



INVESTIGATING THE FACTORS THAT INFLUENCE THE IMPLEMENTATION OF VIRTUAL REALITY IN SCIENCE LEARNING

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ABSTRACT

Advanced virtual reality (VR) holds substantial promise in education and can be seamlessly integrated into classroom instruction, fostering rapid advancements in science education. This research aims to investigate the factors that influence the implementation of VR and the correlation between the technology acceptance model that can lead to its integration in the science educational setting. To address these objectives, structural equation modeling (SEM) is conducted to represent a hypothesis about the causal relationships among factors influencing preservice teachers to implement VR in the classroom, following their engagement in simulated science explorations related to the concept of weightlessness. The results reveal that the proposed model has strong explanatory power in predicting the intention to use VR in the classroom ($R^2=64.7\%$). This intention is influenced by perceived usefulness, perceived enjoyment, and the absence of cybersickness. Notably, our findings also indicate that Usage Attitude (UA), which pertains to participants' positive or negative response towards technological usage, does not mediate the relationship between beliefs (PU, PEU, and PE) and Behavioral Intention (IU), prompting further exploration of the concepts of cognitive and affective attitude. Additionally, the findings from the preservice teachers' responses support the notion that VR is valuable in educational contexts, enabling immersive experiences, authentic learning, and enhancing the learning journey, along with the concept of learning by doing.

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Keywords: science learning; structural equation modeling; technology acceptance model; virtual reality

INTRODUCTION

The emergence of Meta, formerly known as Facebook, and its announcement of a new platform towards the end of 2021 have captivated global attention; the platform promises an expansive metaverse, a concept that offers a boundless virtual universe only constrained by human imagination (Clark, 2021; Metz, 2021). Virtual reality (VR) is the closest term to the metaverse concept discussed by many technologists (Ratan & Lei, 2021; Sparkes, 2021). VR is a simulation

created through computer-generated imagery and audio, representing a real or imagined environment. This immersive experience allows individuals to interact within a virtual space as if they were physically present, facilitated by specialized electronic devices (Park et al., 2019).

Many previous studies have revealed that VR has massive potential for the educational field, for instance, learning benefits that are shown in cognitive studies, especially where highly complex or conceptual problems require spatial understanding and visualization that often occur in teaching scientific topics such as biology or physics (Hamilton et al., 2021). VR can

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also turn abstract concepts into experienceable phenomena and present exciting opportunities to transform science education and public outreach practices (Kersting et al., 2021).

Another advantage of VR in the teaching-learning process is that it allows students to learn authentic concepts. In science learning, for example, in physics and astronomy concepts, learning is no longer restricted to the imagination; students can explore the universe in a virtual world that resembles the real world (Kersting et al., 2021). Moreover, explaining concepts without experiencing phenomena may lead to students' images of the scientific or technological environments being superficial, unreal, and even incorrect (Scher & Oren, 2006). This problem can be overcome using well-known scientific activities, such as scientific demonstrations (Ahtee et al., 2011) or study tours to science and technology facilities (Scher & Oren, 2006). As technology is making a move toward advancing 'peers' for teachers, currently, both approaches as the way to make science classrooms have more 'experience' can be implemented using virtual reality technology.

VR as a tool to understand science concepts has a long story; it can benefit classrooms by making the classroom better than the traditional one. For instance, using VR technology, students can experience almost the same conditions as astronauts working in space stations, even [feeling] touching a celestial object that can create physical immersion within an immersive environment (Suh & Prophet, 2018). As the content of the VR in this research, exploring ISS simulation was chosen in which students would learn the weightlessness concept as part of science education material. ISS represents the most significant scientific and technological cooperative program in history, crafted to be a multipurpose research tool capable of facilitating a broad spectrum of investigations in the realms of physical and biological sciences (Castro et al., 2004) and for conducting experiments under weightlessness condition (Thirsk et al., 2009).

Although VR has shown great potential for classroom modernization (Atli et al., 2021), active learning (Sams & Leither, 2021), better learning motivation, learning outcomes, and positive impacts on students' achievement scores (Liou & Chang, 2018), it is still very rarely applied in the classroom and continues to face challenges that need to be overcome to ensure feasibility for schools (Holly et al., 2021). As classroom leaders, teachers may be wary of issues that circumvent the comprehensive implementation of VR, such

as user complexity compared to desktops (Holly et al., 2021) and cybersickness (Sagnier et al., 2020).

Many researchers focus on VR research regarding its benefits for students. The results are positive, indicating that VR can be widely used as a medium to increase motivation (Vogt et al., 2021), presence (Selzer et al., 2019), engagement (Allcoat & Mühlennen, 2018), and learning outcomes (Merchant et al., 2014). However, few studies have focused on teachers' views, although teachers have an enormous role in implementing technology in the classroom. Jones (2004) has reported that "teachers' lack of technical support, confidence, and realization" of the advantages of using technology in their teaching has become a barrier to effectively integrating technology in teaching and learning. Therefore, this research aims to identify the determinants affecting preservice teachers' intentions to use VR in classrooms and to understand their viewpoints on the practical application of VR in teaching through research investigations. By addressing these aims, the research will contribute valuable insights into the effective integration of VR in science educational settings, thereby highlighting its significance in advancing modern educational practices. To systematically investigate these aspects, the study is guided by the following research questions: (1) What factors influence preservice teachers' intention to utilize Virtual Reality (VR) in the science classroom setting?; (2) How do preservice teachers perceive the implementation of Virtual Reality (VR) in science educational settings?

METHODS

Structural equation modeling (SEM) was conducted to analyze the perceptions of preservice teachers after they engaged in simulated science explorations related to the concept of weightlessness. SEM is employed to test empirical data against substantive theories, commonly used to examine theories that propose specific relationships between mental traits and variables, as well as the loading of variables onto particular factors (Sinharay, 2010). SEM is performed in order to represent a hypothesis about the causal relations among several factors that lead educators to implement VR in the classroom, including belief (perceived usefulness, ease of use, and enjoyment) (Davis, 1992), behavioral intention (intention to use and to purchase) (Venkatesh et al., 2008), curiosity (Manis & Choi, 2019), attitude (Lee et al., 2019), and cybersickness (Sagnier et al., 2020). The causal relations will help educa-

tors to determine the possible intervention to support technology adoption in educational settings.

The sample consisted of 71 students (25 males and 46 females) who were Taiwanese preservice teachers, categorized by gender (25 males and 46 females), level (8 freshmen, 25 sophomores, 15 juniors, 10 seniors, and 13 graduate students), and VR use (44 participants never used VR, and 27 participants used VR less than an hour). In particular, participants in this research were teachers college students in Taiwanese universities who identified as preservice teachers who would become future teachers (Trumper, 2001; Yildiz Durak, 2019).

Given the specialized nature of our research, the intent was not to provide sweeping generalizations applicable to all contexts or populations. Instead, the aim was to gain a deep understanding of this particular group's attitudes and intentions towards VR technology in science educational settings. We explicitly acknowledge the limitations imposed by the sample size, emphasizing that our results may primarily apply to the specific population under investigation. Ideally, the sample size for SEM analysis should be above 200 (Bagozzi & Yi, 2012) but not exceeding 400 (Hair et al., 2009). Considering the fact that this research was conducted among preservice teachers by conducting an intervention through a VR experience of less than 20 minutes, there was a lack of participants due to several reasons; for example, VR technology was still relatively complex to operate among participants and the limitation of research's management over the intervention in large scale.

To begin with, participants willing to join the study were asked to fill out letters of consent, agreeing to voluntary participation and anonymous use of their information for research. Before the intervention, the participants were selected according to the criteria and received the invitation to do VR experience in a specific schedule; the variation of students' technology savvy was very diverse and random. Purposive random sampling was performed to divide the participants into two experiences (360-degree VR and graphics-based

VR) to ensure the diversity of VR acceptance so that both experiences had the same initial condition ($p > 0.05$).

Second, two VR interventions were prepared for participants. In the first experience, the virtual simulation using Cardboard was modified from a 360-degree video of the Home – VR Spacewalk developed by BBC Media Applications Technologies (2017). The second experience was Meta Quest, entitled Mission: ISS, and was designed by Magnopus (2019). To avoid motion sickness, a mat on the floor was used with a fan in the vicinity to create airflow so participants could detect directions (ThrillSeeker, 2020), as shown in Figure 1.

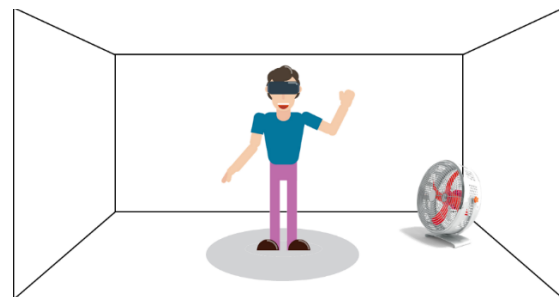


Figure 1. Procedure to Avoid Motion Sickness

It was also necessary to reduce the time spent using the virtual helmet due to the dizziness experienced by students, especially for the experiment involving Cardboard (Bedregal-Alpaca et al., 2020). In this experiment, participants experience 12 minutes for 360-degree VR and approximately 12 – 15 minutes for graphics-based VR. Moreover, virtual environments sometimes provide insufficient information, especially for learning. However, integrating text and audio can enhance these environments, offering a more complete and informative experience (Bowman et al., 1999; Chen et al., 2007). Thus, audio was added to 360-degree VR, and for graphics-based VR, the instructor assisted participants in translating the audio into participants' first language since some simulations only provide the English language.

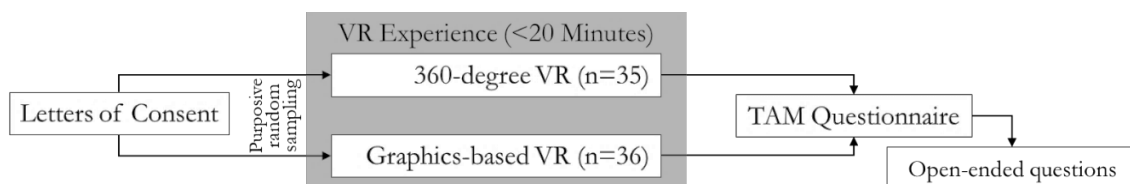


Figure 2. The Procedure of the Current Study

Finally, after the VR intervention, participants completed the technology acceptance model (TAM) and open-ended questions. The paper-based questionnaire and open-ended questions were conducted to assess their perceptions after the VR experience. The illustration of the research flow of the current study is shown in Figure 2. The VR experience consists of two related elements: devices and content. On the one hand, devices improve the VR experience with at least three main features (i.e., stereoscopic vision, head-mounted displays, and head tracking technology (Slater & Sanchez-Vives, 2016)). On the other hand, the content can be displayed in VR and generate the experience when using a VR device (i.e., computer graphics generated images (Slater & Sanchez-Vives, 2016)). The combination of these devices and content can generate a simulated VR experience.

Moreover, several studies have categorized the system, referring to Cardboard VR as the low-end VR and Meta Quest (and related technology, such as HTC VIVE and Meta Rift) as the high-end VR (Elmqaddeem, 2019; Selzer et al., 2019). Although Cardboard VR is far less capable than high-end VR devices, the extremely low cost shifted the VR market from the realm of technology enthusiasts to the ordinary person (Boyles, 2017). However, there is some discussion about whether 360-degree video, which has been used in some research and the classroom, is “really” VR.

The distinction between 360-degree VR and VR is quite complicated because many researchers use the 360-degree feature by using Cardboard and refer to it as VR (Calderon & Rivera, 2017; Fluke & Barnes, 2018). However, according to several studies (Arino et al., 2014; Slater & Sanchez-Vives, 2016; Slater, 2018; Suh & Prophet, 2018), VR refers to the main functions of devices that have specific main features, including computer graphics generated images, stereoscopic, head tracking, head-mounted display (HMD), and hand tracking, which are graphics-based VR.

According to Slater and Sanchez-Vives (2016), computer-generated images are the main differentiating feature of systems considered “really” VR and 360-degree VR. On the one hand, a computer model allows participants to change their point of view to anywhere within the scene. On the other hand, 360-degree VR cannot allow participants the full range of movement through the scene (p. 35). Moreover, graphics-based VR has haptic feedback because of the hand-tracking feature. The emulation of haptic feedback is es-

sential to VR simulation (Våpenstad et al., 2013). The sensation of touching a virtual object to feel its texture has enabled users to examine, search for, and manipulate objects visually (Huang & Liao, 2017); therefore, physical and mental engagement is created within an immersive environment (Suh & Prophet, 2018). Haptic imagery is a feature provided for participants by systems that are considered “really” VR (Våpenstad et al., 2013; Wang et al., 2019). The current article distinguished the device term, which was also characterized by Slater and Sanchez-Vives (2016) within two categories (i.e., graphics-based VR and 360-degree VR) and concluded that computer graphics-based VR and 360-degree VR are different possibilities within the domain of “virtual reality.”

The component of the questionnaire in the study was explored in the previous literature in order to select the important components regarding TAM (Technology Acceptance Model) specialized in VR (Appendix A), which resulted in a compilation of instruments. The main reason for the TAM framework in this study was supported by many studies (Teo, 2009; Camilleri, 2014; Akar, 2019) that have concluded that TAM can be the best measurement of technology implementation, extending to attitudes toward adaptation and change in the classroom. Therefore, the greater the TAM scores of teachers, the greater the possibility that some kind of technology can be applied in the classroom.

The technology acceptance model (TAM) was developed by Davis (1989) as an adaptation of the Theory of Reasoned Action that explains the main determinants of technology acceptance that lead to behavioral intention. Over time, many additional dimensions have been integrated into TAM; each improvement aims to increase the model's predictive power in specific dimensions (Chow et al., 2012). The TAM framework is widely used for different educational research purposes and new technology, as Davis (1989) makes a foundation to explain and predict how individuals perceive and adopt new information technology systems or innovations. The primary dimension of the TAM framework in this research consists of belief (perceived usefulness, perceived ease of use, and perceived enjoyment) (Davis, 1992), behavioral intention (intention to use and intention to purchase) (Venkatesh et al., 2008), curiosity (Manis & Choi, 2019), attitude (Lee et al., 2019), and cybersickness (Sagnier et al., 2020). Table 1 presents each criterion as a main feature of TAM used in this study.

Table 1. The TAM Framework in this Study

Criteria	Operational Definition
Perceived usefulness (PU)	The tendency to use or not use an application to the extent participants believe it will help them perform their job better (Davis, 1989).
Perceived ease of use (PEU)	The degree to which participants believe that using a particular system would be free of effort (Davis, 1989).
Perceived enjoyment (PE)	The extent to which the activity of using the technology is perceived to be enjoyable in its own right (Davis et al., 1992).
Intention to use (IU)	The degree to which a person has formulated conscious plans to use or not use some specified future technology (Venkatesh et al., 2008).
Intention to purchase (IP)	The degree to which a person has formulated conscious plans to purchase or not purchase some specified future technology (Venkatesh et al., 2008).
Curiosity (C)	The desire to seek and obtain new information (Manis & Choi, 2019) several challenges are posed to marketers, developers, and firms alike. These challenges concern futurity in the context of content creation, consumer acceptance, and return on investment (ROI).
Usage attitude (UA)	The degree to which users expect the use of the VR device to be positive (Lee et al., 2019).
Cybersickness (CS)	The negative side effects because of a virtual environment (Sagnier et al., 2020).

First, beliefs are very influential to the teachers' daily pedagogical decisions and serve as a primary source of their approach to pedagogy and student learning (Cross, 2009). The belief dimension in this research consists of perceived usefulness, ease of use, and enjoyment (Davis et al., 1992). According to Davis (1989), the "perceived" dimension is theorized from self-efficacy beliefs by Bandura to function as proximal determinants of behavior (p. 321). In this study, belief is used to predict behavior intention to implement VR in the classroom. Central beliefs are developed through experience; therefore, reflection upon that experience is critical to belief change that can occur gradually in an incremental process; however, for an individual, belief change involves deserting the familiar for the unknown (Grootenboer, 2008).

Second, according to Manis and Choi (2019), behavioral intention theoretically represents an "individual's consciously formulated plan to engage in a particular behavior and has a situationally specific dependence on a given research topic" (p. 506), for example, intention to use (Davis et al., 1992) and intention to purchase (Manis & Choi, 2019). Moreover, the willingness of preservice teachers to employ information technologies in future teaching relates to their intention (Baydas & Goktas, 2016; Yildiz Durak, 2019). Studies have shown that teachers who perceive the value of using technology are more inclined to integrate it into their teaching methods (Ottenbreit-Leftwich et al., 2010).

Third, among the external factors affecting perceived ease of use, curiosity stands out as the most significant predictor compared to other variables; this insight marks an initial effort to blend the Technology Acceptance Model (TAM) literature with studies on inherent curiosity (Manis & Choi, 2019). Fourth, attitude (usage attitude) refers to the use of information technologies by preservice teachers in their future teaching and is affected by their prior experiences with these technologies and their attitudes toward intention in the future (Zhou et al., 2012; Baydas & Goktas, 2016; Yildiz Durak, 2019).

Finally, cybersickness has been discussed in VR studies. Much research has proven that cybersickness cannot be avoided in VR and that it negatively impacts the intention to use (Sagnier et al., 2020) and may prevent using a particular technology again in the future (Diels & Howarth, 2013). These symptoms indicate the presence of motion sickness, but researchers have a different name to represent those symptoms (Rebenitsch & Owen, 2016); consistently, cybersickness (Sagnier et al., 2020) is used in the current research. Therefore, all dimensions that were explored were judged by experts to examine content validity and quality improvement. Then, the dimensions were analyzed to investigate possible correlations between the dimensions that led to VR intention, as shown in Figure 3.

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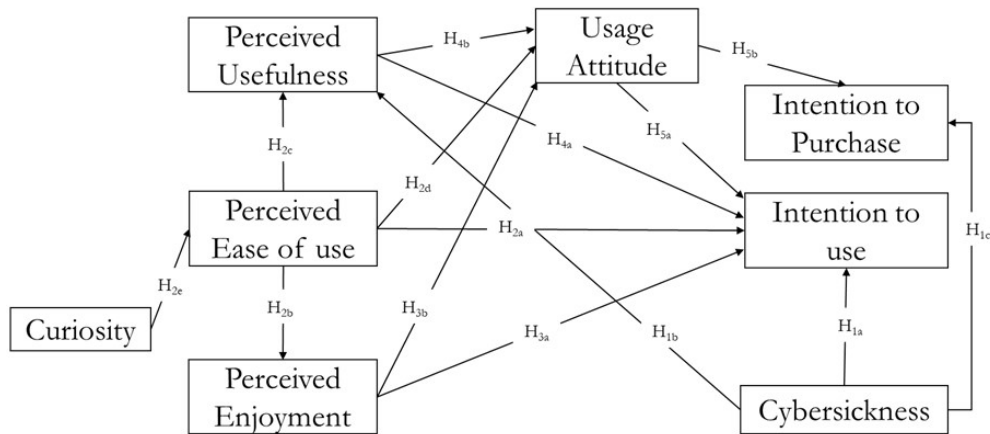


Figure 3. The Conceptual Model that Leads to the Intention to Use

Data from the TAM would be examined using the PLS-SEM approach; then, in order to support the quantitative analysis of the gathered data, thereby enhancing the rigor and comprehensiveness of the study’s findings, the additional open-ended questions performed, which adapted from Lee et al. (2019) concerning educators’ attitudes towards Virtual Reality (VR). A set of five open-ended questions was carefully crafted to elicit more elaborate responses from preservice teachers regarding their experiences (Appendix C). Subsequently, all responses to these open-ended questions were systematically collected and subjected to coding based on four overarching themes that are directly related to teachers’ acceptance of VR technology.

RESULTS AND DISCUSSION

Validity and reliability are important components of quantitative measurement (Jordan & Hoefler, 2001). The validity and reliability of the data were measured using principal component

factor loading with the varimax rotation that aims to uncover the latent structure (dimensions) of a set of variables and reduce the attribute space from a larger number of variables to a smaller number of factors (Garson, 2013). Cronbach’s alpha, composite reliability, and the average variance extracted (AVE) were also measured with the minimum value according to Fornell & Larcker (1981).

After the Kaiser-Meyer-Olkin (KMO) value reached the standard (KMO = 0.885), several tests were performed for content validity, convergent validity, and discriminant validity to assess the overall validity of the SEM approach. First, content validity was achieved using previously tested scales and standard procedures for scale adaptation (Lee et al., 2019; Manis & Choi, 2019; Sagnier et al., 2020). Second, convergent validity was assessed by calculating Cronbach’s alpha, composite reliability, and AVE values, which were greater than the minimum values (Fornell & Larcker, 1981), as presented in Table 2.

Table 2. Validity of Constructs

Construct	Items	Factor loading (≥ 0.7, min 0.5)	Cronbach’s alpha (≥0.7)	Composite reliability (≥0.7)	AVE (>0.5)
PU	PU1	0.83	0.93	0.95	0.79
	PU2	0.90			
	PU3	0.93			
	PU4	0.88			
	PU5	0.89			
PEU	PEU1	0.91	0.90	0.94	0.83
	PEU2	0.90			
	PEU5	0.93			

PE	PE1	0.94	0.95	0.97	0.88
	PE2	0.93			
	PE3	0.93			
	PE4	0.94			
IU	IU1	0.93	0.96	0.97	0.92
	IU2	0.98			
	IU3	0.97			
UA	UA1	0.93	0.91	0.94	0.84
	UA2	0.93			
	UA3	0.89			
CS	CS2	0.30*	0.87	0.88	0.40*
	CS4	0.67			
	CS5	0.51			
	CS6	0.82			
	CS8	0.47*			
	CS9	0.80			
	CS10	0.57			
	CS11	0.84			
	CS12	0.56			
	CS13	0.32*			
	CS14	0.80			
	CS15	0.60			

Note: *Exclusion

Several items with factor loadings of less than 0.5 were deleted (i.e., curiosity, intention to purchase). However, cybersickness items with validity values of less than 0.2 were deleted (i.e., CS1, CS3, CS7), while cybersickness items with factor loadings of more than 0.3 were retained (see Sagnier et al. (2020)). Cybersickness items were retained because previous studies (Israel et al., 2019; Sagnier et al., 2020) revealed that it has a significant influence on VR technology, although it has an improper scale and will be discussed in the limitation section.

Third, the first discriminant validity test was implemented with the Fornell-Larcker criterion. For satisfactory discriminant validity, the square roots of the AVE values (in bold) should be significantly higher than the off-diagonal elements in the corresponding rows and columns (Fornell & Larcker, 1981). The results of the Fornell-Larcker criterion were satisfied because the square roots of the AVE values were greater than other correlations (Appendix B1).

The second discriminant validity test was the heterotrait–monotrait (HTMT). The HTMT

ratio of correlations evaluates the average of the heterotrait–monotrait ratio, which must be below the threshold of 0.85 or 0.90 (Henseler et al., 2015). In all constructs, the HTMT correlation values in the data reach the standard (Appendix B2).

The proposed research model was tested with SmartPLS 3.3.5 (Ringle et al., 2015). A complete bootstrapping procedure with bias-corrected and accelerated (BCa) bootstrap was implemented, and 5000 subsamples were used to estimate path significance. Since the intention to purchase and curiosity were not valid, the dimensions and hypotheses related to the dimensions were excluded from the modeling.

Figure 4 shows the results of the structural model. The model explained 30.8% of the variance in perceived usefulness of VR, 71.2% of the variance in usage attitude, 64.7% of the variance in intention to use VR, and 33.9% of the variance in perceived enjoyment. If the research model reaches more than 50% of the total variance, it implies that the model has a good level of predictability and explanatory power (Chin, 1998).

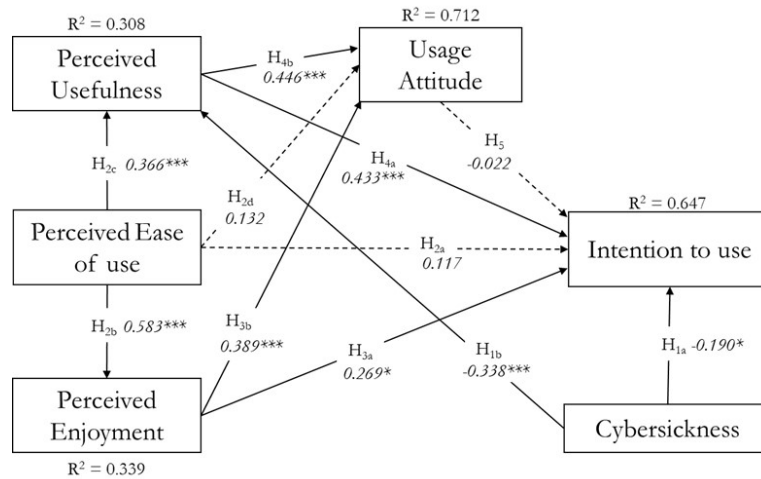


Figure 4. Results of the Structural Equation Model which Correlates the Conceptual Model that Leads to Intention to Use

Based on the R² value (also called the coefficient of determination), perceived enjoyment has a low-level prediction, where 33.9% of the variation in the output variable (i.e., perceived enjoyment) is explained by the input variable (i.e., perceived ease of use). This finding indicates that perceived ease of use does not mean preservice teachers have perceived enjoyment of VR in the

classroom (only a 0.339 possibility of having enjoyment). Regarding behavioral intention to use VR, a 64.7 % probability of true intention can be predicted by cybersickness, perceived enjoyment, and perceived usefulness. The hypotheses revealed from the structural model are presented in Table 3.

Table 3. Hypotheses Testing

Hypothesis	Path	Path coefficient	t	p-value	Supported or not
H _{1a}	CS → IU	-0.19	2.11*	0.035	Yes
H _{1b}	CS → PU	-0.34	3.27***	0.001	Yes
H _{2a}	PEU → IU	0.12	1.02	0.308	No
H _{2b}	PEU → PE	0.58	7.76***	0.000	Yes
H _{2c}	PEU → PU	0.37	3.40***	0.001	Yes
H _{2d}	PEU → UA	0.13	1.92	0.055	No
H _{3a}	PE → IU	0.27	2.35*	0.019	Yes
H _{3b}	PE → UA	0.39	4.16***	0.000	Yes
H _{4a}	PU → IU	0.43	3.86***	0.000	Yes
H _{4b}	PU → UA	0.45	5.38***	0.000	Yes
H ₅	UA → IU	-0.02	0.15	0.884	No

Note. *p < 0.05; **p < 0.01; ***p < 0.001

The results reveal that cybersickness is negatively correlated with intention to use (p = 0.035) and perceived usefulness (p = 0.001); thus, H_{1a} and H_{1b} were supported, similar to Sagnier et al. (2020). Importantly, teaching aids for students should not induce dizziness, and careful consideration of cybersickness for VR tools is necessary to promote widespread use as pedagogical tools (Detyna & Kadiri, 2020).

Perceived ease of use impacts perceived enjoyment and usefulness, similar to previous research (Manis & Choi, 2019); thus, H_{2b} and H_{2c} were supported. However, perceived ease of use does not impact usage attitude and intention to use (H_{2a} and H_{2d} were rejected), although other studies reveal a correlation with VR intention (Manis & Choi, 2019; Moreira et al., 2021). Moreover, perceived enjoyment positively correlates

with the intention to use (H_{3a}). In addition, perceived enjoyment also positively correlates with usage attitude (H_{3b}), similar to previous research (Manis & Choi, 2019; Moreira et al., 2021).

According to Davis (1989), some theories argue that beliefs influence behavior intention only via their indirect influence on attitude, while other views state that belief and attitude act as co-determinants of behavioral intention. However, in the current research, behavioral intention is apparently influenced by belief (PEU, PE, and PU) only via the indirect influence of attitude, whereas the usage attitude has no direct impact on intention to use (H_5 is rejected), although other studies indicate a co-determinant mechanism (Manis & Choi, 2019; Moreira et al., 2021). Furthermore, perceived usefulness correlates with the intention to use (H_{4a}) and usage attitude (H_{4b}) in the current research, similar to other research (Sagnier et al., 2020; Moreira et al., 2021).

After carefully analyzing the preservice teachers' responses to the open-ended questions, all narratives were systematically gathered and organized through a coding process centered on four fundamental themes that directly pertain to the acceptance of VR technology. These themes encompass the following aspects: perceived usefulness (Theme 1), perceived ease of use (Theme 2), perceived enjoyment (Theme 3), and intention to use (Theme 4).

Regarding the perceived usefulness (Theme 1) of VR in 360-degree VR (E1) and Graphics-based VR (E2), preservice teachers expressed a positive attitude toward the usefulness, as shown in the opinions of some participants (P).

"...can go through VR to places you've never been before (E1, P8); Makes people feel immersive (E1, P16).; A novel experience that brings the world into the lens (E1, P21); ... the way you operate it is also interesting (E2, P11); It's very immersive and authentic (E2, P15)."

Preservice teachers can experience places that they have never visited before (P8) and feel that they are in a virtual environment, also known as being immersed (Tomlinson et al., 2019; Tibaldi et al., 2020), as stated by P16 and P15. In addition, participants revealed that VR is a novel experience that brings the world into a lens (P21). A similar opinion is stated by Alfalah (2018): "VR is considered a novel option to add value to the learning journey" (p. 2633). Moreover, P15 also mentioned VR as an authentic experience; this observation is similar to the findings of Yang and Goh (2022), who argued VR could simulate a realistic environment where the learners could perform authentic learning activities, for exam-

le, medical, robotics, and other fields where practical knowledge and training are necessary. In addition, P11 on E2 stated that the mode of operation was interesting; it came from haptic feedback – a feature to experience the sensation of touch in the virtual world (Huang & Liao, 2017).

In terms of perceived enjoyment (Theme 2), participants experience discomfort problems, especially in 360-degree VR, as shown in the opinions of some participants.

"After watching a 10-minute video, my eyes find it difficult to focus (E1, P24); There is only a very low level of discomfort (E2, P18)."

P24 doing E1 revealed that discomfort appears after watching a 10-minute video; the future study is needed to consider the limit time for using 360-degree VR for science content to provide an optimal experience in science classes. Contrary to 360-degree VR, when experiencing graphics-based VR, participants perceived more enjoyment as shown in the opinion of some participants; only a few expressed their discomfort and said that they were slightly dizzy or had a low level of discomfort (P18).

One of the remaining weaknesses of E2 is in terms of ease of use (Theme 3), while participants in E1 thoroughly consider it to be easy, as shown by some participant's opinions.

"Although it was a little confusing at first how to use it, it was finally completed (E2, P13); The first time you use the device, you do not know much about it, and you need someone to assist you (E2, P25)."

According to previous studies, graphics-based VR devices (e.g., Meta Quest) involved complex procedures in order to be used in the classroom, similar to the opinion of P13; thus, a teaching assistant was recruited to support the participants in this experience. According to Fransson et al. (2020), some teachers even warned about a "backlash when implementing VR technology if it was too complicated to use; thus, student support and ideally two teachers in the classroom is recommended" (p. 3394). The use of assistants who helped to process the VR intervention in this study was proven to positively impact participant attitudes regarding the ease of use of VR devices (P25). This process serves as a recommendation so that either students or assistant teachers can assist educators in implementing VR in the classroom.

In terms of intention to use (Theme 4), experiencing either 360-degree VR or Graphics-based VR showed their intention to use VR in their teaching process, as shown in the opinion of some participants.

“... used in teaching students; must be very interesting (E1, P2); Novelty increases students' motivation to learn (E1, P3); It can be applied to teaching (E2, P9); Suitable for teaching (E2, P17); You can learn by doing it (E2, P20).”

Some of the participants revealed that using VR in their teaching will be very interesting (P2), it increases students' motivation to learn (P3), and it can be helpful for both teachers and learners (P8). The argument of preservice teachers is also similar to previous research that reveals that VR as a tool makes the lesson more interesting (Kamińska et al., 2019), it can promote students' motivation (Ho et al., 2019), as well as it helps both teachers and students as a visualization aid for complicated three-dimensional objects (Song & Lee, 2002). In addition, specifically in graphics-based VR, some participants stated that VR could be applied (P9) and is suitable (P17) for the teaching process. There are significant potential benefits of using VR technology to improve learning outcomes and students' motivation, overcome school-based and test anxiety, influence empathy, and ensure students focus on teaching content (Stojšić et al., 2019). A participant also stated that VR could propose “learn by doing” (P20). In addition, graphics-based VR could potentially develop into a hands-on activity and learning by doing, which cannot be developed in 360-degree VR.

The results presented in this research found that highly perceived usefulness, levels of enjoyment, and the absence of cybersickness for preservice teachers will generate more intention to use VR. This is consistent with previous research that states perceived usefulness is a key variable in the intention to use innovative devices such as VR (Sagnier et al., 2020; Moreira et al., 2021). Perceived usefulness also provides evidence to support a predictive role in the intention to adopt VR applications in education, similar to a previous study conducted in a university setting in order to quickly implement digital pedagogy applications (Moreira et al., 2021).

The current study's findings also reveal that the ease of use of VR (PEU) has no significant effect on their attitudes and intention to use VR, although other studies indicate a significant impact (Manis & Choi, 2019; Moreira et al., 2021). Two factors could explain these phenomena. First, based on the analysis, the framework of VR research conducted by other studies, such as the study of Manis and Choi (2019) using only a prior condition approach (participants past use), reveals a limitation because acceptance was only measured without defining the type of VR imple-

mented. Thus, all participants were subjected to a VR intervention with different VR devices in the current research. Second, in the current study, the differences between the two experiments (ranging from the low-end to the high-end systems to represent the current market offerings) in terms of ease of use are pretty significant, making the ease-of-use factor incapable of being used as a predictor in implementing VR in the classroom. The VR research with different VR devices (i.e., head-mounted display (HMD) and the Cave Automatic Virtual Environment (CAVE)) also reveals that perceived ease of use does not correlate with the intention to use (Sagnier et al., 2020).

Furthermore, the current finding reveals that attitude does not have a mediational effect between belief (PU, PEU, and PE) to Intention. David (1989) shows that attitude is a mediation factor in which if technology objectively improves performance and users do not perceive it as useful, they are unlikely to use it. It is further supported by Walker et al. (2020). Usage attitude can be defined as the user's positive or negative response towards the usage of technology (Walker et al., 2020). However, Davis (1989) also warns that attitude does not fully have an immediate effect on perceived usefulness and ease of use on behavior intention (e.g., intention to use). Thus, research finding on attitude may have various conclusions.

Moreover, in order to understand the “attitude” as the mediation effect, Yang and Yoo (2004) differentiated attitude into two different dimensions: Cognitive attitude and Affective attitude. They found that Cognitive attitudes significantly mediate the relationship between belief (PU, PEU, and PE) to Intention, but Affective attitudes do not mediate such a relationship. It is essential to recognize that Affective and Cognitive attitudes are separate socio-psychological constructs. Affective attitude is an attitude regarding their technological perception of happiness/annoyance, positive/negative, and good/bad, while cognitive attitude examines the perception of wise/foolish, beneficial/harmful, and valuable/worthless (Yang & Yoo, 2004). Therefore, this differentiation between cognitive and affective attitudes highlights the nuanced nature of individuals' perceptions when evaluating technology, providing a valuable framework for understanding its role in shaping intentions and behaviors to implement such technology in the classroom.

The cybersickness questionnaire in this research is the same as that used in previous research, which does not yet show an appropriate scale to put in the same dimension as belief and

behavioral intention (Sagnier et al., 2020), although its major influence on the use of VR as revealed by Israel et al. (2019), LaViola Jr (2000), and Servotte et al. (2020). Future research is needed to identify alternative procedures for measuring cybersickness, for example, using brain waves that can be measured using an electroencephalogram (EEG) and providing empirical data on which part of VR content can trigger cybersickness.

This research constitutes a comprehensive investigation into the potential implications of Virtual Reality (VR) within the classroom, with a specific focus on future teachers and their behavioral intentions toward integrating VR technology. Prior research in the realm of VR adoption has predominantly concentrated on its application in particular domains, such as VR for manufacturing processes (Yang & Han, 2021) and VR for specialized training, like flight training (Fussell & Truong, 2021). However, there has been a notable absence of studies that have evaluated acceptance models among preservice and in-service educators, who bear the responsibility of incorporating technology into the educational environment.

Furthermore, the analysis of the open-ended answers also supports the results regarding the factors influencing the implementation of VR, as well as contributes to an understanding of the didactic and pedagogical advantages of incorporating this technology in the classroom. Participants argue that VR is useful in educational contexts, including being immersed in experience (Tomlinson et al., 2019; Tibaldi et al., 2020), engaging in authentic learning (Yang & Goh, 2022), as well as a novel experience that can add value to the learning journey (Alfalah, 2018). In addition, participants proposed that VR could propose “learn by doing” in which graphics-based VR could potentially develop hands-on activity and learning by doing. Radianti et al. (2020) also revealed that the true potential of VR did not lie in better teaching declarative knowledge but in offering opportunities to “learn by doing,” which is often very difficult to implement in traditional lectures (p. 23).

CONCLUSION

The proposed model has strong explanatory power in predicting the intention to use VR in the classroom ($R^2=64.7\%$). The intention to use VR in the classroom is influenced by perceived usefulness, perceived enjoyment, and the absence of cybersickness. It also indicates that Usage Attitude (UA), which pertains to participants' po-

sitive or negative response towards technological usage, does not mediate the relationship between beliefs (PU, PEU, and PE) and Behavioral Intention (IU). Additionally, the findings from the preservice teachers' responses support the notion that they believe VR is valuable in educational contexts, enabling immersive experiences, authentic learning, and enhancing the learning journey, along with the concept of learning by doing.

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