Proceedings of the Informing Science + Information Technology Education Conference

An Official Publication of the Informing Science Institute InformingScience.org

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A Study of University Students' Adoption of 3D Immersive Virtual Worlds

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Abstract

Aim/Purpose	This research aimed to investigate how different factors affected user adoption of 3D Immersive Virtual Worlds (3DIVWs) in higher education. The study's other objective was to look into the effects of using 3DIVWs on variables related to positive outcomes for students in higher education.
Background	3DIVW technology has a lot of promise for the development of the new generation of teaching and learning environments. Virtual environments for teaching and learning have sparked a lot of interest in the educational community and have mostly been embraced to benefit educational settings. With the increasing development of 3DIVW technology in higher education, two concerns have surfaced that substantially impact the technology's usability in the field: user adoption and educational benefits. Thus, the current paper looked into the relationship between several variables and the adoption of 3DIVWs in higher education as well as the positive outcomes of the application of 3DIVW in education.
Methodology	By using Second Life as a 3DIVW platform, a virtual learning environment was created for this study to implement a distance learning program for a first-year undergraduate course. A quantitative approach was used, and a research model

Accepted by Editor Michael Jones │ Received: October 20, 2021 │ Revised: February 6, February 22, 2022 │ Accepted: Maech 9, 2022.

Cite as: Ghanbarzadeh, R., & Ghapanchi, A. H. (2022). A study of university students, adoption of 3d immersive virtual worlds. In M. Jones (Ed.), *Proceedings of InSITE 2022: Informing Science and Information Technology Education Conference*, Article 13. Informing Science Institute. https://doi.org/10.28945/4932

was developed to examine hypotheses to evaluate the relationships between various variables. In order to test the hypotheses, an online questionnaire was developed and distributed among the students. The PLS-SEM approach was employed to analyse the relationship between dependant and independent variables.

Contribution This is one of the first quantitative studies developing an extensive research model to investigate the facilitators and implications of using 3DIVWs in higher education. The research model looked at a number of self-developed variables in relation to the adoption of 3DIVWs and the consequences of the application of the technology that had not been identified or tested previously in this field. The study has several contributions to the research and practitioner body of knowledge by addressing numerous important aspects of establishing a higher education distance learning environment and virtual activities that can be incorporated.

Findings The findings imply that the adoption of a 3DIVW learning environment is influenced by its ease of use, usefulness, enjoyment, and visual attractiveness. The results also reveal that using 3DIVWs significantly impacts student satisfaction, learning outcomes, retention, course engagement, and graduation outcomes. The study found that students' computer self-efficacy has little bearing on their adoption of 3DIVWs in higher education.

Recommendations for Practitioners Curriculum designers should consider developing easy-to-use and user-friendly virtual learning environments for higher education learners and make aesthetic design decisions to draw their attention. A 3DIVW-based learning environment must look realistic to provide students with a sense of presence within the environment. The virtual learning environment's increased delight, pleasure, and playfulness contribute to students' higher level of adoption. In comparison to a traditional face-to-face education system, the costs of creating and maintaining a virtual learning environment and conducting teaching and learning programmes are quite inexpensive. On a global scale, this technology allows for excellent communication, collaboration, teamwork, and networking.

Recommendations for Researchers More research is needed to look at the other factors that influence user adoption and the beneficial outcome of the use of this technology in higher education. Employing this technology in various courses, applying different teaching and learning methods, and establishing creative activities in the virtual environment could all lead to new discoveries in this field. This research could be expanded by using technology in settings other than higher education, such as K–12. New research could look into additional areas of 3DIVWs that weren't covered in the current study, such as how the teaching and learning program can be implemented using other technologies such as virtual reality, augmented reality, and other immersive technologies.

Impact on Society The findings could help higher education institutions in regulating key factors that can impact students' adoption of 3DIVWs and the positive outcomes of the application of this technology. This technology aids educational communities worldwide in developing innovative teaching and learning methods.

Future Research This study could be a starting point for further research on the potential applications of 3DIVW technology in education. Other variables linked with the adoption of 3DIVW in education and the beneficial effects of the technology's application in this field could be identified and investigated in future studies. The new variables introduced in this study can be investigated in a variety of contexts and/or using a variety of technologies. There have been inconsistencies between the current study's conclusions and some prior studies in the field. In a similar context, new studies can meticulously look into those inconsistencies.

Keywords adoption, acceptance, higher education, eLearning, three-dimensional immersive virtual world, Second Life

[**NOTE**: The extended edition of the current paper has already been published as a journal article (see Ghanbarzadeh & Ghapanchi, 2020a).]

INTRODUCTION

3DIVWs are 3D, simulated, computerised, Internet-based, multimedia, and graphical environments that users inhabit and interact with through their own animated, graphical, and digital self-representations known as avatars (Boulos et al., 2007). 3DIVW users interact with the environment and with other users in the virtual space using a computer device. Immersion and social networking features are included in these technologies, and they allow users to navigate in a virtual world and manipulate virtual items. It contains user-created content that allows for user-defined purposes and a sense of presence. This technology provides opportunities for education, innovation, collaboration and entertainment that are not limited by the physical or geographical constraints of the real world. 3DIVWs are distinct from many other virtual environments because they exist permanently online even when their users are not connected or logged in. Avatars also let users create a virtual identity in the virtual world. This virtual identity might or might not be the same as their real-life identities (Childs, 2010). 3DIVWs can be used as serious games; however, they are not always considered games because games have pre-determined rules and objectives and a winner and loser, whereas a 3DIVW-based environment might not.

Compared to traditional face-to-face teaching and learning, online education and distance learning are currently growing at a rapid pace (Norton et al., 2018), and the number of students enrolled in online courses has been steadily rising. In this era of globalisation, 3DIVWs as online platforms are used for delivering education to learners in academic and corporate contexts. They represent a dramatic shift from the traditional face-to-face classroom to modern distance learning, helping students gain knowledge without time or place constraints (Pellas & Kazanidis, 2015).

As a teaching and learning medium, immersive virtual worlds are used to foster and develop constructive learning for students and enable them to learn various concepts without any explicit learning objectives. They are globally connected platforms that can be used in education to have societal implications by bringing students and educators together and challenging them to practise and collaborate in problem-solving tasks. Because learners experience a sense of presence when immersed inside the virtual environment, more interaction and engagements can occur without physical limits (Franklin, 2011).

With educational institutions increasingly offering online programmes, it is critical to investigate different aspects of the application of emerging technologies that can contribute to improved teaching and learning. Although numerous scholars have used 3DIVWs in higher education for a variety of pedagogical reasons (e.g., Linganisa et al., 2018; Lorenzo-Alvarez et al., 2020), there are still gaps in the literature, and more theoretical and empirical studies are needed. Despite the technology's rise as a potential educational tool, there is little research examining its adoption in higher education from multiple viewpoints or suggesting various aspects influencing the acceptance of 3DIVWs by higher education students. Studies of Gallego et al. (2016) and Merchant et al. (2015) can be considered examples. Further studies are required to discover the factors influencing the adoption of this technology as a teaching and learning tool in higher education.

Similarly, few studies have looked at the impact of using 3D virtual environments on students' positive outcomes (e.g., Vrellis et al., 2016). Thus far, studies have introduced limited educational outcomes that are impacted as a consequence of the application of the technology. The effects of using this technology in higher education demand more investigations from different- perspectives, and various variables should be introduced to the educational community based on the needs of today's higher education students (Ghanbarzadeh & Ghapanchi, 2018; Pellas, 2014; Pellas & Kazanidis, 2014b).

This study aimed at two key objectives in order to fill the identified gaps. The first objective was to examine the effects of five factors on the adoption of 3DIVWs in higher education. The second objective was to examine the impact of the use of 3DIVWs on five positive educational outcomes. To achieve the study's objectives, a virtual learning environment was created in Second Life. Within the environment, an online distance learning programme was conducted for a period of one semester.

The remainder of the current paper is organised as follows. The literature review is described in the following section. The theoretical foundation and hypotheses development are presented in the third section. The research methodology, data analysis, and study results are detailed in the fourth and fifth sections. The last sections discuss the findings and contributions before the conclusion.

LITERATURE REVIEW

Recently, 3DIVWs have become more sophisticated, and they have the potential to dramatically change the way people communicate and interact. Recent advancements in this technology have led to its increasing applicability in a range of fields (Berg & Vance, 2017). Instead of being limited to illustrations of a fantasy world, the virtual world can be built to be more like the real world, with real-world rules and real-time actions, interaction, and communications. The fundamental rules of physics for environments continue to apply in the majority of 3DIVWs, making navigation within their environment resemble what one is used to in the real world. Through the sensory illusion, users become cognitively engaged and interact with the virtual environment (Radianti et al., 2020). Virtual worlds allow for the simulation of the real world as well as the creation of new and unique fantasy worlds (Mandal, 2013).

3DIVWs are of considerable significance and potential for creating a new generation of educational platforms, and they have been largely used to favour teaching and learning (Maresky et al., 2019). There has been a lot of interest in using virtual environments for distance learning in the educational community (Cho & Lim, 2017). 3DIVWs support higher interactivity and richness in interaction, collaboration, and communication compared to traditional media. They provide learners with engaging and meaningful experiences (Siau et al., 2010) and have the ability to offer an engaging environment for transformational constructionist learning as one of the innovative technologies being employed in higher education (Girvan & Savage, 2019).

When educational institutions implement new technologies, they face several challenges, including adoption, user acceptance, user engagement, valid instructional design, and suitable learning accomplishment metrics. It is critical to comprehend the sophisticated characteristics of a particular technology when it becomes a sophisticated and mainstream tool in a field (Ghanbarzadeh & Ghapanchi, 2021). With the increasing application of 3DIVWs in the education sector, two uncertainties have emerged concerning higher education that may influence the applicability of the technology in the field: adoption of the technology and its educational benefits for both individuals and institutions (Ghanbarzadeh & Ghapanchi, 2018).

Although 3DIVWs provide significant advantages for the higher education sector, their use raises concerns about their adoption by students. Many 3DIVW-based learning experiences fail because an extensive enough user population does not accept the technology. User acceptability has become one of the most important aspects of a technology's development and success, as it influences its users' ability to use it. Thus, the factors impacting the 3DIVWs' adoption in higher education should be further examined. User acceptance was defined by Venkatesh et al. (2004) as "a decision made by an individual at a particular point in time in order to use technology intentionally." A large number of studies in the literature have looked into the adoption of various technologies in a variety of contexts. For instance, students' acceptance of an online learning environment was examined by Estriegana et al. (2019). Park (2020) introduced a comprehensive research model to examine user acceptance of smart wearable devices.

A wide range of studies have documented the application of 3DIVWs as virtual learning platforms in higher education and K-12; however, only a small number of them have looked at various aspects of 3DIVWs, such as student adoption in higher education. For example, Linganisa et al. (2018) evaluated the potential and constraints of Second Life as a virtual learning platform in their qualitative study. Ahmad and Abdulkarim (2019) looked into some factors that influence whether or not users choose to utilise 3DIVW. Gallego et al. (2016) suggested a model that explained the acceptance of Second Life in education. Chen et al. (2008) used a quantitative study method to investigate the impact of several factors on students' intentions to use a 3DIVW environment. Thus, based on the first objective, this study examines the impact of five factors on the adoption of 3DIVWs in higher education.

Researchers have recently become interested in the application of virtual classrooms in education (Asadi et al., 2019). The engagement and learning opportunities provided by 3DIVW-based classrooms are clearly different from those provided by traditional classes as these immersive environments have a unique combination of a three-dimensional environment and a variety of embedded tools and resources, offering the learners and educators a unique educational experience. However, it is debatable whether or not a 3DIVW-based education enhances the learning process and positive outcomes. The consequences of using this technology for students and institutions are not yet certain. Thus, the extent to which 3DIVWs are beneficial and efficient for students and the ways in which they might improve educational outcomes should be thoroughly examined.

After a thorough assessment and evaluation of the relevant literature, it was discovered that there were limited studies that focused on the consequences of the application and adoption of 3DIVW technology in a higher education setting. For example, with respect to learning outcome, student satisfaction, and presence, Vrellis et al. (2016) provided a comparison of a laboratory problem-based learning activity implemented in both the real and virtual worlds. Masters and Gregory (2010) investigated the effects of the use of a virtual world on student learning and engagement. On the basis of the second objective of the current study, after a thorough assessment of the net benefits of the application of various technologies in higher education, this study introduces five factors that are classified as consequences of student adoption of 3DIVW technology and its application. Some of the examined factors have already been investigated in previous studies and were considered the net benefits or positive outcomes of the application of the technology. Accordingly, the current study introduces some new factors which were intended to be seen as net benefits or positive outcomes.

In a large number of studies in the literature, the two-dimensional (2D) form of virtual worlds has been used for different educational purposes. For instance, a virtual 2D learning environment incorporating chatbots in dialogue-centric settings was used by Othlinghaus-Wulhorst and Hoppe (2020) for the training of specific social skills. Abidin et al. (2020) used a two-dimensional game-based virtual environment with various interactive multimedia elements for information delivery to Halus students. Although the 2D virtual environments are widely used in various educational settings, the focus of the current study is specifically on 3D virtual environments and their application in higher education.

THEORETICAL FOUNDATION

A quantitative approach was used in the current study. A research model was created to investigate the impacts of five independent variables on the adoption of 3DIVWs. The factors are *perceived usefulness, perceived ease of use, perceived enjoyment, attractiveness, and computer self-efficacy*. Furthermore, the study tested the impact of the adoption of 3DIVWs on five dependent variables relevant to positive outcomes. The dependent variables are *student satisfaction, learning outcome, retention, course engagement, and graduate outcome*. Some previously examined variables, such as student satisfaction and perceived ease of use, were also added to the research model, in addition to new self-developed elements, due to their importance. Because no theoretical model was found in the literature that could cover all of the mentioned constructs, three well-known theoretical models were used to include all of the intended variables.

In the research model for the current study, the following information system theories and models were incorporated: Technology Acceptance Model (TAM) (Davis, 1989), updated Delone and McLean IS Success Model (Delone, 2003), and e-Learning Success Model (Holsapple & Lee-Post, 2006). A few variables were also adapted from the literature. Additionally, the model includes some new self-developed variables. The new variables are *3DIVW engagement, course engagement, and graduate outcome*, and to the best of our knowledge, they were new in this context; however, these variables may have been studied in the literature in a different context.

TAM (Davis, 1989) suggests that an information system or technology's acceptability is assessed by perceived usefulness and perceived ease of use factors. In the research model for this study, the mentioned two factors were adapted from TAM. Delone and McLean's information system success model was developed by DeLone and McLean (1992) based on a review of 180 empirical studies. They developed a comprehensive model for information success, which identified six different constructs that are interrelated and interdependent: "system quality, information quality, use, user satisfaction, individual impact, and organisational impact." The updated Delone and McLean IS Success Model (Delone, 2003) introduced some different constructs: "information quality, system quality, service quality, use, user satisfaction, and net benefits." The main structure of the research model for the current study was developed based on this model. The e-Learning Success Model (Holsapple & Lee-Post, 2006) was developed based on the DeLone and McLean IS success to introduce a model for the success of eLearning systems. According to this model, success in an e-learning system is defined as "a multifaceted construct that can be assessed along six dimensions including system quality, information quality, service quality, use, user satisfaction, and net benefits occurring in three stages." In the research model for the current study, the positive outcomes of the adoption and use of 3DIVWs were adapted from the e-Learning Success Model as the variables of positive net benefits.

RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

The current study's research model focuses on two aspects of the application of 3DIVW in higher education: The impact of five factors on the adoption of 3DIVW and the effect of the use of this technology on five factors. The research model and its hypotheses are demonstrated in Figure 1.

As stated earlier, Delone and McLean's Updated Information Systems Success Model (Delone, 2003) was used as the base model for this study's research model. Independent variables are associated with 'use', and 'use' is associated with the net benefits. The base model's 'user satisfaction' variable was replaced with a new self-developed variable named '3DIVW engagement' to make the research model consistent with the nature of the technology.

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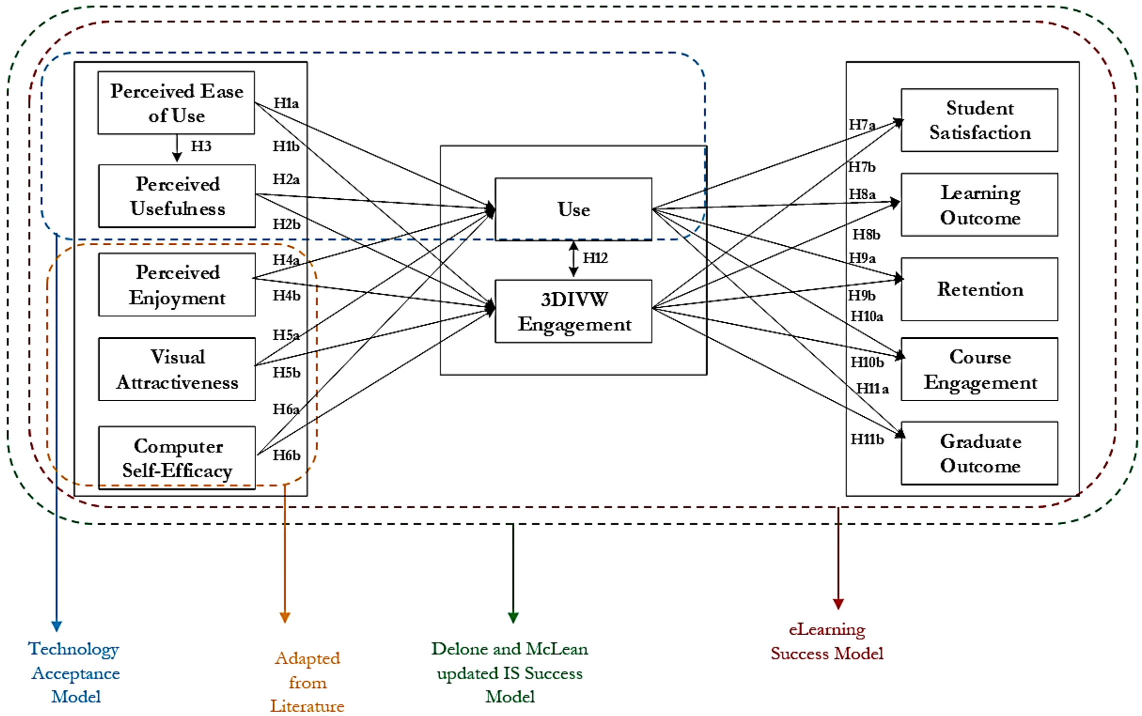

Figure 1. The research model

The e-Learning success model, which is based on the DeLone and McLean IS Success model for e-learning systems, was also suitable for the study's objectives. Five independent variables were adapted from TAM and previous studies and incorporated into the eLearning Success Model's 'System Design' section. The adapted variables from TAM are: 'Perceived Ease of Use' and 'Perceived Usefulness'. The other three variables, 'Perceived Enjoyment', 'Visual Attractiveness', and 'Computer self-efficacy', were adapted from the literature. The five dependent variables were selected as 'Positive Aspects' of 'Net Benefits' in the 'System Outcome' section of the eLearning Success Model. Two variables, 'Student Satisfaction' and 'Learning Outcome', were adapted from the studies in the literature, and the other three, 'Retention', 'Course engagement' and 'Graduate Outcome', were defined specifically for the current study. 'Use' and '3DIVW Engagement' were defined as variables of 'System Delivery' of the eLearning Success Model.

Research Hypotheses and Theoretical Support

This section provides literature-based theoretical justification for the study hypotheses and summarises them.

Definition of 'use' and '3DIVW Engagement'

'Use' in the current study refers to students' regular use of the environment in the learning process according to a scheduled timetable as part of the learning programme. '3DIVW engagement' refers to students' higher level of interest and engagement in the technology, which leads to mindfully use, cognitive effort, and deep processing.

The literature has looked into several aspects of system use, such as the 'intention to use, 'attitude towards use', and 'actual system use'. A wide range of studies has shown that a person's attitude towards using a system significantly influences the behavioural intention to use that system. Several studies have shown the positive impact of behavioural intention to use a system on the actual system use. These three factors are integrated into a single variable in this study, named 'Use', which is defined as "a student's use of one or more features of a 3DIVW-based learning environment to do a task in relation to his/her education." The association between the above variables and 'Use' is depicted in detail in Figure 2.

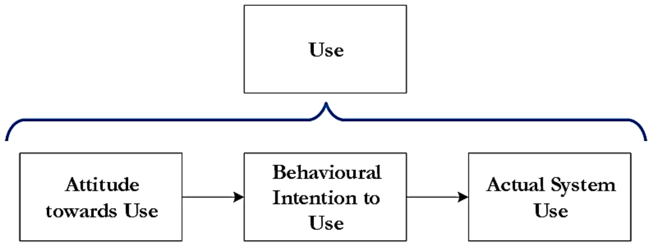

Figure 2. The 'Use' variable

The concept of engagement is difficult to define, and the literature has suggested different definitions. Engagement is defined by Schuetz (2008) as "a state of interest, mindfulness, cognitive effort, and deep processing of new information that partially mediates the gap between what learners can do and what they actually do." Pellas and Kazanidis (2014a) defined engagement in virtual worlds as "the level of interaction with other users that is achieved, the level of feedback from the virtual environment, and the level of engagement promoted from various learning activities." In line with Pellas and Kazanidis (2014a) and Schuetz (2008), 3DIVW engagement is defined for this study as "a state of interest, mindfulness, cognitive effort, and deep processing of 3DIVW environment, which promotes a strong relationship between the student and the technology".

In the current study, 'use' and '3DIVW engagement' are seen as two aspects of the adoption of 3DIVW in higher education.

Hypotheses and theoretical background

The research model developed for this study aims to examine the following 21 hypotheses.

Hypotheses 1, 2, 3: TAM (Davis, 1989) suggests that the fundamental drivers of technology acceptance are perceived usefulness and perceived ease of use. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance." Perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort". According to Davis (1989), perceived usefulness and perceived ease of use impact an individual's attitude towards using a system. Perceived ease of use also positively impacts the perceived usefulness, and both of these variables are impacted by the external variables.

Students must regard 3DIVW-based learning environments as an easy and useful tool that can improve their learning outcomes, contributing to a variety of learning achievements and enhanced communication. In line with TAM, it was believed that perceived usefulness and perceived ease of use would have a positive impact on the adoption of 3DIVW in higher education. TAM also suggests that users who find an IS to be simple to use will find it useful in addressing their needs. As a result, users will benefit from a system that performs simple functions. We expected this relationship to hold true in a 3D immersive virtual learning environment, meaning that the more user-friendly a 3DIVWs-based virtual environment is, the more useful it will be. Thus, we hypothesised:

H1a: Perceived ease of use has a positive impact on the use of 3DIVWs

H1b: Perceived ease of use has a positive impact on 3DIVW Engagement

H2a: Perceived usefulness has a positive impact on the use of 3DIVWs

H2b: Perceived usefulness has a positive impact on 3DIVW Engagement

H3: Perceived Ease of Use of 3DIVW will have a positive impact on its perceived usefulness

Hypothesis 4: Perceived enjoyment has been used extensively, and it has different definitions in various studies in the literature. For example, based on definitions of Davis et al. (1992) and Koufaris (2002), M.-C. Lee (2010) stated that "perceived enjoyment as an intrinsic motivation has been found to have a significant impact on a technology acceptance, especially for hedonic systems." Users of technology will be intrinsically motivated to adopt the technology if using it brings fun, joy and pleasure (M.-C. Lee, 2010). J. Lee et al. (2019) defined Perceived enjoyment of virtual reality as "the degree to which the user perceives the use of a VR device to be enjoyable." Adapted from the existing literature, perceived enjoyment is defined for this study as "the extent to which the activity of using 3DIVW technology is perceived to be enjoyable for students". It was believed that perceived enjoyment would positively impact the use of 3DIVW. Thus, it was hypothesised:

H4a: Perceived Enjoyment has a positive impact on the use of 3DIVWs

H4b: Perceived Enjoyment has a positive impact on 3DIVW Engagement

Hypothesis 5: Visual attractiveness refers to the visual components and elements, graphical structure, colours, patterns, and overall view of an immersive virtual environment. Van der Heijden (2003) defined visual attractiveness as "the degree to which a person believes that the website is aesthetically pleasing to the eye" and assumes that "aesthetics play a role in the decision to use an information system, especially a website." Yang et al. (2016) stated that the visual attractiveness of wearable technology has a positive impact on the perceived enjoyment and social image. These arguments can be extended to 3DIVW, as the technology aids in the creation of visually appealing environments intending to provide students with game-like experiences. On the basis of the definition by Van der Heijden (2003), visual attractiveness is defined as "the degree to which a person believes that a virtual environment is aesthetically pleasing to the eye". It was predicted that the visual attractiveness of a virtual learning environment would be positively associated with its use and engagement. Accordingly, we hypothesised:

H5a: Visual attractiveness has a positive impact on the use of 3DIVWs

H5b: Visual attractiveness has a positive impact on 3DIVW Engagement

Hypothesis 6: Computer self-efficacy was incorporated in the research model as the application of 3DIVWs involves using computers. Self-efficacy was defined by Bandura (1986) as "people's judgments of their capabilities to organise and execute courses of action required to attain designated types of performances." According to Compeau and Higgins (1995), in information systems, computer self-efficacy is associated with the self-assessment of a person's ability to use computer-related skills for performing specified tasks. They defined computer self-efficacy as "the degree to which individuals believe they can accomplish difficult tasks using a computer." In this study, computer self-efficacy is defined as "the degree to which students believe they can accomplish tasks in 3DIVW-based learning environments using a computer". We expected that computer self-efficacy would positively impact the use and engagement of 3DIVW. Thus, we hypothesised:

H6a: Computer self-efficacy has a positive impact on the use of 3DIVWs

H6b: Computer self-efficacy has a positive impact on 3DIVW Engagement

According to Delone and Mclean's IS Success Model and the e-Learning Success Model, there is a relationship between the use of a system and the net benefits. In this study, the five dependent variables were considered the net benefits of the application of 3DIVWs in higher education and the following are the hypotheses relevant to the use and engagement and those five variables.

Hypothesis 7: Student satisfaction was defined by Stuntz (2020) as the "measurement of how satisfied a student was with the course; including the content, design, and delivery." Alruwath (2015) defined student satisfaction as "the student's perceived value of his or her educational experiences at an educational institution." Ghabarzadeh and Ghapanchi (2020b) defined student satisfaction as "the students' perceived value of their educational experiences through a virtual environment at an educational institution." In line with Alruwath (2015) and Ghabarzadeh and Ghapanchi (2020b), in this study, student satisfaction was defined as "the students' perceived value of their educational experiences through a 3DIVW-based virtual environment at an educational institution." It was believed that there would be a positive relationship between the use and engagement of 3DIVWs and student satisfaction. Thus, we hypothesised:

H7a: Use of 3DIVWs leads to student satisfaction

H7b: 3DIVW engagement leads to student satisfaction

Hypothesis 8: Learning outcome was defined by Saadé et al. (2007) as "the observed results in connection with the use of learning tools", which could be measured with "performance improvement, grades benefit, and meeting learning needs." Panigrahi et al. (2018) defined learning outcome as "the measure of the effectiveness of a learning platform." Learning outcome was also defined by Novak et al. (2019) as "a statement of what a learner knows, understands and is able to do upon the completion of a learning process." Students' learning outcome has been widely cited in the literature as a variable to measure the effectiveness of eLearning systems (e.g., Ewais et al., 2020; Selzer et al., 2019). In line with Saadé et al. (2007), in the current study, the learning outcome is defined as "the observed results in connection with the use of 3DIVWs." It was believed that the use and engagement of a 3DIVW could positively impact students' learning outcome; thus, we posited that:

H8a: Use of 3DIVWs has a positive impact on the learning outcomes

H8b: 3DIVW engagement has a positive impact on the learning outcomes

Hypothesis 9: Retention was defined by Villano et al. (2018) as "students who remain enrolled at university; they do not discontinue through formal administrative processes nor do they lapse their enrolment where the student fails to undertake any units of study which count towards a degree." Mostafa (2019) defined student retention as "the intention of the student to remain in the same university from first year to graduation." Retention was defined by DeVilbiss (2014) as "the process of retaining or continuing to enrol students at the same institution from one semester to the next and from one year to the next." Ghabarzadeh and Ghapanchi (2020b) defined retention as "continued student participation in a virtual learning programme for another course in addition to the current course." Based on the definitions by DeVilbiss (2014) and Ghabarzadeh and Ghapanchi (2020b), in this study, retention is defined as "continued student participation in a 3DIVWs-based learning programme for another course in addition to the current course." Therefore, it was hypothesised:

H9a: Use of 3DIVWs has a positive impact on retention

H9b: 3DIVW engagement has a positive impact on retention

Hypothesis 10: Many research classified 'engagement' as a multi-dimensional phenomenon, including behavioural and affective components in many of them. For instance, Mosenthal (1999), defined engagement as follows: "engagement is grounded in the cognitive and affective systems of learners and readers." According to other studies, engagement has an interpersonal component, and students' interactions with other students and teachers can be regarded as a part of it (Connell & Wellborn, 1991; Guthrie & Anderson, 1999). Hew (2015) found that the more active students are in a course, the more engaged they are with it. Pellas and Kazanidis (2014a) suggested that a framework of engagement should validate three concepts of behavioural, emotional or affective, and cognitive factors. Sun et al. (2014) defined engagement as "the extent to which a learner is cognitively, emotively, and behaviourally involved in or committed to a learning activity or goal." Based on Sun et al. (2014), course engagement is defined for this study as "the degree to which students are cognitively, emotively, and behaviourally involved in or committed to learning activities related to an enrolled course within a 3DIVW-based educational environment". Course engagement is a measure of actively participating in various aspects of a course inside a 3DIVW-based learning environment. Thus, we hypothesised:

H10a: Use of 3DIVWs has a positive impact on course engagement

H10b: 3DIVW engagement has a positive impact on course engagement

Hypothesis 11: Graduate outcome refers to the impacts of the use of 3DIVW technology in students' education, resulting in skill learning, future career, and professional field. It was believed that the application of a 3DIVW-based learning environment would assist students in advancing in their future careers. Graduate outcome can be considered as "the knowledge and proficiency that students achieve in accordance with their future career and professional field" (Ghanbarzadeh & Ghapanchi 2020b). Based on the above definition, graduate outcome is defined as the effects of using the 3DIVW technology on students' education, resulting in their skill learning, future career and professional field. Therefore, it was hypothesised that:

> **H11a:** Use of 3DIVWs will have a positive effect on the graduate outcome
>
> **H11b:** 3DIVW Engagement will have a positive effect on the graduate outcome

RESEARCH METHODOLOGY

This section presents a description of how the current research was conducted. It discusses the methodological considerations, including the research method, design, and data collection.

RESEARCH DESIGN

The current study was completed in seven stages. Figure 3 demonstrates different stages of the conduction of the study. To achieve the objectives of the current study, an online eLearning programme was conducted using a 3DIVW-based environment for a duration of one semester. In the first stage, a suitable course with a reasonable number of enrolled students from a diversity of study backgrounds and disciplines was selected for the experiment. The content and learning activities of the selected course were then reviewed and defined to ensure they could be implemented in the virtual platform, and the course could be delivered through a distance learning program. Next, an advanced 3DIVW platform, Second Life, was selected that offered capabilities and facilities to be utilised as a means of teaching and learning for the selected course.

According to the content, the course's major activities were determined, including lectures, workshops, discussion boards, and course material access. Then, a 3D environment was designed to implement each of the activities. Accordingly, the actual virtual campus with buildings and other facilities was created in Second Life. All the course resources were collected and reformated to be more suited for the virtual environment before being uploaded to appropriate areas within a virtual building called the resource room. Various course materials, including videos, presentations, study guides, book chapters, lecture recordings, and so on, were uploaded to the resource room so that students could access every material in one location within the virtual campus. Furthermore, a virtual lecture theatre for delivering lectures and virtual laboratories for conducting tutorials, and areas and buildings for other student activities, were created inside the virtual environment.

At the start of the semester, a training session was held to familiarise students with Second Life and the virtual learning environment with instructions. In this training session, the system's performance was evaluated during peak login times, and students created a Second Life account and chose a unique avatar for themselves. Their user names included their first and last names and their student numbers, and their avatars were required to be female or male to reflect their gender.

Figure 3. Stages of the execution of the current study.

A variety of activities was designed for students to participate in the experiment for a duration of one semester. For instance, conducting weekly tutorials in the virtual computer laboratories was one of the program's main activities. Students had a weekly timetable for their tutorial sessions throughout the semester. They had to log into Second Life and teleport their avatars to the virtual campus, then attend their virtual lab to join the tutorial sessions. Tutors used virtual slide shows inside virtual computer labs to deliver the contents of the tutorials and voice and text communications transmitted using a built-in messenger in Second Life. Students could initiate a conversation with their tutors and/or other classmates.

Student discussions were another activity in the experiment. Multiple discussion and consultation opportunities were provided for students in the virtual discussion room according to particular timetables to meet their tutors and lecturer based on a weekly schedule in the virtual campus. Other collaborative activities were also available for students to participate in groups. The activities were devised and developed as part of students' class exercises, and they required students to discuss the problem with others in groups before submitting their solutions individually.

Additional activities were also set up for students, such as course orientation, socialisation, intercultural communication, and in-world internet browsing. Table 1 lists all tasks and activities completed during the research, with their virtual location and a brief explanation.

Table 1. List of educational tasks during the experiment

TASK	VIRTUAL LOCATION	TASK DESCRIPTION
Virtual laboratory	Computer labs: Replicas of a real computer laboratory with virtual laptops connected to the Internet	A topic/question was given to students by the instructor to discuss and post their answers and ideas about the given topic in the online discussion forum.
Meeting and discussion	Discussion rooms: rooms with five seats and a table suitable for meetings and consultations	Students and the teaching team could get together in the designated discussion room to discuss course topics
Course material	Resource room: a building with various rooms housing all relevant course material	Students were able to access and download updated course materials 24/7 in various formats
Course orientation	Orientation area within the virtual campus	There was a designated area for course orientations inside the campus to give students information about course contents
Socialisation and intercultural communication	Virtual Campus	Opportunities for socialisation and intercultural awareness
Student collaboration	Computer labs and discussion room	Teamwork on course assignments in groups of 4 to 5
In-world internet browsing	Browser billboards	Internet browsers were available in a billboard format to access and open websites

Case study

In the experiment for this study, a first-year undergraduate subject course was selected and delivered through the online virtual distance learning programme for a duration of one semester. Students from various study backgrounds and disciplines were enrolled in the course. The following section details the features of the virtual learning environment that was created in Second Life.

Environment understudy

As stated earlier, the current study employed Second Life as the primary platform to develop the virtual learning environment. A virtual land was rented within Second Life to create a virtual environment specifically for this research, including buildings and other facilities. It was planned to design and implement the virtual campus as realistic as possible and avoid creating an unrealistic, fantasy or dreamy environment. Second Life's advanced building tools and Linden Scripting Language (LSL) were utilised to develop the environment and learning activities. Various facilities, buildings, and rooms were constructed within the virtual campus, including a lecture theatre, four computer laboratories, a building with three rooms for resources, a discussion building with five rooms and a meeting area. Students and instructors were able to log in and attend the campus to virtually visit the environment and participate in the online distance learning programme using their avatars.

Tutorials were held in computer labs, while the weekly lectures were delivered in the lecture theatre. The resource room, a virtual building that housed all course material such as lecture slides, book slides, sample exam questions, videos, and documents, was another building on the campus. The discussion room was created to allow students to participate in collaborative and interactive activities such as meetings and discussions. There was the opportunity to contact and speak with other students or the teaching team using a microphone and speaker in all of the buildings featured on the virtual campus.

SAMPLE

Purposive convenience was used in the study as a sampling technique, and a total of 250 students were invited to participate in the research. Students were from various disciplines and had the basic knowledge of information technology and the necessary skill to use Second Life. The participants' ages ranged from 17 to 24, with 63 per cent of males and 37 per cent of females taking part. The demographic information for the participants is shown in Table 2. 135 students completed the survey and participated in the research.

Table 2. Participants' demographic information

TOTAL NUMBER OF ENROLLED STUDENTS	NUMBER OF PARTICIPATING STUDENTS	NUMBER OF THE FEMALE PARTICIPANTS	NUMBER OF THE MALE PARTICIPANTS	MEAN AGE
250	135	49	86	20.05

MEASUREMENT

Research instrument

Survey was the data collection method for the study. A questionnaire with 32 questions to evaluate the hypotheses was developed. Based on a Likert scale approach (Matell & Jacoby, 1971), the questionnaire analyses the participants' level of agreement with the questions. The responses were based on a five-point Likert scale, with 1 denoting 'strongly agree,' 2 denoting 'agree,' 3 denoting 'neutral,' 4 denoting 'disagree,' and 5 denoting 'strongly disagree.'

Students' participation in the survey was fully voluntary, and responding to the questions was completely optional, with students having the option to refuse, and it had no bearing on their grade in the course or any other aspect of their studies. The questions were answered anonymously, and no questions about the students' names or identities were asked or recorded during the completion of the survey. The university's Human Research Ethics Committee approved the research project, questionnaire and consent form.

DATA COLLECTION

An online questionnaire website (www.surveymonkey.com) was used for the survey and to collect the responses. The survey instrument contained two sections: (A) an informed consent form to the participants and (B) the questionnaire. The consent form was given to the students before the commencement of the survey. The survey was considered complete if the participants answered the majority of the questions. Otherwise, if less than half of the survey questions were answered, the survey was judged incomplete and not included in the final data pool. One hundred thirty-five students in total completed the survey.

ANALYSIS AND RESULTS

DATA ANALYSIS

Before analysing data, a data preparation process was performed to determine how to cope with missing data. The questionnaires with 50% or more unanswered questions were removed from the analysis. For cases with missing data, the 'Mean Replacement' method was used. Structural Equation Modelling (SEM) implementing Partial Least Square (PLS) was employed to analyse the study's data. SEM can analyse all paths in one regression analysis (Wu & Zhang, 2014), and PLS uses a component-based approach for the estimation (Karahanna et al., 2006). It is feasible to analyse the structural and measurement models using PLS.

In order to assess the fitness of the proposed model, the 2-step procedure proposed by Anderson and Gerbing (1988) was used. For evaluating the reliability and validity of measures, the measurement model was tested first, followed by a structural model test to evaluate the strength and direction of correlations between variables. Version 3.0 of SmartPLS (Ringle et al., 2015) was used for parameter modelling and estimation (to analyse both structural and measurement models).

EXAMINING THE MEASUREMENT MODEL

Table 3 demonstrates the construct reliability and convergent validity. As can be seen from the table, Cronbach's alpha scores of at least 0.7 indicate strong internal reliability of each construct, meaning that the survey items selected for each construct are reliable measures. Additionally, all standard factor loading (λ) values obtained in the CFA of the measurement model exceeded 0.8, and they were significant at $p \leq 0.001$. Moreover, composite reliabilities of constructs ranged between 0.874 and 0.975, and AVE ranged from 0.743 to 0.951, with both above the suggested threshold of 0.70, indicating modest levels of internal consistency. All three conditions for convergent validity were met based on the above values. Regarding the model's fit indices, NFI and SRMR are 0.812 and 0.047, respectively.

Table 3. Construct reliability and convergent validity

CONSTRUCT	QUESTIONNAIRE ITEM	FACTOR LOADING	CRONBACH'S ALPHA	COMPOSITE RELIABILITY	AVERAGE VARIANCE EXTRACTED
Perceived Ease of Use	PEU1	0.814	0.829	0.897	0.743
	PEU2	0.893			
	PEU3	0.878			
Perceived Usefulness	PU1	0.945	0.950	0.967	0.908
	PU2	0.960			
	PU3	0.954			
Perceived Enjoyment	PE1	0.943	0.921	0.950	0.864
	PE2	0.933			
	PE3	0.913			
Visual Attractiveness	VA1	0.922	0.926	0.953	0.871
	VA2	0.952			
	VA3	0.925			
Computer Self-Efficacy	CSE1	0.943	0.868	0.918	0.789
	CSE2	0.903			
	CSE3	0.814			
Use	USE1	0.894	0.712	0.874	0.776
	USE2	0.868			

CONSTRUCT	QUESTION-NAIRE ITEM	FACTOR LOADING	CRONBACH'S ALPHA	COMPOSITE RELIABILITY	AVERAGE VARIANCE EXTRACTED
3DIVW Engagement	ENG1	0.922	0.910	0.943	0.847
	ENG2	0.927			
	ENG3	0.911			
Student Satisfaction	SS1	0.936	0.809	0.911	0.837
	SS2	0.893			
Learning Outcome	LOUT1	0.861	0.827	0.897	0.744
	LOUT2	0.910			
	LOUT3	0.814			
Retention	RET1	0.975	0.949	0.975	0.951
	RET2	0.976			
Course Engagement	CE1	0.919	0.803	0.910	0.835
	CE2	0.909			
Graduate Outcome	GOUT1	0.906	0.895	0.934	0.826
	GOUT2	0.914			
	GOUT3	0.907			

Table 4 shows the construct inter-correlations and the square root of AVE for each of the 12 constructs in the measurement model. In all of the cases, the variance square root is above the corresponding construct correlations, which satisfies the discriminant validity criteria.

Table 4. Correlation matrix and discriminant validity

CONSTRUCT	3DIVW Engagement	Computer Self-Efficacy	Course Engagement	Graduate Outcome	Learning Outcome	Perceived Ease of use	Perceived Enjoyment	Perceived Usefulness	Retention	Student Satisfaction	Use	Visual Attractiveness
3DIVW Engagement	**0.92**											
Computer Self-Efficacy	0.288	**0.888**										
Course Engagement	0.584	0.245	**0.914**									
Graduate Outcome	0.417	0.277	0.612	**0.909**								
Learning Outcome	0.622	0.308	0.731	0.584	**0.863**							
Perceived Ease of use	0.42	0.422	0.227	0.261	0.34	**0.862**						
Perceived Enjoyment	0.792	0.313	0.578	0.389	0.56	0.477	**0.93**					
Perceived Usefulness	0.78	0.264	0.529	0.32	0.556	0.534	0.75	**0.953**				
Retention	0.772	0.283	0.591	0.397	0.518	0.403	0.779	0.74	**0.975**			
Student Satisfaction	0.811	0.248	0.701	0.481	0.735	0.467	0.800	0.755	0.754	**0.915**		
Use	0.572	0.296	0.395	0.274	0.496	0.464	0.482	0.478	0.494	0.498	**0.881**	
Visual Attractiveness	0.486	0.179	0.383	0.289	0.344	0.16	0.488	0.358	0.402	0.432	0.279	**0.933**

FINDINGS

The structural model was tested to assess the predictive validity measures. 21 hypotheses were evaluated by applying the SEM method. A bootstrap resampling was performed on the structural model to examine the significance levels of all the paths (N = 500). Figures 4, 5, and 6 illustrate the PLS model, bootstrapping model, and hypothesis testing results.

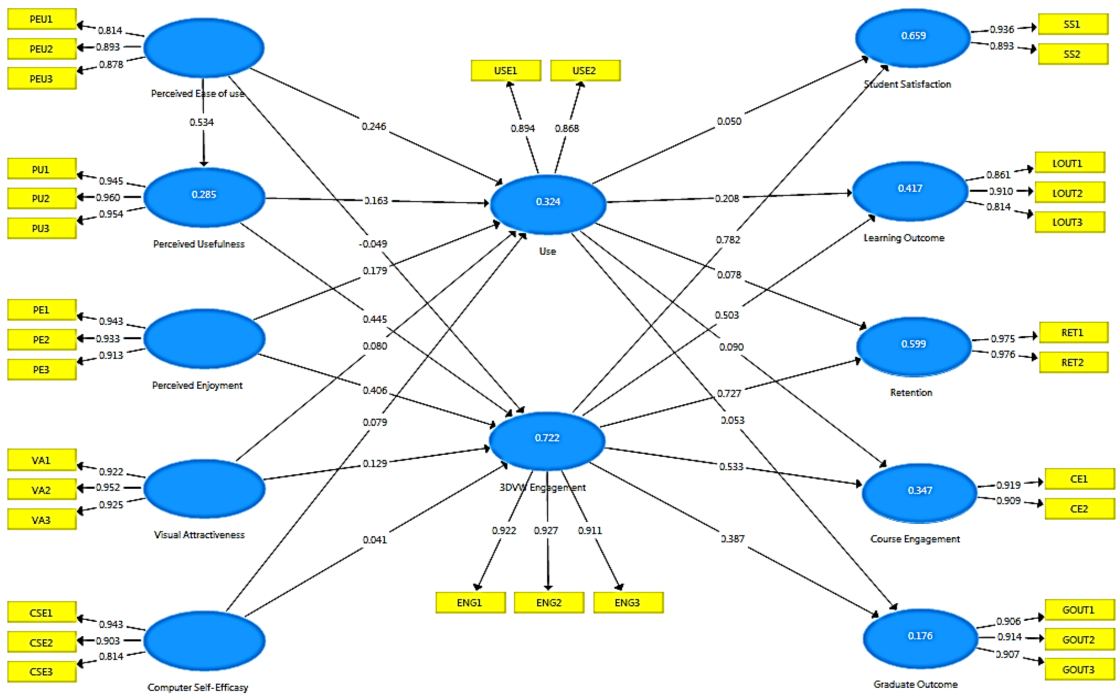

Figure 4. Result model (path coefficients and factor loadings)

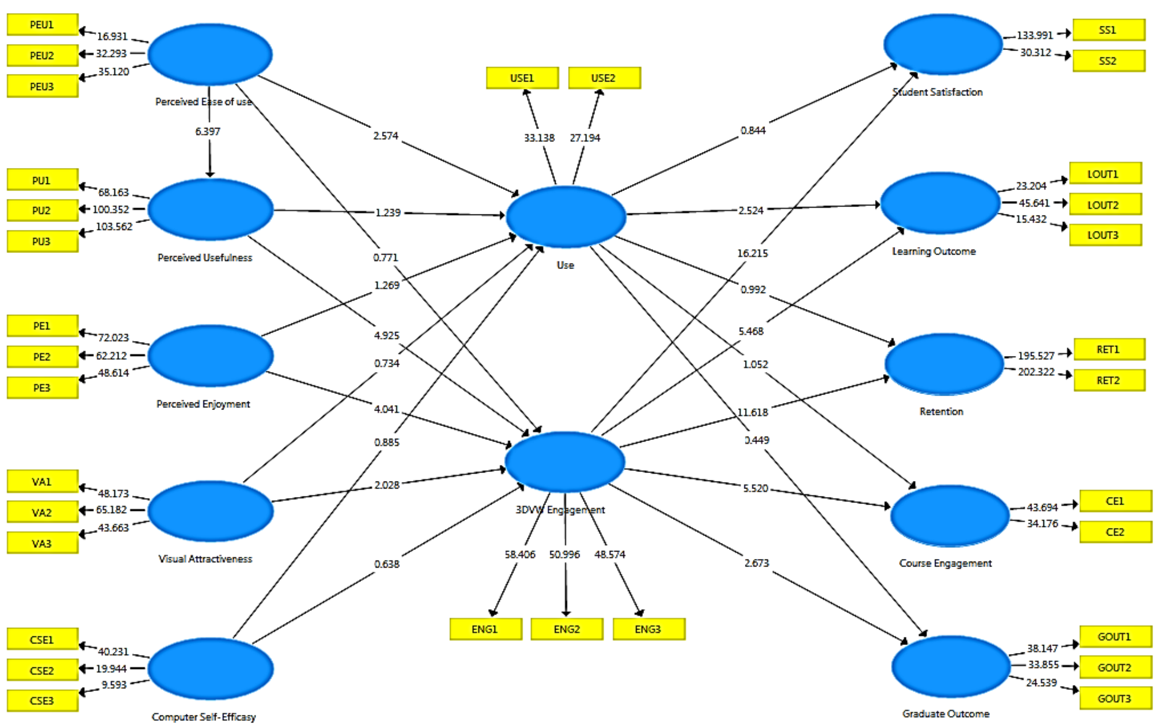

Figure 5. Bootstrapping model (t-values)

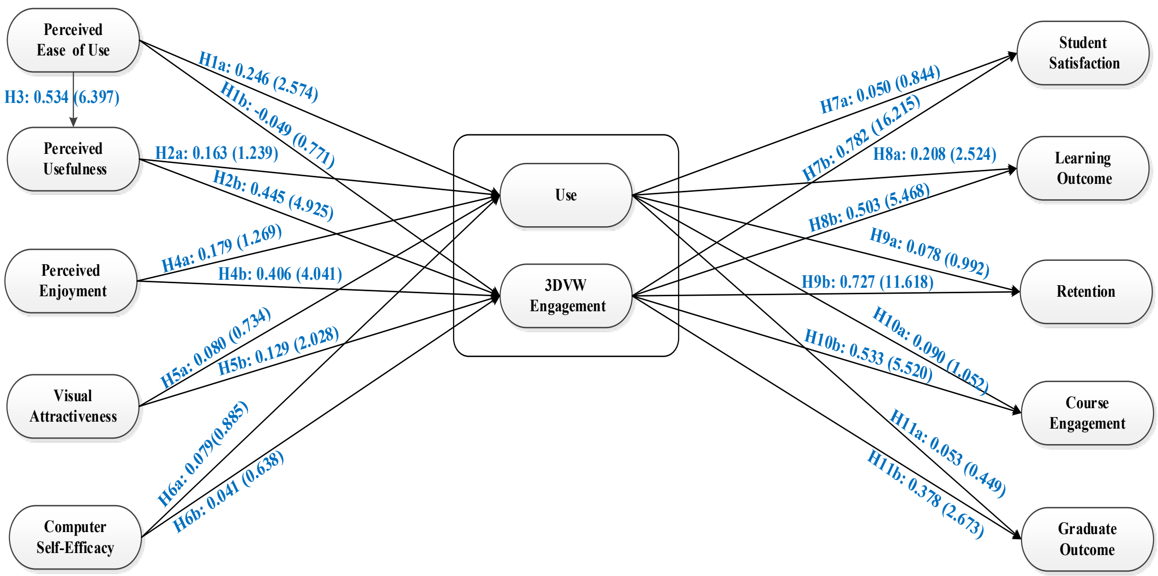

Figure 6. Hypotheses testing results

Table 5 shows the results of the structural model. Path coefficient indicates the strength of the relationships.

Table 5. Summary of hypothesis testing

Hypotheses		Path coefficient	t-Value	p-Value	Significance	Supported
H1a	Perceived Ease of Use → Use	0.246	2.574**	0.011	(p≤0.01)	Yes
H1b	Perceived Ease of Use → 3DIVW Engagement	-0.049	0.771	0.441		No
H2a	Perceived Usefulness → Use	0.163	1.239	0.216		No
H2b	Perceived Usefulness → 3DIVW Engagement	0.445	4.925***	0.000	(p≤0.001)	Yes
H3	Perceived Ease of Use → Perceived Usefulness	0.534	6.397***	0.000	(p≤0.001)	Yes
H4a	Perceived Enjoyment → Use	0.179	1.269	0.206		No
H4b	Perceived Enjoyment → 3DIVW Engagement	0.406	4.041***	0.000	(p≤0.001)	Yes
H5a	Visual Attractiveness → Use	0.080	0.734	0.464		No
H5b	Visual Attractiveness → 3DIVW Engagement	0.129	2.028*	0.043	(p≤0.05)	Yes
H6a	Computer Self-Efficacy → Use	0.079	0.885	0.377		No
H6b	Computer Self-Efficacy → 3DIVW Engagement	0.041	0.638	0.524		No
H7a	Use → Student Satisfaction	0.050	0.844	0.399		No
H7b	3DIVW Engagement → Student Satisfaction	0.782	16.215***	0.000	(p≤0.001)	Yes
H8a	Use → Learning Outcome	0.208	2.524**	0.012	(p≤0.01)	Yes
H8b	3DIVW Engagement → Learning Outcome	0.503	5.468***	0.000	(p≤0.001)	Yes
H9a	Use → Retention	0.078	0.992	0.322		No
H9b	3DIVW Engagement → Retention	0.727	11.618***	0.000	(p≤0.001)	Yes
H10a	Use → Course Engagement	0.090	1.052	0.294		No
H10b	3DIVW Engagement → Course Engagement	0.533	5.520	0.000	(p≤0.001)	Yes
H11a	Use → Graduate Outcome	0.053	0.449	0.654		No
H11b	3DIVW Engagement → Graduate Outcome	0.378	2.673	0.008	(p≤0.001)	Yes

*** Significant at 0.05; ** Significant at 0.01; Significant at 0.001**

Hypotheses 1, 2, 3: According to Table 5, perceived ease of use has a significant impact on the use (path coefficient = 0.246; t-value = 2.574; $p \leq 0.01$). Perceived ease of use also significantly impacts the perceived usefulness (path coefficient = 0.534; t-value = 6.397; $p \leq 0.001$). This means the data supported both H1a and H3 hypotheses. That is to say, students who perceived the virtual environment as easy intended to use it. Furthermore, students who perceived 3DIVW as easy to use found it beneficial for their education.

The results did not support H1b, the relationship between perceived ease of use and 3DIVW engagement, (t-value=0.771 and path coefficient=-0.049). and also the relationship between the perceived usefulness and the use (H2a) was not supported (t-value = 1.239 and path coefficient = 0.163).

Perceived usefulness significantly impacts 3DIVW engagement (H2b) (path coefficient = 0.445, t-value = 4.925, and $p \leq 0.001$). Therefore, the usefulness of the virtual learning environment positively impacts 3DIVW engagement.

Hypothesis 4: The results support the relationship between the perceived enjoyment and the 3DIVW engagement (H4b), and it is statistically significant at the 0.001 level (path coefficient = 0.406, t-value = 4.041). This indicates that students' engagement with technology is increased when they have fun and enjoy using the 3DIVW-based learning environment. Hypothesis H4a, hypothesised a positive impact of the perceived enjoyment on the use, was not supported (path coefficient = 0.179 and t-value = 1.269).

Hypothesis 5: According to results, visual attractiveness significantly impacts 3DIVW engagement (H5b) (path coefficient = 0.129; t-value = 2.028; $p \leq 0.05$). Therefore, creating a visually appealing virtual learning environment will help students in higher education engage more with technology. In contrast, the relationship between visual attractiveness and the use (H5a) was not supported (path coefficient = 0.080 and t-value = 0.734).

Hypothesis 6: Both H6a and H6b were not confirmed by the results. Thus, computer self-efficacy has no positive effect on the use or 3DIVW engagement, with t-values of 0.885 and 0.638, respectively. This indicates that their computing competence does not necessarily influence students' adoption of 3DIVWs.

Hypothesis 7: H7b, the positive impact of the 3DIVW engagement on student satisfaction, was supported in this study ($p \leq 0.001$, path coefficient = 0.782 and t-value = 16.215). This means engagement with 3DIVWs positively increases students' satisfaction; however, the use of 3DIVWs did not significantly impact students' satisfaction (H7a). Thus, the relationship between use and student satisfaction was not supported by the results (path coefficient = 0.50 and t-value = 0.844).

Hypothesis 8: Both H8a and H8b were supported, meaning, use has a positive and significant impact on learning outcome (H8a) (path coefficient = 0.208; t-value = 2.524; $p \leq .01$), and 3DIVW engagement has a positive and significant impact on students' learning outcome (H8b) (path coefficient = 0.503; t-value = 5.468; $p \leq 0.001$). This suggests that students' use or participation in the 3DIVW-based learning environment has a positive impact on their learning outcomes.

Hypothesis 9, 10, 11: Path coefficients 0.078, 0.090, and 0.053 and t-values 0.992, 1.052 and 0.449, respectively for hypotheses H9a, H10a and H11a, indicate that the relationships between use and retention, course engagement and the graduate outcome were not supported. This shows that students' casual usage of this technology without engagement did not result in any positive outcomes, except learning outcome (H8a).

H9b was also supported (path coefficient = 0.727; t-value = 11.618; $p \leq 0.001$), meaning that being engaged with the technology significantly impacts student retention. The relationship between 3DIVW engagement and course engagement (H10b) and graduate outcome (H11b) were also supported (path coefficient = 0.533 and 0.378; t-value = 5.520 and 2.673; $p \leq 0.001$). Thus, engagement with 3DIVW impacts students' course engagement and graduate outcome positively.

DISCUSSION

To determine the relationship between 12 variables, the current study aimed at examining 21 hypotheses. The findings supported 11 out of 21 hypotheses, and the other ten were not supported. This section discusses the findings of this study in-depth.

The perceived ease of use significantly impacts the use (H1a), whereas it has no significant impact on 3DIVW engagement (H1b). A reason behind this is that the ease of using the environment was important for students who used the learning environment only on a casual basis and did not engage in it, as they prefered using a simple tool only to complete the required tasks. In contrast, the ease or difficulty of the technology was not a significant factor for students interested in and engaged deeply with technology. This suggests that the more the students involved with the technology, the less important the easiness or hardness of the technology was to them. On the other hand, when students utilised the technology for a short period of time and did not form a deep bond with it, the ease or difficulty of the environment impacted their use. The relationship supported by H1a is consistent with a number of previous research, including TAM (Davis, 1989) and TAM2 (Venkatesh & Davis, 2000). H3, which was supported by this study, indicates the positive impact of the easiness of the technology on its usefulness. The significance of H3 also confirms the findings of the TAM (Davis, 1989) and TAM2 (Venkatesh & Davis, 2000). This relationship has also been confirmed by a wide range of studies in the literature in the field of education, and the finding is consistent with many other studies (e.g., Al-Emran et al., 2020; Estriegana et al., 2019; Joo et al., 2018).

H2b, which was supported in this study, has not been examined in the literature previously. It shows the significant impact of perceived usefulness on 3DIVW engagement. In contrast, the relationship between perceived usefulness and the use was not supported (H2a). This finding reveals that usefulness was not an effective element for students who only used the technology occasionally; However, the usefulness of the technology was a major consideration for those who were engaged with it. Because they cognitively form a deep connection to the technology, its usefulness impacts their engagement, increasing their intention to adopt it. Their impression of the technology's usefulness motivated them to use and interact with it more. It can be concluded that the usefulness of a 3DIVW-based learning environment contributes to its acceptance and adoption.

The results did not support H2a, which is in contrast to the findings of TAM and TAM2. However, it confirms the findings of many studies in the literature which did not find any significant relationship between perceived usefulness and the intention to use a technology, such as Tahar et al. (2020) and Oum and Han (2011). This finding suggests that the usefulness of a technology does not always contribute to intention to use or attitude towards its use. Therefore, the perceived ease of use and the perceived usefulness influence different aspects of user acceptance of 3DIVW. Perceived ease of use has a positive impact on the use of the technology, whereas perceived usefulness has a positive impact on the engagement with the technology.

Perceived enjoyment significantly impacts 3DIVW engagement (H4b). This relationship has not already been examined in the literature. The relationship between perceived enjoyment and use (H4a), however, was not supported, which confirms the studies by Agrebi and Jallais (2015), Venkatesh et al. (2003), and Mun and Hwang (2003), who did not find the direct impact of perceived enjoyment on the intention to use. As a result, this conclusion contradicts Van der Heijden's (2004) findings, which suggest that perceived enjoyment is a determinant of intention to use. Hypothesis H4b shows that the more students enjoy the virtual learning environment, the more engaged to use it over time. Perceived enjoyment does not necessarily lead to casual usage of the technology (H4a), but it does lead to engagement with and persistent use of the technology, creating a deep involvement with the technology.

The relationship between visual attractiveness and use and engagement is similar to perceived enjoyment. Visual attractiveness positively impacts 3DIVW engagement (H5b). The influence of visual attractiveness on the use was not confirmed (H5a), and this contradicts the conclusions of Van der Heijden (2003) and

Verhagen et al. (2009). An attractive virtual learning environment positively influences the technology's adoption and fosters a deep bond, resulting in continued use and engagement. The visual attractiveness of a virtual learning environment does not contribute to casual usage, but it does establish a cognitive effort and feelings of involvement among students.

Many studies previously confirmed the relationship between computer self-efficacy and the use of technology in the literature (e.g., Lew et al., 2019; Mensah & Mi, 2019; Verhagen et al., 2009). Contrary to our prediction, this study did not support the impact of computer self-efficacy on the use (H6a) and 3DIVW engagement (H6b). These findings are in accord with other studies such as Shiau and Chau (2016). This suggests that having knowledge of computers does not impact the adoption of 3DIVWs. An explanation for this result is that the younger generation has a basic understanding of computers, and they grow up with computers, and it is a part of their basic literacy. They are aware of the benefits of computers in their personal lives and their studies. Consequently, computer anxiety does not exacerbate their condition when they use it or are engaged in new computer-based technology, and students do not consider computer self-efficacy an important facilitator in using 3DIVW.

3DIVW engagement significantly and positively impacts all five dependent variables (H7b, H8b, H9b, H10b, H11b). This means that when students are interested in this technology and use it mindfully, with cognitive effort and deep processing, they would form a strong relationship with it, which leads to increased satisfaction, improved learning outcomes, increased retention, course engagement, and graduation outcomes. The application of 3DIVW without engaging with it, on the other hand, has no meaningful effect on positive outcomes. Only the relationship between use and learning outcome was supported, indicating that the technology helps students achieve better learning outcomes. This study did not support the relationship between use and the other four dependent variables. It is concluded from this finding that for achieving positive outcomes, students need to be engaged with 3DIVW technology.

PRACTICAL AND THEORETICAL CONTRIBUTIONS

The study's main focus was on the adoption of technology, particularly in higher education. Only a few research studies have looked into the adoption of 3DIVW technology in higher education; earlier studies have largely looked at different variables that are not relevant to the current study. The study aimed to take a step forwards by looking into the consequences of using the technologies in higher education. Most of the research in the field focused on the 'use' of 3DIVWs in the educational setting, whereas the current study attempted to consider '3DIVW engagement,' which is a variable linked to not only the usage of the technology but also a continued use and deeper involvement with it.

An extensive research model was developed for this study to examine 21 hypotheses to evaluate the relationships between 12 different factors. The model has a rich theoretical background as it has incorporated three well-known theories and models. The research model looked at numerous self-developed variables related to the antecedents and consequences of using technology in higher education that had never been examined before in this field.

IMPLICATIONS FOR PRACTICE

The study provides a number of implications for different practitioner groups, including educators, study designers, virtual world developers, higher education institutions, universities, colleges and polytechnics, online universities, and other educational communities.

Implications for curriculum designers and developers

Designing an easy-to-use 3D immersive virtual learning environment and offering simple interactive options in it, as supported by hypothesis H1a, helps students quickly understand the platform's features, contributing to technology adoption. According to hypothesis H5b, designers should make aesthetic design decisions in order to develop an appealing virtual space that will draw students' attention. Visual effects, graphics, multimedia features, patterns, and the overall look of the environment are all key variables to consider when building a virtual learning environment. The 3DIVW-based learning environment would be better designed and created in a realistic manner, boosting students' sense of presence to achieve a superior teaching and learning outcome. According to the findings regarding hypothesis H4b, incorporating game-like activities in the learning environment to offer game-based learning and equipping the virtual environment with exercises that can increase enjoyment, fun, and playfulness lead to students' higher level of adoption of 3DIVWs. The majority of 3DIVW platforms include building tools and programming languages; programmers and developers have the opportunity to create and modify to improve the contents of the virtual environment, as well as integrate other software or hardware, such as BlackBoard, into it.

Implications for higher education institutions

The application of 3DIVW in teaching and learning is very cost-efficient and advantageous for students as well as institutions. In comparison to the traditional educational system, the costs of establishing and maintaining a virtual environment and implementing a teaching and learning programme are extremely minimal. 3DIVWs are ideal for distance learning programmes in which lectures, workshops, meetings, seminars, teamwork, collaboration, and other activities can all be done online. As a result, students and educators from all around the world can virtually participate in the programme. 3DIVW-based eLearning programmes may contribute to student retention. Moreover, institutions can efficiently reduce their carbon footprint by employing e-learning systems as alternatives to paper-based systems, as reducing our carbon footprint is no longer a distant dream.

Implications for educators and course conveners

On a global scale, 3DIVWs provide opportunities for collaboration and networking, and educators and instructors can use 3DIVWs to encourage student collaboration and teamwork. Despite the advantages of 3DIVW-based learning, students may find that using a virtual learning environment is distracting due to the technology's entertaining features. For example, game-like activities and other attractive features may divert students' attention away from their academics and engage them in role-playing and entertainment. In traditional classrooms, educators typically use body language to communicate and convey knowledge depending on students' reactions. In a 3DIVW-based classroom, this is not possible unless the platform provides advanced facial expressions and gestures features for the avatars. Substantial resources should be supplied and made available to students in order to rectify this drawback. 3DIVWs, as a multi-functional platform, allow educators and teachers to create virtual learning environments and materials based on various teaching and learning theories and techniques to deliver lessons.

Implications for Research

It is believed that this study can serve as a starting point for future research into many aspects of 3DIVW technology in education. Some future study directions are recommended below based on the findings of the study.

As stated earlier, there were a few inconsistencies between the current study's findings and some of the previous studies. The hypotheses H2a, H4a, H5a, H6a and H7a are not supported by this study, which contradicts the findings of other studies in the literature. Future studies can look into the inconsistent relationships to assess their significance in a similar context.

Only five variables were defined and examined as antecedents of adoption as well as five variables for the positive outcome of the adoption of the technology in the study's research model. Additional research could more thoroughly identify and investigate new variables relevant to the adoption of 3DIVW in educational activities and the positive outcomes. Four new variables were defined in this study: 3DIVW engagement, course engagement, graduation outcome, and retention. These variables can be tested in other contexts and/or the application of different technologies.

This study was conducted in higher education; hence the results may not be applicable to other educational settings such as K–12. The findings can provide some direction to future researchers who want to use the technology in different educational settings. Future research can also investigate the current study's findings in the other platforms of 3DIVW technology, specifically virtual, augmented and mixed reality. It is also expected that the outcome of the application of the technology on other hardware, such as smart devices, will differ significantly from the outcome of this study. Using different educational methods in the classroom could lead to new discoveries in the field.

Age, gender, cultural diversity, employment, and other criteria associated with the participated students were not examined in this study. By taking into account the factors indicated, this study can be expanded to include different cohorts of higher education students in the experiment to validate the scale employed in this study.

Limitations

Despite the extraordinary capabilities of 3DIVWs, there are a number of limitations, challenges, and requirements that developers and designers should be aware of before developing a virtual distance learning programme.

3DIVW is an Internet-based technology that has a client/server architecture. This technology necessitates a large amount of data transfer due to the higher degree of graphics used in generating virtual environments. Users need to have access to a high-speed internet connection for using these platforms. Without an appropriate network or internet connection, the regular activities within the virtual space would lag, and the connected users would not be able to complete the activities synchronously, which causes significant problems in the learning process. Thus, without having a decent high-speed Internet connection, the application of the technology is very limited. Despite the remarkable increase in the access to the Internet for higher education students, a large number of students still have limited Internet access, especially in remote and rural areas. Therefore, this is a considerable problem that can negatively impact higher education students' adoption of this technology.

3DIVW is also heavily reliant on computer hardware. Implementing educational programmes using this technology without accessing powerful PCs, laptops, or smart devices with an adequate processor, memory, and graphics could be troublesome. Users are required to use computers with reasonable specifications and hardware configuration to access the content and navigate easily in the environment. Not all students have access to the mentioned facilities.

Not having proper access to high-speed Internet or the lack of powerful electronic devices to connect to the virtual learning environment are major drawbacks of the application of this technology for higher education users. The main objective is to easily connect to the learning environment, access the content and material, and be present in a live virtual environment. Thus, the hardware dependency and Internet dependency of 3DIVWs negatively affect users' adoption of this technology.

These platforms are still in their early stages of development and have some technical barriers and challenges to overcome. Software bugs, technical difficulties, operation speed, and glitches are also considered the major issues that decrease the reliability of 3DIVWs. However, it is expected that these concerns will be rectified over time and that the value they bring to the educational community will outweigh the challenges they face now.

Conclusion

The purpose of this study was to look at the impacts of various factors on the adoption of 3DIVW technology in higher education and the impact of users' adoption on students' positive outcomes. For this study, a 3DIVW-based learning virtual environment was created and used to deliver an undergraduate subject for one semester. Accordingly, a quantitative research model was created, and the effect of five independent variables on the adoption of 3DIVW was investigated. The study also looked at the impact of using this technology on five dependent variables that are associated with positive outcomes. A survey comprising 32 questions was prepared and distributed to the students to evaluate the hypotheses, and 135 students completed the questionnaire. After data collection, a PLS-SEM method was used for data analysis, and as a result, 11 out of 21 hypotheses were supported, and ten were not supported. According to the findings, the adoption of 3DIVWs as a platform for online learning in higher education is influenced by their perceived ease of use, perceived usefulness, perceived enjoyment, and visual attractiveness. The study confirms that the use of 3DIVW technology without engagement with it will not significantly impact the positive outcomes. Findings indicate that despite the fact that 3DIVW technology is still in its early stages of development and faces some limitations and challenges, it has the potential to be used and adopted as a platform for developing distance learning programmes in higher education and will have positive outcomes for students.

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