Instructional Design, Learning Satisfaction, and Learning Outcome in a Virtual Reality Learning Environment Aimed at Improving the Cognition of Computer Hardware Components

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Received 03 June 2022; received in revised form 23 October 2022; accepted 24 October 2022

DOI: https://doi.org/10.46604/ijeti.2023.10247

Abstract

The integration of teaching materials with virtual reality (VR) technology is a common method for improving student interaction in courses, providing students with experience related to real-life spatial environments in class. This study developed a cost-effective and portable device that offers an immersive VR experience for learning the identification of computer hardware components. This device enables teachers to train technicians in computer hardware fabrication. The experimental group comprised 12 participants. According to the results of the learning satisfaction analysis, the students highly enjoyed the immersive learning experience. Descriptive statistics and the Wilcoxon matched-pairs signed-rank test are used for statistical analysis. Analysis of cognitive learning outcomes indicated that all students accurately identified all computer components after the intervention. By using the immersion teaching method, teachers could considerably improve the learning outcomes of students related to their cognition of computer hardware components.

Keywords: virtual reality, immersive experience, cognitive learning, learning outcome, computer hardware component

1. Introduction

Regarding the objectives of technical and vocational education, senior vocational schools focus on cultivating entry-level technicians, junior colleges emphasize training intermediate-level technicians, and universities of science and technology aim to train executive-level technicians [1]. An occupational license is not only a quality assurance mechanism but also a seniority control measure in the job market. The appropriate certification of technical and vocational education prepares students for the workplace, facilitates dialogue between supply and demand, and aligns education with industry requirements; thus, such a certification has beneficial outcomes for schools and industries and can enable students to enhance their competitiveness [2]. Computer maintenance is a basic service provided by computer repair technicians who work for computer companies.

A search on the website of 1111 Job Bank (a Taiwanese job portal) revealed that the duties of computer repair technicians mainly include resolving computer problems that customers experience, assembling computer software and hardware and peripheral equipment, detecting and diagnosing product failure, performing system security installation and testing, and conducting network installation. The aforementioned job responsibilities align with the content specified by the Ministry of Labor in Taiwan for the Level B and Level C computer hardware fabrication exams. Obtaining this type of license helps cultivate the technical skills required by computer repair technicians [3]. Host computers vary by field. A training institute may

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not be able to provide all types of host computers for students to practice. This makes teaching the technical skills required for professional computer repair difficult. Ensuring all types of host computers are available for training is crucial to improving students' computer maintenance skills.

Integrating teaching materials with virtual reality (VR) technology is a common method for improving student interaction in courses, providing students with experience related to real-life spatial environments in class, and overcoming the limitations of conventional teaching (which cannot provide experience related to relevant spatial environments). A virtual simulation environment can be constructed with a three-dimensional (3D) model to allow learners to interact virtually with objects [4]. VR refers to a 3D virtual world generated through computer simulation. The auditory and sensory experiences delivered by VR make users feel as if they are in the actual environment. VR is a medium that connects cyberspace, the real world, and users, and the interaction between these three entities is controlled by the VR system [5]. The three major elements of VR (i.e., imagination, real-time interactivity, and strong immersion) immerse users in a computer-simulated virtual world [6]. The virtual 3D scenes in VR leave considerable room for imagination because they allow users to operate in any way that the users deem appropriate [7].

The application (app) of VR in education can improve students' interest in learning as well as provide them with an immersive learning environment, new perspectives, and a natural learning interface [8]. The virtual world is an ever-changing environment that familiarizes learners with what they have learned through repeated practice. VR as an auxiliary teaching tool can easily create a visual presentation of abstract problems for learners to practice repeatedly and freely. In a VR environment, learners are stimulated to solve problems by using various methods. Moreover, they can directly interact with virtual objects and take mock tests to obtain first-hand experience. In VR, learner errors can be recorded to provide feedback, and the real-time collection and display of complex information can help learners set and achieve learning goals. Immersion and an environment that resembles nature can enhance learners' memory and problem-solving abilities [9].

Psychologists have proposed distinct learning theories, which can be classified into three major categories: behaviorism, cognitivism, and constructivism theories. Among these three theories, constructivism theory is the most commonly used learning theory in VR-based digital learning. Lin and Hsu [10] applied the concepts of constructive learning and online learning community to develop a constructive process and flexible hierarchical course structure for automated English vocabulary learning. English vocabulary learners exhibited improved learning outcomes after using the system proposed by Lin and Hsu [10].

Chan and Lai [11] discussed the use of digital learning platforms to satisfy the needs and characteristics of each discipline, design more diverse teaching and assessment methods, suitably evaluate learning outcomes and adapt and adjust the assessment weight according to the feedback of learners regarding their learning outcomes. By doing so, Chan and Lai [11] enhanced the accuracy of follow-up learning suggestions and guidance, stimulated learning interest, and improved learning outcomes. Constructivism is an epistemological theory that emphasizes the process of learning through inquiry.

During the learning process, learners attempt to connect the acquired information with their prior knowledge and beliefs, thereby changing their existing concepts. In constructivism theory, adaptation is used to describe the process of knowledge construction. The viability of knowledge is confirmed through the interaction between the learning experience and the external environment [12]. Knowledge, which is acquired through a process of active construction rather than passive acceptance, does not reflect the truth of the world. Instead, knowledge is the rationalization of personal experience, and it develops and evolves rather than remaining static [13].

Based on prior knowledge and experience, learners actively construct new concepts; that is, instead of learning directly from teachers, learners actively acquire knowledge in the cognitive process through exploration and discovery [14]. This study developed a cost-effective and portable VR device that offers various virtual computers to help students identify computer hardware components, and it created a teaching strategy with constructivism theory that aligns well with the developed device to train Level B and Level C technicians in computer hardware fabrication by teachers, thereby improving students' learning satisfaction and learning outcome concerning their cognition of computer hardware components.

2. Literature Review

The objectives of the study are to develop a cost-effective and portable VR device and a teaching strategy based on constructivism theory, thereby improving students' learning satisfaction and learning outcomes. This study conducted the literature review for two dimensions, involving the literature of VR and learning outcomes and VR glasses categories and usage time.

2.1. VR and learning outcome

Many scholars have deemed VR to be of considerable potential in improving students' learning abilities [15-17]. VR learning can enhance learning effects because it allows learners to assume a more active role and achieve their full potential [18-19]. Most students had positive feedback toward the integration of VR with classroom learning, which increased their interest in learning. VR learning effectively improved learners' concentration, enjoyment of learning, and learning intention [20-21]. Using VR outside of class or at home may also ensure the effectiveness of self-directed learning [22].

2.2. VR glasses categories and usage time

Most studies used a personal computer (PC)-connected VR glasses in the teaching experiment; the VR glasses required strong performance from the host computer, and locating a digital classroom suitable for the experiment was challenging. Because of the limited number of VR devices in the study, usage time was limited. Students were grouped and used the VR glasses for approximately 5-10 min; their experience was limited in terms of time and interactivity [17, 19-21].

3. Instructional Design and System Implementation

After the literature review, the study designed the teaching strategy and implemented the VR device for the teaching experiment. The VR device assisted with the teaching strategy in the teaching experiment, thereby analyzing students' learning satisfaction and learning outcome.

3.1. Instructional design

Constructivism theory emphasizes that knowledge is constructed by learners through active exploration and discovery. Through the process of learning through inquiry, learners attempt to connect the acquired information with their prior knowledge and beliefs, thereby changing their existing concepts. The interaction between the learning experience and the external environment confirms the viability of knowledge and the construction of new concepts. Constructivism theory is a commonly applied theory in digital learning with VR. In the present study, constructivism theory was used as the foundation for creating an immersive VR-based teaching strategy that aligns well with the proposed VR device for learning the identification of computer hardware components. The objective of this study was to enhance students' cognitive learning in their training for the Level B and Level C computer hardware fabrication exams conducted in Taiwan.

The adopted teaching strategy is the following. During the course, students are instructed to use the proposed device that offers an immersive VR experience for learning the identification of computer hardware components. The use of VR enables them to explore freely in the virtual world and interact with virtual objects to create knowledge connections. Moreover, the teacher guides students by requesting them to search for certain computer hardware components. Students are thus instructed to identify and describe the differences between similar components in their own words. Identifying the correct computer hardware components marks the completion of students' cognitive learning.

3.2. System implementation

The structure of this study and the procedure for implementing the system was based on guidelines for research on information systems [23-24]. Hevner et al. [23] designed a science research guideline that provided a structured path in the study for designing a cost-effective and portable VR device that offers various virtual computers to help students identify computer hardware components (Fig. 1) [23].

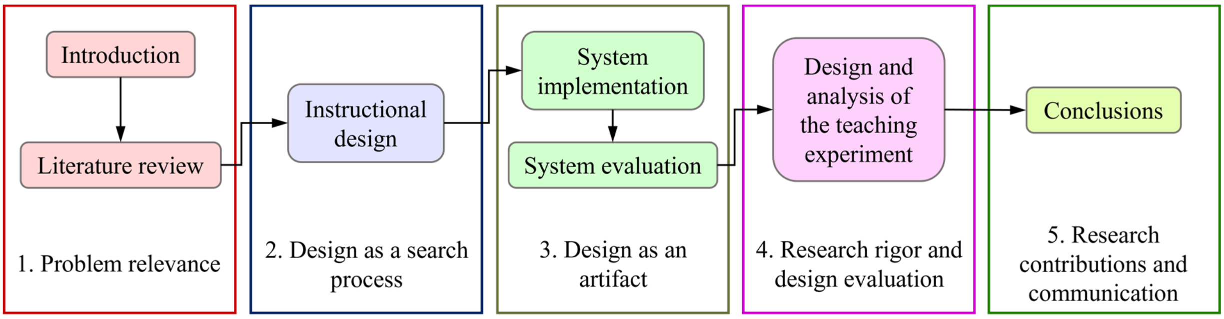


Fig. 1 Design science research process of the system [23]

3.2.1. System analysis

VR glasses can be roughly divided into three categories: smartphone-connected, all-in-one, and PC-connected VR glasses. The first type of VR glasses is designed to pair with a smartphone and constitute a simple, economical, and affordable means for everyone to engage in an immersive viewing experience. Users need to only place their smartphones on their VR glasses to experience the charm of VR. Among the three types of VR glasses, smartphone-connected VR glasses cost the least. All-in-one VR glasses do not require a connection to any additional hardware equipment to function. Users can engage in a VR experience by using the built-in host of the glasses. PC-connected VR glasses are high-standard products that require pairing with a host computer to function. Although PC-connected VR glasses usually require a large space to set up, they offer the optimal gameplay experience—in terms of display resolution and smoothness of the operation running on the hardware host—to other similar products [6].

This study aimed to develop a device that offers an immersive VR experience for learning the identification of computer hardware components. Teachers may use the proposed device to engage students in VR experience for the cognitive learning of computer components. To ensure smooth teaching, all students must be able to use the VR device. With convenience and setup cost being the primary concerns, smartphone-connected VR glasses were selected for subsequent development. This study paired the foldable Google Cardboard headset (Fig. 2) with an Android smartphone to create an immersive VR experience. The adopted setup met the present study's requirements of cost-effectiveness and portability.

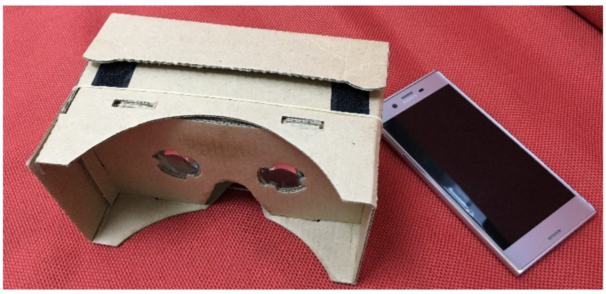


Fig. 2 VR device developed in this study

Table 1 presents the product costs. The products were the Unity engine and smartphone-connected VR glasses (Google Cardboard and smartphone). The version of the Unity engine for personal use is free [25]. The price of Google Cardboard is approximately NT$50 [26]. Because the students used their personal smartphones, the total product cost was approximately NT$50.

Table 1 Product costs

Item	Price (NTD)	Remarks
Unity Engine	0	Version for personal use is free
Google Cardboard	50	-
Smartphone	0	Students' smartphones
Total cost	50	-

3.2.2. System design

A. Development tool: In this study, Unity 2019 was used as the development platform, GoogleVRForUnity_1.200.1.unitypackage, and Android SDK was used as the software development kit.

B. System operation mode: The main objective of the developed device was to assist in the exploration of the cognitive learning of computer hardware components. Therefore, the description of a component appeared and disappeared when users looked at and away from the component, respectively.

C. System development: The system development process is described as follows:

(1) Download and install related packages, including Unity 2019, GoogleVRForUnity_1.200.1.unitypackage, and Android SDK.

(2) Create a virtual environment for a VR experience.

Step 1: Create a new project.

Step 2: Add a 3D plane and terrain, and set the terrain as the subhierarchy of the plane.

Step 3: Adjust the position of the terrain to be the same as that of the plane.

Step 4: Download free standard assets from the Assets Store.

Step 5: Use the free objects in standard assets, such as stones, trees, and turf, to create a customized VR environment (Fig. 3).

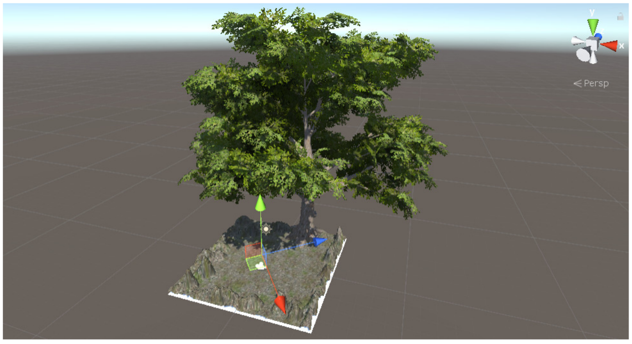


Fig. 3 Self-developed VR environment

(3) Import the Google virtual reality (GVR) unity package.

(4) Configure the basic settings of Unity:

Step 1: Add the Open Scenes.

Step 2: Add the Company Name and Product Name of the Player.

Step 3: In the Player setting/Player/XR settings, select "Virtual Reality Supported."

Step 4: In the Player setting/Player/Other settings/Graphics API, check "OpenGLE3."

Step 5: Add the Package Name in the Player setting/Player/Other settings/Identification, and set the Minimum API Level to API Level 19.

(5) Add 3D cubes to form the bodies of computer hardware components.

(6) Create different computer hardware components by pasting corresponding pictures on the 3D cubes. A total of 10 computer hardware components specified in the Level B and Level C computer hardware fabrication exam were created: graphics card, CD-ROM drive, memory module, central processing unit (CPU), hard disk drive or solid-state drive, network interface card, keyboard, mouse, flat cable, and monitor (Fig. 4).

(7) Add 3D text, and set it as the subobject of each 3D cube shown in Fig. 5 (i.e., Cube/Text).

(8) Add GvrEditorEmulator to provide in-editor emulation for Google VR.

(9) Add GvrEventSystem to trigger events.

(10) Add GvrReticlePointer to simulate the beam ray that follows the point of focus of eyes for event triggering in VR scenes (Fig. 6).

Fig. 4 Creation of 3D computer components in the VR environment

Fig. 5 Addition of 3D text to the VR environment

Fig. 6 Simulation of the beam ray to trigger events

(11) Create a camera rig with null objects to form GvrReticlePointer layers shown in Fig. 7 (Camera Rig/Main Camera/GvrReticlePointer).

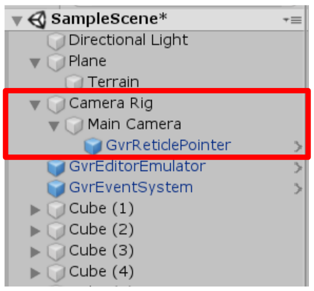


Fig. 7 Setting up the camera rig with null objects

(12) Add Gvr Pointer Physics Raycaster (script) to the main camera so that GvrReticlePointer triggers events.

(13) Add a new script, whose name is customizable, in assets, and create a trigger by using the C# program (Fig. 8).

(14) Drag the new script to the cube property of the computer hardware component to be triggered. Configure the text object to be triggered.

(15) Add an event trigger to the cube, and add the “point enter” and “point exit” events. Assign the new script to the event, and select the event action. Finally, set the text to be invisible (Fig. 9).

(16) Finally, after exporting and installing the created application (app), users can use Google Cardboard to engage in a VR experience for the cognitive learning of computer hardware components.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
public class changeword : MonoBehaviour
{
    public GameObject component_explain;
    public void ShowComponent()
    {
        component_explain.SetActive(true);
    }
    public void HideComponent()
    {
        component_explain.SetActive(false);
    }
}
```

Fig. 8 Event trigger in the C# program

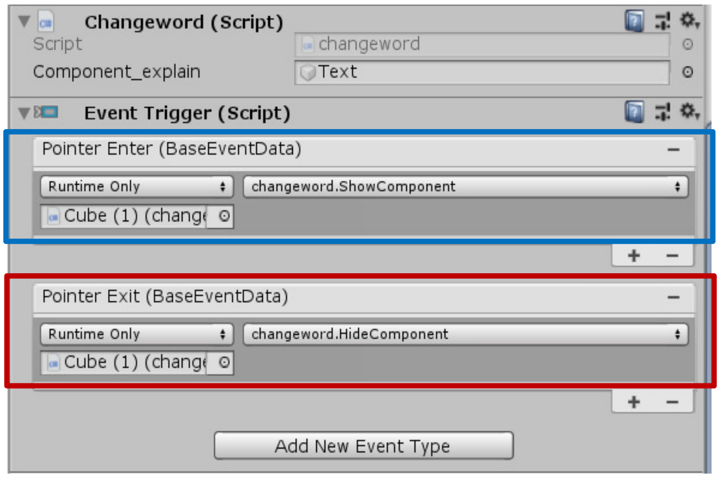
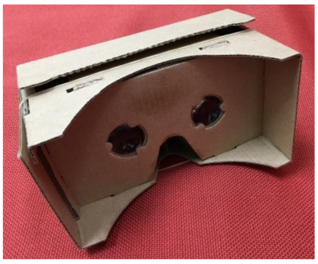
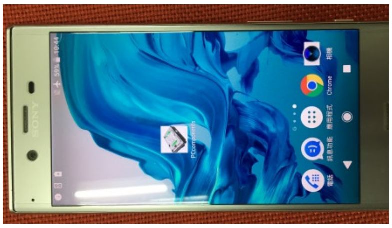


Fig. 9 Setting the text action for when an object is triggered

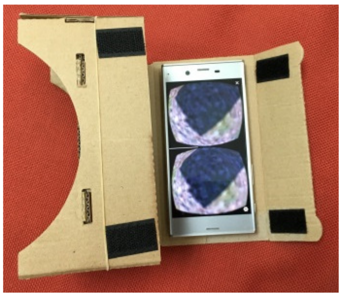
D. System evaluation: After the VR system was developed, a foldable Google Cardboard headset and an Android smartphone were prepared. Users can click on the icon of the developed app on the Android smartphone to open the VR system and place the smartphone into Google Cardboard to construct the VR experience device. By wearing the device, users can experience the cognitive learning of computer components. Fig. 10 illustrates the system assembly and testing process.



(a) Prepare a Google Cardboard

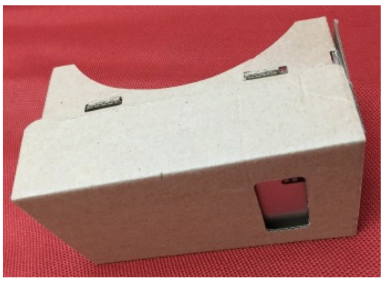


(b) Prepare an Android smartphone

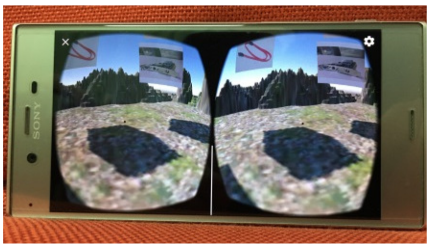


(c) Put the smartphone in the Google Cardboard

(d) Close the cardboard cover



(e) Complete the assembly



(f) Look around to view computer components

(g) Description of a component appears when the user looks at the component

Fig. 10 System assembly and testing process

4. Design and Analysis of the Teaching Experiment

The study designed the teaching experiment for exploring students' learning satisfaction and learning outcome. The researcher conducted the VR device that assisted with the teaching strategy in the experiment, and the experiment result was discussed and verified for study objectives.

4.1. Experimental design

The study designed the research framework as the foundation of the teaching experiment, and it also designed the experiment planning considering the experiment duration, research tool, participants, and analysis tool for implementing the teaching experiment.

4.1.1. Research framework

Fig. 11 depicts the research framework of this study. Before the teaching experiment, a pre-test was administered to participants. The proposed immersive VR-based teaching strategy was applied in conjunction with a cost-effective and portable device that offers an immersive VR experience for learning the identification of computer hardware components. After the teaching experiment, a learning satisfaction survey and post-test were conducted. 5 weeks later, a second post-test was administered.

Subsequently, a learning satisfaction analysis was performed to compare the results of the first post-test and pre-test for determining whether the students exhibited significant changes in learning outcomes after immersive VR-based teaching. The results of the second post-test and pre-test were then compared to verify whether the students' learning outcome improvements related to the cognition of computer hardware components remained significant after a 5-week interval.

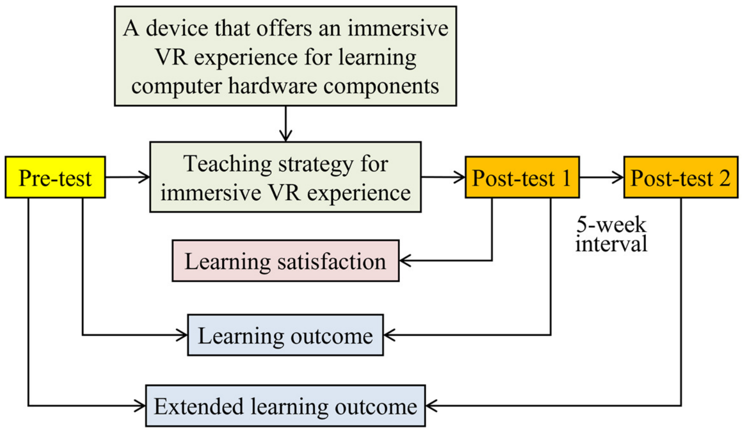


Fig. 11 Research framework

4.1.2. Experiment planning

(1) Experiment duration: A teaching experiment was conducted during school hours (8 hours per day) between December 2 and December 9, 2021. The learning satisfaction survey and first post-test were conducted on December 9, 2021. 5 weeks later, the second post-test was administered on January 13, 2022. The implementation of the teaching experiment is shown in Fig. 12.

(2) Research tool: The second segment of the computer hardware fabrication exam for Level B technicians conducted by the Skill Evaluation Center of Workforce Development Agency, Ministry of Labor (2019), Taiwan, requires examinees to identify, disassemble, and reassemble10 components of a computer: the graphics card, CD-ROM drive, memory module, CPU, hard disk drive or solid-state drive, network interface card, keyboard, mouse, flat cable, and monitor. Therefore, the cognitive test scale (i.e., the research tool) was designed based on these 10 computer hardware components [3].

(3) Participants: A total of 12 students enrolled in the Level B computer hardware fabrication course in the 2021 academic year participated in this study.

(4) Analysis tool: SPSS statistics 21.0 was used for analysis.

Fig. 12 Implementation of the teaching experiment

4.2. *Analysis of the experimental results*

The teaching experiment was implemented after the experimental design, and the experimental result was analyzed in three dimensions, involving the learning satisfaction analysis, learning outcome, and learning outcome 5 weeks after the experiment.

4.2.1. *Learning satisfaction analysis*

Table 2 Questionnaire on learning satisfaction with immersive VR experience

Dimension	Item No.	Item
Fondness	1	The implementation of VR-based learning activities fascinates me.
	4	I enjoy learning about computer assembly through VR-based learning activities.
	5 (negatively worded)	Engaging in VR-based learning activities stresses me out and causes me to lose focus in class.
	12	Engaging in VR-based learning activities helps me reduce the time required to assemble a computer.
Motivation	2	Engaging in VR-based learning activities helps me prepare for computer assembly exams.
	3	Engaging in VR-based learning activities is an important learning method for me.
	7	I work hard in all VR-based learning activities, which stimulate my interest in learning.
	8 (negatively worded)	VR-based learning activities **do not fit** my learning style well.
	11	I enjoy practicing computer assembly skills by engaging in VR-based learning activities.
Resistance	6	Engaging in VR-based learning activities directly helps my learning of computer assembly.
	9 (negatively worded)	VR-based learning activities make me feel bored in class.
	10	VR-based learning activities stimulate my interest and curiosity in learning.

(1) Questionnaire design: To design the questionnaire, the researcher referenced and revised Yang and Chen [27] to make a questionnaire on the perception toward English learning [27]. Table 2 presents the questionnaire on learning satisfaction with immersive VR experience that was adopted in the present study. The proposed questionnaire comprised 12 items under three dimensions, namely fondness, motivation, and resistance. Specifically, items 5, 8, and 9 were negatively worded, whereas the remaining items were positively worded. Each item was scored on a 5-point Likert scale.

(2) Analysis results: A total of 12 questionnaire copies were retrieved on the day of distribution, of which two were deemed invalid because they failed to indicate the degree of respondent perceptions; thus, 10 valid questionnaire copies were collected. Item analysis was performed to determine the critical ratios for each item; nonsignificant questions (questions 5, 8, and 9) were deleted. Table 3 presents the results of the item analysis.

Table 3 Item analysis

Dimension	No.	Item	*t*-test	Remarks
Fondness	1	The implementation of VR-based learning activities fascinates me.	0.038*	
	4	I enjoy learning about computer assembly through VR-based learning activities.	0.038*	
	5	Engaging in VR-based learning activities **does not** stress me out and causes me to lose focus in class.	0.184	Delete
	12	Engaging in VR-based learning activities helps me reduce the time required to assemble a computer.	0.038*	
Motivation	2	Engaging in VR-based learning activities helps me prepare for computer assembly exams.	0.016*	
	3	Engaging in VR-based learning activities is an important learning method for me.	0.038*	
	7	I work hard in all VR-based learning activities, which stimulate my interest in learning.	0.038*	
	8	VR-based learning activities **fit** my learning style very well.	0.158	Delete
	11	I enjoy practicing computer assembly by engaging in VR-based learning activities.	0.038*	
Resistance	6	Engaging in VR-based learning activities directly helps my learning of computer assembly.	0.016*	
	9	VR-based learning activities **do not** make me feel bored in class.	0.158	Delete
	10	VR-based learning activities stimulate my interest and curiosity in learning.	0.038*	

* $p < .05$

Cronbach’s α was used to measure the reliability of the questionnaire. According to Gay and other scholars, the acceptable minimum reliability value is >0.7 [28]; items should be deleted if their α value is <0.65 [29]. Table 4 summarizes the results of the reliability analysis; α values of 0.949, 0.958, and 0.773 were obtained for the fondness, motivation, and resistance dimensions, respectively. The total α value of all dimensions was 0.893. Thus, the questionnaire has satisfactory reliability.

Table 4 Reliability analysis

Dimension	No.	Item	α value for each dimension	Total α value
Fondness	1	The implementation of VR-based learning activities fascinates me.	0.949	0.893
	4	I enjoy learning about computer assembly through VR-based learning activities.		
	12	Engaging in VR-based learning activities helps me reduce the time required to assemble a computer.		
Motivation	2	Engaging in VR-based learning activities helps me prepare for computer assembly exams.	0.958	
	3	Engaging in VR-based learning activities is an important learning method for me.		
	7	I work hard in all VR-based learning activities, which stimulate my interest in learning.		
	11	I enjoy practicing computer assembly by engaging in VR-based learning activities.		
Resistance	6	Engaging in VR-based learning activities directly helps my learning of computer assembly.	0.773	
	10	VR-based learning activities stimulate my interest and curiosity in learning.		

The results of the learning satisfaction analysis are presented in Table 5, with scores of 4.37, 4.30, and 4.40 points being obtained for the fondness, motivation, and resistance dimensions, respectively. According to the aforementioned results, learners were very fond of learning through immersive VR experiences, which aroused their learning motivation and generated little learning resistance.

Table 5 Analysis of learning satisfaction with immersive VR experience

Dimension	No.	Item	Score for each item	Dimension score
Fondness	1	The implementation of VR-based learning activities fascinates me.	4.40	4.37
	4	I enjoy learning about computer assembly through VR-based learning activities.	4.40	
	12	Engaging in VR-based learning activities helps me reduce the time required to assemble a computer.	4.30	
Motivation	2	Engaging in VR-based learning activities helps me prepare for computer assembly exams.	4.40	4.30
	3	Engaging in VR-based learning activities is an important learning method for me.	4.40	
	7	I work hard in all VR-based learning activities, which stimulate my interest in learning.	4.10	
	11	I enjoy practicing computer assembly by engaging in VR-based learning activities.	4.30	
Resistance	6	Engaging in VR-based learning activities directly helps my learning of computer assembly.	4.40	4.40
	10	VR-based learning activities stimulate my interest and curiosity in learning.	4.40	

4.2.2. Learning outcome

Speaking of Analysis Method, when the population distribution is unknown and nonnormal or when the sample is small, the nonparametric method can be used for statistical analysis. The Wilcoxon signed-rank test compensates for the inability to perform a signed-rank test by using not only the sign but also the size of the difference [30]. The 12 participants formed an experimental group, and no control group existed in this study. Because of the absence of a control group, descriptive statistics and the Wilcoxon matched-pairs signed-rank test (a nonparametric statistical test) were used to analyze the learning outcome (as indicated by cognition of computer hardware components). Power analysis was performed using a paired t-test; the power obtained using a sample size of 12 was 0.985; reducing the sample size to 7 resulted in a power of 0.8, as expected.

According to the analysis results, 58% of the participants had previous experience in computer assembly. To evaluate the participants' learning outcomes concerning their cognition of computer hardware components, a teaching strategy involving immersive VR experience was applied. In this teaching strategy, the participants were asked to wear a VR device.

As presented in Table 6, the mean score of the participants in the pre-test was 87.5 points, with the standard deviation (SD) being 17.122 points. Thus, the participants already had some understanding of computer hardware components before the experiment. However, a large gap existed in the participants' cognitive abilities. After the teaching experiment was implemented, the mean score of the participants in their first post-test was 100 points, with the SD being 0 points. Thus, all the participants gained the cognitive ability to identify all the computer hardware components correctly.

Table 6 Descriptive statistics for immediate learning outcomes

	N	Mean	SD
Pre-test	12	87.50	17.122
Post-test	12	100.00	0.000

The results of the nonparametric two-sample test for immediate learning outcomes (Table 7) indicated that the scores in the pre-test and first post-test differed significantly (p = 0.041 < 0.05). Thus, the VR experience allowed teachers to generate a significant improvement in the learning outcomes of the participants regarding their cognitive learning of computer hardware components.

Table 7 Results of the nonparametric two-sample test for immediate learning outcomes

	Cognitive ability to recognize computer hardware components in the pre-test and post-test
Z-test	-2.041*
Asymptotic 2-tailed test	0.041

* $p < 0.05$

4.2.3. Learning outcome 5 weeks after the experiment

Because this study only involved an experimental group, no comparison was made between the proposed teaching method and other teaching methods. The researcher conducted a second learning outcome assessment (i.e., the second post-test) 5 weeks after the experiment. The results of the pre-test and second post-test were analyzed to verify whether the proposed teaching method provided long-term learning benefits (i.e., long-term memory).

As presented in Table 8, the mean score of the participants in the second post-test was 98.33 points, with the SD being 5.774 points. Of all the participants, only one did not receive the highest score. The participants were still able to identify the computer hardware components correctly after 5 weeks. They did not lose their cognitive ability over time, which indicates that they had benefited from the proposed teaching method and developed long-term memory.

Table 8 Descriptive statistics for learning outcomes 5 weeks after the experiment

	N	Mean	SD
Pre-test	12	87.50	17.122
Post-test	12	98.33	5.774

Subsequently, the researcher analyzed the learning outcome by comparing the scores in the pre-test and second post-test. The results of the nonparametric two-sample test for learning outcomes 5 weeks after the experiment (Table 9) indicated that a significant difference existed between the scores in the pre-test and second post-test (p = 0.042 < 0.05). Learning outcomes were analyzed by comparing the scores on the first and second post-tests. The nonparametric two-sample test for learning outcomes with two post-tests (Table 10) indicated a nonsignificant difference between the scores on the first and second post-tests (p = 0.317 > 0.05). Thus, the participants' learning outcome (i.e., cognitive ability to recognize the computer hardware components) improvements remained significant 5 weeks after the experiment.

Table 9 Results of the nonparametric two-sample test for learning outcomes 5 weeks after the experiment

	Cognitive ability to recognize computer hardware components in the pre-test and post-test
Z-test	-2.032*
Asymptotic 2-tailed test	0.042

* $p < 0.05$

Table 10 Results of the nonparametric two-sample test for learning outcomes with two post-tests

	Cognitive ability to recognize computer hardware components in the pre-test and post-test
Z-test	-1.000
Asymptotic 2-tailed test	0.317

* $p < 0.05$

4.2.4. Summary

The teaching experiment improved the participants' learning satisfaction and outcomes significantly. These findings are consistent with those of studies suggesting that incorporating VR into digital learning improves learning outcomes, motivation, and intention. Smartphone-connected VR glasses were used to develop the device. Owing to the cost-effectiveness and portability of the device, students can use it at any time. They can also use their smartphones for the VR experience, which reduces costs, eliminates the need for grouping, and increases usage time. Students can use the VR device at a fixed position by the programming control; this reduces the interactive range. Thus, the problems identified through the literature review were solved.

5. Conclusions

In this study, the researcher created a cost-effective and portable device that offers an immersive VR experience for learning the identification of computer hardware components. This device offers various virtual computers and thus facilitates technical training (Levels B and C) in the fabrication of computer hardware. Specifically, each recruited participant was provided a VR device for the cognitive learning of computer hardware components. In addition, the researcher developed a constructivism-based teaching strategy that can be used in conjunction with the proposed VR-based teaching method. Before the teaching experiment, a pre-test was administered to the participants. The proposed immersive VR-based teaching strategy was applied in the teaching experiment. After the experiment, a learning satisfaction survey and post-test were conducted. 5 weeks later, a second post-test was administered.

According to the results of the learning satisfaction analysis, the participants highly enjoyed the immersive learning experience. The adopted VR-based teaching method aroused strong learning motivation and caused little resistance to learning. The analysis of cognitive learning outcomes indicated that all the participants accurately identified all the relevant computer components after the teaching intervention. By using the proposed teaching method, teachers could considerably improve the participants' learning outcomes regarding their cognition of computer hardware components. Compared with their learning outcomes before the teaching experiment, the participants still exhibited improved learning outcomes after a 5-week interval. The participants' cognition of computer hardware components did not decrease over time, and the proposed teaching method provided them with long-term learning benefits (i.e., long-term memory).

Conflicts of Interest

The authors declare no conflict of interest.

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