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A Study on the Impact of STEAM Education for Sustainable Development Courses and Its Effects on Student Motivation and Learning

Peng-Wei Hsiao [1] and Chung-Ho Su [2,*]

[1] Department of Fine Arts in Digital Media, Macau University of Science and Technology, Macao; pwhsiao@must.edu.mo

[2] Department of Animation and Game Design, Shu-Te University, Yanchao, Kaohsiung 824, Taiwan

* Correspondence: mic6033@stu.edu.tw; Tel.: +886-917-231-831

Abstract: In 2019, the United Nations released its 10-year policy of "ESD for 2030". Many schools around the world have actively participated in the transformation and have included the United Nations Sustainable Development Goals (SDGs) in Education for Sustainable Development (ESD). Many developed countries hope to combine the concept of STEAM education (Science, Technology, Engineering, Art, and Mathematics) with interdisciplinary learning, and apply it to ESD. This study intended to integrate the sustainability concept into Virtual Reality (VR) system-aided STEAM education, in order to provide school children with integrated interdisciplinary STEAM education. A literature review was conducted and the research hypotheses were proposed. The empirical method and questionnaires were used as research methods to investigate the influence of the proposed system on the students' satisfaction, self-efficacy, and learning outcomes after cognition learning. The results of this study showed that the combination of STEAM education, with VR-aided experience courses, could help to improve the learning satisfaction and outcomes of students and to arouse their learning motivation. However, the proposed system needs an ESD that is based on students' traditional culture (such as designing a role-playing game), so that they can improve their self-efficacy through playing a VR game. Although VR games are interesting, they are difficult for some students to play. Therefore, it is necessary to adjust the teaching materials, methods, and strategies appropriately by using information technology, so that ESD can be achieved by inspiring students to explore continuously. The findings can serve as a reference for further relevant studies.

Keywords: Education for Sustainable Development (ESD); STEAM; VR; learning motivation; learning effect

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1. Introduction

Education for Sustainable Development (ESD) was first put forward in 1992. Based on the values of sustainable development, it aims to develop the students' concepts and their ability to face a future sustainable environment through interdisciplinary teaching and collaboration. In 2019, the United Nations released the 10-year policy of "ESD for 2030". Many schools around the world have actively participated in the transformation and have included the United Nations Sustainable Development Goals (SDGs) in ESD. Many studies have discussed ESD and other related topics. Bucea-Manea-Ţoniş et al. (2020) used extended reality (XR) to investigate the impact of virtual technology on the work, study, and social lives of the respondents. They found that the immersive experience of students has a significant impact on their culture, living standards, and learning. In Austria, the University of Graz built an academic center for teacher–student interaction, based on a new teaching method that combines the interdisciplinary collaboration of STEAM (Science, Technology, Engineering, Art, and Mathematics) education and ESD [1]. Velázquez (2018) mentioned that the integration of augmented reality (AR) technology in the classroom can improve the students' motivation to learn, and that AR technology is systematic and procedural. When combined with information and communication technologies, it will be helpful for ESD [2]. Besides identifying the impact of STEM (Science, Technology, Engineering, and Mathematics) education programs on the academic performance of elementary students, Fernández-Martín et al. (2020) observed the key focus of sustainability on the employability of college students through mentoring programs. They used the course materials provided by the Nurture Thru Nature (NtN) program to evaluate the impact of STEM courses on Spanish elementary students and the effect of mentoring programs on the employability of college students [3]. Studies in Vietnam have shown that STEM education could motivate students and enhance their attitude towards learning [4]. Moreover, experienced science teachers could bring about the most obvious changes through STEM, while novice teachers could improve the students' learning motivation. STEM education is of value to ESD. In Guangzhou, China, Fan et al. (2020) integrated traditional lacquer art learning and electronic technology into the course design, and found that the learning effectiveness of the lacquer art culture was improved, which contributed to sustainable development [5]. The above literature indicates that ESD can be integrated into STEAM education for different disciplines, and can be combined with culture and digital technology. However, as STEM education places an emphasis on technology, how to integrate art into STEM education has become an emerging topic in recent years.

According to the British Education Research Association (BERA), STEAM has been adopted worldwide to indicate the involvement of art, or artistic practice, in education. The concept was first put forward by Professor G. Yakman from Virginia Tech in 2006, who suggested that besides the four pillars of STEM, namely Science, Technology, Engineering, and Mathematics, the perspective of aesthetics and society should also be included [6]. In February 2018, the Australian Summit Group advocated for art education in schools, developed art education policies, promoted quality teaching in the arts, and collaborated with government agencies, teachers, schools, and tertiary institutions [7]. STEAM education is presented to broaden the interest in the STEM fields, to enhance the creativity of STEM students, and to spur innovation [8]. On the other hand, research has found that STEAM courses that incorporate exploratory learning and plentiful topics can deepen the cognitive abilities of children. STEAM activities can also attract the attention of students and encourage and improve their creativity [9,10]. Su (2019) explored the Effect of the Users' Behavioral Intentions on Gamification Augmented Reality in Stem (Gar-Stem) Education. Advanced technology and teaching can enhance the effectiveness of STEM learning and improve the learners' participation in, and attitude towards, learning [11]. STEAM education is therefore an integrated approach to education [12]. Many developed countries have begun to emphasize interdisciplinary learning and application, and they have adopted education for sustainability to foster the thinking and creativity of the younger generation [13]. The purpose of education is to guide students to integrate interdisciplinary knowledge, to trigger their interest in STEAM learning, and to develop their employability through STEAM [14]. Relevant studies have found that combining the STEAM concept with the learning elements of games could improve the academic performance of students, compared with the lecture-centered teaching model. In one study, the cognitive load of students in the experimental group was lower than that of the control group [15]. Flintoff (2017) combined the dynamic digital technology resources of Makerspace in a library with STEAM education, so as to offer learning activities that could be traced by local customers and students. These activities could be linked with the academic courses for continuous development [16].

Internet technology has been applied to numerous fields, such as the virtual learning environment [17], as well as mobile devices, multimedia, and computer assistance [18,19]. In the coming 5G era, VR technology is expected to have a good experiential effect, as well as unique characteristics (e.g., being tangible, visible, and controllable), which can arouse the students' learning motivation more effectively and make the teaching model more diversified and interesting [20]. Relevant studies have found that the immersive

VR experience has a better interactive effect than the traditional mouse operation, and that students using an immersive VR experience can retain more information and absorb knowledge more efficiently in the learning process [21]. The learning effect is significantly improved by VR teaching [22,23]. VR can also create a highly immersive English learning environment to enhance the participation of learners, so that they can continuously enhance their proficiency in English [24].

As discussed above, ESD has been explored continuously in many fields, and the interdisciplinary concept of STEAM education can be integrated into ESD. With the technological advancements, the VR interactive design has made a significant breakthrough in education and sustainable development. Therefore, this study focuses on the essence of education and technology coding, visual art design, and immersive experience integration, which aim to combine the concept of sustainability, STEAM education, and VR in experiential learning courses. Furthermore, the effect of experiential courses on the students' self-efficacy, learning motivation, satisfaction, and learning outcome are discussed. The research purposes of this study are as follows:

1. To integrate STEAM education into VR-aided traditional culture experience courses and investigate the effects of this immersive system on the students' learning motivation, satisfaction, and outcomes.
2. To learn about the influence of self-efficacy on the learning motivation, satisfaction, and outcomes of students who are in the VR-aided experience courses on traditional culture.
3. To investigate whether students are willing to explore traditional culture after learning about sustainability concepts through their VR-aided experience, so as to realize ESD.

2. Background

2.1. Education for Sustainable Development

ESD was recognized by the General Assembly of the United Nations in 1987. The Assembly mentioned that the root of sustainable development lies in education, which is an important activity and concept that the United Nations must continue to carry out systematically, along the sustainable development axis. Agenda 21 points out that it is the shared responsibility of the international community to provide ESD as essential general knowledge for its world citizens. Therefore, besides the common issues of sustainable development in human society, with all its environmental changes, the combination of education and the concept of sustainability is the foundation for sustainable development. Many studies, programs, and courses have been developed on the sustainable development in "communities", "regions", and "countries", as well as on the development of environmental, cultural, social, and economic sustainability. Topics on sustainable development and the extension of education also tend to be diversified.

In 1983, Gardner mentioned in *Frames of Mind: The Theory of Multiple Intelligences* that each person has a different type of intelligence with which to think and learn [25], and it was mentioned that ESD is a holistic course that can promote the development of multiple intelligences. The goal of ESD is to enable students to attain knowledge that is related to ESD and to raise their awareness of sustainability. It also aims to develop the students' ability to engage in critical thinking, to solve environmental problems, and to form good behavior habits in the process of resolving conflicts on environmental issues. In *Technique, Creativity, and Sustainability of Bamboo Craft Courses: Teaching Educational Practices for Sustainable Development*, it was also mentioned that different education courses will affect the different technologies and creativity. The combination of ESD and bamboo art courses has an impact on the students' learning of traditional culture [26]. According to the 2020 College of Cultural Heritage of the Taiwan Ministry of Culture, many education workers have recognized the improvement of cultural literacy as an important educational goal in the future. In the United States, this trend has been regarded as an important course change. Starting from the core quality of sustainable development, the educators are expanding the students' horizons on issues related to cultural heritage and are undertaking sustainability-focused cross-topic courses [27].

2.2. STEAM Education

STEAM education is a teaching approach that fosters the learners' interest in STEAM courses by fostering their individual capabilities of expression, innovation, and aesthetic perception [28], of which innovation is the most important. Many studies have pointed out that art can help learners to develop their innovation capability by using different kinds of technologies, and that art can also improve the development of their cognitive skills (e.g., listening, thinking, problem solving, and decision making) as well as the capability of self-expression, observation, cooperation, and communication [29,30].

STEAM education integrates art courses into STEM education, so as to balance the science and technology courses in STEAM, and create a more inclusive and integrated interdisciplinary education model. Under the basic mathematical logic, along with teaching on engineering and art aesthetics, students can learn the connotations of science and technology, in which art is a personal cognition of beauty, the accumulation of experience, and a process that cannot be replaced by others. The combination of art and STEM education can promote the integration and coordination of various disciplines, and it can cultivate the students' creativity and innovation ability and strengthen their artistic edification and humanistic backgrounds [31].

Relevant studies have discussed the application and effects of STEAM in various disciplines. In the United States, STEAM education is considered to be an important national education reform strategy, from kindergarten to high school. It encourages students to understand the world through diverse knowledge and perspectives, which is conducive to cultivating their innovation capability [32,33]. Patterson and Muna (2019) combined the STEAM concept with 3-D printing technology, as an integrated art and technology method. They found that interdisciplinary applications are more effective than single methods. STEAM education enables students to learn cooperatively through "learning by doing", to solve practical problems through practical processes, and to connect knowledge with real life [34]. It also encourages the use of technology (e.g., gamification, animation, AR, and VR) to facilitate STEAM education. In Thailand, STEAM has been reported to offer practical help in the lives and learning of Thai students [35].

2.3. Application of the Experiential Gaming Model and VR in Education

Kiili (2005) proposed a gaming model for STEAM, based on experiential learning, which could serve as a connection between educational theory and game design. The experiential gaming model is divided into two cycles: the game cycle and the design cycle. The game cycle includes the experience loop, solution loop, and challenge bank. The design cycles have four stages, which were, respectively, needs analysis, implementation, reflective evaluation, and design knowledge. According to the model, learning is not only about cognitive construction, but also about the coping behaviors of learners in the process of learning [36]. Therefore, learning in the gaming model refers to the cognitive construction of individuals through their actions and practices in a game.

The experiential gaming model consists of three parts. Part 1 is the ideation loop, which is about the four solution stages that students come up with, as detailed below:

(1) Pre-invative idea generation: a solution, regardless of the reality of the situation.
(2) Idea generation: a solution subject to the limitations in the real world.
(3) After the addition of creative new ideas, old solutions that were tested in the experience loop are tested again, as new solutions, in the experiment loop.
(4) A better effect can be achieved if this stage proceeds through group collaboration.

Part 2 is the experience loop, which is similar to experience learning. Players find the new solution by conducting experiments with a clear goal, reflecting and observing feedback from the experiments, and then converting the results to schemata in the mind and improving their skills for better control of the game. Part 3 is the challenge bank (the core of the experiential gaming model), where all thinking begins and all kinds of questions and challenges are designed according to the education goal. As they are stimulated by these challenges, learners start to think about problem solutions and enter the experience learning loop. The difficulty of the game is adjusted according to the developmental speed of the learners, in order to keep them interested in learning and to maintain their learning motivation in the game.

VR is highly convenient and highly flexible, and it has a better stimulation effect and lower stimulation costs. According to an investigation by CyberEdge Information Services in 2002, VR is the most widely used in education and training [37]. In earlier years, Winn (1993) proposed that computer-aided education entered a new era, after the emergence of VR. Overcoming the barriers of physical interfaces, the immersive first-person environment could facilitate self-directed learning through interactive games. By providing situational simulation, learners could experience and acquire knowledge directly. According to the theory of situational learning, it can improve the learning outcomes [38]. Engage VR, a VR education platform, allows users to make presentations, receive remote courses, and practice skills through real-time interactive games. Water Bears, a 3D VR quiz game, uses digital methods to teach students about system construction and spatial concepts through games. Many studies have demonstrated that VR can be used as a learning tool for learners to acquire spatial capability and to develop spatial cognition [39,40]. As discussed above, VR games have been increasingly applied in education and are having a significant effect.

2.4. Self-Efficacy

Bandura (1977) put forward the self-efficacy theory, which refers to the degree of an individual's confidence in believing that he or she can complete a job. Moreover, human behavior, internal factors, and the environment influence the students' learning motivation of continuous persistence [41]. The expectation component refers to the learner's belief in whether a certain learning task can be expected to succeed [42]. Therefore, the expectation component includes the mastery of the ability to complete certain target work, a belief in the ability to control the target, and the degree of expectation of the success of the work, which is closely related to self-efficacy. Pintrich (1999) proposed that a reward incentive mechanism is a goal-oriented approach to improve self-efficacy, thus enhancing the learning value and interest [43]. The STEAM concept has been integrated into different technology platforms, such as Flash and Second Life, to develop interdisciplinary educational content. Students can learn more effectively from 3D games than from 2D games, and the greater cognitive burden will affect the students' self-efficacy [44].

2.5. Learning Motivation

Lumsden (1994) suggested that learning motivation refers to a kind of attitude in which students naturally and willingly participate in learning, and work towards the teaching goal and the internal psychological process set by the teachers. In addition, as learning motivation management also involves elements of self-control, especially the role of willpower, some scholars have proposed motivation adjustment strategies, from the perspective of willpower control [45]. These willpower adjustments are regarded as a way of maintaining motivation [46,47]. Johnson (2018) conducted an experiment with the after-school STEAM program in an elementary school in California. The results showed that the students liked to do hands-on work and to engage in interactive STEAM activities. When faced with open STEAM problems, the students actively participated in STEAM activities and learned with each other [48]. The interest development model was later developed to enhance the students' learning interests and outcomes in STEAM. The results showed that course experience has a significant effect on the motivation, creativity, and learning of college students. Moreover, the learning environment and course experience can maintain the learning interest of college students in STEAM learning. The KidsProgram platform, developed for remote STEAM courses, uses module programming to design animation and games that stimulate and challenge the curiosity of students. According to the survey, the platform stimulated the students' learning interest and motivation and provided them with an environment for the comprehensive application of multidisciplinary knowledge [49]. As discussed above, it is important to improve the learners' confidence and enthusiasm in learning by using motivational strategies, which guide them to observe problems carefully and offer encouragement in the learning process.

2.6. Learning Effect

According to Brown (1981), the learning effect refers to the change in attitude of the knowledge, understanding, or skills acquired by learners through special experiences in formal courses and teaching design [50]. Achievement refers to an individual showing his/her ability in some aspect, based on his/her innate inheritance and through the experience and study of teaching design. When an individual or group achieves a goal or level of success in some fields, after great effort, it is a kind of effect. Relevant studies have explored the use of different teaching strategies and objectives on learners, from different perspectives, and they have compared the differences between traditional and online students in learning by using grades, satisfaction, and self-assessment. The results showed that learning type, learning motivation, and learning performance are significantly correlated with learning satisfaction, and that learning motivation and learning performance are positively correlated. The more online experience the students have, the higher their learning satisfaction and learning performance will be [51]. By using the digital learning system to combine the STEAM concept with game learning, Chen and Huang (2020) found that students in the experimental group had better learning results than those in the control group. Moreover, the cognitive load of the students in the game group was lower than that of the control group. By using the impact of STEAM education on the students' concept acquisition and creativity in learning light and optics, Wandari (2018), Perignat and Katz-Buonincontro (2019) found that there was an obvious improvement in the students' concept acquisition and creativity [52,53].

3. Research Hypotheses

This research uses STEAM education to integrate experiential VR courses for teaching experiments, and to further explore the relationship between self-efficacy and experiential learning for learning motivation, learning satisfaction, and learning effectiveness.

3.1. The Influence of Self-Efficacy on Learning Motivation, Satisfaction, and Learning Effectiveness

Schunk (1995) suggested that self-efficacy helps to predict motivation and performance [54], while Chang and Eric Zhi-Feng Liu (2014) found that when college students have higher online self-efficacy, the influence on their learning motivation and performance is greater [55]. Yang and ErsanlÕ (2015) studied the correlation between self-efficacy and language learning motivation, and found that gender and family background differences affect the level of self-efficacy and willingness to learn [56]. Kim and Park (2015) indicated that self-efficacy affects student satisfaction in E-learning courses [57]. Therefore, this paper proposes the following hypotheses:

Hypothesis 1 (H1). *Self-efficacy affects learning motivation.*

Hypothesis 2 (H2). *Self-efficacy affects learning satisfaction.*

Gist et al. (1989) used computer software to train students from 108 colleges, and they proved that the learning effect of students with a higher self-efficacy is higher than those with a lower self-efficacy [58]. Pintrich and Schunk (1996) mentioned that the improvement of self-efficacy positively affects the learners' learning [59]. Zimmerman (2000) indicated that students' belief in self-efficacy can stimulate learning effects through self-supervision, self-evaluation, and learning strategies in the process of setting goals and learning [60]. Therefore, H3 is proposed as follows:

Hypothesis 3 (H3). *Self-efficacy affects the effect of learning.*

3.2. The Influence of Experiential Learning on Learning Motivation, Satisfaction, and Learning Effectiveness

Holtzman (2011) discussed the motivation of college students to participate in relevant experiential courses (e.g., internships or plans for studying abroad) outside the classroom, so as to understand what students want to learn and how to arouse their motivation to participate [61]. Weinberg et al. (2011), from the University of Colorado (USA), designed four experiential learning plans with mixed methods and assessed whether they had any impact on the interest and motivation of middle school students in mathematics and science [62]. Therefore, H4 is proposed as follows:

Hypothesis 4 (H4). *Experiential learning affects learning motivation.*

The research of Chhatwal et al. (2010), of the Richard Stockton University, examined the determinants of student satisfaction and the correlation of integrated experiential learning techniques in business courses [63]. Gutierrez (2011) used interactive simulation to offer experiential learning to nursing students and examined the quality of nursing to determine the learning results [64]. Dzan et al. (2015) used experiential learning as the theoretical basis for science education planning and designed six themes, in collaboration with the National Science and Technology Museum (NSTM). The learners' satisfaction and activity preferences were measured, and it was found that the learning themes improved the learners' learning and satisfaction, and enhanced their willingness to participate in activities [65]. Based on the above, the following hypotheses are proposed as follows:

Hypothesis 5 (H5). *Experiential learning affects learning satisfaction.*

Hypothesis 6 (H6). *Experiential learning affects the effect of learning.*

3.3. The Influence of Learning Motivation, Satisfaction, and Learning Effectiveness

In terms of the influence of learning motivation on satisfaction, many theoretical and empirical studies have shown a positive relationship. When the learner's needs are met in their learning activities, their learning motivation will be relatively improved; and learning motivation is one of the important factors affecting satisfaction [66,67]. Jung and Choi (2002) found that they have a good satisfaction and learning level in the experiment, which helps and improves the participation and effectiveness of activity learning significantly [68]. User satisfaction is an important predictor of learning outcomes. A specific online teaching model, meaningful learning, and timely feedback will have an impact on the satisfaction and learning effectiveness of students [69].

There is also a positive correlation between learning motivation and learning effectiveness, namely, the stronger the learning motivation, the higher the learning effectiveness; in contrast, the weaker the learning motivation, the lower the learning effectiveness [70,71]. There are many teaching platforms and interactive media today, and interactive game-based teaching platforms are often compared with traditional teaching. Research also shows that digital teaching helps to induce learning motivation and improve learning outcomes [72]. Based on the above, the following hypotheses are proposed as follows:

Hypothesis 7 (H7). *Learning motivation affects learning motivation.*

Hypothesis 8 (H8). *Learning satisfaction affects the effect of learning.*

Hypothesis 9 (H9). *Learning motivation affects the effect of learning.*

4. Research Method

This study designed the learning content, based on the concepts of STEAM and ESD. By using the STEAM theory and experiential learning concepts, it designed the course structure and system content with integrated VR applications. Game interaction was adopted for the learning process, and a problem-oriented approach was used to guide learners to solve problems and challenge levels in the game. By scoring and breaking through the levels, learners could improve their confidence. The function of mutual assistance and cooperation among peers could promote the continuity of learning motivation and encourage the learners to actively seek challenges (Table 1).

Table 1. Game system content design for each unit.

Experiential Learning Cycle Concept	Learning Objectives	ESDs and STEAM	Learning Content Design
Specific experience	Learn and understand the teaching content, and learn and absorb new knowledge in the learning process	Traditional culture and art + mathematics and program coding + science and technology (STEAM education concept) is integrated into the experiential course of VR interdisciplinary design, which can provide sustainable learning (ESD concepts)	This part of the teaching content is explained by image and text and the researcher: 1. Design an interface icon using cartoon characters to attract the attention of children and use interesting images to match the course description. 2. Use diagrams to inform students of errors and correct content and instructions.
Observation and reflection	Use animation to observe and think		In this part, an animated short story is designed, and the students learn to observe and analyze it through the interactive experience of the characters.
Concept formation	Use the concepts formed through observation and understanding for experience and interaction		In this part, interactive game operations are designed, and the content is presented as learning by drawing cards to see whether learners have acquired the correct conceptual knowledge.
Application verification	Use experiential games for challenge activities		In this part, interactive experiences and games are carried out using a two-handed lever. When the enemy attacks, correct actions must be taken to dodge or counterattack. When the blood amount is all deducted, the enemy will pass and the hero will fail.

The researchers built an experimental environment in the classroom with digital content and VR devices. When the students put on VR glasses, the virtual sensors would send signals to provide digital content in an immersive experience. Before the VR operation, the researchers explained the purposes of the experiment and the use of the devices. During the VR operation, the researchers also assisted in ensuring the smooth flow of the experiment. While the students played the game, a screen was placed behind them to show their operations, so that the researchers could observe their learning processes and outcomes (Figure 1). In Figures 2 and 3, the teacher is teaching the students, and the students follow the course for VR operation and learning:

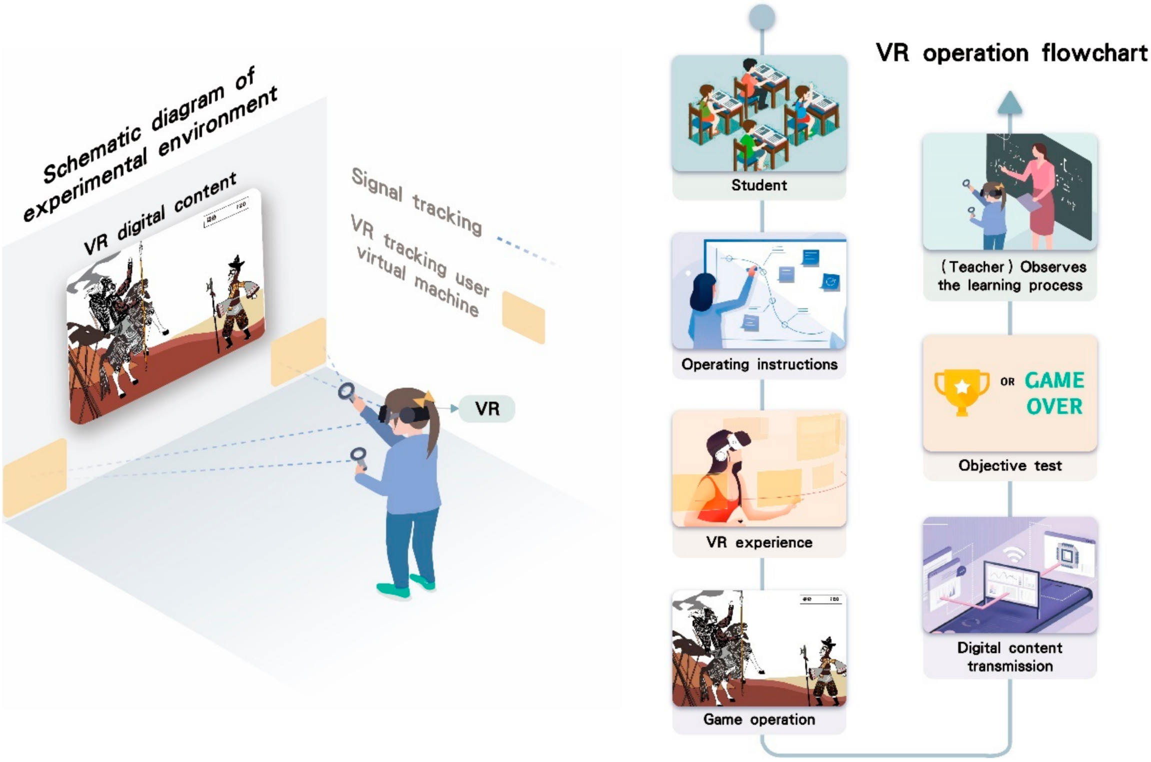

Figure 1. Diagrams of environment and operation of the VR experience activity.

Figure 2. Students actually operating.

Figure 3. Teacher leading students to operate.

The VR experience course of this study was designed digitally, as shown in Table 1. The basic operation, content description, and the VR game were the test items. The subjects included three groups of students: (1) 33 students in a computer class of the Makung Elementary School, who were tested on the afternoon of 11 September 2019; (2) 68 junior and senior students in the first and second remedial classes of the Wenguang Elementary School, who were tested on the afternoons of 16–17 September 2019; and (3) 202 students in an art class of the Zhongzheng Elementary School, who were tested on the afternoons of 27 September and 3 October 2019. The total number of subjects was 303. Besides oral instruction, the subjects watched a short video to learn about the operation of the system. The subjects then played the game and were guided by the researchers on how to fill out the questionnaires (Table 2).

Table 2. Experiment process.

Experiment Process	Experiment Process	Time
1	(1) Explanation of operations through videos The students learned how to operate and observed the movements of joints (e.g., hands, feet and other special movements) through pictures and videos. (2) Operation of characters and mission-oriented games The students used two VR joysticks to control the movement and behavior of their characters and thus played the game through the corresponding operation modes of the characters.	5 min 5 min 10 min
2	Questionnaires: After the operation, the researchers guided the students to fill out the questionnaires.	10 min

4.1. Questionnaire

The structured items of this research questionnaire are based on past theoretical or research references or revisions, and the expert validity is tested by two scholars in the education field. These items are evaluated by using Likert's five-point scale, with a range from 1 to 5 and with "strongly disagree" to "strongly agree" as the evaluation standards (Table 3).

1. The experiential learning dimension

Kolb (1971) mentioned that effective learning requires the following four stages of ability: concrete experience (feeling), reflection and observation (seeing), abstract concept (thinking), and active experimentation (implementation). This research refers to the strategy experience module theory proposed by Schmitt (1999), and is compiled by referring to the research of Hsieh et al. (2014) [73–75].

2. The self-efficacy dimension

Based on the self-efficacy theory proposed by Bandura (1977, 1986, 1997) and Printrich and Schunk (2002), the part on learning self-efficacy can be divided into five aspects: the attitude towards learning setbacks, the achievement of learning goals, the fact of learning challenges, the current situation of learning, and the understanding of self-learning conditions [76–79].

3. The learning motivation dimension

The learning motivation part of this research is adapted from the "Motivated Strategies for Learning Questionnaire, MSLQ" compiled by Printrich et al. (1987) and Crede and Phillips (2011), and it includes three major aspects, namely, value, expectation, and emotion [80,81].

4. The learning satisfaction dimension

Learning motivation is one of the important factors affecting learning satisfaction. Lam and Wong (1974) believe that if the learning content meets the students' interests and needs, it will improve their learning satisfaction, while Tough (1982) points out that learning satisfaction is a feeling or attitude towards learning activities, and if students gain knowledge and expectations in activities that meet their needs, they will get a sense of satisfaction [82,83].

5. The learning effectiveness dimension

This research explores how students experience the course on system operation and how they learn to understand personal changes, obtain information and perform tasks. It was redesigned and edited by Peterson et al. (2010) who researched learning effectiveness issues [84].

Table 3. Items of each dimension.

Aspect	Measured Variables	Q.NO	Item	References
Experiential learning	Specific experience	ELSE1	Using the experiential VR system allows me to experience a rich and interesting visual and auditory experience.	[73–75]
		ELSE2	Using the experiential VR system lets me increase my understanding of the overall learning content.	
	Observation and reflection	ELOR1	I clearly observe the actions of the characters through system experience.	
		ELOR2	I can associate and think about character movements through system experience.	
	Forming abstract concepts and generalizations	ELAG1	It lets me understand how the character operates through learning.	
		ELAG2	Through learning I will understand how the character moves.	
	Active experimentation	ELAE1	After using the experiential VR system, I want to learn and operate actively.	
		ELAE2	After using the experiential VR system, I can learn to operate with my classmates.	
Self-efficacy	Learning objectives reached	SeLO1	I can set a goal for my study.	[76–79]
		SeLO2	I can achieve the learning goals I set.	
		SeLO3	I can plan a study table and know the most effective way to study is for me.	
	Learning challenges	SeLC1	When the level fails I will try to play again.	
		SeLC2	I am willing to face challenging learning.	
	Understanding of self-learning situation	SeUss1	The learning during the course makes me feel very happy.	
		SeUss2	I can clearly know my learning situation, and I can reflect on it for better.	
Learning motivation	Intrinsic goal orientation	MoIG1	The content of the system is full of challenges and it makes me want to learn new things.	[80,81]
		MoEG1	I am very satisfied with the course objectives, which gives me a good evaluation.	
	Task value	MoTV1	It is very important for me to absorb the course knowledge and learning content.	
		MoCB1	Using appropriate learning methods, I can successfully complete the course content.	
	Extrinsic goal orientation	MoSP1	I believe I can get good grades in the course.	
		MoES1	When I complete the experiential VR system, I can learn knowledge.	

Table 3. *Cont.*

Aspect	Measured Variables	Q.NO	Item	References
Learning Satisfaction	Learning Content	LSLC1	The content of Experiential VR system is rich.	[82,83]
		LSLC2	I like the arrangement of learning content.	
		LSLC3	The experiential VR system is helpful for me to learn character movement skills.	
	Teaching strategies	LSTS1	The content of Experiential VR system is rich.	
		LSTS2	I like the arrangement of learning content.	
		LSTS3	The experiential VR system is helpful for me to learn character movement skills.	
	Learning outcomes	LSLO1	The learning of the textbook makes me feel very fulfilled.	
		LSLO2	The teaching materials make me better at learning performance.	
		LSLO3	Learning to play with teaching materials can inspire my sense of honor.	
		LSLO4	On the whole, I can learn from the textbook and apply it to learning.	
Learning effect	Learning to understand	LALU1	I learned how to deal with problems.	[84]
		LALU2	I really understand what I learned.	
		LALU3	I can make full use of knowledge and explain clearly to my peers.	
		LALU4	I can apply what I learned to any situation.	
	Personal changes	LAPC1	After I study, I can add new knowledge.	
		LAPC2	I get knowledge value from learning.	
		LAPC3	After learning, I can use this knowledge to deal with different situations.	
	Access to information	LAAI1	I can get ideas through knowledge.	
		LAAI2	Learning can help me enrich my knowledge.	
		LAAI3	I can get facts and information through the learning process.	
	Job responsibilities	LAJR1	Although I know that learning is a difficult task, I still try to complete.	
		LAJR2	I can perform best at any moment through learning.	

4.2. Research Model

In addition to the ESD concepts, experiential learning can often be defined as "learning by doing and reflection", which is an active, rather than a passive, process that requires learners to be self-motivated and accountable for their learning. In this study, therefore, art and traditional culture, mathematics and program coding, science and technology, and VR were integrated into the design of the experiential courses, so that the students could conduct interactive operations, and experience and learn in person. Challenging games were added in the learning process to arouse learning motivation, and the students' learning satisfaction and its effects were measured at the end of the experiment. This study aimed to explore the impact on the students' self-efficacy, learning motivation, satisfaction, and learning outcomes in VR experiential learning through the integration of ESD and STEAM, and to observe, evaluate, and analyze whether the results helped or hindered the students. The hypothesis framework of this study is reflected in Figure 4 below:

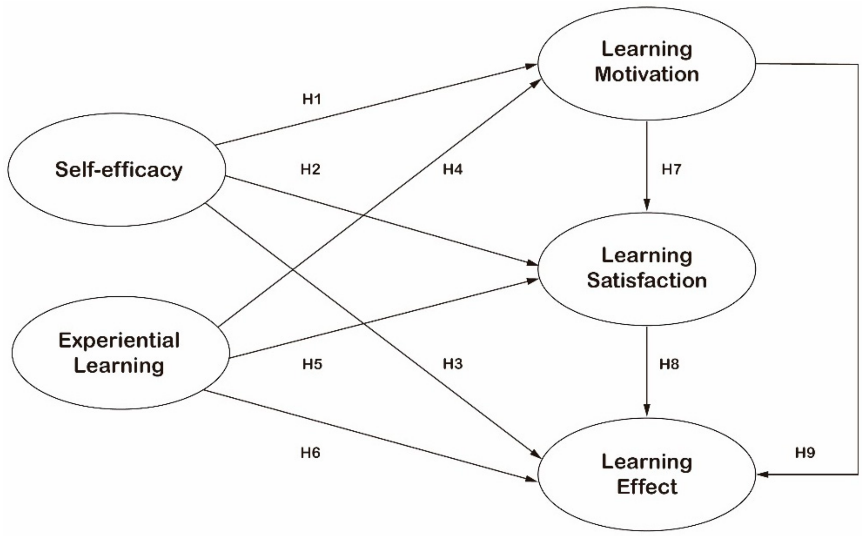

Figure 4. Research framework diagram.

This study used a questionnaire survey as the research tool to measure the students' experiential learning, self-efficacy, motivation, satisfaction, and learning effects. The questionnaire survey was conducted at the end of the experiment. The collected data were analyzed by the statistical software SPSS 22.0 and AMOS structural equations. The influencing factors of the relevant aspects were estimated and verified.

5. Results

5.1. Predictive Test Analysis

To measure the influence of the VR experiential courses that integrate STEAM and ESD on the students' self-efficacy, learning motivation, satisfaction, and learning effect, this study developed a questionnaire containing 47 items. Prior to the pre-test, two experts were invited to evaluate the questionnaire, in order to increase its effectiveness. In addition, the students had all gained VR operational experience by undergoing a course before the questionnaire was implemented. SPSS 22.0 statistical software was used for a reliability analysis of the questionnaire, to ensure its validity. The reliability of the measurement was based on the Cronbach's α value, which was improved by deleting and modifying the question items. The Cronbach α values of the five aspects in the questionnaire, namely experiential learning, self-efficacy, learning motivation, learning satisfaction, and learning effect, were greater than 0.7, and the value of the total scale was 0.842, which indicates that there is a high correlation between the items in all the aspects, as well as in the single aspects (Table 4). Table 4 shows that the number of boys accounted for 57.76% of the total number of boys, and that the number of girls accounted for was 42.24%, while 70.30% students had operated VR once before, 22.11% had operated it twice before, and at least 7.59% had operated it more than twice. The number of operations will affect the fluency of students in the game process.

Table 4. Frequency and percentage of the observable variables.

Variables	Level	School	Number	Frequency	Percentage
Gender	Boy	Makung Elementary School	20	175	57.76%
		Wenguang Elementary School	40		
		Zhongzheng Elementary School	115		
	Girl	Makung Elementary School	13	128	42.24%
		Wenguang Elementary School	28		
		Zhongzheng Elementary School	87		
How many kinds of games you have played with VR experience	One			213	70.30%
	Two			67	22.11%
	More than two			23	7.59%

5.2. Evaluation of the Measured Model

The analysis of this study was based on Structural Equation Modeling (SEM), by using Amos and SPSS. The SEM includes two basic models: the measured model and the structural model. The Amos analysis involves two stages, with the first stage being used for testing the measurement reliability and validity and the model measurement, and the second stage being used for estimating the explanatory power of the prediction and verification of the model by the path coefficient.

5.2.1. Measured Model Analysis

Anderson and Gerbing (1988) stated that the following two steps must be completed for a measured model: (1) under the consideration of the overall model, it is necessary to verify whether each measured variable in the model can accurately measure its latent variable; and (2) a test must be conducted to check whether there are complex measured variables with different latent variants under a load, in which both the convergent validity and discriminant validity must meet the standard. Based on the suggestions of Bagozzi and Yi (1988), this study selected the two most commonly-used pointers to evaluate the measured model, which are described as follows [85,86]:

(1) Individual item reliability: This pointer evaluates the factor loading of the measured variable against the latent variable, and detects the statistical significance of the load of each variable. All factors in this study were significantly higher than the recommended value of 0.5, and they presented a significance. The factor load coefficients in the sample group of students were 0.74 for experiential learning, 0.79 for self-efficacy, 0.77 for learning motivation, 0.70 for learning satisfaction, and 0.71 for learning effect, which all met the values recommended by Hair et al. [87].

(2) Composite reliability (CR): The CR value of the latent variables is the component of the reliability of all measured variables, which indicates the internal consistency of the construct indicators. With a higher reliability, these latent variables will be more consistent. The value suggested by Fornell and Larcker (1981) is above 0.6. According to Table 3, the CR values of each variable in this study (0.89, 0.85, 0.86, 0.91, and 0.92, respectively) were above 0.6 [88]. The CR values ranged from 0.85 to 0.92, indicating the good internal consistency of the research model (Table 5).

Table 5. Dimension table of reliability and validity.

Aspect	Measured Variables	Q.NO	Avg	*t*-Value	Factor Loading	CR	AVE	Cronbach's α
Experiential learning	Specific experience	ELSE1	4.55	14.106	0.82	0.89	0.74	0.85
		ELSE2	4.51					
	Observation and reflection	ELOR1	4.33	11.320				
		ELOR2	4.49					
	Forming abstract concepts and generalizations	ELAG1	4.40	10.287				
		ELAG2	4.41					
	Active experimentation	ELAE1	4.48	7.912				
		ELAE2	4.47					
Self-efficacy	Learning objectives reached	SeLO2	3.92	5.171	0.81	0.85	0.79	0.78
		SeLO3	4.03					
	Learning challenges	SeLC1	4.04	14.375				
		SeLC2	4.06					
	Understanding of self-learning situation	SeUss1	4.37	14.636				
		SeUss2	4.31					
Learning motivation	Intrinsic goal orientation	MoIG1	4.56	9.508	0.80	0.86	0.77	0.80
		MoEG1	4.46					
	Task value	MoTV1	4.21	8.361				
		MoCB1	4.15					
	Extrinsic goal orientation	MoSP1	4.37	5.674				
		MoES1	4.41					
Learning Satisfaction	Learning content	LSLC1	4.50	10.095	0.83	0.91	0.70	0.88
		LSLC2	4.46					
		LSLC3	4.37					
	Teaching strategies	LSTS1	4.48	9.663				
		LSTS2	4.41					
		LSTS3	4.46					
	Learning outcomes	LSLO1	4.36	10.793				
		LSLO2	4.24					
		LSLO3	4.24					
		LSLO4	4.42					
Learning effect	Learning to understand	LALU1	4.39	10.673	0.80	0.92	0.71	0.89
		LALU2	4.42					
		LALU3	4.36					
		LALU4	4.29					
	Personal changes	LAPC1	4.40	9.879				
		LAPC2	4.42					
		LAPC3	4.41					
	Access to information	LAAI1	4.39	10.037				
		LAAI3	4.46					
	Job responsibilities	LAJR1	4.45	8.674				
		LAJR2	4.44					

The construct validity was examined in accordance with the three principles of convergent validity, as suggested by Fornell and Larcker (1981). They are as follows: (1) the factor loading (λ) should be significant and higher than 0.5; (2) the composite reliability (CR) should be larger than 0.6; and (3) the average variance extracted (AVE) should be higher than 0.5 [88,89]. All factor loadings show high results, and all items between 0.80 and 0.83 are higher than 0.5; the CR average value > 0.86 and the range is between 0.85 and 0.92; the AVE average value is 0.74 higher than 0.5, and between 0.70 and 0.79. The three results all meet the three principles of convergence validity. The Cronbach α for all projects is higher than 0.78, indicating a high degree of confidence. Therefore, all items show a convergent validity [88–92].

5.2.2. Structural Model Analysis

The structural model analysis includes a model fitness analysis and the explanatory power of the overall research model. According to Bagozzi and Yi (1988), Jöreskog and Sörbom (1992), and Bentler (1990; 1992), six indicators were selected in this study to evaluate the overall model fitness, including the χ^2 test, the ratio of χ^2 to its CMIN/DF, the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the root mean square error of approximation (RMSEA), and the comparative fit index (CFI) [86,93–95]. The results are summarized in Table 6.

Table 6. Model fitness of the questionnaire developed for this study.

Statistical Verification	Fitness Standard or Threshold	Verification Result Data	Model Fitness Judgment
Absolute GFI			
χ^2 (Chi-square)	$p > 0.05$ (not significant)	1202.382 ($p = 0.752 > 0.05$)	Yes
RMR value	<0.05	0.038	Yes
RMSEA value	<0.08	0.045	Yes
GFI	>0.8	0.839	Yes
AGFI	>0.8	0.815	Yes
Value added GFI			
NFI value	>0.9	0.908	Yes
RFI value	>0.9	0.902	Yes
IFI value	>0.9	0.913	Yes
TLI value (NNFI value)	>0.9	0.904	Yes
CFI	>0.9	0.912	Yes
Contracted CFI			
PGFI value	>0.50	0.733	Yes
PNFI value	>0.50	0.732	Yes
PCFI value	>0.50	0.837	Yes
CN value	>200	303	Yes
Ratio of χ^2 to its CMIN/DF	<2	1.599	Yes
AIC value	The theoretical model value is smaller than the independent model value and is also smaller than the saturated model value	1420.382 < 1722.000 1420.382 < 6038.919	Yes
CAIC value	The theoretical model value is smaller than the independent model value and is also smaller than the saturated model value	1934.179 < 5780.524 1934.179 < 6232.182	Yes

According to the Chi-square value of $p = 0.752$ that is shown in Table 4, there was a good fit between the research model and the observed data. When the model fitness was measured by the ratio of χ^2 to its CMIN/DF, the p value was greater than 0.05, and the value of 0.752 in this study was significant. Chin and Todd (1995) and IHairi et al. (2006) suggested that the CMIN/DF value should not exceed 2 as the standard [96,97]. The ratio of χ^2 to its CMIN/DF in this study was 1.599 and smaller than 2, indicating that this study was an acceptable model, considering the influence of sample size. Hair et al. (1998) suggested that it is better when the value of the GFI and AGFI is closer to 1, but there is no absolute standard value to determine the fitness between the observed data and the model [87]. Between 1977 and 1994, Baumgartner and Homburg (1996) studied 184 articles that used SEM in the research of marketing and consumers. They found that 24% and 48% of the articles did not reach the recommended GFI and AGFI values, respectively [98]. Therefore, the auxiliary indices of the GFI and AGFI were relaxed to 0.8, while the overall comparative fitness index (CFI) was set at over 0.9. The value was 0.912 in this study. On the whole, the research model and the observed data showed a good fitness.

5.2.3. Path Relationship Analysis and Comparison

SEM was used to estimate the path relationship between each dimension, and the path value was a standardized coefficient. All nine of the hypotheses verified in the research model were greater than $p < 0.05$ and reached a significance level. The structural model path analysis coefficients of the student samples were as follows: self-efficacy -> learning motivation (0.260); self-efficacy -> learning satisfaction (0.270); self-efficacy -> learning effect (0.304); experiential learning -> learning motivation (0.505); experiential learning -> learning satisfaction (0.839); experiential learning -> learning effect (0.522); learning motivation -> learning satisfaction (0.444); learning satisfaction -> learning effect (0.318); and learning motivation -> learning effect (0.533). Among the learner path relationships of the students, the empirical results showed that learning motivation and the learning effect were positively and significantly affected by self-efficacy; that the students' learning motivation, learning satisfaction and learning effect were positively and significantly affected by their experiential learning; and that the significant differences in the learning effect were positively affected by the students' learning motivation and learning satisfaction. The results are all significant as shown in Figure 5.

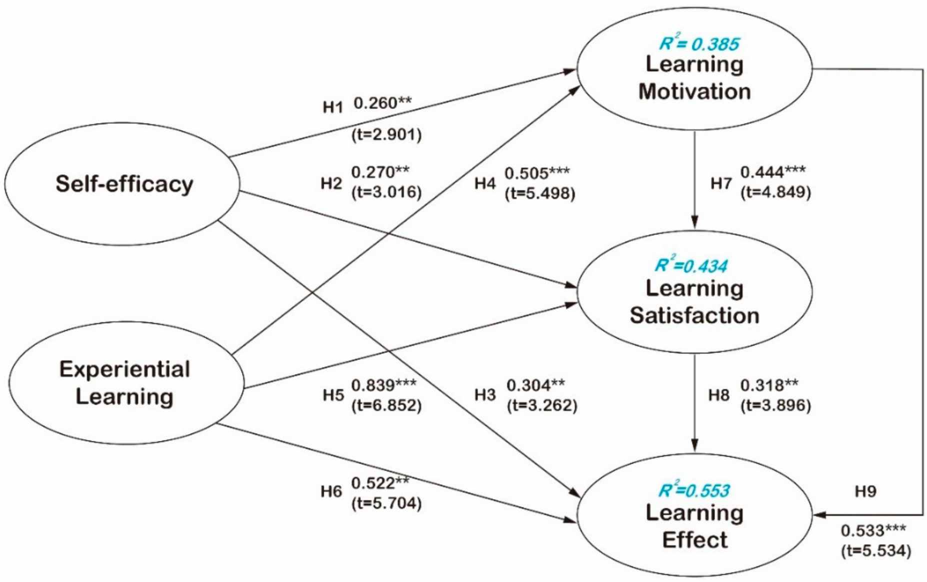

Figure 5. Path coefficient and regression in this study. Note: $p < 0.01$(**), $p < 0.001$(***).

According to the model structure diagram of the VR experiential course, the variation of the explanatory power (R^2) of each latent dependent variable in the overall model of the sample group of students (Figure 5) is as follows: learning motivation (0.385 = 39%), learning satisfaction (0.434 = 43%), and learning effect (0.553 = 55%). The total average R^2 is 0.457 (46%). According to Chin (1998), the grades of R^2 are 0.670 (high), 0.333 (medium), and 0.190 (weak). In this research, $R^2 > 0.333$ is the medium explanatory power. Subsequently, the explanatory power of the learning effects (55% in this study and related studies) were further discussed. The explanatory power of this study lies in the empirical research on technology media learning [99–101]. The explanatory power of the learning effect in the above relevant studies was 30~56%, suggesting a good explanatory power for the learning satisfaction and effect. The students could clearly understand the content of the VR course, and they showed a high learning motivation and satisfaction. The findings confirm that incorporating STEAM into the teaching of the traditional culture is effective.

6. Discussion

This research uses sustainable education and STEAM concepts for curriculum design and planning for exploring the relationship between self-efficacy, learning motivation, satisfaction, and learning effectiveness. The results of the study found that different teaching strategy designs have a positive effect on learning motivation, satisfaction, and learning effectiveness. The learning process and status will affect the effect of self-efficacy on learning motivation, satisfaction, and learning effectiveness, which will also influence each other individually. This will be discussed and explained as follows:

6.1. The Relevance between Self-Efficacy, Learning Motivation, Satisfaction, and Learning Effectiveness

As indicated by H1, when learners become familiar with the immersive VR experience system, they can achieve their goals and make friends quickly, and they are thus more motivated to play and learn, thereby improving their self-efficacy. This finding is consistent with that of Schunk and Chang (1996) and Yang and ErsanlÕ (2015), who stated that when the system provided in a teaching environment is reliable and the learning media and tools are sufficient and full-equipped, learners can set higher learning goals through active learning and can have a greater confidence [54,56]. During the experience, improvements in the self-efficacy of the students significantly affected their learning satisfaction and learning outcomes. This finding is consistent with the findings of Kim and Park (2015) and Rashidi and Moghadam (2014), who stated that the self-efficacy of students in learning digital courses directly affects their learning satisfaction, and that having a guide with a sound self-efficacy significantly helps to improve the learning satisfaction and learning outcomes of students [57,102]. This also proved H2 in this study. H3 is consistent with the findings of Linnenbrink and Pintrich (2003) and Gist et al. (1989), who used computer software to offer learning and training to students in 108 colleges and proved that students with a better self-efficacy had greater learning outcomes [58,103]. Pintrich and Schunk (1996) also pointed out that the improvement in self-efficacy has a positive impact on the learning outcomes of learners, and that greater confidence in self-efficacy results in greater learning outcomes [54].

6.2. The Relevance between Experiential Learning, Learning Motivation, Satisfaction, and Learning Effectiveness

The immersive VR-aided experiential course significantly affected the self-efficacy, learning motivation, and learning satisfaction of the learners. H4, H5, and H6 were supported by the empirical data. This study found that students showed a higher confidence and would be more focused on the next game after the VR-aided course. Holtzman (2011) and Weinberg et al. (2011) pointed out that experience courses affect the learning motivation of students, and that courses with different design methods can significantly affect the interest and motivation of students in learning math and science [61,62]. H5 hypothesizes that immersive VR-aided experiential courses could greatly affect the learning motivation of students, and the results indicate that the students found the system interesting and wanted to continue playing the game. This finding is consistent with that of Hofer (2006), who stated that the effective incentive strategies of instructors have a positive impact on the learning motivation, learning process, and learning satisfaction of learners [104]. Antonio (2011) designed interactive simulation courses for nursing students, as well as medical and healthcare students, and found they were highly satisfied with the courses [64]. Dzan et al. (2015) used experiential learning as the theoretic basis for the planning of science education, and found that learner satisfaction was positively correlated with their preference for various activities [65]. The results of other studies also show that experiential learning significantly improves the learning outcomes and satisfaction of learners and affects their willingness to participate in activities. Therefore, H5 and H6, which hypothesize that the immersive VR-aided experiential courses have a positive impact on learning satisfaction, and learning outcomes, are supported. After taking the course in this study, most students wanted to continue exploring their traditional culture; however, some of them found it difficult to operate. Therefore, digital learning, with only technologies or technological newness, and without appropriate teaching design or simple operations, only has a short-term effectiveness. Information technology should be adjusted according to the textbook contents and teaching methods, as well as the strategies [105], in order to achieve ESD.

6.3. The Relevance between Learning Motivation, Satisfaction, and Learning Effectiveness

H7 hypothesizes that learning motivation is a key factor affecting learning satisfaction. According to Howard and Maxwell (1982), the learning motivation of students before learning can predict their satisfaction with teachers better than their learning performance and progress [106]. Frederick and Morrison (1996) suggested that learning motivation and learning satisfaction affect each other [107]. The results of this study indicate that the immersive VR-aided experiential courses could significantly improve the effects of motivation on satisfaction. H8 and H9 hypothesize that learning satisfaction and motivation are significantly and positively correlated with the learning outcomes. The results of this study suggest that the immersive VR-aided experiential courses could arouse greater learning motivation and satisfaction in students when learning relevant content, and this could also improve their learning outcomes. This finding is consistent with those of Duncan and McKeachie (2005), McClure et al. (2011), and Tella (2007), who stated that learning motivation and learning satisfaction significantly affect the learning outcomes in science education [108–110].

7. Conclusions and Suggestions

7.1. Theoretical and Practical Implications

Because of the advancements in technology, many studies have tried to introduce technology into the classroom to help students learn different subjects. In recent years, experiential VR education has been a new technological application that can improve students' motivation and interest in learning [111]. When the element of a "game" is added, learning can be made more interesting [112]. Students also want to continue learning because learning courses will be interesting and their self-efficacy will also improve during the learning process. VR learning materials or environmental resources can also help students to answer questions and solve problems more effectively [113]. The results of this study have found that when learners are familiar with the immersive VR experience system, they can quickly achieve their goals and make friends. Playing and learning improves self-efficacy more actively. A good learning environment is all about undergoing an experience, and the improvement of students' self-efficacy greatly affects their learning satisfaction and learning outcomes. However, the experience of the game mechanism should be gradual, to avoid giving players too much information in a short period of time, and so as not to cause an excessive cognitive load, which could decrease their motivation, satisfaction, and effectiveness.

In this study, the movements of the characters in the system were revised by expert programmers, by using interviews after the models were built. The basic movements of the characters were refined, and clearer learning instructions were added. The interface of the

VR system was designed, based on the advice of a lecturer and a programmer in the digital gaming sector. Overspeed movements, the delayed operation of characters, and bugs in the skeleton movements, operation modes, and programming of the characters were discussed two to three times, and they were revised until the final version was completed. As the difficulty of the missions and the complexity of the movements also affected the smoothness of the game, different characters, as well as more supportive courses, could be added in the future, to enrich the game.

7.2. Limitations and Future Work

The VR requires good equipment and a good environment, so there will be restrictions on the research site. In addition to clarifying the concepts of STEAM and sustainable education, this research must think about how to effectively apply it to the VR experience system. On the other hand, there are still a few combined applications of STEAM education, traditional culture, and VR, in addition to thinking about ways of how to effectively convey traditional culture. Exploring whether different operating system modes will affect learning is also one of the directions that can be explored in the future. Moreover, differences in the operating habits and cooperation modes of male and female students may affect the learning status of the learners. Finally, based on the ESD concept, this study proposed the following suggestions for future study:

(1) An investigation into whether the integration of STEAM into different interactive media could affect learning outcomes and the willingness of sustainable learning

This study investigated whether the students are interested in learning more about their traditional culture after the immersive VR experience. Future studies can explore whether the introduction of interactive media and advances in science and technology could improve learning outcomes, whether such outcomes are different from those brought about by immersive experiences, and whether the students are willing to receive sustainable learning.

(2) An investigation into whether there are differences between male and female students in the strength and weaknesses of their operations

This study mainly investigated the effects of self-efficacy on learning motivation, learning satisfaction, and learning outcomes after the immersive VR-aided experiential course. However, it did not discuss the strengths and weaknesses of the operations between male and female students, and the ratio of male to female students in this study was also not equal. Therefore, the differences in operations between male and female students and their strengths and weaknesses can be discussed in future studies.

(3) An investigation into the learning benefits provided by mission-oriented games requiring operation

The game developed by this study is a single-player game, and the players could not interact or communicate with each other. In the future, two-player and multi-player modes can be added and the characters can be made more realistic. Team learning can be facilitated to discuss the feasibility and outcomes of cooperative learning and diversified ESD models.

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