching problems.

Manuscript received April 10, 2021; revised June 12, 2021.

Chin-Chieh Juh and Chow-Chin Lu are with the Department of Science Education, National Taipei University of Education, Taiwan (e-mail: jackjuh84@gmail.com, luchowch@tea.ntue.edu.tw).

Jon-Chao Hong is with the Department of Industrial Education, National Taiwan Normal University, Taiwan (e-mail: tcdahong@gmail.com).

Elementary school students come into contact with insects frequently in their daily life, so insects are included in the fourth-grade curriculum. Teaching about insects in-vivo is difficult since they could be moving around and that being able to access insects depends on various factors such as the weather, environment, and resources [2]. Some elementary students have phobias against insects. In the teaching of entomology, it is found that girls are more afraid of insects than boys. Some students are afraid of butterflies because they are allergic to butterflies [3][4]. Therefore, new teaching strategies are needed to assist teachers in teaching about insects curriculum.

With the development of science and technology, many digital teaching techniques were used in education to improve the efficiency of teaching. Some evidence showed that teaching with digital games was better than traditional teaching [5]. Among various digital games, VR (virtual reality) was a commonly used tool in teaching [6]. VR is a 3D virtual environment, which requires specialized equipment and wearable devices (such as computers, sensors, and screen helmets) to generate a close-to-reality and interactive space [7]. As a teaching tool, VR allows learners to quickly integrate themselves with the vivid and virtual world of learning, and it generates learning benefits [8]. Ho and Dzeng [9] stated that more and more teachers were trying to use VR to teach, hoping to help students learn~~ed~~ lessons that are not easy to understand or difficult to teach due to time and space constraints.

Effective exploration activities still required students to have a high degree of learning motivation [10]. Gee [11] believed that games could promote learners' learning motivation, and that games could stimulate learners' desire for persistence and continuous participation in learning. According to the cognitive-affective theory of learning with media (CATLM) proposed by Moreno [12], multimedia would affect the effectiveness of learning methods and improved the smooth performance of cognitive and emotional processes. Multimedia learning refers to media types such as pictures, text, images and audios. In the game of "learning by playing," students' attention was captured. Especially in competitive games, students' curiosity was boosted [13], their self-efficacy was enhanced, and the fun of the game was experienced [14].

Self-efficacy is a key factor related to learners' self-confidence, learning behavior, learning outcomes and learning environment [15]. Self-efficacy is also a factor that has a positive impact on learning performance [16], Kim and Ko's [17] research results confirmed that the use of VR in education could enable participants who were not interested

in the target movement to have a strong sense of participation after experiencing VR, indicating that the application of VR technology could help strengthen the learning experience. However, if participants experienced frustration, anxiety, stress and other negative feelings when using VR, they couldn't concentrate on participating in the VR experience, and the learning effect couldn't reach the expected goal. It could be seen that the cognitive load of the learner while playing the game, and the frustration caused by being unfamiliar with the game's operating interface or task failure would affect the intention of learners to continue participating and learning effectiveness.

As stated above, insects are a suitable subject for elementary students to learn about. While having lectures about insects, students might be afraid of insects or teachers may be restricted by the teaching environment, which makes it difficult for teachers to teach and students to understand abstract concepts. The interactive learning structure provided by VR hopes to help students overcome the fear of insects and focuse on the learning process. Therefore, this study intended to explore the learning methods of primary school students through VR in learning self-efficacy, cognitive load, failure attribution, intention to continue with participation related to the situation. This study also developed an affective factors research model of VR for future research reference.

II. Insects Garden VR Game

The insects garden VR game was developed by the team of professor Hong at National Taiwan Normal University. It was developed for elementary school students and other research purposes. The game takes place in a first-person perspective. Players could be educated with basic entomology and learn from reflective observation and inductive inference. There are four different insect-feeding tasks in the game. After entering the game, students must follow the insect's breeding needs. Conditions for the game, include food, growing environment, natural predators and other factors affecting growth. Players are to manipulate all growth conditions to allow insects to grow up smoothly. There is no restriction on the type and number of insects to be kept, and students are free to choose the tasks in the game. On the starting page of the game, an eye-catching picture of an insect is presented to attract students' attention (see Fig. 1).

Fig. 1. Logo page for insects garden VR game.

A. The Game Operation and Rules

1) Each student registers their own account number to manage the growth of the insects they keep.
2) Enter the operating instructions to understand how to choose insects, find food, problem-solve and be careful with natural predators.
3) In order to increase the chances of successful breeding, an insect encyclopedia is provided. The encyclopedia includes information about the characteristics, lifespan, food, natural predators and living environment of insects such as praying mantis, rhinoceros beetle, stag beetle and ladybugs (see Fig. 2).

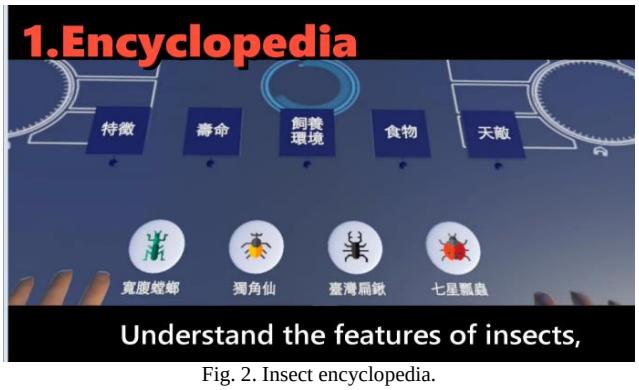


Fig. 2. Insect encyclopedia.

4) Keep insects in a culture room to observe the growth of insects and provide good conditions for growth during the process (see Fig. 3).

Fig. 3. Culture room.

5) In the culture room, check the health status of insects, including its length and weight (see Fig. 4), clean the space, control the temperature and feed.

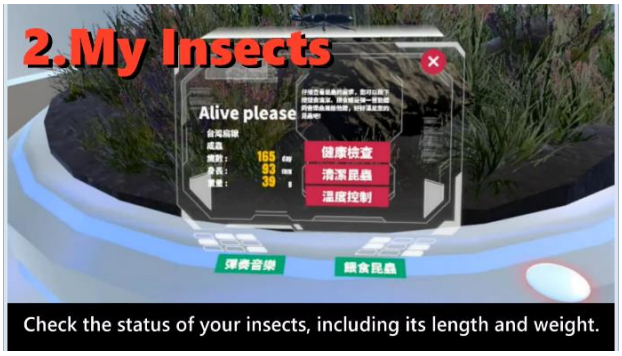


Fig. 4. Health check-up.

6) Build an outdoor environment (see Fig. 5) where players can get the water and food required to raise insects. Many animals, such as elephants and birds are added to the environment to increase the fun of the game.
7) Human Machine Interface (HMI) operation of the game

uses colored arrows to point out the correct locations of the insects, uses the virtual hand in the game to select, and uses the blue indicator to direct movements (see Fig. 6).

Fig. 5. outdoor environment.

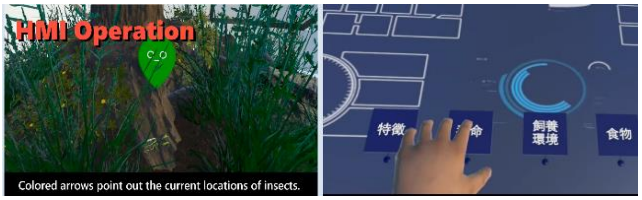


Fig. 6. Visualized operating interface.

8) During the game, the situation of breeding insects will be simulated. If problems occur, ask the students to solve the problem in time, otherwise the insects will die or be eaten by their predators.

B. Insect Growth Conditions

The main growth conditions in the game are divided into three parts: food, environment and predators. Different insects may have different growth conditions. The items needed for food and environment can be picked up in the game and coins can be collected at the same time. Buy the tools you need at the store to increase the fun of the game, or when the insects die, you may buy eggs and restart.

1) Different insects have different food conditions (see Table I).

TABLE I: FOOD CONDITIONS

	praying mantis	rhinoceros beetle	Stag beetle	ladybug
water	✓	✓	✓	✓
fruit		✓	✓	
soil		✓	✓	
Offal-timber		✓	✓	
aphids				✓
insect	✓			✓

Fig. 7. Different events of the game.

2) In the game, insects will have many troubles. When they happen, the game will remind the students and ask the students to solve the problems according to the instructions (see Fig. 7):

a) The ambient temperature is too high or too low.
b) The living environment is messy and needs to be cleaned.
c) The insect body needs to be cleaned.
d) The insect needs food
e) The insect needs water
f) Let the insects play the music, this is to add some fun to the game.

III. METHODOLOGY

A. Research Mode

Based on the purpose of the study, this study used "insects garden VR game" to investigate and collect relevant data using questionnaires to understand the relevance of self-efficacy, cognitive load, failure attribution and intention of continuous participation. Before the insects garden VR game, the students were informed of the purpose of the learning and the rules of the game for 10 minutes. The students used Acer OJO500 to play the game for 15 minutes in the classroom (see Fig. 8). After the game was completed, the students were required to complete the questionnaire so that the data could be analyzed by SPSS and AMOS, which are used to explore the relationship among all the dimensions.

Fig. 8. Students use Acer OJO500 for games.

B. Research Design

1) Research objects and data collection

This study was approved by research ethics review (No. 201812HS037). The participants were 4th-grade students in Taipei. In this study, each student could use Acer OJO500 to carry out insects garden VR games. During the game, students could ask questions or request help, and there would be an adult next to each student to ensure safety during the operation. In the course of the experiment, the researchers encouraged students to find ways to solve problems and play the game. A total of 160 valid questionnaires were collected in this study.

2) Preparing the questionnaire

The content of this questionnaire was based on a questionnaire from previous research and had been revised. The elements were categorized as self-efficacy, cognitive load, failure attribution and intention of continuous participation. The item of each dimension was verified with confirmatory factor analysis (CFA), and the Likert five-point scale was used to calculate the scores.

IV. Result

This study was based on three steps to analyze data. The order was reliability and validity analysis, test of model fit and path analysis.

A. Reliability and Validity Analysis

1) The composite reliability (CR) test of the construct was used to determine the consistency of the questionnaire [18]. All CR values in this study ranged from 0.84 to 0.92, exceeding the recommended value of 0.80 [19]. All values were consistent with acceptable composite reliability.
2) In order to evaluate internal consistency, the internal reliability of the questionnaire was examined using Cronbach's α. The α values of each dimension ranged from 0.891 to 0.946, all values of α were greater than 0.8, and the α values of the questionnaire was 0.934 [20]. Hancock and Mueller [21] All suggested that α values were more than 0.8. High confidence levels were high..
3) Considering the verification validity of this study, the average variance extracted (AVE) of each dimension were between 0.57 and 0.75. [18], Bagozzi and Yi [22] recommended that the value of AVE should preferably be more than 0.50.
4) Table II shows that all values meet all necessary conditions [23], indicating that the construct validity of the questionnaire was acceptable.

TABLE II: Confirmatory Analysis (Convergence Validity and Combination Reliability)

Dimension	M	SD	Cronbach's α	CR	AVE
Self-efficacy	4.08	1.10	0.944	0.89	0.68
Cognitive load	3.63	1.69	0.891	0.84	0.57
Failure attribution	3.53	1.67	0.927	0.85	0.58
Intention of continue participation	3.95	1.23	0.946	0.92	0.75

B. Test of Goodness-of-Fit

Through the statistical analysis of the Structural Equation Modeling (SEM), the model fit index is shown in Table III. The x^2/df was 1.808, which is less than 5. RMSEA was 0.079, which is less than 0.1. GFI and AGFI were 0.86 and 0.807, both of which are greater than 0.8. NFI was 0.865, TLI was 0.919, CFI was 0.933, IFI was 0.935, and RFI was 0.836. PNFI and PCFI were 0.713 and 0.77, both of which are greater than 0.5. On the whole, the above indicators of the verification values were conformed to standard, showing that the SEM had a good model fit.

TABLE III: Model Fit Index

Index	Standard	Verification value	Result
X^2		179.051	
df		99	
X^2/df	<5	1.808	PASS
GFI	>0.80	0.860	PASS
AGFI	>0.80	0.807	PASS
RMSEA	<0.1	0.079	PASS
NFI	>0.80	0.865	PASS
TLI	>0.80	0.919	PASS
CFI	>0.80	0.933	PASS
IFI	>0.80	0.935	PASS
RFI	>0.80	0.836	PASS
PNFI	>0.50	0.713	PASS
PCFI	>0.50	0.770	PASS

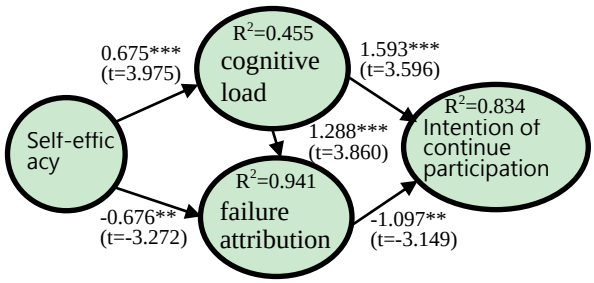
C. Path Analysis

Through the model, the path coefficients between the dimensions were analyzed to understand whether the collected data agree with the research hypothesis. The results of the study are shown in Table IV. After the AMOS statistical analysis, the path diagram of the hypothetical model path was drawn, as shown in Fig. 9.

TABLE IV: Path Analysis Table

Codename	Research hypothesis	Path coefficient	*t* value	Result
H1	The game's self-efficacy of student was negative correlated with cognitive load.	.675***	3.975	rejected
H2	The game's self-efficacy of student was negative correlated with failure attribution.	-.676**	-3.272	accepted
H3	Cognitive load of student was positively correlated with failure attribution.	1.288***	3.860	accepted
H4	Cognitive load of student was negative correlated with the intention of continue participation.	1.593***	3.596	rejected
H5	Failure attribution of student was negative correlated with the intention of continue participation.	-1.097**	-3.149	accepted

*p <.05,**p<.01,***p <.001



*p <.05,**p<.01,***p <.001

Fig. 9. Path analysis diagram.

This research model had a total of five sets of hypothetical paths. There was a statistically significant relation between each dimension.

V. Discussion

Many studies have shown that self-efficacy and cognitive load has a negative correlation. But those results are not consistent with this study. The insects garden VR games could promote learners' learning motivation described in CATLM. The task of cultivating insects made students feel that they had cognitive load, and students with high self-efficacy were able to accept the challenge. And the same result reflected between cognitive load and the intention of continuous participation. Games can stimulate learners' desire for persistence and continuous participation.

Many studies had shown that self-efficacy and failure attribution had significant predictive effects. The results were consistent with this study. Described in social learning theory, when self-efficacy is improved, one will be confident to encounter and solve problems. When students are confident

in the game, it is not easy to attribute the game's failure to the game's HMI design.

Game-based-eLearning environment helped to improve students' learning motivation but did not mean that they would continue to participate in learning. This study showed that failure attribution could affect students' intention to continue to participate. According to the theory of social cognitive learning, behavior is influenced by the people and environment. When problems were solved or the operation was smooth in game, the self-efficacy would be improved and the intention to continue participate would be generated. Therefore, it is necessary to reduce the frustration of failure in the game.

VI. Conclusion and Suggestion

The conclusions of this study were:

1) The game's self-efficacy of student was significantly positively correlated with cognitive load.
2) Self-efficacy of student was significantly negative correlated with failure attribution.
3) Cognitive load of student was significantly positively correlated with failure attribution.
4) Cognitive load of student was significantly positively correlated with the intention of continue participation.
5) Failure attribution of student was significantly negative correlated with the intention of continue participation.

The suggestions of this study for educators were:

1) Focus on improving the self-efficacy of students' in VR-game-based-eLearning that could enhance students to challenge the tasks in the game.
2) Many tasks can be designed in the game. Although it will increase the cognitive load of the students, it can increase the intention to continue participation.
3) The game operation is simple, the equipment can be used normally, the experience of failure is reduced, and the intention of continue participation can be improved.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Juh conducted the research; Juh and Hong analyzed the data; Juh and Lu wrote the paper; all authors had approved the final version.

References

[1] Ministry of Education, *White Paper on Scientific Education*, Taipei: Ministry of Education, 2003.

[2] C. C. Liu, and H. C. Shih, "Playing insects playing board games to cultivate the scientific process skills of primary school students," *Chinese Journal of Science Education*, vol. 24, no. 1, pp. 1-30, 2016.

[3] J. A. Buchanan and D. Houlihan, "The use of in vivo desensitization for the treatment of a specific phobia of earthworms," *Clinical Case Studies*, vol. 7, no. 1, pp. 12-24, 2008.

[4] Q. X. Han and Z. W. Yao, "Survey And analysis of the interactive experiencing teaching on entomology," *China Electric Power Education*, vol. 14, pp. 109-110, 2009.

[5] N. Thompson and T. J. McGill, "The application of affective computing technology to e-learning," *Pedagogical considerations and Opportunities for Teaching and Learning on the Web*, pp. 109-128, Hershey, PA: IGI Global, 2014.

[6] J. M. Laffey, L. Espinosa, J. Moore, and A. Lodree, "Supporting learning and behavior of at-risk young children: Computers in urban education," *Journal of Research on Technology in Education*, vol. 35, no. 4, pp. 423-440, 2003.

[7] C. Fowler, "Virtual reality and learning: Where is the pedagogy?" *British Journal of Educational Technology*, vol. 46, no. 2, pp. 412-422, 2015.

[8] M. Billinghurst, "Augmented reality in education," *New Horizons for Learning*, vol. 12, 2002.

[9] C. L. Ho and R. J. Dzeng, "Construction safety training via e-learning: Learning effectiveness and user satisfaction," *Computers & Education*, vol. 55, pp. 858-867, 2010.

[10] B. R. Lim, "Challenges and issues in designing inquiry on the Web," *British Journal of Educational Technology*, vol. 35, no. 5, pp. 627-643, 2004.

[11] J. P. Gee, *Good Video Games+ Good Learning: Collected Essays on Video Games, Learning, and Literacy*, New York: Peter Lang, 2007.

[12] R. Moreno, "Does the modality principle hold for different media? A test of the method affects learning hypothesis," *Journal of Computer Assisted Learning*, vol. 22, pp. 149-158, 2006.

[13] J. Webster, L. K. Trevino, and L. Ryan, "The dimensionality and correlates of flow in human-computer interactions," *Computers in Human Behavior*, vol. 9, no. 4, pp. 411-426, 1993.

[14] D. Potosky, "A field study of computer efficacy beliefs as an outcome of training: The role of computer playfulness, computer knowledge, and performance during training," *Computers in Human Behavior*, vol. 18, no. 3, pp. 241-255, 2002.

[15] L. Stankov, J. Lee, W. Luo, and D. J. Hogan, "Confidence: A better predictor of academic achievement than self-efficacy, self-concept and anxiety?" *Learning and Individual Differences*, vol. 22, no. 6, pp. 747-758, 2012.

[16] A. Bandura, *Self-efficacy: The Exercise of Control*, NY: Worth Publishing Ltd, 1997.

[17] D. Kim and Y. J. Ko, "The impact of virtual reality (VR) technology on sport spectators' flow experience and satisfaction," *Computers in Human Behavior*, vol. 93, pp. 346-356, 2019.

[18] C. Fornell and D. F. Larcker, "Evaluating structural equation models with unobservable variables and measurement error," *Journal of Marketing Research*, vol. 18, no. 1, pp. 39-50, 1981.

[19] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 7th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2009.

[20] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, *A Primer on Partial Least Squares Structural Equation Modeling*, Thousand Oaks, CA: Sage, 2013.

[21] G. R. Hancock and R. O. Mueller, *Structural Equation Modeling: A Second Course*, 2nd ed. Charlotte, NC: Information Age, 2013.

[22] R. P. Bagozzi and Y. Yi, "On the evaluation of structural equation models," *Journal of the Academy of Marketing Science*, vol. 16, no. 1, pp. 74-94, 1988.

[23] B. M. Byrne, *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*, 3rd ed. London, UK: Routledge, 2016.

Copyright © 2021 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).

Juh Chin-Chieh is doctoral student that studies in the Department of Science Education, National Taipei University of Education, Taiwan. To study nature curriculum that focuses on inquiry and implementation, emphasizing the importance of students' self-learning and problem-solving skills.

Lu Chow-Chin received the Ph.D. degree in zoology from National Taiwan University, Taipei, Taiwan, in 1994. Chow-Chin Lu is a professor working at the Department of Science Education, National Taipei University of Education, Taiwan. Her research interest has been focused on curriculum and instruction development, Biological concept research, elementary school teacher training, and science textbook research. She has over 100 papers published in the journals or presented in the conferences. Major journals that her papers published

include *Journal of Mathematics Science and Technology Education* (SSCI), *Learning and Individual Differences* (SSCI), *Thinking Skills and Creativity* (SSCI), *International Journal of Science and Mathematics Education* (SSCI), and *Asia-Pacific Forum on Science Learning and Teaching*. Her research interests are focusing on three major areas: (1) Elementary school teacher training, teaching strategy mechanism and change process of teacher believes. (2) Inquiry teaching and implementation including STEM, STEAM curriculum design. (3) Bio-bionics curriculum design and teaching.

Hong Jon-Chao has received his doctoral degree in education from the University of Illinois, Champaign-Urbana, and is currently working as a chair professor in the Department of Industrial Education at National Taiwan Normal University (NTNU). As the director of digital game-based learning laboratory (GBL), he has developed 9 web games, 24 educational Apps and VR for skill training and language learning.

As the secretary general of Taiwan Creativity Development Association, he also organizes several creative contests relevant to STEAM, such as PowerTech Contest to invite elementary, junior and senior high school students to produce robots or miniatures in the morning and using these to compete in the afternoon to ensure students' hands-on creation without parents or teachers' assistance. As the executive secretary of International Exhibition for Young Inventors (IEYI), he also promotes the innovative contest to give students an opportunity to stimulate their science inquiry abilities, and also cultivated students' creativity and thinking attitude of STEAM. In addition, he has published a number of academic articles in international journals related to digital game-based learning and thinking skills and creativity about 45 articles on Social Sciences Citation Index(SSCI) journals and received the Outstanding Research Prize from Ministry of Science and Technology in Taiwan.