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An Analysis of Learners' Intentions Toward Virtual Reality Learning Based on Constructivist and Technology Acceptance Approaches

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Abstract

Within a constructivist paradigm, the virtual reality technology focuses on the learner's actively interactive learning processes and attempts to reduce the gap between the learner's knowledge and a real-life experience. Recently, virtual reality technologies have been developed for a wide range of applications in education, but further research is needed to establish appropriate and effective learning techniques and practices to motivate meaningful learning. Results showed that perceived self-efficacy and perceived interaction are two crucial factors affecting perceived ease of use, perceived usefulness and learning motivation. Furthermore, learning motivation is also a predictor to affect perceived usefulness. After that, perceived ease of use, perceived usefulness, and learning motivation are three important factors affecting learner intention to use the virtual reality learning environment.

Keywords: virtual reality (VR), constructivism, technology acceptance model (TAM), perceived self-efficacy, learning motivation, perceived interaction

Introduction

The past few decades have seen accelerated use of information technology to support learning, with new learning opportunities arising through the integration of digital media in the classroom. The Internet in particular has had a great impact in the field of education, with virtual learning environments emerging as powerful tools for teaching and learning, especially for the development of online learning communities to facilitate distance learning (Liu, Chen, Sun, Wible, & Kuo, 2010). Both educators and researchers have contributed to an improved understanding of how to best integrate real life activities into online learning. In recent years, significant improvements have been made to virtual reality (VR) technologies, allowing learners to interact with virtual worlds. Such technologies support many educational activities that integrate traditional classroom teaching and online learning (Carmigniani et al., 2001; Dunleavy, Dede, & Mitchell, 2009; Shim et al., 2003).

This continuing technological shift is highly likely to result in the development of more powerful, intuitive, interactive, and efficient communication modes, along with increased integration of rich media and the delivery of high quality learning content generated and managed by instructors. Indeed, virtual reality supports real-time simulations in which 3D computer graphics are applied to mimic the real world (Burdea & Coiffet, 2003). Advanced VR technologies feature multi-sensory interfaces which allow the learner to explore and interact with immersive environments. A virtual reality system is a computer application capable of generating a 3D environment in which the learner is an active participant, interacting with the virtual learning world through a range of multisensory interfaces. Virtual reality allows instructors to immerse learners within authentic contexts, thus providing a safe, convenient and low-cost environment in which to practice and develop new skills and knowledge (Lave & Wenger, 1991).

Based on a constructivist approach, instructional theories focus on real-life activities as a means of motivating learners. Context is an important factor which affects learning performance and also enhances learning interest and efficiency. Learners actively interact with the real world, applying their knowledge to daily life activities, thus increasing the effectiveness of learning outcomes (Chen, 2011; Chen & Tsai, 2012). Knowledge should be acquired in situated learning contexts which reflect that actual conditions under which learners are expected to apply their new knowledge and skills (Collins, 1988; McLellan, 1994). Reeves (1993) suggested that well-designed simulated multimedia environments allow for the development of apprenticeship-type tasks to support real life activities. Many researchers and educators have accepted that Web-based systems could offer an alternative to real-life learning environments (Herrington & Oliver, 2000). Advanced virtual reality learning environments could be designed to bridge the gap between the theoretical learning in formal instruction provided in traditional classrooms and the real-life application of knowledge in virtual reality environments. Along with the Internet and other innovative technological tools for communication, visualization, and simulation, virtual reality provides important technological support for creating constructivist learning environments to provide learners with a more authentic learning experience (Chang, Lee, Wang, & Chen, 2010; Lombardi, 2007).

How to best assess learner attitudes toward virtual reality learning environments is a critical issue that requires a theory-based approach. Davis's (1989) technology acceptance model (TAM) aims to explain user acceptance toward information technology. In the TAM, learner behavioral intention to use a system reflects system acceptance (Lee & Lehto, 2013). Based on constructivist and technology acceptance approaches, the present study seeks to build virtual-real worlds capable of employing constructivist learning approaches for use in educational applications. To evaluate learner perceptions of novel learning technologies, the present study examines learners' behavioral intention to use such a virtual reality learning environment. The following section summarizes the theoretical background. Research model and hypotheses section proposes the research model and hypotheses for this study. After that, covers the proposed system design, along with experimental methodology and measures. Furthermore, model testing results and discussion will be presented. Finally, the research will discuss conclusion and propose future research directions.

Theoretical Background

Constructivist and technology acceptance approaches are used to explore learner behavioral intention toward virtual reality learning environments. TAM has emerged as a particularly promising method for assessing user attitudes and intention towards using computer technology (Vankatesh & Davis 1996). Many researchers (Islam, 2013; Weibel, Stricker, & Wissmath, 2012) have found that user perception of ease of use, usefulness, enjoyment, playfulness, system quality, information quality, and service quality affect learner attitudes towards a given technology. Liaw and Huang (2014) found that learner self-efficacy had a significantly positive impact on learner attitudes towards technologies including e-learning systems.

Constructivist Approach Toward VR

Within a constructivist paradigm, learners take an active role in their learning, since they not only absorb information, but also connect it with previously assimilated knowledge to construct new knowledge (Huang, Rauch, & Liaw, 2010). A growing body of research suggests that constructivist principles are fundamental to our understanding of learning in virtual reality learning (Cheng & Wang, 2011; Huang et. al., 2010; Sánchez, Barreiro, & Maojo, 2000). Dewey (1916) suggested that the main function of education was to enhance the learner's reasoning processes. A learner who is not motivated will not really perceive a problem, so problems selected for study should be derived from learner interests (Dewey, 1916). The constructivist approach emphasizes the development of a learner's abilities to solve real-life problems. Integrating problem solving and free discovery triggers the learner's motivation and perceived self-efficacy to improve learner abilities in solving real-life problems.

Vygotsky (1980) proposed that learning is a socially mediated activity. His theory of social constructivism emphasized the critical importance of interaction with other learners and teachers, and he suggested problem solving could be categorized as three types. First, some learning activities can be performed independently by the learner himself/herself. Second, some learning cannot be achieved even with help from others. And third, between these two extremes are tasks that learners can perform with the help from others such as teachers or fellow learners. Previous studies have established perceived self-efficacy, interaction, and motivation as crucial factors to establish a constructivist learning environment (Chu & Chu, 2010; Liaw & Huang, 2013; Wu, Lee, Chang, & Liang, 2013). Therefore, perceived interaction is a key factor to enhance learners' ability to solve problems. Many educators employ a variant of problem-based learning to encourage learners to solve problems by outlining them, since much of the knowledge taught in schools may not be retrievable in real life (Herrington & Oliver, 2000). Virtual reality technologies can build synthetic real worlds capable of simulating, representing, or recreating the different faces and sides of reality (Carmigniani et al., 2011; Sánchez, Barreiro, & Maojo, 2000).

Perceived self-efficacy. Self-efficacy refers to a learner's belief that he or she is capable of performing a task and reaching a goal (Bandura, 1977). Bandura (1986) defined self-efficacy as a "generative capability in which cognitive, social, and behavioral subskills must organized into integrated courses of action to serve innumerable purposes" (p. 391). For Liaw and Huang (2013), self-efficacy is a positive characteristic of effective learning. Thus, a high degree of perceived self-efficacy leads to improved learning performance and better behavioral retention in e-learning environments (Chu & Chu, 2010; Liaw & Huang, 2013). As a result, learners' self-efficacy influences their learning attitudes, skill acquisition, choice of activities, and continuing motivation to learn.

Perceived interaction. Virtual reality is typically a 3D graphic system combined with different interface devices to immerse the viewer in an interactive virtual environment (Pan, Cheok, Yang, Zhu, & Shi, 2006). For Sánchez, Barreiro, and Maojo (2000), learner-environment interaction consists of learners making use of a range of mechanisms for creating and modifying virtual worlds. Learners interact with VR environments through special interfaces designed to input a learner's commands into the computer and provide the learner with feedback from the simulation. The mode of interaction is designed to be as intuitive as possible through a variety of sensory channels. On the other hand, the learner can interact with the learning content by using scale functions, allowing the learner to alter the scale of the virtual environment and change the size of the virtual world's 3D objects (Bricken, 1991; Byrne, 1996; Sánchez, Barreiro, & Maojo, 2000; Zeltzer, 1992; Winn, 1997). At the same time, learners interact with the environment and learning objects in real-time. Information can be presented through simulated real-life settings and relevant situations, to create authentic learning experiences. Authentic content situated in the learner's daily experience is an important factor in triggering reflective thinking. Virtual reality learning environments allow learners to interact with the simulated environment, and thus learn and solve problems through an immersive and interactive experience (Wollensak, 2002).

Learning motivation. To investigate learning motivation to use virtual reality learning systems, we apply Keller's (1987) ARCS model to analyze learner behavior. The ARCS model is designed to assess how motivational aspects of learning environments (i.e., Attention, Relevance, Confidence, and Satisfaction) stimulate and sustain learner motivation to learn (Keller, 1987). Keller suggested that attention can be secured in two ways: (1) Perceptual arousal uses surprise or uncertainly to increase interest through the presentation of novel, surprising, incongruous, and uncertain events; (2) Inquiry arousal captures interest and stimulates engagement in questioning or problem solving. Relevance establishes that a learning process is relevant to the learner's needs and goals and will thus increase learner motivation. This concept emphasizes that learning should be tied to learners' personal experiences and be important to their further learning. Confidence holds that learners should achieve competence and success as a result of their abilities. To achieve their learning objectives, teachers should prepare appropriate performance requirements and evaluative criteria. Satisfaction refers to the encouragement and support of learners' intrinsic enjoyment of the learning experience, as well as extrinsic rewards for success.

Technology Acceptance Model (TAM)

According to TAM, system acceptance is represented by intention to use, which is determined by the learner's attitude toward using the system and perceived usefulness. Perceived usefulness (PU) and perceived ease of use (PEOU) determine an individual's attitude toward using a system. PU is the extent to which a user believes that using an information system will improve his or her learning performance (Davis, 1989). PEOU is a measure of a user perception regarding a system's ease of implementation. Furthermore, TAM indicates that PEOU is a predictor of PU (Davis, 1989). An individual's attitude is seen as influencing his or her behavior when using an information system, and will eventually affect his or her actual performance. PU is a major determinant of behavioral intention to use an information system (Davis, 1989). In addition, PU and PEOU can be affected by various external variables. These external variables could be learner characteristics, system features, and the setting in which the system is used (Wojciechowski & Cellary, 2013). TAM has been used successfully by many researchers to predict behavioral intent towards the use of various information systems, as shown in Figure 1.

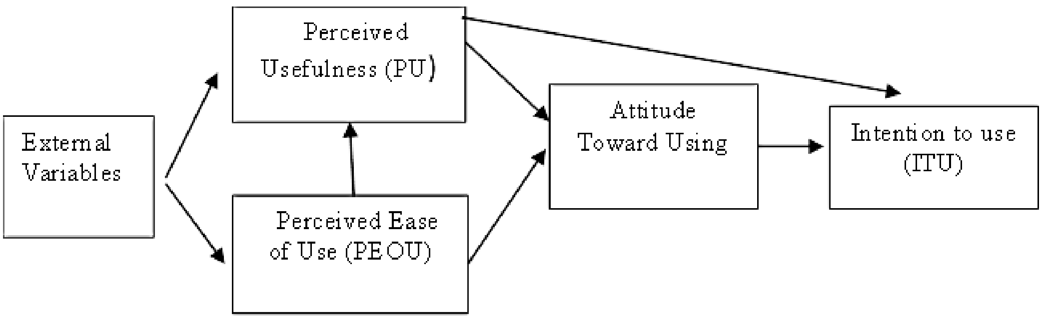

Figure 1. Technology acceptance model.

Research Model and Hypotheses

The technology of virtual reality has been broadly accepted by researchers and educators as being useful for creating an alternative to real life settings which can be used without sacrificing contextual authenticity, which is such a critical element of TAM (Herrington & Oliver, 2000). As a result, when learners interact with a virtual reality learning environment, they treat their surroundings as authentic in situated learning approaches (Chittaro & Ranon, 2007). However, it is important to evaluate actual learner motivation and intention to use a virtual reality learning environment before investing time and effort in the new technology. Based on the TAM model, perceived self-efficacy, perceived interaction, and learning motivation, we propose the following the research model (Figure 2).

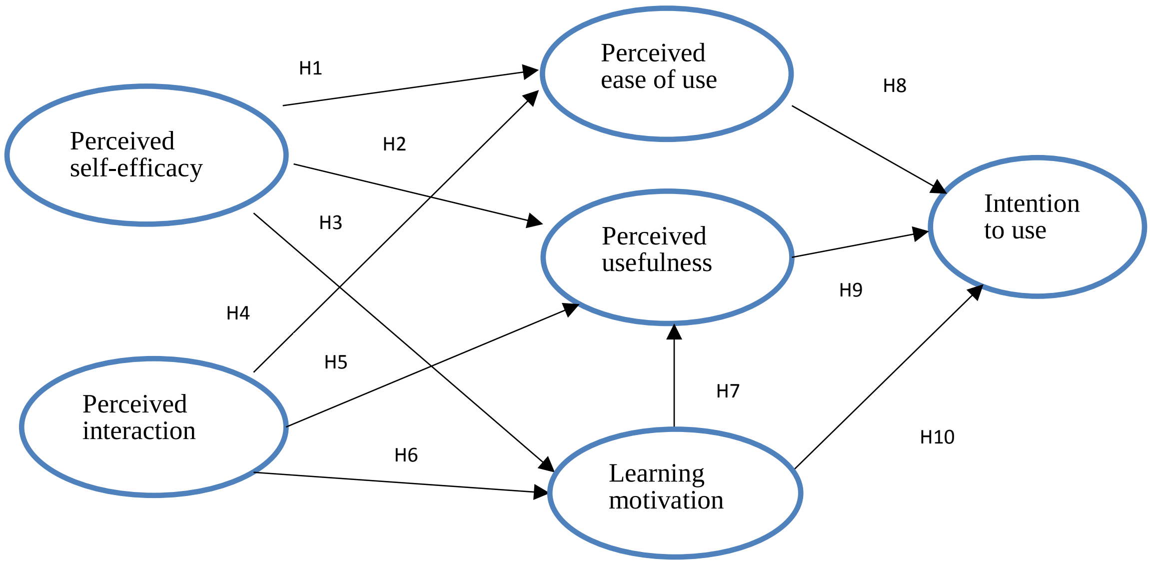

Figure 2. Research model.

Learners who perceive themselves as highly self-efficacious are able to overcome difficulties or challenges (Bandura, 1977) and will persist in their efforts longer and more actively. Learners who feel competent and experienced will gradually increase their learning motivation (Ryan & Deci, 2000; Yoo, Han, & Huang, 2012). This concept also supported by Huang and Liaw's (2007) findings that learners who believe themselves to be competent are more likely to be motivated. Perceived self-efficacy is correlated with performance, learning motivation, and learning activities (Bandura, 1986). In particular, both self-efficacy and motivation theory support that learners who have confidence in their skills and the usefulness of a particular task will perform better in technology-mediated environments (Huang & Liaw, 2007). We thus propose the following hypotheses:

> H1. Learner perceived self-efficacy will have a positive impact on perceived ease of use toward virtual reality learning systems.

> H2. Learners perceived self-efficacy will have a positive impact on perceived usefulness toward virtual reality learning systems.

H3. Learners perceived self-efficacy will have a positive impact on learning motivation toward virtual reality learning systems.

While a well-designed user interface can help learners use a learning system more easily, online instructions should be arranged with clearly comprehensible explanatory figures and text (Liu et al., 2010). The efficiency of immersive authoring tools depends on the degree of perceived interaction and perceived ease of use, since the learning system will neither be effective nor popular if it is difficult to use (Lee & Kim, 2009; Huang, Liaw, & Lai, 2016). Virtual reality technology provides a powerful feature to allow learners to interact with 3D objects in real-time (Thomassen & Rive, 2010), and such objects can be designed to be rotated and translated by the user (Shen, Ong, & Nee, 2010). The process of engaging with virtual reality technology also helps improve spatial cognition, making it useful for spatial instructions (Merchant et al., 2012). Moreover, Merchant et al.'s (2012) research results showed that 3D VR features support the development of learners' spatial awareness only when the learners perceive the learning experience as useful and the system as easy to use.

Learners find virtual reality learning environments to be intrinsically interesting and intuitive, which contributes to their developing a positive attitude toward the use of virtual reality learning environments (Shim et al., 2003). Thus, learners interact with either real or simulated worlds to assist their learning. Many researchers are likely to employ 3D virtual worlds to represent their perceptions into useful insights (Sherman & Craig, 2003). Immersive and interactive learning environments are more conducive than 2D animated environments to increased learner engagement and motivation (Limniou, Roberts, & Papadopoulos, 2008). Virtual reality has the potential to increase learner engagement and motivation to explore interactions between instructional content and virtual objects. Hsiao and Rashvand (2011) proposed three important factors to motivate learners by using intuitive interaction, a sense of physical imagination, and a feeling of immersion. Consequently, interactivity and environmental factors can improve learning motivation (Ryan & Deci, 2000). Based on these discussions and with reference to the conceptual model, the following hypotheses are derived:

H4. Perceived interaction will have a positive impact on perceived ease of use toward virtual reality learning systems.

H5. Perceived interaction will have a positive impact on perceived usefulness toward virtual reality learning systems.

H6. Perceived interaction will have a positive impact on learning motivation toward virtual reality learning systems.

Virtual reality learning environments could be used as a useful tool to enhance, motivate, and stimulate learner acquisition of knowledge (Shim et al., 2003). For instance, medical students perceive Web-based anatomy instruction as enjoyable and interesting (Nicholson, Chalk, Funnell, &

Daniel, 2006). Virtual reality learning environments offer learner enhanced access to learning content and thus increase leaner motivation and interest in learning (Wu et al., 2013). Thus, the following hypothesis is proposed:

> H7. Learning motivation will have a positive impact on perceived usefulness toward virtual reality learning systems.

An e-learning system can offer added value for learners in two ways (Johnson, Hornik, & Salas, 2008; Islam, 2013). First of all, the e-learning system provides useful functions to manage and control the learning process. Secondly, the e-learning system can offer many useful features such as collaborative learning. Therefore, learners who perceive e-learning systems as providing many types of learning assistance will perceive the system as useful to their learning (Islam, 2013). This perception of learning utility, in turn, increases their willingness to adopt and continue to use the system (Lok et al., 2006). As a result, perceived usefulness and perceived ease of use have a significant impact on an individual's intention to use a new technology or system (Huang & Liaw, 2007; Liaw, Huang, & Chen, 2007; Weibel, Stricker & Wissmath, 2012). We thus propose the following hypotheses:

> H8. Perceived ease of use will have a positive impact on a learner's behavioral intention to use virtual reality learning systems.

> H9. Perceived usefulness will have a positive impact on a learner's behavioral intention to use virtual reality learning systems.

Intrinsic learning motivation is an important factor which affects learner behavior (Deci & Ryan, 1985; Yoo, Han, & Huang, 2012). When learners enjoy the learning process through the use of a particular technology, learners will have a strong desire to continue to use that technology (Sørebø, Halvari, Gulli, & Kristiansen, 2009). Furthermore, learning motivation is to be found to have a positive impact on learner satisfaction and intention to continue their e-learning usage (Sørebø et al., 2009; Yoo, Han, & Huang, 2012).

> H10. Learning motivation will have a positive impact on a learner's behavioral intention to use virtual reality systems.

System Overview

The system was designed in three parts: website, web server, and virtual reality. The system offers an E-commerce virtual reality learning system (ECVRLS) built using Virtools 4.0. The system's 3D graphic modules were drawn and rendered using 3DsMax. Apache and PHP were used for the web server, with MySQL used to access text data. The architecture of the ECVRLS system is shown in Figure 3. For the E-commerce learning system, there are six learning topics: logistics, cash flow, online marketing, e-commerce types, information security, and mobile commerce. Learners can browse the learning environment's 3D scenes through their web browser. Figure 4 shows an example of a 3D shopping mall learning scenario. The learner's can direct the movement of his/her avatar in the scene, navigating the virtual situated scenario (the shopping mall) to acquire (shopping/commerce-related) knowledge. Each learning topic is situated in a narrative, and the teacher's avatar explains the learning contents and introduces learning subjects (e.g., information security). The learner can click the mouse to access individual learning subjects.

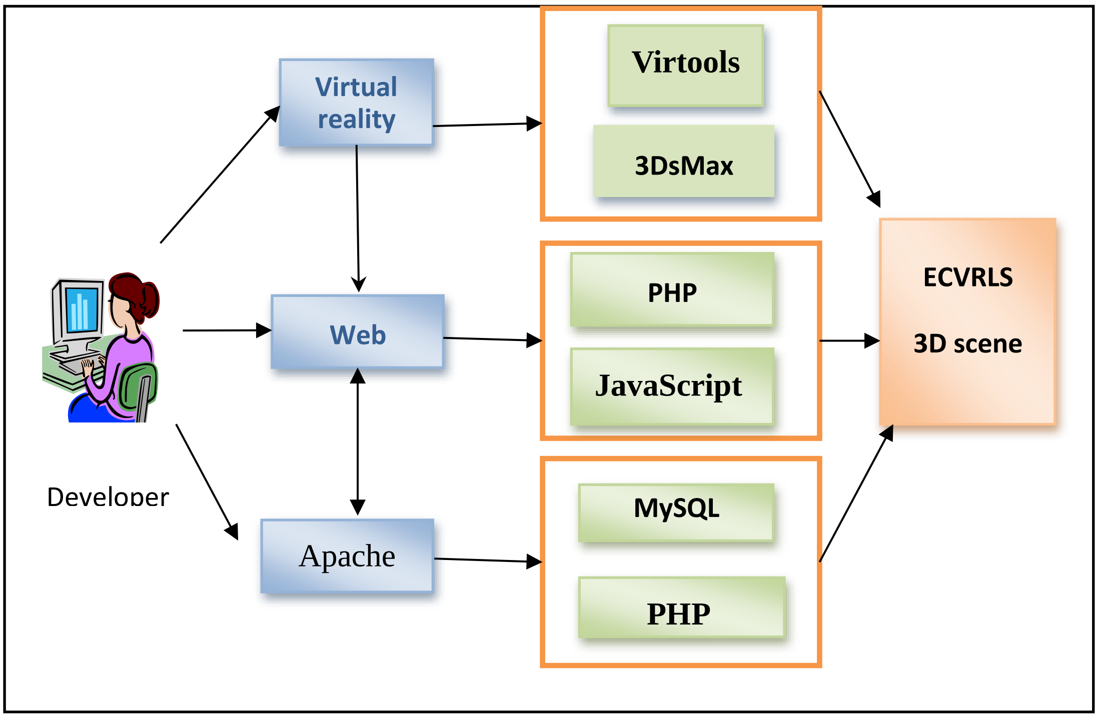

Figure 3. ECVRLS system architecture.

Figure 4. A virtual 3D shopping mall learning scenario.

Methodology

Participants and Measurement

This study surveyed learners' attitudes toward the use of virtual reality leaning environments. VR installations for E-commerce courses were set up in a university of Science and Technology of central Taiwan. Each VR installation was composed of a desktop PC with a monitor and the proposed E-commerce virtual reality learning system (ECVRLS). All participants were undergraduates majoring in the Department of Information Management. A total of 308 students (170 females and 138 males) completed the study successfully and completed a confidential questionnaire. According to the results, 54.7% of participants have over 10 years of experience using computers, while 47.7% had previously used virtual reality systems, but only 27.2% had used virtual reality environments for educational purposes.

Data were collected by using a paper-and-pencil survey. The questionnaire was initially drafted by referencing survey questions used in previous studies related to VR and TAM (e.g., Davis, 1989; Huang, Liaw, & Lai, 2016; Liaw, Huang, & Chen, 2007). Table 1 summarizes the research constructs, definitions, and references. Three experts in the field were invited to review the questionnaire and to ensure the content validity, with unclear constructs either revised or removed. Results of a pre-test of 28 students resulted in four questions as discarded, leaving 20 questionnaire items formatted using a 5-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Six constructs were measured in the current study: Perceived self-efficacy (PSE – 3 items; Liaw & Huang, 2013; Ryan & Deci, 2000; Liaw & Huang 2007), perceived interaction (PI – 3 items; Burdea & Coiffet, 2003; Chen & Tsai, 2012; Huang, Rauch, & Liaw, 2010), perceived ease of use (PEOU – 3 items; Davis, 1989; Merchant et al., 2012; Liaw & Lai, 2013; Liaw, Huang, & Chen, 2007), perceived usefulness (PU – 4 items; Davis, 1989; Huang, Liaw, & Lai, 2013; Liaw, Huang, & Chen, 2007), learning motivation (LM – 3 items; Keller 1987; Huang, Rauch, & Liaw, 2010), and intention to use (ITU – 4 items; Davis, 1989; Huang, Rauch, & Liaw, 2010; Liaw & Lai, 2013; Liaw, Huang, & Chen, 2007).

Table 1

Research Constructs, Definitions, and References

Research constructs	Definition	References
Perceived interaction	Degree to which a learner is able to interact with other learners or with the learning system.	Burdea & Coiffet, 2003; Chen & Tsai, 2012; Huang, Rauch, & Liaw, 2010
Perceived Self-efficacy	Degree to which a learner has confidence that he/she is able to operate the learning system.	Liaw & Huang, 2013; Ryan & Deci, 2000; Liaw & Huang 2007
Learning motivation	Degree to which a learner stimulates and sustains the desired learning behaviors.	Keller 1987; Huang, Rauch, & Liaw, 2010
Perceived usefulness	Degree to which a learner believes that using a learning system would be beneficial to his/her learning.	Davis, 1989; Huang, Liaw, & Lai, 2013; Liaw, Huang, & Chen, 2007
Perceived ease of use	Degree to which a learner believes that using a learning system would be effortless.	Davis, 1989; Merchant et al., 2012; Liaw & Lai, 2013; Liaw, Huang & Chen, 2007
Intention to use	Degree to which a learner intent to adopt the learning system.	Davis, 1989; Huang, Rauch, & Liaw, 2010; Liaw & Lai, 2013; Liaw, Huang, & Chen, 2007

Measurement Model

Smart PLS 2.0 was used to test the proposed model. PLS uses an estimation approach that places minimal demands on sample size and residual distributions (Chin, 1998). Two stages are used to evaluate of the model fit (Chin, 1998; Hulland, 1999). First, the construct validity and reliability of the measures are assessed for the measurement model. After that, the structural model with hypotheses is examined.

Validity and Reliability

To verify the validity and reliability of the measures, we observed indicators' composite reliabilities, average variance extracted (AVE), factor loadings and construct intercorrelations (Chin, 1998; Thatcher & Perrewé, 2002). For reliability analysis, composite reliability was assessed. In Table 2, composite reliability (CR) values vary from 0.89 to 0.93 and thus all are above the minimum value of 0.7 (Nunnally & Bernstein, 1994), meeting the criteria for strong reliability. To insure internal consistency, the Cronbach's Alpha values (α) of all constructs are from 0.82 to 0.91, as shown in Table 2, which exceeds the threshold level of 0.7 (Fornell & Larcker, 1981). The high Cronbach's Alpha values and composite reliability demonstrated the reliability of the measurement model.

Average variance extracted (AVE) and factor loading were used to measure validity. The results showed that the factor loadings from the confirmatory factor analysis (CFA) provide evidence for convergent validity as the loading for all items is sufficiently high on the corresponding constructs (Thatcher & Perrewé, 2002). All items exceed 0.82, thus exceeding the threshold value of 0.50 suggested by Peterson (2000). The corresponding fit measures can be found in Table 2. To check for discriminant validity, we applied the Fornell and Larcker (1981) test. The procedure shows that the square root of each construct's average variance extracted (AVE) value is significantly higher than the correlations with other latent constructs to achieve discriminant validity. An AVE value should exceed 0.5 (Barclay, Thompson, & Higgins, 1995), as shown in Table 3. All constructs satisfactorily pass the test, as the square root of the AVE (on the diagonal) exceeds the corresponding correlations among the latent constructs.

Table 2

Latent Variables Statistics

Construct	Item	Loading	Mean	α	CR	AVE
Perceived Self-efficacy (PSE)	PSE1	0.8761	3.5019	0.9101	0.9369	0.7877
	PSE2	0.8773	3.4710			
	PSE3	0.8664	3.4633			
Perceived Interaction (PI)	PI1	0.8336	3.7375	0.826	0.8962	0.7423
	PI2	0.8929	3.5444			
	PI3	0.8571	3.3668			
Perceived Ease of use (PEOU)	PEOU1	0.9066	3.2703	0.8835	0.9279	0.8109
	PEOU2	0.8874	3.2162			
	PEOU3	0.9073	3.3205			
Perceived Usefulness (PU)	PU1	0.8948	3.4170	0.845	0.906	0.7627
	PU2	0.8736	3.4981			
	PU3	0.8753	3.4903			
	PU4	0.9060	3.4903			
Learning motivation (LM)	LM1	0.8276	3.7645	0.8377	0.901	0.7522
	LM2	0.9000	3.5637			
	LM3	0.8728	3.7104			
Intention to use (ITU)	ITU1	0.8913	3.0927	0.9076	0.9355	0.7841
	ITU2	0.9010	3.0888			
	ITU3	0.9195	3.1892			
	ITU4	0.8275	3.3822			

Note. α- Cronbach's Alpha.

Table 3

Discriminant Validity for the Measurement Model

Construct	PSE	PI	PEOU	PU	LM	ITU
PSE	**0.8733**					
PI	0.3872	**0.8616**				
PEOU	0.4228	0.5808	**0.9005**			
PU	0.4895	0.4899	0.3989	**0.8875**		
LM	0.3790	0.5389	0.3425	0.4585	**0.8673**	
ITU	0.5363	0.5760	0.5493	0.6317	0.5376	**0.8855**

Note. Bold values indicate the square root of the average variance extracted (AVE) of each construct.

Model Testing Results

The structural model was applied to test these hypotheses using Smart PLS 2.0. A bootstrap procedure with 2000 samples was used to obtain t-statistics values and check the significance of the loadings. Rubin (1987) proposed a formula to combine estimates across imputed dataset results and to perform inferential hypothesis testing. The results of path coefficients and corresponding level of significance are shown in Figure 5. Perceived self-efficacy ($ß=0.233$, $p <0.01$), perceived interaction ($ß=0.491$, $p <0.001$) are two strong predicators of perceived ease of use, contributing to 38.3% of variance explained ($R^2=0.383$). Perceived self-efficacy ($ß=0.313$, $p <0.001$), perceived interaction ($ß=0.261$, $p <0.001$), and learning motivation ($ß=0.199$, $p <0.01$) are strong predicators of perceived usefulness, contributing to 37.2% of variance explained ($R^2=0.372$).

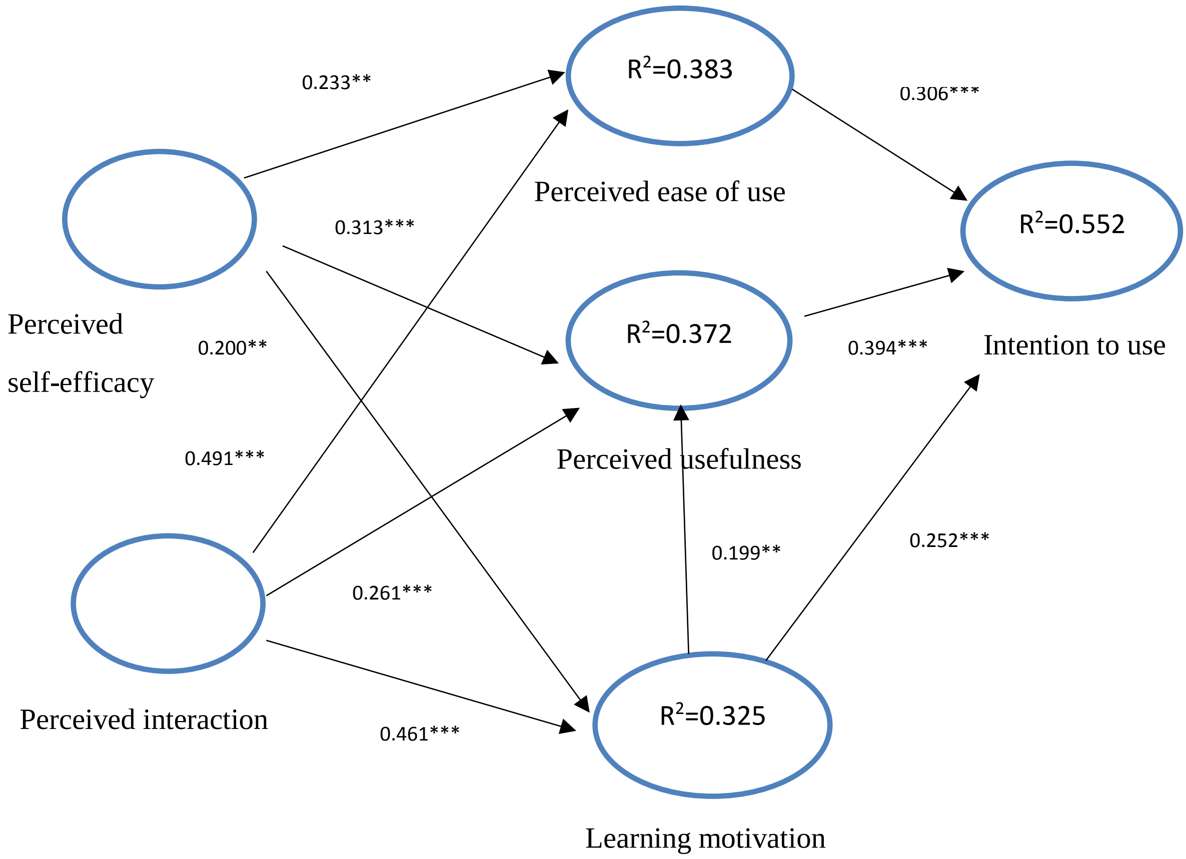

Figure 5. PLS analysis of the research model (**=P<0.01; ***=P<0.001).

Perceived self-efficacy (ß=0.200, p <0.01) and perceived interaction (ß=0.461, p <0.001) are two strong predicators of learning motivation, contributing 32.5% of variance explained (R^2=0.325). Meanwhile, perceived ease of use (ß=0.306, p <0.001), perceived usefulness (ß=0.394, p <0.001), and learning motivation (ß=0.252, p <0.001) are found to be strong predicators of learners' intention for system use, accounting for 55.2% of variance explained (R^2=0.552).

The quality of a PLS model can be determined by examining the R^2 values of the endogenous constructs (Hulland, 1999), while R^2 values indicate the predictive power to explain the proportion of variance in the criterion for the model (Barclay, Thompson, & Higgins, 1995). As Chin (1998) noted, R^2 values of approximately 0.67 are substantial, those around 0.33 are average, and those of 0.19 and lower are weak. Overall, the model explains 38.3% of variance in perceived ease of used, 37.2% of variance in perceived usefulness, 32.5% of variance in learning motivation, and 55.2% of variance in intention to use in this study. Therefore, our research model yielded substantial predictive power for perceived ease of use, perceived usefulness, learning motivation, and intention to use constructs.

Discussion

Both perceived self-efficacy and perceived interaction have significant positive impacts on learners' perceived ease of use. In particular, the path coefficient for perceived interaction is very strong and is the most important antecedent for learners' perceived ease of use. The results support that the 3D learning system could be effective and popular for learners depending on the degree of perceived interaction and perceived ease of use (Lee & Kim, 2009). Perceived self-efficacy, perceived interaction, and learning motivation would significantly affect learners' perceived usefulness. Perceived self-efficacy is the most important antecedent of perceived usefulness. Many studies have also shown that learners' perceived self-efficacy is a critical predictor of perceived usefulness for advanced learning technology (Chu & Chu, 2010; Tsai, 2009). Perceived self-efficacy and perceived interaction are two significant predictors of learning motivation. Furthermore, the path coefficient of perceived interaction is the strongest ($ß=0.461$), making it the most important antecedent of learning motivation. The result also supports that 3D immersive and interactive learning environments increase learning motivation (Limniou et al., & Papadopoulos, 2008; Ryan & Deci, 2000). Perceived ease of use, perceived usefulness, and learning motivation then significantly affect learners' intention to use the virtual reality learning system. Perceived usefulness has consistently been seen as the most influential predictor of behavioral intention to use virtual reality systems (Islam, 2013; Sun & Cheng, 2009; Verhagen,Feldberg, Hooff, Meents, & Merikivi, 2012). As a result, perceived usefulness, perceived ease of use, and learning motivation constitute a significant influence on a learner's intention to use a virtual reality learning system.

Conclusion and Implications

While interaction with a simulated environment through virtual reality can be a reasonable and valuable substitute for real-world experience, design efforts can be minimized by basing technology usage on appropriate learning theory (e.g., constructivist learning theory). From the results of the case study, six implications are found which could possibly assist educators in designing virtual reality learning systems:

1. Perceived interaction positively affects perceived ease of use and learning motivation.

   One powerful feature of virtual reality technology is that it allows users to intuitively interact with 3D objects in real-time (Thomassen & Rive, 2010), thus assisting the learning process. Virtual reality technology creates a highly intuitive and interactive user experience (Chittaro & Ranon, 2007), making the system easy to use.

Motivation is an important factor influencing learning outcomes and thus positive learning motivation can increase learning effectiveness (Sutcliffe, 2003). The immersive aspect of virtual learning environments is found to motivate learners, thus use of virtual reality systems can improve knowledge acquisition and retention (Burdea & Coiffet, 2003) beyond what is possible with 2D animated environments (Limniou et al., 2008). Therefore, educators should seek to maximize learner motivation by increasing interactivity in learning activities, especially for online learners.

2. Perceived self-efficacy can positively affect perceived ease of use, perceived usefulness, and learning motivation.

   Feelings of competence and experience help learners face difficult challenges when dealing with new technologies. Learners with a high degree of perceived self-efficacy will have better learning achievements (Chu & Chu, 2010). Therefore, perceived self-efficacy is an important predictor of perceived usefulness for advanced learning technology (Chu & Chu, 2010; Tsai, 2009), and online learners with sufficient confidence in their skills using technology will feel confident in negotiating new learning processes. As a result, learners' self-efficacy influences their learning attitudes, leading them to be more persistent and active in their learning efforts, and then they gradually increase their learning motivation (Bandura, 1986; Ryan & Deci, 2000; Yoo, Han, & Huang, 2012).

3. Virtual reality learning environments can create a positive learning experience to improve learners' perceived ease of use and perceived usefulness.

   The potential of virtual reality as a useful educational tool has been recognized by educators and researchers for many years (Shen et al., 2010; Guttentag, 2010). Virtual reality technology also permits learners to access a variety of useful learning resources and serves as a useful complement to class lectures (Guttentag, 2010). The integration of real-time displays facilitates changes to the visualization of the 3D objects, so the proposed virtual reality learning system provides realistic, immersive, simulated learning environments. Thus virtual reality technology can offer learners a user-friendly situated learning environment.

4. Perceived usefulness is still the most important factor for learners' intention to use virtual reality learning environments.

   For Davis (1989), perceived usefulness is a major predictor for behavioral intention to use a particular information system. In addition, perceived usefulness both directly affects learners' usage of a virtual environment and indirectly improves their enjoyment of the experience (Verhagen et al., 2012). The results of the present study support the suggestion that perceived usefulness is the most significant contributor to positive learner attitudes toward using 3D virtual reality systems (Sun & Cheng, 2009; Verhagen et al., 2012), since learners find the course content created using virtual reality to be useful.

5. Learner attitudes toward and intention to use a given technology system increase with learning motivation.

   A user's willingness to accept and use a virtual reality system is also impacted by the individual's motivations to engage in a particular learning experience (Guttentag, 2010). Sun and Cheng (2009) noted that perceived playfulness could serve as a motivator to raise learner intention to engage with 3D virtual reality systems. Users will be positively disposed towards using a virtual reality system that satisfies his/her need for pleasure and fun (Verhagen et al., 2012). The results of the present study also supported many other previous findings that learning motivation is a crucial determinant of virtual reality system usage (Guttentag, 2010; Sun & Cheng, 2009).

6. The theoretical conceptual model that integrates constructivist and TAM approaches is acceptable for investigating learner attitudes toward virtual reality learning environments.

   Based on the research statistical results, the theoretical conceptual model is useful for realizing learner perceptions of the usefulness of virtual reality learning environments. In such environments, perceived self-efficacy and perceived interaction are both significant factors impacting perceived ease of use, usefulness, and learning motivation. Moreover, perceived ease of use, perceived usefulness, and learning motivation are all key factors to influence learners' intention to use virtual reality learning environments. This conceptual model has practical implications for the design of virtual reality learning systems, and for enhancing learner perceived self-efficacy, interaction, ease of use, usefulness, and learning motivation. For the design of educational applications, this research provides a different perspective in that perceived self-efficacy, interaction, and learning motivation are all crucial factors to establish constructivist virtual reality learning environments (Cheng & Wang, 2011; Huang et al., 2010; Sánchez, Barreiro, & Maojo, 2000).

Future Research

Educators need to explore the potential effectiveness of virtual reality learning environments. The results of the present study validate the importance of learning motivation for learner attitudes toward using such tools. However, few empirical studies have investigated the relationship between learning motivation and learning outcomes. Educators need to be appropriately assured of the educational effectiveness of virtual reality learning before it is widely applied in school settings. Future research could focus on investigating how virtual reality learning influences the relationship between learning motivation and learning achievement, since this study only focuses on learner perceptions of perceived usefulness. It is important to evaluate actual learning outcomes based on the use of such learning systems.

The virtual 3D shopping mall simulated in the present study is still clearly a virtual world. Chittaro and Ranon (2007) argued that virtual environment which attempt but fail to mimic will leave learners disappointed and can negatively influence their willingness to participate in learning. Future research could integrate virtual 3D information into a learner's physical environment through augmented reality (AR) technology, thus allowing learning environments to offer easy and flexible support for constructing more authentic learning activities. The integration of new advanced learning technologies would also help to improve both the realism and the usefulness of such systems.

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