Computers & Education 154 (2020) 103910

Contents lists available at ScienceDirect

Computers & Education

journal homepage: http://www.elsevier.com/locate/compedu

Self-regulated mobile game-based English learning in a virtual reality environment

Yu-Li Chen, Ph.D. [*,a], Chun-Chia Hsu, Ph.D. [b,1]

[a] Department of Applied Foreign Languages, Graduate Institute in International Tourism & M.I.C.E. Industries, Lunghwa University of Science and Technology, Taiwan, ROC

[b] Department of Multimedia and Game Science, Graduate Institute in Multimedia and Game ScienceLunghwa University of Science and Technology, Taiwan, ROC

ARTICLE INFO

Keywords:
Mobile learning
Virtual reality
Game-based learning
Self-regulated learning
Engagement

ABSTRACT

Various studies over the past few decades have been exploring the educational advantages and potential of virtual reality (VR) and the idea that students engage with their learning materials more effectively when using their own devices. This study uses a newly created VR game-based English mobile learning application and investigates student English learning effectiveness, student game engagement, and self-regulated learning from a cognitive and psychological perspective. In total, 274 students from a Taiwan university of science and technology participated in this study. Statistical results indicate that both game engagement and game experience were significantly influenced by self-efficacy, intrinsic value, and test anxiety. Immersion, flow, and presence enhanced self-efficacy while absorption and immersion enhanced self-regulation. Self-efficacy and self-regulation affected each other. Student self-regulation in the learning environment was at a moderate level. The results imply that the interaction feature of the VR application and the challenges of game-based design enable students to enter the state of flow easily and enhance their motivation to learn.

1. Introduction

For the past decade, higher education institutions have undergone profound transformation and are facing new technological challenges in the educational arena (Altbach, Reisberg, & Rumbley, 2019). The Higher Education Edition of the NMC Horizon Reports each year has discussed the trends, challenges, and technologies for higher education; its series charts the next five-year plan for the influence of emerging technologies in learning communities across the globe (Alexander et al., 2019; L. Johnson, Adams Becker, Estrada, & Freeman, 2015). The Bring Your Own Device (BYOD) movement and any institution-created policies reflect the contemporary life style in which people are actively bringing their own laptops, tablets, smartphones, or other mobile devices to learning or work environments (Chen, Wang, Zou, Lin, & Xie, 2019; Giotopoulos, Halkiopoulos, Papadopoulos, & Antonopoulou, 2019; Jahnke & Liebscher, 2020). Intel first coined the term in 2009, and the implementation of BYOD policy resulted in higher productivity gains (Afreen, 2014). Studies have revealed that educators have been increasingly incorporating mobile devices into their instructions and

* Corresponding author. Lunghwa University of Science and Technology, Address: No.300,Sec.1, Wanshou Rd., Guishan District, Taoyuan City, 33306, Taiwan, ROC Tel.: 886 2 82093211, ext. 2500.

E-mail addresses: ylchen@mail.lhu.edu.tw, chen9598@ms19.hinet (Y.-L. Chen), anthsu@mail.lhu.edu.tw, anthsu@gmail.com (C.-C. Hsu).

[1] Tel.: 886 2 82093211, ext. 5811.

https://doi.org/10.1016/j.compedu.2020.103910
Received 22 October 2019; Received in revised form 16 April 2020; Accepted 24 April 2020
Available online 25 April 2020

that students engage with their learning materials more effectively when using their own devices (Ahmed & Kabir, 2018; Alexander et al., 2019; Kacetl & Klimova, 2019; Klimova, 2018). In just the year 2019 alone, hundreds of papers on mobile learning in various disciplines were published. Dixon and Tierney (2012) pointed out that the focus of the BYOT program is changing from teaching to learn and work to being a flexible, self-directed, and confident lifelong learner (Bartholomew, 2019; Carey, 2015; Lai & Zheng, 2018). Mobile learning supports Vygosky's social learning theory by enabling students to interact with their peers through mobile platforms for cognitive development during the learning process (Carey, 2015; Troussas, Krouska, & Sgouropoulou, 2020).

Mobile game-based learning has been a prevalent issue in recent literature because it not only boosts student learning in an enjoyable way (Chen, Liu, & Huang, 2019; Huizenga, Admiraal, ten Dam, & Voogt, 2019) but also enhances learner motivation (Daungcharone, Panjaburee, & Thongkoo, 2019; Gamlo, 2019). Troussas et al. (2020) advocate that it tends to create a unique experience in order to maintain student interest in the learning process; hence, it affects learner immersion, participation, and engagement in game-based learning environments. Mobile game-based learning has been an effective approach to student-centered learning and supports constructivism which people construct their own knowledge through experiencing things and reflecting those experiences.

Along with the development of technology in recent years, virtual reality (VR) has been increasingly employed in various fields such as vocational training, education, and entertainment (Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017). The VR industry is predicted to reach a value of US$120 billion by 2020 (Martín-Gutiérrez et al., 2017). Over the past few decades, various studies have explored the educational advantages and potential of VR. Vesisenaho et al. (2019) argue that the most significant advantage of a VR learning environment is its ability to arouse the feelings of presence and immersion in its users.

Educational institutions worldwide are seeking innovative ways to prepare students for the coming technology transformation (Adukaite, vanZyl, & Cantoni, 2017; Chiao, Chen, & Huang, 2018). In addition, English has been highly emphasized in Taiwan universities for a long time. The purpose of this study is to create a VR game-based English learning platform in the form of a mobile application (app) and examine student English learning effectiveness. The English VR game-based mobile app is aimed at not only enhancing college student linguistic competence and career competitiveness but also at motivating employees to learn English and increase their international competitiveness.

Various studies have investigated the usability and acceptance of mobile learning software (Ahmed & Kabir, 2018; Alasmari & Zhang, 2019; Bakhsh, Mahmood, Sangi, & Iqbal, 2019; Briz-Ponce, Pereira, Carvalho, Juanes-Méndez, & García-Peñalvo, 2017; Fagan, 2019; Hamidi & Chavoshi, 2018; Jahnke & Liebscher, 2020; Kim, Lee, & Rha, 2017; Nikou & Economides, 2019; Santos & Bocheco, 2020). However, there has been little research done on mobile learning in a VR environment. Hence, the present study looks at how well the app creates experiences for learners. In addition to student English learning effectiveness, the purpose of the study is to investigate the learner game engagement and self-regulated learning from a cognitive and psychological perspective. Hence, the research questions of this study are as follows:

1. To what extent do students improve their English learning in mobile game-based virtual reality environment?
2. What are the factors that influence student engagement in terms of motivation in mobile game-based virtual reality environment?
3. What are the factors that enhance student self-regulated learning in mobile game-based virtual reality environment?

2. Literature review

2.1. Mobile learning

Mobile devices have "an affinity with movement between indoors and outdoors, across formal and informal settings, allowing learners to lead at least some of the way" (Kukulska-Hulme, 2009, p. 164), and students are the usual owners of such devices at a relatively low-cost (Bere & Rambe, 2019; Olmos, Cavalcanti, Soler, Contero, & Alcañiz, 2018). Learning with mobile technology allows students to expand their discussions and investigations beyond the classroom setting and to take the device wherever they are (Looi et al., 2016). Mobile devices allow students to work together to learn and create knowledge while interacting with a vast amount of content. As such, mobile learning supports a constructivist view of learning (Padirayon, Pagudpud, & Cruz, 2019; Soleimani, Jalilifar, Rouhi, & Rahmanian, 2019; Sun, 2019) since it provides learner-centered pedagogies (Crompton, 2013; Crompton & Traxler, 2019) and can enhance student self-directed learning toward a goal (Bartholomew, 2019; Curran et al., 2019; Lai & Zheng, 2018).

Integrating technology into instruction broadens the amount of possibilities for creating different learning activities that synchronize with various contemporary student learning styles (Hwang, Hsu, & Hsieh, 2019; Naimie, Ahmed Abuzaid, & Shagholi, 2010). Mobile technologies solve modern society's need for convenience (Briz-Ponce et al., 2017; Jordan & Mitchell, 2015; Kim et al., 2017; Wu & Perng, 2016) such as downloading large amounts of learning resources in electronic format and learning anywhere and anytime (Conole & Paredes, 2018; Cross, Sharples, Healing, & Ellis, 2019; Hwang & Tsai, 2011; Wenyuan, 2017). A survey showed that 94% of college students wanted to use their cell phones in class (Kelly, 2017). However, even though students have indicated their desire to use mobile technology, the implementation of the BYOT programs rests with institutions and teachers (Carey, 2015; Project Tomorrow, 2014). Clark (2011) states that mobile technology is not simply about a device; it can empower students and provide them with a feeling of sense of control over their learning through the support of their teachers and peers.

2.2. Mobile-assisted language learning

Mobile-assisted language learning (MALL) first made appearance within the field of English language teaching (ELT) around 2009, which was developed by the British Council and closely followed by major ELT publishers producing stand-alone and course book-related apps (Dudeney & Hockly, 2012). Since the introduction of portable devices, there has been constant interest in exploring their potential use in learning. The evolution of technology has continued to provide new possibilities for learning and challenges when providing instruction. Despite computer-assisted language learning (CALL) having been around since the early 1960s, the past decade has seen CALL literature addressing the potential effects of MALL (Godwin-Jones, 2011; Hwang & Fu, 2019; Kukulska-Hulme & Viberg, 2018; Luef, Ghebru, & Ilon, 2019; Tan & Zhang, 2018).

Kukulska-Hulme and Viberg (2018) reviewed mobile collaborative language learning publications from 2012 to 2016. In addition to raising orthographic awareness and supporting social constructivism promotion, various studies reveal positive effects such as motivation enhancement, engagement and enjoyment, mutual encouragement, and a decrease in nervousness and embarrassment while negative effects show feelings of uncertainty, technical problems, and safety concerns. Smartphones offer the greatest potential for invisible integration of technological hardware into mobile learning. These devices are technologically superior to standard mobile phones, running on advanced operating systems that allow the employment of high-resolution touch-screen interfaces and smartphone-specific apps. In Hao, Lee, Chen, and Sim's study (2019), the app used provided a feasible path for individual and cooperative learning. It boosted student confidence in learning and enhanced positive learning attitude. The design of the app served as an effective tool to support mobile instruction.

2.3. *Virtual reality*

Over the past few decades, various studies have explored the educational advantages and potential of VR. For example, Lau and Lee (2015) observed eight college students using ActiveWorlds, an online VR platform popular for educational purposes. Lau and Lee found that the students were highly engaged in the learning process. They actively explored the virtual world by using their avatars to perform default gestures and to walk around the virtual environment, as well as trying out new functions. Based on the findings, Lau and Lee conclude that VR learning should be explorative and fun so that it can motivate students to explore new ideas.

Freina and Ott (2015) point out that VR provides users with an opportunity to live and experience situations that "cannot be accessed physically" due to time constraints, physical inaccessibility, dangers in the real situation, and ethical issues (p. 139). Jang, Vitale, Jyung, and Black (2017) make a similar claim arguing that VR "affords investigation of distant locations, exploration of hidden phenomena, and manipulation of otherwise immutable structures" (p. 151). In addition, Siegle (2019) contends that VR allows users to "immerse themselves into environments in which they are not physically present, but they feel like they are experiencing the environments" (p. 46).

Chung (2012) further indicates that VR has the following three features: "real-time interactivity," "strong immersion," and "high imagination" (p. 251). With these features, VR is capable of providing a learning environment that enables students to "learn from experiencing the context" so they can "go beyond textbooks and develop more flexible and fitting learning strategies" (Chung, 2012, p. 251). Among the three features, immersion and interactivity are essential to creating an experience of reality that facilitates learning (Martín-Gutiérrez et al., 2017). Vesisenaho et al. (2019) also argue that the most significant advantage of a VR learning environment is its ability to arouse feelings of presence and immersion in users. Due to the immersive nature of VR, it is more likely for users to emotionally engage in learning situations and, thus, cognitively process learning materials more deeply (Vesisenaho et al., 2019).

Nilsson, Nordahl, and Serafin (2016) defined immersion in three ways: "as a property of a system, a subjective response to narrative contents, or a subjective response to challenges within a virtual environment" (p.108). System immersion is viewed as the major factor to determine a learner's experience of presence. Narrative immersion enhances the sense of presence positively and attracts attention to a scenario. Challenge-based immersion has shown indirect effect on the sensation of being when learners are exposed to a higher level of virtual reality. Brockmyer, Fox, Curtiss, Burkhart, and Pidruzny (2009) state that some individuals may experience a continuum from immersion, to presence, to flow, and, finally, to absorption when their engagement becomes deeper. One study indicates that flow and absorption are important explanatory variables for human behavior and both are holistic experiences with technology (Kampling, 2018). Flow can be a completely indulged and intoxicating experience ((Nakamura & Csikszentmihalyi, 2009, pp. 195–206; Norman, 2013). Takatalo, Hakkinen, Kaistinen, and Nyman (2010) proposed the Presence-Involvement-Flow Framework (PIFF) which studies experiences in digital games on the basis of extensive concepts of presence, involvement, and flow. These concepts include elements relevant to technical game components and psychological factors of user experiences.

2.4. *Game-based language learning*

As computer games, or online games, grow increasingly popular, educators have turned to game-based learning, or *gamification*, to facilitate student learning. Gamification is defined as "the integration of game mechanics into normal activities in order to influence participant behavior and engagement" (DuBravac, 2012, p. 67). Those mechanics include competitiveness, character development and improvement, inspiring and creative challenges, and activity (Danowska-Florczyk & Mostowski, 2012) with the purpose to motivate and improve user experience and engagement (Barclay & Bowers, 2020; Shu & Liu, 2019). Sharp (2012) further defined the combination of digital gaming and education as *gamucation*, which "promotes, attracts, engages, motivates and helps" (p.24) students to learn actively. Gao, Wan, Chang, and Huang (2019) proposed a framework for designing learning activities to increase flow experience, enhance immersion and engagement, and feel enjoyment in smart learning environment. Troussas et al. (2020) studied how mobile game-based learning can assist learners by advancing student knowledge levels and foster their learning.

With language learning being difficult for many individuals, it is important to provide learners with methods to maintain their interest in the learning process. Accordingly, integrating a game or game-like environment into the language learning process can be a successful strategy (Berns, Gonzalez-Pardo, & Camacho, 2013; Yang, Chang, Hwang, & Zou, 2020; York, 2020). As a game provides an environment for an application, the use of language in such an environment becomes meaningful; therefore, learners can experience and appropriately express themselves within the environment. Games also offer an opportunity to practice the language repeatedly as learners progress through the game; therefore, games provide a meaningful opportunity for the practice of knowledge and technique along with inspiring learners to continuously learn (Huang, 2020; Jung, 2020).

Game-based learning activities can significantly improve students' speaking skills if driven by a mobile system (Hwang, Shih, Ma, Shadiev, & Chen, 2016). Being skilled in the game and the challenge of the game positively affect being engaged and immersed in the game (Hamari et al., 2016). Even though games may bring a positive influence, designing a game environment for language learning that balances both gameplay and learning is a very difficult task, and maintaining that delicate harmony is the key to a successful language learning game. In addition, the way the game and learning content or activities are combined must be well thought out to allow learners to acquire knowledge smoothly as they play the game. A poorly designed game for learning purposes will lose balance, as it may focus more on the gaming aspects than the learning aspects or the other way around; therefore, the method of implementing learning materials or events into game design must be well thought out to achieve effective learning.

Bouvier, Lavoué, and Sehaba (2014) argue that the concepts of engagement and engaged-behaviors overlap, so they characterize and provide consistent terminology for the terms: attention, immersion, involvement, presence, and flow. They identified four types of engaged-behaviors based on the self-determination theory. As to the action-directed engaged-behaviors, the balance between a learner's skill level and the challenges is crucial. Hence, designers should be concerned with maintaining an appropriate fit between task difficulty and student skill level to attain flow experience (Dörner, Göbel, Effelsberg, & Wiemeyer, 2016).

2.5. Self-regulated learning

Underwood and Banyard (2011) mentioned that moving toward learner-centered learning and increasing reliance on technology-based learning are two current trends in education. Technology-enhanced learning environments (TELEs) provide formal and informal opportunities for learning across different age levels. Further, they encourage self-regulation by providing supportive environments. According to Zimmerman, *self-regulation* refers to the degree of which students are "metacognitively, motivationally and behaviorally active participants of their own learning process" (Zimmerman, 1989, p. 329). A later definition of *self-regulated learning* (or self-regulation) refers to "the process by which learners personally activate and sustain cognitions, affects and behaviors that are systematically oriented toward the attainment of learning goals" (Zimmerman & Schunk, 2008, p. vii). Self-regulation roots in the cognitive engagement styles of Corno and Mandinach's theory (1983), which has three components: 1) metacognition or strategic actions including planning, monitoring and evaluating progress against a standard; 2) learning motivation including engagement; and 3) self-efficacy or beliefs about the ability to attain a goal.

Haq's study (2019) showed that mobile language learning affect student self-regulated learning strategies and there was no significant difference in self-regulated learning strategies among students with different proficiency levels. Pintrich and De Groot (1990) examined the relationships between student motivational orientation, self-regulated learning, and classroom academic performance. Results showed that self-regulation, self-efficacy, and intrinsic value were positively related to cognitive engagement and performance. Self-efficacy affects learning, motivation, achievement, and self-regulation (Schunk & DiBenedetto, 2016; Williams & Williams, 2010). Nikou and Economides (2017) define *mobile self-efficacy* as "an individual's perceptions of his or her ability to use mobile devices to accomplish particular tasks" (p.86). Learning in a virtual learning world help increase self-efficacy in real life. Meanwhile, students who perceived higher self-efficacy in VR have higher learning motivation (Hanafi, Said, Wahab, & Samsuddin, 2017). Those who are good at problem solving, persist, and tackle difficult tasks when dealing with challenges had a better experience than those who had lower degree of self-efficacy (Norman, 2013).

3. Methodology

3.1. Research design

The study looked at how well the software app created experiences for learners. In addition to English learning effectiveness, the purpose of the study is to investigate the learners' game engagement and self-regulation from a cognitive and psychological perspective.

This two-stage study was primarily designed to be an action research. Action research adopts a methodical, iterative approach embracing problem identification, action planning, implementation, evaluation, and reflection. The insight gained from the initial cycle feed into planning of the second cycle, for which the action plan is modified and the research process repeated. Kolb (1984) extended this model to offer a conception of the action research cycle as a learning process, whereby people learn and create knowledge by critically reflecting upon their own actions and experiences, forming abstract concepts, and testing the implications of these concepts in new situations. Practitioners can create their own knowledge and understanding of a situation and act upon it, thereby improving practice and advancing knowledge in the field.

In this study, the first stage was mainly the design stage, which included the development of ESP content, game ideas, and functions. After the planning and designing of the learning system and modules, the implementation stage initially was to conduct a pilot study in which modification of the learning materials followed by reflection upon these actions and experiences. In the second cycle, experiments followed using the improved materials to analyze and evaluate student game-based learning experience, engagement, self-efficacy, and self-regulated learning. The method employed to evaluate the effectiveness of student English learning followed a quasi-experimental design (Cohen, Manion, & Morrison, 2007). Pretests and posttests were given to the selected participants to determine the effectiveness of their English learning in the VR app.

3.2. Virtual reality application design

The system was designed using Unity software combined with the gyro sensor in a smart mobile device with Google VR SDK, which allows users to hold the smart mobile device and freely turn their bodies to observe at different angles and interact with the virtual content to enhance the immersion effects. The content was presented in the form of dialogues. The game concept was incorporated into the learning content and test items in order to motivate students to learn English (See Figs. 1–4).

3.3. Participants

The study adopted purposeful sampling. This quasi-experimental design is referred to as the compromise design because the random selection or assignment of schools and classrooms is impracticable (Kerlinger & Lee, 1999). Mostly, the researchers attempted to employ something approaching a true experimental design in which the control over what Campell & Stanley, 1963 refer to as the who and whom of measurement is important. Students in a technological university in Taiwan were selected for a quasi-experiment. There were 274 valid responses. Their ages range from 18 to 20 years old with more females (F = 173; 63.14%) than males (M = 101; 36.86%). There are 123 (44.89%) non-English majors (F = 65; 23.72%; M = 58; 21.17%) and 151 (55.11%) English majors (F = 108; 39.42%; M = 43; 15.69%). Their English levels are as follows: 60.58% (166) are Beginner (F = 97; 35.40%; M = 69; 25.18%), 35.04% (96) are Intermediate (F = 69; 25.18%; M = 27; 9.86%), and 4.38% (12) are Advanced (F = 7; 2.56%; M = 5; 1.82%).

3.4. Research instruments

3.4.1. The pretest and posttest

The methodology employed to evaluate the effectiveness of student English learning follows a quasi-experimental design (Cohen et al., 2007). The pretests and posttests were produced based on the content of the learning modules. The abstract pretest-posttest control group design is very common in educational research and is appropriate for examining innovation effects (Dugard & Todman, 1995). The pretests and posttests including three sections: vocabulary knowledge, listening, and reading comprehension were conducted. For the reliability of the test, Cronbach's Alpha coefficient (α) was used to calculate the internal consistency of the items. The value is 0.729 at p value < 0.001, which is significant. The α value above 0.7 is acceptable (Santos, 1999). As to the construct and content validity of the test, two experts in TEFL were invited to review the test, and they all agreed that the test measures what it was intended to measure (Zlatkin-Troitschanskaia, Shavelson, & Pant, 2018, pp. 686–698).

3.4.2. The survey questionnaire

The questionnaire consists of the following three sections: 1) Game engagement: It was developed based on a validated survey developed by Brockmyer et al.'s (2009) Game Engagement Questionnaire (GEQ). The GEQ has 19 items with four dimensions: absorption, flow, presence, and immersion. 2) Self-regulated learning: Pintrich and Groot's (1990) Motivated Strategies for Learning Questionnaire (MSLQ) was adapted to measure student self-regulated learning. The MSLQ includes 56 items on student motivation, cognitive strategy use, metacognitive strategy use, and management of effort. 3) Demographics: Students were instructed to respond to all the items on a 5-point Likert scale (1 = *not at all true of me* to 5 = *very true of me*) in terms of their behavior in using the app.

Fig. 1. Scene 1.

Fig. 2. Scene 2.

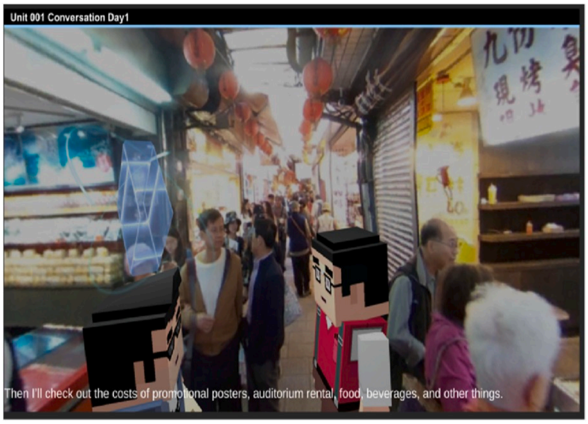

Fig. 3. Scene 3.

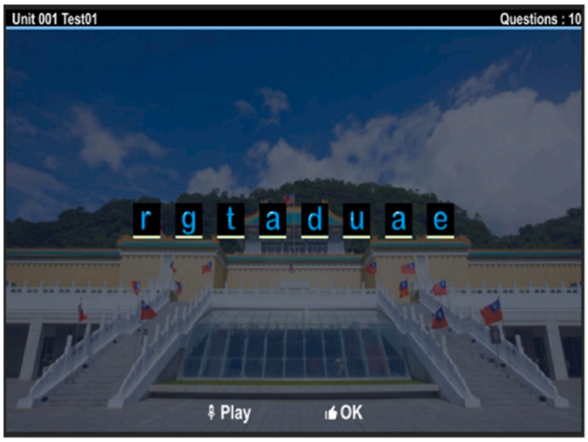

Fig. 4. Vocabulary game.

3.5. Research process

Students initially did a pretest before they were assigned to study English using a newly created mobile learning app and then they did posttest afterwards. The learning lasted for 2 months. In addition, the questionnaire was administered after the student completed the mobile virtual reality environment (VRE) assignment. The research ethics approval was obtained from the Research Ethics Committee at the National Chengchi University in Taiwan. The approval number is NCCU-REC-201605-E020. Students signed a consent form before the pretest and intervention phase.

3.6. Data analysis

The collected data were statistically analyzed using the mean, standard deviation, frequency and percentage, correlation, regression, and analysis of variance (ANOVA). Paired sample *t*-tests were used for an analysis of the differences of the scores between the pretest and the posttest. The results indicate how well the students were learning from the mobile learning app. In addition, the survey results collected from Brockmyer et al.'s (2009) GEQ were analyzed in two parts. First, the authors applied exploratory factor analysis (EFA) to yield two factors (game engagement and experience) and examined whether the variables in the motivational beliefs of Pintrich and de Groot's (1990) MSLQ affected these two factors. Second, the authors used the original four variables (immersion, presence, flow, and absorption) to predict student self -regulated learning.

4. Results of the study

The findings of this study are presented based on the three research questions proposed in the Introduction section. Paired sample *t*-test analysis results from the pretest and posttest answer the first question regarding student English learning effectiveness. Findings from regression and ANOVA analysis answer Research Questions 2 and 3.

***Research Question 1*:** To what extent do students improve their English learning in mobile game-based virtual reality environment?

A paired sample *t*-test was used to analyze the differences of the scores between the pretest and the posttest. The results indicate that there were statistically significant mean differences from the pretest (M = 34.21, SD = 16.52) to the posttest (M = 52.88, SD = 24.47) at $p < 0.001$ for this mobile learning. Paired samples correlation is 0.619 at $p < 0.001$. The test examined whether students improved in the aspects of vocabulary knowledge, listening, and reading comprehension. For the vocabulary knowledge, there were statistically significant mean differences from the pretest (M = 18.13, SD = 6.83) to the posttest (M = 20.38, SD = 6.926) for this mobile learning, $p < 0.001$. For the listening practice, there were statistically significant mean differences from the pretest (M = 4.87, SD = 7.393) to the posttest (M = 14.89, SD = 10.59), at $p < 0.001$. As to reading comprehension, there were statistically significant mean differences from the pretest (M = 11.49, SD = 7.74) to the posttest (M = 17.82, SD = 11.10), at $p < 0.001$. Hence, the results reveal that students improve their English learning in vocabulary, listening, and reading (Table 1).

Research Questions 2: What are the factors that influence student engagement in terms of motivation in mobile game-based virtual reality environment?

The author applied EFA to yield two factors: game engagement and experience from Brockmyer et al.'s (2009) GEQ. Three factors: self-efficacy (SE), intrinsic value (IV), and test anxiety (TA) in the motivational beliefs of Pintrich and de Groot's (1990) MSLQ were used to investigate the relationship between game engagement and game experience to explain student cognitive and psychological aspects of learning. A principal component analysis with a varimax rotation to maintain orthogonality among the factors was conducted. The factorability of the 19 items was examined.

The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.922, above the commonly recommended value of 0.6, suggesting that the sample was factorable and Bartlett's test of sphericity was significant ($\chi 2$ (136) = 3301.23, $p < 0.001$). The communalities were all above 0.3; loadings less than 0.30 were excluded, further confirming that each item shared some common variance with other items. Given these overall indicators, factor analysis was deemed to be suitable with 17 items. EFA yielded two factors (Table 2) explaining a total of 62.05% of the variance for the entire set of variables. Factor 1 was labeled *Game Engagement* and explained 35.83% of the variance. The second factor derived was labeled *Game Experience* and explained 26.22% of the variance.

The average mean scores and the standard deviation for the variables are as follows: game engagement (M = 3.072; SD = 0.752), game experience (M = 2.808; SD = 0.822), self-efficacy (M = 3.086; SD = 0.716), test anxiety (M = 2.895; SD = 0.885), and intrinsic value (M = 3.276; SD = 0.764). All variables from the Pintrich and Groot's (1990) Motivational Beliefs survey were correlated being significant at the $p < 0.01$ level (2-tailed), except for the one intrinsic value with test anxiety, $p > 0.05$ ($r = 0.112$, $p = 0.065$). There

Table 1
Paired Samples Test.

Major			Paired Differences					t	df	Sig. (2-tailed)
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
						Lower	Upper			
Vocabulary	Pair 1	pretest - posttest	−2.252	7.501	0.463	−3.164	−1.339	−4.86	261	0
Listening	Pair 2	pretest - posttest	−10.011	10.518	0.65	−11.291	−8.732	−15.407	261	0
Reading	Pair 3	pretest - posttest	−6.32443	10.47446	0.64711	−7.59866	−5.0502	−9.773	261	0
Total		pretest - posttest	−18.669	19.271	1.182	−20.996	−16.343	−15.801	265	0

Table 2
Factor Loading.

Items	game engagement (GEN)	game experience (GEX)	Cronbach Alpha	Mean	Std. Deviation	Communalities
I lose track of time.	.603		.914	3.11	.833	.372
Things seem to happen automatically.	.587			3.11	.798	.391
The game feels real.	.695			3.07	.738	.644
I get wound up.	.688			3.07	.712	.535
Playing seems automatic.	.787			3.04	.689	.682
My thoughts go fast.	.713			3.15	.680	.510
Playing makes me feel calm.	.739			3.05	.771	.638
I played longer than I meant to.	.710			3.07	.800	.558
I really get into the game.	.813			3.09	.706	.722
I feel like I just can't stop playing.	.778			2.96	.788	.755
I feel scared.		.702	.900	2.66	.941	.505
If someone talks to me, I don't hear them.		.799		2.77	.828	.728
Time seems to kind of stand still or stop.		.704		2.88	.780	.711
I feel spaced out.		.763		2.80	.806	.722
I don't answer when someone talks to me.		.844		2.66	.863	.771
I lose track of where I am.		**.730**		**2.79**	**.816**	**.766**
I play without thinking about how to play.		.535		2.94	.756	.519

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in three iterations. KMO and Bartlett's Test, Kaiser-Meyer-Olkin Measure of Sampling Adequacy. 0.922 df 136, Bartlett's Test of Sphericity Approx. Chi-Square 3301.23 Sig. 0.

was a positive correlation between game engagement and game experience, $r = 0.66$; self-efficacy, $r = 0.655$ intrinsic value, $r = 0.63$; test anxiety, $r = 0.259$; cognitive strategy use, $r = 0.56$; self-regulation, $r = 0.43$. Correlation is significant at the level of $p < 0.001$.

A multiple linear regression was calculated to investigate both game engagement and game experience, respectively, based on their self-efficacy, intrinsic value, and test anxiety. Preliminary analyses were performed to ensure there was no violation of the assumption of normality, linearity, and multicollinearity. SE, IV, and TA influence game engagement with an adjusted R^2 of 0.501 (Table 3) and game experience with an adjusted R^2 of 0.394 (Table 4).

A significant regression equation was found in both game engagement ($F(1, 270) = 92.391$) and game experience ($F(3, 270) = 60.06$) at $p < 0.001$ (Table 5). The results from stepwise regression indicate that participants' game engagement increased 0.382 for each SE level, 0.348 for intrinsic value level, and 0.14 for TA level. Their game experience increased 0.388 for each TA level, 0.56 for SE level, and −0.247 for intrinsic value level (Table 6).

The stepwise multiple linear regression analysis revealed that three variables, SE, IV, and TA, influence the degree of *game engagement* and/or *game experience*. For SE, these respondents were certain that they would be able to learn the content of this game (M = 3.26, SD = 0.757) and that they could understand the ideas taught in this game (M = 3.24, SD = 0.742). They expected to do very well in this game (M = 3.11, SD = 0.69). Most thought that their playing skills were excellent compared to others who were competing in the game (M = 3.03, SD = 0.726). Compared with their classmates who were playing the game, they thought they knew a great deal about the game (M = 3.07, SD = 0.718).

As to intrinsic value, according to the survey items, these students preferred games that were challenging so they could learn new things (M = 3.3, SD = 0.78). The respondents often chose learning materials they would learn something from even if it required more work (M = 3.3, SD = 0.78). Even when some students failed to do well on the tests in the game, they still tried to learn from their mistakes (M = 3.43, SD = 0.71). They thought what they were learning in this game was useful to know (M = 3.38, SD = 0.73) and interesting (M = 3.34, SD = 0.73). They enjoyed what they were learning in this game (M = 3.34, SD = 0.78).

The mean and standard deviation scores for the TA items are as follows. These respondents worried a great deal about the tests in the game (M = 2.89, SD = 0.87) and when they did the tests in the game, they thought how poorly they were (M = 2.89, SD = 0.91). They were so nervous during the tests in the game that they could not remember facts they have learned (M = 2.89, SD = 0.91). They had an uneasy, upset feeling when they did the tests in the game (M = 2.89, SD = 0.87).

Table 3
Game engagement model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.655a	0.429	0.427	0.42846	0.429	204.598	1	272	0
2	.698b	0.488	0.484	0.40665	0.059	30.958	1	271	0
3	.712c	0.507	0.501	0.39988	0.019	10.262	1	270	0.002

[a] Predictors: (Constant), SE.
[b] Predictors: (Constant), SE, IV.
[c] Predictors: (Constant), SE, IV, TA.

Table 4
Game Experience Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.477a	0.227	0.224	0.57753	0.227	79.98	1	272	0
2	.608b	0.369	0.365	0.52271	0.142	61.045	1	271	0
3	.633c	0.4	0.394	0.51067	0.031	13.929	1	270	0

[a] Predictors: (Constant), TA.
[b] Predictors: (Constant), TA, SE.
[c] Predictors: (Constant), TA, SE, IV.

Table 5
ANOVA.

Model	**Sum of Squares**	Df	Mean Square	F	Sig.
Game Engagement	44.32	3	14.773	92.391	.000
	43.173	270	0.16		
	87.494	273			
Game Experience	46.987	3	15.662	60.06	.000
	70.41	270	0.261		
	117.398	273			

Note. game engagement Predictors: (Constant), SE, IV, TA.
game experience Predictors: (Constant), TA, SE, IV.

Table 6
Coefficients.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Game Engagement	(Constant)	0.637	0.154		4.151	0
	SE	0.368	0.059	0.382	6.274	0
	IV	0.303	0.052	0.348	5.807	0
	TA	0.102	0.032	0.14	3.203	0.002
Game Experience	(Constant)	0.741	0.196		3.779	0
	TA	0.326	0.041	0.388	8.041	0
	SE	0.624	0.075	0.56	8.337	0
	IV	−0.249	0.067	−0.247	−3.732	0

Note. Dependent Variable: **g**ame engagement and **g**ame experience.

Research Questions 3: What are the factors that enhance student self-regulated learning in mobile game-based virtual reality environment?

Four variables (immersion, presence, flow, and absorption) in Brockmyer et al.'s (2009) GEQ were used to investigate student self-regulation (SR) in their game-based learning. Preliminary analyses were performed to ensure there was no violation of the assumption of normality, linearity, and multicollinearity. SR was significantly influenced by absorption and immersion with an adjusted R^2 of 0.258 (Table 7). SE was significantly influenced by immersion, presence, and flow with an adjusted R^2 of 0.456 (Table 8). Student SE affects their SR with an R^2 of 0.311.

A significant regression equation was found in SE ($F(3,270) = 77.386$, $p < 0.001$) and SR ($F(2,271) = 48.37$, $p < 0.001$) (Table 9). Participants' SR increased 0.366 for each absorption level and 0.21 for immersion level. Participants' SE increased 0.371 for each immersion level, 0.227 for flow level, and 0.154 for presence level (Table 10).

A simple linear regression was calculated to predict SE based on SR. A significant regression equation was found (F (1,272) =

Table 7
Self-Regulation Model Summary.

Model	R	R Square	Adjusted R Square	**Std. Error of the Estimate**	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
1	.482a	0.232	0.229	0.41673	0.232	82.275	1	272	0
2	.513b	0.263	0.258	0.40903	0.031	11.338	1	271	0.001

a Predictors: (Constant), absorption.
b Predictors: (Constant), absorption, immersion.

Table 8
Self-Efficacy Model Summary.

Model	R	R Square	Adjusted R Square	**Std. Error of the Estimate**	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
1	.640a	0.41	0.408	0.45245	0.41	189.154	1	272	0
2	.672b	0.451	0.447	0.43722	0.041	20.272	1	271	0
3	.680c	0.462	0.456	0.43358	0.011	5.571	1	270	0.019

a Predictors: (Constant), immersion.
b Predictors: (Constant), immersion, flow.
c Predictors: (Constant), immersion, flow, presence.

Table 9
ANOVA.

Model	**Sum of Squares**	df	Mean Square	F	Sig.
SE	43.644	3	14.548	77.386	.000
	50.758	270	0.188		
	94.403	273			
SR	16.185	2	8.092	48.37	.000
	45.34	271	0.167		
	61.525	273			

Note. Dependent Variable SE; Predictors: (Constant), immersion, flow, presence.
Dependent Variable SR; Predictors: (Constant), absorption, immersion.

Table 10
Coefficients.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
SE	(Constant)	0.985	0.149		6.617	0
	immersion	0.31	0.058	0.371	5.349	0
	flow	0.226	0.075	0.227	3.014	0.003
	presence	0.154	0.065	0.154	2.36	0.019
SR	(Constant)	1.871	0.126		14.88	0
	absorption	0.27	0.046	0.366	5.867	0
	immersion	0.141	0.042	0.21	3.367	0.001

Note. Dependent Variable: SE; SR.

122.67, $p < 0.001$), with an R^2 of 0.311. Participant's SE increased 0.691 for each level of self-regulation. In addition, a simple linear regression was calculated to predict self-regulation based on SE. A significant regression equation was found (F (1,272) = 13.189, $p < 0.001$), with an R^2 of 0.311. Participant's self-regulation increased 0.45 for each level of SE (Tables 11 and 12).

According to students' responses to the SR items, they would ask themselves questions to make sure they understood the content of the game (M = 3.16, SD = 0.71). Before they began playing, they thought about the things they would need to do to learn (M = 3.17, SD = 0.7). They finished all the stages even when not required (M = 3.11, SD = 0.71). They responded that even when the game stopped being fun and became more challenging, they kept working until they finished (M = 3.16, SD = 0.69). They worked hard to get good scores even when they were pressured (M = 3.21, SD = 0.71). In addition, some students only completed the easy tasks or gave up when the game got hard (M = 2.99, SD = 0.83).

The immersion variable in Brockmyer et al.'s (2009) GEQ has only one item. Presence includes four items, the highest of which are: their thoughts went fast (M = 3.15, SD = 0.68), learners lost track of time (M = 3.11, SD = 0.83), and things seemed to happen automatically (M = 3.11, SD = 0.8). There are nine items in flow, the highest of which are: learners got wound up (M = 3.07, SD = 0.71), the game felt real (M = 3.07, SD = 0.74), and playing made them feel calm (M = 3.07, SD = 0.77). Absorption has five items, the highest of which are: learners felt different (M = 3.02, SD = 0.78), they were not completely conscious of what was happening (M = 2.8, SD = 0.81), and time seemed to stand still or stop entirely (M = 2.88, SD = 0.78).

5. Discussion

The results based on the three research questions reflect the following concepts of learning in this mobile game-based VRE.

Table 11
ANOVA.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.123	1	19.123	122.67	.000
	Residual	42.402	272	0.156		
	Total	61.525	273			

a Dependent Variable: SR.
b Predictors: (Constant), SE.

Table 12
Self-Regulation Self-Efficacy Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.558a	0.311	0.308	0.39483

a Predictors: (Constant), SE.

5.1. Student engagement

This mobile game-based VR software app was designed to improve student experience and engagement in English learning, the results of which parallel the studies by Troussas et al. (2020), Gao et al. (2019), and Shu and Liu (2019). Integrating gaming and VR into mobile language learning enhanced engagement for the participating students and gave them unique experiences. In addition, several crucial psychological states and factors, including immersion, presence, flow, and absorption, in this type of learning fostered student game engagement and experience. This is in accordance with the PIFF (2010) theory, in which the created environment allows certain real-time psychological states of mind in the learner to occur. Students who participated felt like they were physically present in the VRE and actually experiencing its scenarios, which is consistent with Siegle's (2019) contention regarding VR. Students concentrated more on the scenario and were more motivated to learn. Students developed a sense of SE, had fun, and felt challenged, involved, and immersed. However, they experienced tension and negative emotion.

5.2. Self-regulated learning

According to the study's results, the mobile game-based VRE influenced student self-regulated learning (SRL) and self-regulation (SR) was at a moderate level. Haq's study (2019) demonstrates SRL in mobile language learning. The current study shows that SE and SR were positively related to each other. Zimmerman and Schunk (2008) and Corno and Mandinach (1983) theories indicate that the two components, learning motivation and SE, have an impact on SR. Schunk and DiBenedetto SE theory in education (2016) also concluded that SE affects learning, motivation, achievement, and SR. Students who had higher confidence believed that they were competent, they were using cognitive strategies, and were increasingly self-regulating using metacognitive strategies. Additionally, they were more persistent when dealing with dull or difficult tasks.

SR, however, was not significantly influenced by metacognitive strategy when SE was included in the regression analysis. This implies that increasing student SE may result in more use of cognitive strategies but developing more metacognitive strategies may be more crucial to enhance a higher degree of their SR in mobile game-based VR language learning.

5.3. Self-efficacy

The current study also found that student SE influenced game engagement and experience. Students who perceived higher SE in the VRE had higher learning motivation, were willing to accept challenges, and strived to accomplish tasks or goals. When students accomplished more tasks, they became more confident and developed a sense of SE in the VR mobile learning, which shows the same outcome as the Hanafi et al. study (2017). Student SE affected their SR, which parallels the studies by Schunk and DiBenedetto (2016) as well as Williams and Williams (2010), showing that SE affects learning, motivation, achievement, and SR in virtual reality environments. The current study demonstrates that as long as students believed that they were competent in such learning, they became confident and were willing to keep trying. Hence, they were more engaged and had a better experience, as implied by Schunk and DiBenedetto (2016).

Additionally, immersion, presence, and flow affected student SE. Some students had the typical flow experience: they lost track of time, felt separated from the real world, and played longer. They got carried away by the VR game and felt physically present in its virtual environment, which allowed the learners to lose track of real-world time. When the learners increased their ability to manage difficulties, it enhanced their ability to self-regulate their learning. This is similar to what Pietschman, Valtin, and Ohler (2012) concluded about digital game immersion.

5.4. Immersion

The stepwise multiple linear regression analysis results indicate that immersion, flow, and presence enhanced SE, while absorption and immersion enhanced SR. Both SE and SR were influenced by immersion. Immersion is an important factor and contributes to learning in many ways. Nilsson, Nordahl, and Serafin's theory (2016) mentioned three different types of immersion in VRE: system, narrative, and challenge immersions. In this study, an English language app was created and distributed into mobile device for the participating students to immerse themselves. System immersion occurred as soon as the students installed the app to their device, which was the first and necessary step for immersion. Story plots and vocabulary games (e.g., hangman) were developed for game-based learning in the VR app. Narrative immersion happened when learners traveled to VR destinations to learn English, which showed student subjective responses to narrative content. Challenge immersion kept the learners focus on challenges using vocabulary related to VR scenarios. Challenge immersion was reinforced through quizzes.

Results indicate that when learners were immersed in the VR, they became engaged, which is similar to the result of the Lau and Lee's study (2015). What happened in the VRE was just like how things happen in a naturally occurring order in real life, which is consistent with Siegle's (2019) contention that VREs allow students to immerse themselves and feel like they are actually experiencing the context. Students were the 'first person' instead of 'third person' in the story. They were the avatars themselves in the scenario and did not regard their avatars as separate entities. So, VREs arouse feelings of presence and immersion in students, as mentioned by Vesisenaho et al. (2019).

Challenges in a virtual world can occur consecutively in an intensive manner with little time to pause or hesitate. The moment the learners entered, they were confronted with problems that needed solving. Students emotionally engaged in learning situations and, thus, cognitively processed the learning materials, which correlates the Vesisenaho et al. study (2019). The participants felt like they were thinking faster and making impromptu decisions in English quickly. Their quick decision-making in English gave them an increase in flow experience. Students became completely immersed in the challenges, even if it was only for a few moments.

5.5. Test anxiety

From the study results, student TA influenced both game engagement and experience, and TA was at a moderate level. Some attributes in game experience, such as negative emotions, tension, and feelings of uncertainty, are related to TA. Students had to complete a game-based test so that they could continue the next unit. Any fun the game provided did not reduce any uneasiness some of the students may have had due to their uncertainty. Encountering these unknown situations within the VRE made them feel nervous. Kukulska-Hulme and Viberg's meta-analysis (2018) of mobile language learning demonstrates feeling of uncertainty as a negative effect as well. As students progressed, they got frustrated when their existing ability was inadequate to cope with and solve problems. Frustration resulting from an imbalance between skill and difficulty can reduce flow experience. Flow experience comes from a balance between learner skill level and the challenges in digital learning as implied by Bouvier et al. (2014) and Dörner et al. (2016). Students didn't feel as confident and felt anxious when the challenge level was much higher than their knowledge and skill level. It implies that the difficulty levels for the learning content and tests should be gradual so that learners can learn according to their pace.

5.6. Intrinsic value

Engagement levels increased when student perception of intrinsic value increased. Most students recognized the learning app's value, and thought it was useful for English education. The importance of learning English combined with the new VRE learning technology made it possible for students to anticipate a greater synergistic outcome and is possibly why they put more effort into its learning challenges. Students were not afraid of making mistakes because they were aware of the important VRE learning benefits and wanted to experience how this new technology could better help them to learn English.

Overall, students responded positively to the use of mobile VR game-based learning. They specifically found the English learning app created for this study interesting and enjoyed it. However, students may not have had much experience with VR learning apps. Intrinsic values did have a negative effect on game experience levels. The game may not have been as interesting and exciting as typical non-educational games. Finding a reasonable balance between the education and gameplay factors when designing a game environment for language learning is a very difficult task, which implies that more engaging and attention-grabbing game elements should be considered in further learning app development in order to enhance VREs and improve student game experience in the future.

6. Conclusion

The goal of the overall research plan was to create a VR game-based English mobile learning app and investigate student English learning effectiveness, game engagement and their SRL from a cognitive and psychological perspective. In total, 274 students from a Taiwan university of science and technology participated in the study. Results indicate that student performance was improved by the VRE game-based mobile learning. Additionally, the survey results indicate that both game engagement and game experience were significantly influenced by SE, IV, and TA. Moreover, immersion, flow, and presence enhanced SE while absorption and immersion enhanced SR. Student SR and SE affected each other. Student SR in the VR mobile learning environment was at a moderate level.

This mobile game-based VR English learning app indicates a potentiality for enhancing student learning. Mobile learning indeed brought convenience and fit into contemporary student learning styles. Virtual reality allows students to experience and immerse themselves in situations which are similar to real life and inspire engagement. Additionally, integrating games into a learning environment motivates and maintains student interest in a learning process. Such design facilitates student learning and affects motivation, engagement, achievement, and SR. It engages, enriches, and enhances learning and makes it more relevant to digital natives. Most importantly, it is in line with current and future developments in technology (Troussas et al., 2020).

The study is a course design for mobile learning, which has high potential and can be applied in different language learning situations as well as various disciplines. More interdisciplinary research regarding technology-integrated learning is encouraged. Educators should increasingly rely on technology in education and ponder how to apply learner-centered approaches in order for learners to be a more flexible, self-directed, and confident lifelong learner. Further, achieving instructional goals and feeling of fun for gamification is still challenging. More research regarding learning and design should be conducted in order to improve performance. The way a VR game and learning content are combined must be well thought out. TELEs encourage SR by providing supportive environments and provide formal and informal opportunities for learning (Underwood & Banyard, 2011). As a myriad of research including the current study has evidenced, students engage with their learning materials more effectively using their own devices (e.g., Troussas et al., 2020). Policy-makers should ponder whether BYOD or BYOT should be implemented in institutions or classrooms for a change of curriculum design.

The limitations of the study are that the experiment only lasted two months. Participants were students from different disciplines taking an English course, so their English proficiency varied. In addition, the mobile VR game-based learning strategy was different from a traditional classroom, so an improved, more suitable survey for examining VR mobile learning can be developed to understand more about learner metacognitive strategy use in VR mobile learning. Moreover, future test games should include more game elements that reduce learner anxiety in a VRE and allow for a better game-like experience.

Future studies should look at how mobile learning in VREs can be designed to assist in student cognitive and metacognitive strategy development and how the learning content can be created to enhance the balance between learning and playing VR games to achieve an educational goal. Researchers can develop more VR learning environments in different domains, subjects, or disciplines to see whether students can transfer their learning to real world scenarios.

CRediT authorship contribution statement

Yu-Li Chen: Conceptualization, Investigation, Methodology, Project administration, Writing - original draft, Writing - review & editing. **Chun-Chia Hsu:** Software, Methodology, Project administration, Visualization, Writing - original draft.

Acknowledgements

This work was entirely supported by a grant from Taiwan Ministry of Science and Technology, Taiwan (Project Ref. No. MOST105-2410-H-262-007-MY2 and MOST107-2622-H-262-001-CC3).

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