Technology, Pedagogy and Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rtpe20

An extended technology acceptance model on immersive virtual reality use with primary school students

Rafael Villena-Taranilla, Ramón Cózar-Gutiérrez, José Antonio González-Calero & Pascual D. Diago

To cite this article: Rafael Villena-Taranilla, Ramón Cózar-Gutiérrez, José Antonio González-Calero & Pascual D. Diago (2023) An extended technology acceptance model on immersive virtual reality use with primary school students, Technology, Pedagogy and Education, 32:3, 367-388, DOI: 10.1080/1475939X.2023.2196281

To link to this article: https://doi.org/10.1080/1475939X.2023.2196281

Published online: 05 Apr 2023.

TECHNOLOGY, PEDAGOGY AND EDUCATION
2023, VOL. 32, NO. 3, 367–388
https://doi.org/10.1080/1475939X.2023.2196281

Routledge
Taylor & Francis Group

An extended technology acceptance model on immersive virtual reality use with primary school students

Rafael Villena-Taranilla [a], Ramón Cózar-Gutiérrez [b], José Antonio González-Calero [b] and Pascual D. Diago [c]

[a]LabinTic Lab of Technology Integration in Classrooms, San Cristóbal School, Albacete, Spain; [b]LabinTic Lab of Technology Integration in Classrooms, Faculty of Education, University of Castilla-La Mancha, Albacete, Spain; [c]Department of Teaching Mathematics, University of Valencia, Valencia, Spain

ABSTRACT
Virtual Reality (VR) is an emerging technology with an increasing number of studies assessing its benefits in educational settings. However, there is a shortage of empirical studies aimed at evaluating the acceptance of this technology in primary education. The authors propose an extended version of the Technological Acceptance Model to examine students' intention to use immersive VR. To this end, 111 fourth-graders completed a history teaching unit using immersive VR. Structural equation modelling was employed to assess causal relationships between six variables: prior knowledge, perceived attention, perceived utility, perceived ease of use, perceived enjoyment and attitude towards the use of immersive VR. The results indicate that students' prior knowledge was not significant in explaining their intention to use immersive VR. However, perceived attention had a significant effect on this variable mediated through perceived utility. These results have important implications regarding the design and use of VR tools for educational purposes.

ARTICLE HISTORY
Received 30 April 2021
Accepted 22 August 2022

KEYWORDS
Virtual reality; primary education; history teaching; technology acceptance model

1. Introduction

In recent years, research into the teaching of Social Sciences has highlighted the need to transform traditional teaching practices, characterised by the predominance of textbooks, lectures, memorisation, examinations and low motivation (Carretero, 2005; Gómez-Carrasco & Miralles-Martínez, 2017). In this process, it is fundamental to incorporate active learning methodologies based on inquiry, the use of sources or the integration of technology, in line with the changes that are happening in our society and that require new teaching strategies and new purposes. These help build a citizenry with a critical spirit and awareness of belonging to a broad and multicultural world (Gómez Carrasco et al., 2020).

Social Sciences have become one of the subjects in which there is a greater degree of students' disinterest or rejection, partly because it is one of the disciplines that pose considerable difficulties of assimilation and understanding, caused by inadequate teaching of sufficiently complex content (Liceras, 2000), the excessive use of lower-order thinking activities based on memorisation and repetition of content (VanSledright, 2011) and instructional media that lead to the subject perceived as boring and unhelpful, which leads to poor academic performance (Carretero & Voss, 2004). In this regard, Barton and Levstik (2004) stated that no one likes the way in which Social Sciences are

CONTACT Ramón Cózar-Gutiérrez ramon.cozar@uclm.es LabinTic. Lab of Technology Integration in Classrooms, Faculty of Education, University of Castilla-La Mancha, Albacete, Spain

currently taught in schools; researchers criticise teachers for their teaching methods, teachers generally blame students for their apathy, and the students see the textbooks as boring.

Pagès (2009) pointed out that another problem faced by the teaching of Social Sciences is that it has very little impact on the formation of young people who have a lot of information at their disposal. This phenomenon, together with the predominance of insufficiently participative teaching methods, clashes with the new possibilities that arise with the integration of information and communications technology (ICT). In this way, an adequate use of ICT in classrooms aimed not only at facilitating knowledge but also at guaranteeing its understanding, can promote the methodological change that students demand (Miralles et al., 2019).

In the last decade, research on the teaching of Social Sciences, as in other fields, has insisted on the need to integrate technology into the classroom (Miralles et al., 2013, 2019). Technological advances in recent years offer new learning environments that make it possible to promote educational proposals to work on heritage in Social Sciences classrooms through technology, as well as new approaches and methodologies with which we can interact, to extend global accessibility to heritage environments and the knowledge of culture to a larger part of the population (Ibañez-Etxeberria et al., 2020). In this sense, virtualisation is having a great impact on history education, thanks to the increasing number of video games and digital applications that reconstruct distant or unconserved historical sites and monuments through 3D recreations, which facilitate learning processes (Ibáñez-Etxeberria et al., 2019; Rivero & Feliu, 2017; Vicent et al., 2015).

1.1. Virtual learning environments

Virtual Reality (VR) has aroused great interest and fascination in the educational field (Brown et al., 2020), owing to its possibilities to emulate reality and evoke sensations, emotions and behaviours very similar to those experienced in our daily lives, through an increasingly affordable and user-friendly tool (Gaitatzes et al., 2001; Wiederhold & Bouchard, 2014; Yildirim et al., 2018). Ye (2016) defined VR as a new type of interaction between user and computer, in which users interact in an immersive experience. El-Tamini et al. (2017) specified that it is a technology mainly focused on the creation and manipulation of three-dimensional and immersive computer-made worlds. Similarly, Grotzer et al. (2015) specified that it is a 3-D graphic world that allows immersive experiences where participants have the opportunity to move around interacting with digital objects and tools in that fictitious world.

Based on these defined characteristics, there are different possibilities for using VR depending on the degrees of immersion that the system offers. Di Natale et al. (2020) recognised three levels: a non-immersive virtual reality system, also called desktop VR system or 3D virtual worlds; semi-immersive virtual reality systems, such as fulldome systems, embodied mixed reality learning environments or Smart Glasses; and immersive virtual reality systems, which generate environments that perceptually envelop users, among which cardboard, head-mounted displays and the cave automatic virtual environment stand out, which are much more complex and less widespread.

Despite the fact that VR has existed in the educational field for more than half a century (Kavanagh et al., 2017), in recent years its rapid technological development and the reduction in cost have allowed it to extend its access to formal educational contexts and, in turn, have generated numerous publications of scientific literature on the subject. As early as 1994, Hedberg and Alexander (1994) claimed that these immersive environments presented great potential by offering a superior learning experience, with greater fidelity and active participation of the students. Currently, we have a good number of meta-analyses (Lee, 1999; Merchant et al., 2014; Sitzmann, 2011; Vogel et al., 2006) and systematic reviews (Di Natale et al., 2020; Hew & Cheung, 2010; Jensen & Konradsen, 2018; Kavanagh et al., 2017; Mantziou et al., 2018; Pellas et al., 2021; Potkonjak et al., 2016; Scott et al., 2017) that corroborate the growth in interest in this technology.

Undoubtedly, what is making VR so popular in such a short time in education are its immersive, interactive and imaginative features (Burdea & Coiffet, 2003; Gavish et al., 2015). Several authors have emphasised the importance of immersion and considered it the aspect that makes the difference among the multiplicity of existing technological tools (Kalyvioti & Mikropoulos, 2014; Mikropoulos & Strouboulis, 2004; Webster, 2016), giving it great potential and relevance in the educational field (Jensen & Konradsen, 2018). Dede (2012) stated that, in these enveloping and immersive experiences, users actively participate with digital objects and tools within a virtual physical environment in which active research is encouraged, facilitating active observation and metacognitive learning processes.

Another of the key concepts of VR is presence (Jensen & Konradsen, 2018). Immersive VR also offers students a variety of situated learning experiences, greater than those provided in traditional classroom settings (Huang et al., 2010), creating a strong sense of presence and leading to positive impacts on their learning with increases in attention, level of commitment, participation and motivation (Lee et al., 2010; Salzman et al., 1999), as well as on students' cognitive processes in which better memorisation of key objectives and concepts takes place (Bailenson et al., 2008). In two systematic reviews of the literature, Mikropoulos and Natsis (2011) and Freina and Ott (2015) confirmed that the sense of presence plays an important role in learning, as well as the possibility of giving the student access to situations that would otherwise not be available, either because they are inaccessible (in time or space) or because of other problems (danger, lack of ethics etc.). Along the same lines, Blascovich et al. (2002) and Kilmon et al. (2010) pointed out that VR allows students to be immersed in controlled simulated environments, without any of the interferences that can interrupt learning in a classroom.

Therefore, VR applications impact anyone who uses them (Ludlow, 2015). Educators and institutions foresee great potential in the use of games, applications, platforms and devices based on virtual environments for teaching and learning at all educational levels since they offer the possibility of enriching student participation (Dalgarno & Lee, 2010; Molina-Carmona et al., 2018). Furthermore, VR can be employed regardless of the school subject. The reviews by Pellas et al. (2021) and Di Natale et al. (2020), for example, evidenced that VR has been used in K–12 disciplines such as environmental science, biology, geology, geography, technology, mathematics, history, English language learning or music, among others.

From a particular point of view, history education presents favourable conditions to benefit from this technology. It allows students to be brought closer to digital settings or spaces to which they would hardly have access (Fontal & Ibañez, 2017). Historical places can be visited, with students analysing their structure and characteristics in the first person, freely exploring the virtual environment, thus making teaching a more effective study environment (Yildirim et al., 2018). For example, VR allows students to access the most representative sites and buildings of the Hellenic world (Gaitatzes et al., 2001); to visit a Byzantine Basilica church (Getchell et al., 2009) or a medieval cathedral (St. Andrews, fourteenth century) so as to learn concepts related to archaeology and heritage (Fabola & Miller, 2016); to learn about history and ways of life in a Spanish city of the sixteenth century, by playing in the streets; or to delve into the military attack on Pearl Harbor in World War II to find out its effects on the US entry into the war and the subsequent economic depression (Cheng & Tsai, 2019).

VR provides unprecedented access to any real or reconstructed space, avoiding displacements and providing more availability that allows a greater approach, from anywhere and at any time of the day (Redondo, 2012). In this sense, Delgado-Algarra (2020) emphasised that VR technology can become a powerful tool to reconstruct the past, and that history education and heritage education can be greatly enriched with the use of these immersive virtual environments since it allows students to access how some pieces, heritage buildings or contexts were in the past. In summary, VR is an emerging technology prepared to produce a change in educational environments, owing, among others, to its immersive and interactive features. Although it has been documented that most of the research has been developed on secondary and tertiary education, with few studies on younger or lower-level students (Di Natale et al., 2020; Freina & Ott, 2015), in recent years, different literature reviews (Maas & Hughes, 2020; Tilhou et al., 2020) and meta-analyses (Villena-Taranilla, Tirado-

Olivares et al., 2022) have underlined the benefits of using VR at elementary levels. In the same way, studies have been mainly focused on analysing applications, motivations and problems in educational contexts, but not much is known about users' acceptance of this technology in the classroom (Abd Majid & Mohd Shamsudin, 2019).

1.2. Technology Acceptance Model (TAM)

At present, there are various theoretical models aimed at assessing the users' acceptance and their behaviour when using a technology (Venkatesh et al., 2003). Among all of them, the Technological Acceptance Model (TAM) (Davis, 1989) stands out for its wide application to different technologies and educational levels. Based on the Theory of Reasoned Action (Fishbein & Ajzen, 1975) and the Theory of Planned Behavior (Ajzen, 1991), the model proposes that two variables – perceived utility and ease of use – determine the accepting attitudes and behaviours of individuals towards technology and, consequently, their intention to use it. Davis (1989) defined perceived usefulness as 'the degree to which a person believes that using a particular system would enhance his or her job performance' (p. 320), and perceived ease of use as 'the degree to which a person believes that using a particular system would be free of effort' (p. 320). Therefore, the TAM assumes that the behavioural intention to use a technology is determined by the attitude towards using it, which in turn is affected by the perceived usefulness and perceived ease of use. Consequently, perceived usefulness and ease of use become the two main predictors of individual acceptance and effective use of technology (Padilla-Meléndez et al., 2013). Furthermore, perceived ease of use is hypothesised to be a predictor of perceived usefulness, and perceived usefulness has a direct effect on the behavioural intention to use (Liu et al., 2009).

In recent years, TAM has evolved to be adapted to new technologies, contexts and users. In 2013, Marangunić and Granić (2015) published a literature review analysing studies that, on the one hand, try to offer new knowledge related to TAM variables, while, on the other hand, developing and/or expanding it with new versions of the model. These new models aim to capture additional factors and to increase the predictive power of the original model and expand its applicability to specific technologies. One of these adaptations incorporated into the model the variable perceived enjoyment, as an intrinsic motivational element that can play an important role in the users' acceptance of technology (Davis et al., 1992). Venkatesh (2000) defined perceived enjoyment as 'the extent to which the activity of using a specific system perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use' (p. 351). Perceived enjoyment has been used successfully as a predictor of perceived usefulness, perceived ease of use and behavioural intention to use technology (e.g. Teo & Noyes, 2011; Wojciechowski & Cellary, 2013).

The TAM model has evolved over the years, although it still maintains the design and variables identified in its first formulation at its core, which has been a great advantage for its application (Cabero & Pérez, 2018). In fact, numerous studies have used TAM to predict the acceptance of different technologies such as e-learning (Al-Gahtani, 2016; Cabero et al., 2018; Chen & Tseng, 2012; Mohammadi, 2015; Park, 2009; Tarhini et al., 2014; Zhu et al., 2020), blended learning scenarios (Padilla-Meléndez et al., 2013), mobile learning (Adov et al., 2020; Chang et al., 2012; Islamoglu et al., 2021), open education resources (Kelly, 2014), virtual learning environments (Yim et al., 2019), learning management systems (Alharbi & Drew, 2014; Cheng & Yuen, 2019; Sanchez-Franco, 2010; Schoonenboom, 2014; Teo et al., 2019), library web portals (Chen & Chengalur, 2015), e-portfolio systems (Shroff et al., 2011), applications for collaborative learning (Chen, 2019; Cheung & Vogel, 2013), digital game-based learning (Chen & Lin, 2016; Cheng et al., 2013), augmented reality (Cabero & Pérez, 2018; Wojciechowski & Cellary, 2013) and mobile applications (Chen et al., 2013), among others. TAM has also been used to predict VR acceptance by users (Sagnier et al., 2020).

In addition, different extensions of the model have been proposed, including variables that could also indirectly affect behaviour intention to use through their direct influence on perceived usefulness and perceived ease of use (Armenteros et al., 2013). These variables may include dimensions of other related models (e.g. subjective norm, perceived behavioural control, self-efficacy), additional belief factors (e.g. triability, visibility, content richness) and other external variables (e.g. gender, age, experience, educational background, computer self-efficacy) (Sagnier et al., 2020).

In our study, primary school students used an immersive virtual reality system through head-mounted displays, which allowed them to immerse themselves in an ancient historical Roman city. Specifically, the VR system showed students 3D virtual recreations of historical cities and buildings. A prior piece of research found evidence to support the potential of this experience for the teaching of history in terms of students' performance and motivation (Villena-Taranilla, Cózar-Gutiérrez, et al., 2022). In this study, we present an extended model incorporating students' prior knowledge and attention as external variables to evaluate primary school students' intention to use VR. In the first place, students' prior knowledge of the subject has been identified as an important factor influencing students' learning (e.g. Dochy et al., 1999; Li, 2019), as it may allow students to achieve greater motivation, understanding and learning performance (Lin et al., 2011). Similarly, prior knowledge affects the way teachers and students interact with learning materials (Moos & Azevedo, 2008). Along these lines, some studies have shown that students with a higher level of prior knowledge have a more positive attitude towards certain teaching materials, such as video lectures (Li, 2019) or learning systems (Chen & Huang, 2013). Although some studies have investigated how students' prior knowledge can be related to their participation and performance in technology-mediated learning environments (e.g. Chang et al., 2020), to the best of our knowledge, there are no previous studies that take into account whether prior knowledge can have an effect in the intention to use a technology. In our case, we think that a valuable contribution to the field may arise from an analysis of the eventual role that prior knowledge of the subject could play to predict the intention to use VR. In this study, prior knowledge of the subject refers to what the student knows before the teaching unit about the historical contents addressed in that unit. Regarding the other external variable, attention has been incorporated as it is considered an additional motivational factor that can improve the predictive power of TAM, as it is an indirect measure of the ability of the tool to capture attention and its influence on the intention of use. According to Keller (1987, 2010), attention is a motivational element that includes human characteristics – such as curiosity and humour – and also a prerequisite for learning. Attention usually occurs when the student perceives a gap between their present knowledge and that which she/he is trying to acquire. In this sense, this study tries to respond to a demand established by different authors, who highlight the need to incorporate other variables and motivational theories in specific studies to improve TAM (Sanchez-Franco, 2010). In fact, some studies already support the potential of this variable (perceived attention) to directly and positively influence students' attitudes towards using educational technology. Thus, for example, Galbis-Córdoba et al. (2017) found that those students who consider that online educational video games draw their attention show a more positive attitude towards using these educational video games. Similarly, another study with university students revealed that the ability of an augmented reality book to hold students' attention played a role in their behavioural intentions to adopt this technology in the future (Cheng, 2017). In this context, we consider that, in the same way, students' perceived attention may be a variable worth considering when determining students' intention to use VR technologies. In particular, this study aims to evaluate the intention to use immersive VR among primary school students with TAM as the research framework. This work may contribute to the field of TAM research by empirically assessing the TAM model in a compulsory educational setting (elementary school) and extending it by including two new variables external to the model: students' prior knowledge and perceived attention.

2. Materials and methods

2.1. Participants

Participants were 111 fourth-grade students (9–10 years old) from two state-owned schools and one privately owned, but state-funded school in the region of Castilla-La Mancha (Spain). Among the participants, 59 (53.15%) were male while 52 were female (46.85%). Informed consent was obtained for all cases, and all ethical requirements were observed during the study. The experiment was conducted with fourth-grade students because, after a revision of the regional curriculum for this year, some learning standards related to heritage education were identified. In particular, these assessable learning standards were: '1.2. S/he respects the historical remains and values them as a heritage that we must bequeath', and '14.7. S/he describes some artistic and cultural manifestations of the different periods of history studied'.

2.2. Research design and data collection

A structural equation modelling approach was employed to develop a research model that represents the relationships among six variables: prior knowledge (PK), perceived attention (PA), perceived usefulness (PU), perceived ease of use (PEU), perceived enjoyment (PE) and behavioural intention towards the VR use (BI). Different instruments were used to collect participants' responses to each of the constructs defined in Figure 1.

The experimental phase consisted of three sessions. In the first session, all the participants completed a test aimed at measuring their prior knowledge of historical contents. These contents were related to the unit of work 'The Roman Civilisation', and the test consisted of tasks similar to those included in exams for this unit from different textbooks.

The second session consisted of a regular lesson on the subject of social sciences, in which parts of the unit of work 'The Roman Civilisation' were explained. The session lasted 45 minutes and was based on the study of the archaeological ensemble of Augusta Emerita, one of the biggest and most important in Spain, which introduces students to some relevant Roman buildings, such as the theatre, the circus, the aqueduct, the amphitheatre, the forums, the walls or the roads, among others. The session started with a short explanation of the functioning of the VR device that the pupils were about to use, VR glasses, the *Netway Vita* model, with an incorporated processor and a 5.5-inch screen. In the lesson, the students used the app VirTimePlace, which offers a catalogue of 3D virtual recreations of complete cities and buildings. In particular, participants visited the virtual reconstruction of the Roman Augusta Emerita, so that they can observe different examples of the most representative types of houses and buildings on their virtual walk tour around the city (see Figure 2).

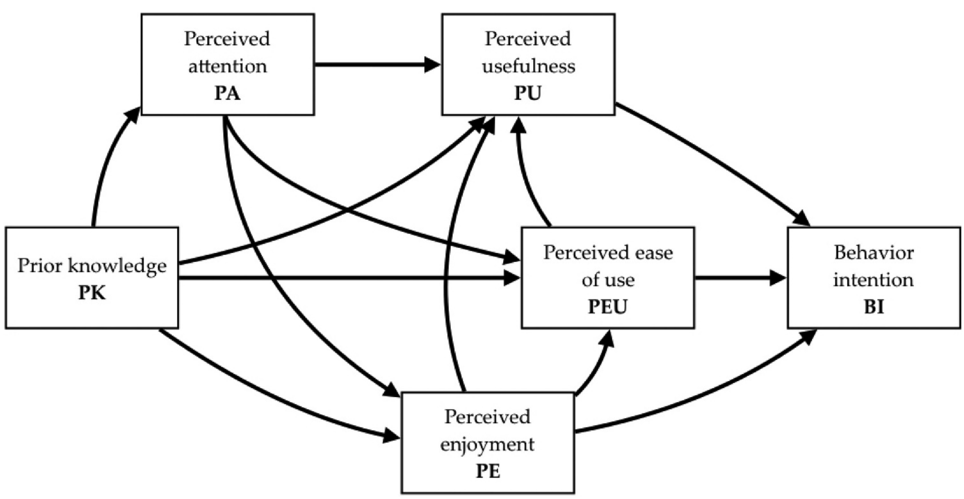

Figure 1. Proposed research model.

Figure 2. Examples of the virtual recreation of the app. Source: images from the app VirTimepPlace.

Finally, in the last session, all the students were administered two questionnaires to measure the rest of the variables of the model: perceived attention, perceived usefulness, perceived ease of use, perceived enjoyment and behavioural intention towards immersive VR use.

2.3. Instrument and measures

As previously mentioned, data were gathered through a test and two questionnaires to elicit participants' responses to multiple items related to each of the constructs included in the research model. The construct prior knowledge was measured through the participants' score on an ad hoc test designed to measure curricular learning in the subject of social sciences in the fourth year of primary education.

Concerning the rest of the variables, two multiple-item questionnaires were employed. The first survey consisted of 15 items from the validated instrument of analysis of the Technology Acceptance Model (TAM; Davis, 1989) on augmented reality (Cabero & Pérez, 2018). In this survey, the items were addressed to assess perceived usefulness (PU, four items), perceived ease of use (PEU, three items), perceived enjoyment (PE, three items) and behavioural intention towards immersive VR use (BI, four items). Each statement was measured on a 7-point Likert scale (1 = *strongly disagree*, to 7 = *strongly agree*). In this study, the second survey was employed to measure participants' perceived attention (PA) to the immersive VR tool. To this end, three items were used from the validated ARCS-based Instructional Materials Motivation Survey (IMMS; Keller, 2010), aimed at measuring perceived attention to self-directed instructional materials. These items were measured using a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). All the items used are listed in Table 1.

2.4. Hypotheses

On the basis of the research model, the following hypotheses were formulated (Figure 3 contains a diagram based on these hypotheses):

- H_{01}: Prior knowledge (PK) will have a significant influence on perceived attention (PA) towards immersive VR.
- H_{02}: Prior knowledge (PK) will have a significant influence on perceived enjoyment (PE).
- H_{03}: Prior knowledge (PK) will have a significant influence on perceived ease of use (PEU).
- H_{04}: Prior knowledge (PK) will have a significant influence on perceived usefulness (PU).
- H_{05}: Perceived attention (PA) will have a significant influence on perceived usefulness (PU).
- H_{06}: Perceived attention (PA) will have a significant influence on perceived ease of use (PEU).
- H_{07}: Perceived attention (PA) will have a significant influence on perceived enjoyment (PE).
- H_{08}: Perceived usefulness (PU) will have a significant influence on behavioural intention towards immersive VR use (BI).

Table 1. List of constructs and corresponding items.

Construct	Item	
Perceived usefulness (PU, adapted from Cabero & Pérez, 2018)	PU_{01}	Using the VR system will improve my learning and achievement in this subject.
	PU_{02}	Using the VR system during classes would facilitate my comprehension of certain concepts.
	PU_{03}	I think that the VR system is helpful when learning.
	PU_{04}	Using virtual reality will enhance my achievement.
Perceived ease of use (PEU, adapted from Cabero & Pérez, 2018)	PEU_{05}	I find virtual reality easy to use.
	PEU_{06}	Learning how to use the VR system is not a problem for me.
	PEU_{07}	Learning how to use VR system is clear and understandable.
Perceived enjoyment (PE, adapted from Cabero & Pérez, 2018)	PE_{08}	Using the VR system is fun.
	PE_{09}	I enjoyed using the VR system.
	PE_{10}	I think that the VR system allows playing while learning.
Behaviour intention towards VR use (BI, adapted from the intention to use – IU – and attitudes towards use – AU – from TAM (Cabero & Pérez, 2018)	BI_{11}	The use of the VR system makes learning more interesting.
	BI_{12}	I got bored while using the VR system.
	BI_{13}	I think that the use of the VR system in the classroom is a good idea.
	BI_{14}	I would like to use the VR system in the future if I have the opportunity.
	BI_{15}	I would like to use the VR system to learn Social Sciences as well as other subjects.
Perceived attention (PA, adapted from ARCS, IMMS, Keller, 2010)	PA_{16}	The quality of the activities helps me to maintain the attention.
	PA_{17}	The variety of activities helps keep my attention in the class.
	PA_{18}	The way in which information is organised helps me to maintain attention.

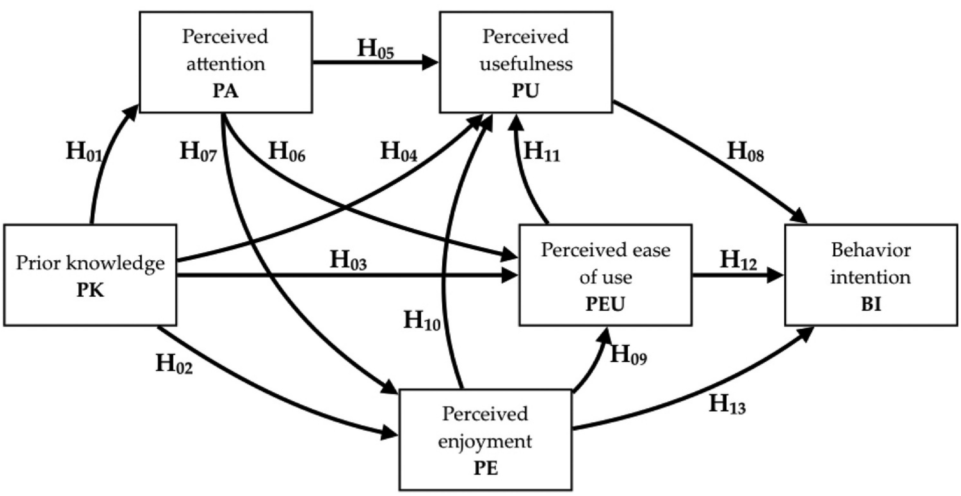

Figure 3. Proposed hypotheses for the research model.

- H_{09}: Perceived enjoyment (PE) will have a significant influence on perceived ease of use (PEU).
- H_{10}: Perceived enjoyment (PE) will have a significant influence on perceived usefulness (PU).
- H_{11}: Perceived ease of use (PEU) will have a significant influence on perceived usefulness (PU).
- H_{12}: Perceived ease of use (PEU) will have a significant influence on behavioural intention towards immersive VR use (BI).
- H_{13}: Perceived enjoyment (PE) will have a significant influence on behavioural intention towards immersive VR use (BI).

3. Results

The analysis and statistical interpretation of the research model comprised three stages. In the first stage, we performed exploratory factor analysis (EFA) in order to identify clusters of measured variables that relate to each other. The EFA allowed us to confirm that the data fit into the five constructs defined in the research model. The second stage was devoted to reporting the descriptive statistics, reliability, convergent validity and discriminant validity of the measured items, according to the research model presented. Finally, in the third stage, we tested the assessment of the structural model by means of structural equation modelling (SEM). This sequence ensures that we have valid and reliable measures of constructs before attempting to draw conclusions regarding our hypotheses and based on the relations among the constructs.

3.1. Exploratory factor analysis

In order to confirm the research model and understand the structure of the measured items we performed an exploratory factor analysis (EFA). A principal components analysis (PCA) was conducted on the 18 items with orthogonal rotation (varimax). Oblique rotation (oblimin) demonstrated a negligible correlation structure between items from different extracted factors; thus, the original orthogonal solution was reasonable (Pedhazur & Schmelkin, 1991). An initial Kaiser-Meyer-Olkin (KMO) test on the overall dataset indicates that the item BI_{12} does not fulfil the Kaiser (1974) criterion (MSA = 0.41). Consequently, this item was removed from the dataset, and the 17 remaining variables verified the sampling adequacy for the analysis (KMO = .74, considered good according to Kaiser (1974)), and all KMO values for individual items were larger than .56, which is above the acceptable limit of .5. Bartlett's test of sphericity ($x^2(136) = 541$, $p < .001$) indicated that correlations between items were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for each component in the data. Consistently with the proposed research model, five components had eigenvalues over Kaiser's criterion of 1 and, in combination, explained 60.9% of the variance. In addition, the scree plot showed a point of inflexion that justified retaining five components. Given the sample size, and the convergence of the scree plot and Kaiser's criterion, five components were retained in the final analysis. Table 2 shows the factor loadings after orthogonal rotation. The items that cluster on the same component (depicted in bold) suggest that construct 1 represents attention to the instructional material (PA), construct 2 perceived enjoyment (PE), construct 3 perceived usefulness (PU), construct 4 perceived ease of use (PEU) and construct 5 behavioural intention towards immersive VR use (BI).

After identifying the factor structure, we rearranged the measured variables in the described five constructs. We retained those items whose factor loading was greater than .55, following the criterion suggested by Stevens (2002), who established a minimum value of .512 for sample sizes around 100 subjects. Consequently, items PU_{01}, BI_{11} and BI_{15} were eliminated from further analysis, and the other items were retained.

Table 2. Principal components analysis from the 18 initial items.

Item	Perceived attention (A)	Perceived enjoyment (PE)	Perceived usefulness (PU)	Perceived ease of use (PEU)	Behavioural intention (BI)
PA_{16}	**.76**	.10	.30	.05	.14
PA_{17}	**.73**	.10	.07	.31	.17
PA_{18}	**.67**	-.12	.38	-.08	-.08
PU_1	.54	.32	.08	.10	.25
PE_8	.16	**.85**	-.02	.10	.25
PE_{10}	.07	**.80**	.11	-.09	.06
PE_9	-.08	**.60**	.26	.22	.25
PU_3	.19	.02	**.79**	.12	.13
PU_4	.26	.21	**.69**	.69	.19
PU_2	.13	.44	**.57**	.14	.08
BI_{11}	.36	.02	.44	-.19	.06
PEU_5	-.11	-.06	.27	**.73**	.02
PEU_7	.21	.25	.08	**.72**	.16
PEU_6	.12	.02	-.08	**.68**	-.016
BI_{14}	.05	.06	.10	.01	**.84**
BI_{13}	.19	-.01	.22	-.04	**.71**
BI_{15}	.34	.36	-.30	-.07	.44
Eigenvalues	2.36	2.30	2.17	1.80	1.72
% of variance	13.9	13.5	12.7	10.6	10.1

3.2. Statistical analysis of the measurement model

3.2.1. Descriptive statistics

Descriptive statistics for each construct item are shown in Table 3. All means were greater than 3.0 for the 5-point scale (construct PA) and greater than 4 for the 7-point Likert scales (rest of constructs). This indicates an overall positive response to the constructs that are measured in this study. The standard deviations for all variables were less than one for three of the five constructs, indicating that the item scores were relatively close to the mean scores. The skewness ranged from -3.70 to -1.23, and the kurtosis ranged from 1.52 to 17.11. Following Kline's (2010) suggestion that the skew and kurtosis indices should be below 3.0 and 10.0, respectively, there were no severe problems in the data, and the data were considered normal for all the variables except for perceived enjoyment. In this case, greater values on kurtosis and skewness on the PE construct were a reflection of the generally high scores given by the students on the enjoyment they derived from the use of immersive VR.

3.2.2. Reliability and convergent validity

Following recommendations from Fornell and Larcker (1981), three analyses were performed in order to check the reliability and convergent validity of this study. In the first place, reliability at item level was assessed by its factor loading onto the underlying construct by means of the PCA. As depicted in Table 2, all items considered in our analysis ranged from .55 to .85, demonstrating convergent validity at the item level.

Secondly, we checked the reliability of each construct. The convergent validity for the proposed model is supported by the reliability of each construct, measured by means of Cronbach's α. As

Table 3. Descriptive statistics.

Construct	Mean	Standard deviation	Skewness	Kurtosis
PA	4.40	.70	-1.77	3.66
PE	6.65	.69	-3.70	17.11
PU	6.05	1.06	-1.80	3.11
PEU	5.81	1.22	-1.23	1.52
BI	6.57	.75	-2.65	8.98

Table 4. Results for the research model on convergent validity and reliability.

Latent variable	Item	Factor loading (>.55)*	AVE extracted	Cronbach's α
Perceived attention (PA)			.52	.72
	PA_{16}	.76		
	PA_{17}	.73		
	PA_{15}	.67		
Perceived enjoyment (PE)			.75	.70
	PE_8	.85		
	PE_{10}	.80		
	PE_9	.60		
Perceived usefulness (PU)			.68	.74
	PU_3	.79		
	PU_4	.69		
	PU_2	.57		
Perceived ease of use (PEU)			.71	.58
	PEU_5	.73		
	PEU_7	.72		
	PEU_6	.78		
Behavioural intention towards immersive VR (BI)			.78	.61
	BI_{14}	.84		
	BI_{13}	.71		

*Acceptable level of reliability derived from Stevens (2002).

reported in Table 4, the perceived attention (PA), perceived enjoyment (PE) and perceived usefulness (PU) subscales all had high reliabilities, all Cronbach's $\alpha > .7$. However, the perceived ease of use (PEU) and behavioural intention towards immersive VR use (BI) subscales had relatively low reliability, Cronbach's $\alpha \sim .6$. Although a value of .70 or higher is recommended for composite reliability to be adequate (Nunnally & Bernstein, 1994), Cortina (1993) suggested that for samples with more than 12 fairly correlated items, $\alpha \sim .6$ can also be considered acceptable.

Finally, we performed the third convergent validity analysis by measuring the overall amount of variance attributed to each construct in relation to the amount of variance attributable to measurement error. Table 4 shows the average variance extracted (AVE) for each latent variable. AVE is computed by adding the squared factor loadings divided by number of factors of the underlying construct. As stated by Segars (1997), convergent validity is judged to be adequate when the AVE equals or exceeds .50. The extracted AVE values support the convergent validity of the five proposed constructs.

3.2.3. Discriminant validity

The assessment of discriminant validity was addressed at two levels. Firstly, at the constructs level we examined the correlations between constructs. As stated by Fornell et al. (1982), discriminant validity is satisfied if the square root of the AVE for a given construct is greater than the correlations between that construct and all other constructs. As shown in Table 5, the criterion for discriminant validity was met in all constructs.

Secondly, discriminant validity at the item level requires that no item load more highly on another construct than it does on the construct it intends to measure (Barclay et al., 1995). This criterion is satisfied when the PCA was carried out in the first stage of the analysis. As stated in the previous EFA

Table 5. Correlation between constructs depicted together with square root of corresponding AVE (diagonal).

Construct	PA	PE	PU	PEU	BI
PA	(.72)				
PE	.18	(.87)			
PU	.50	.35	(.82)		
PEU	.18	.17	.28	(.84)	
BI	.29	.18	.30	.02	(.78)

section, the optimum value derived from the Bartlett's test guaranteed discriminant validity at the item level. The PCA calculation with oblique rotation performed on the items confirmed this statement. Thus, we can assume discriminant validity was fulfilled both at item and construct levels. In consequence, the constructs in our proposed research model were assumed to be adequate.

3.3. Assessment of the structural model and hypothesis testing

In order to delve into the causal relationships stated posed as hypotheses, a path analysis was performed by means of SEM. Before testing for the significant relationships, we tested the validity and fit between the research model (Figure 1) and the measured data.

Although a variety of indices are used to measure model fitting in SEM research studies (Kline, 2010), the values of x^2 and x^2/df (df being the degrees of freedom) together with the indices CFI (*Comparative Fit Index*), RMSEA (*root-mean-square error of approximation*) and SRMR (*Standardised Root Mean Residual*) were computed for our proposed model. The model chi-square $x^2(2, N = 111) = 3.74$, $p = .154$ shows no significant differences between the model and the data. As the estimated model has two freedom degrees, the index $x^2/\text{df} = 1.868$. Although there exists no consensus regarding an acceptable value for this statistic, recommendations range from as high as 5.0 (Wheaton et al., 1977) to as low as 2.0 (Tabachnick & Fidell, 2007), ≤ 3 being an optimum value (Kline, 2010). The value of the RMSEA was equal to .088, which was slightly further than the typical acceptable level (recommendation criterion for RMSEA establishes a cut-off point from .05 to .08, MacCallum et al., 1996). Nevertheless, the incremental fit index based on the CFI obtained was CFI =.970, indicating that the specified model fit well to an alternative baseline model (CFI acceptable criterion ≥.95; (Hu & Bentler, 1999; Schumacker & Lomax, 2010). As stated by Fan et al. (1999), CFI index is one of the least effected by sample size measures and, accordingly, one of the most popularly reported fit indices. Finally, the difference between the observed and predicted correlations, measured in terms of the mean absolute correlation residual, was found as SRMR =.033, which can be considered an acceptable value (<.05; Schumacker & Lomax, 2010).

These results support the validity acceptability of the model, and, consequently, it can be employed to examine the regression coefficients for the estimated structural mode. Table 6 provides a summary of the results on the tested hypotheses from the analysis of the path coefficients provided in Figure 3.

The results (Table 6) show that the hypotheses H_{05}, H_{08}, H_{10} and H_{11} were supported by the data. Specifically, it indicates that perceived attention (PA) influences perceived usefulness (PU = by 41.8% ($\beta = .418$, $p < .001$), supporting hypothesis H_{05} in the research context. The results also indicate that perceived ease of use (PEU) by 16.6% ($\beta = .166$, $p = .036$) and perceived enjoyment (PE) by 25.1% ($\beta = .251$, $p = .001$) help to predict perceived usefulness (PU), supporting hypotheses H_{11} and H_{10}, respectively. Finally, perceived usefulness (PU) influences

Table 6. Supported hypotheses derived from the results.

Hypothesis	Causal path	Path coefficient (β)	Std error	p-value	Result
H_{01}	PK -> PA	.063	.016	.509	Not supported
H_{02}	PK -> PE	-.017	.016	.858	Not supported
H_{03}	PK -> PEU	-.001	.027	.990	Not supported
H_{04}	PK -> PU	.010	.020	.625	Not supported
H_{05}	PA -> PU	**.418**	**.119**	**< .001**	**Supported**
H_{06}	PA -> PEU	.159	.163	.090	Not supported
H_{07}	PA -> PE	.176	.092	.059	Not supported
H_{08}	PU -> BI	**.287**	**.070**	**.004**	**Supported**
H_{09}	PE -> PEU	.139	.069	.140	Not supported
H_{10}	PE -> PU	**.251**	**.121**	**< .001**	**Supported**
H_{11}	PEU -> PU	**.166**	**.069**	**.036**	**Supported**
H_{12}	PEU -> BI	-.075	.058	.425	Not supported
H_{13}	PE -> BI	.087	.105	.365	Not supported

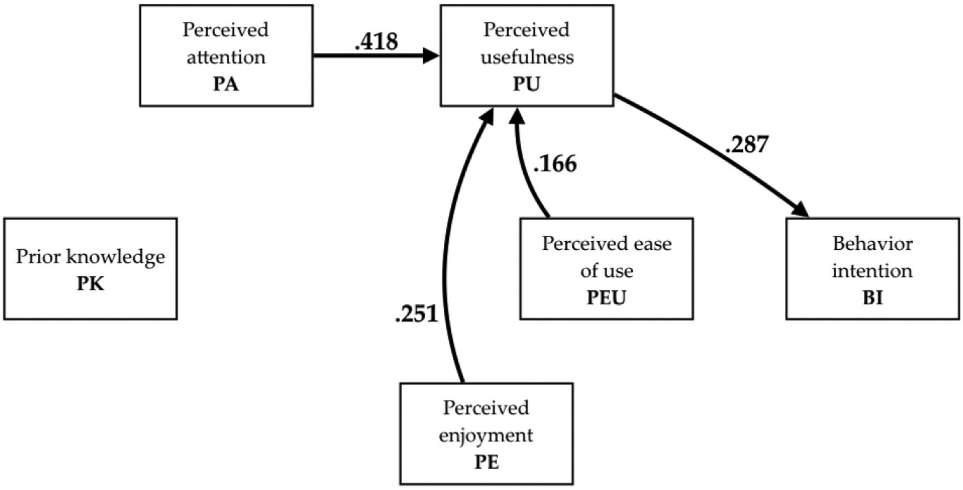

Figure 4. Path coefficients of the research model.

behavioural intention towards VR use (BI) by 28.7% ($\beta = .287$, $p = .004$), supporting hypothesis H_{08}. The supported paths can be graphically described in Figure 4. Concerning students' prior knowledge (PK), none of the internal variables was found to be significantly determined by this external variable.

To evaluate the influence that each variable had on the rest of variables of the model, the standardised total effects, direct and indirect effects associated with each of the six variables were examined (Table 7). Results indicate that the most dominant determinant of BI is perceived usefulness, with a medium effect of .287 according to Cohen (1988). This followed by perceived enjoyment (PE) and perceived attention (PA), with medium effects of .156 and .139, respectively. Perceived attention (PA) has a large effect on perceived usefulness (PU), at 0.493, while the effects of PA on perceived ease of use (PEU) and perceived enjoyment (PE) can be classified as medium-sized, at 0.166 and 0.274, respectively. At the same time, perceived enjoyment and perceived attention affect perceived ease of use (PEU), at 0.139 and 0.159, respectively. Finally, perceived attention has a small to medium-sized effect on perceived enjoyment. This findings support existing research that demonstrates the strong relationship among PU, PEU and BI (e.g. Teo, 2010; Teo et al., 2007).

Table 7. Direct, indirect and total effects in the research model.

		Standardised estimates		
Outcome	Determinant	Direct	Indirect	Total
Behaviour intention towards VR use (BI) ($R^2 = .099$)	PU	0.287		0.287
	PEU	-0.075	0.048	-0.028
	PE	0.087	0.068	0.156
	PA		0.139	0.139
	PK		0.018	0.018
Perceived usefulness (PU) ($R^2 = .345$)	PEU	0.166		0.166
	PE	0.251	0.023	0.274
	PA	0.418	0.075	0.493
	PK	0.038	0.026	0.064
Perceived ease of use (PEU) ($R^2 = .052$)	PE	0.139		0.139
	PA	0.159	0.024	0.184
	PK	-0.001	0.007	0.006
Perceived enjoyment (PE) ($R^2 = .031$)	PA	0.176		0.176
	PK	-0.017	0.011	-0.006

4. Discussion and conclusions

This study aimed to evaluate the potential of the Technology Acceptance Model to explain primary school students' behavioural intention to use immersive VR and the role that two external variables (prior knowledge and perceived attention) can play in mediating behavioural intention to use technology. The results show interesting relationships between the TAM constructs using data gathered from elementary school students in an environmental setting after addressing curricular contents with the help of an immersive VR tool.

VR offers interesting opportunities in the teaching of social sciences in primary education. In this sense, it is essential, along with analysing its potential in the educational process, to evaluate students' acceptance and their intention to use this technology. To this aim, an intervention was carried out with students in their fourth year of primary education, in which the students participated in a session where they worked on the teaching unit 'The Roman Civilisation' with an immersive virtual reality system through a head-mounted display, which allowed them to immerse themselves in an interactive three-dimensional world. The students visited a 3D virtual reconstruction of Augusta Emerita, focusing their attention on some of the most significant buildings of the Roman period. These contents are part of the curriculum at this educational stage. Using this approach, this study contributes to shedding light on the scarce literature on the acceptance of immersive VR at school age, with TAM as a research model. The acceptance of the use of immersive VR among primary school students has been analysed using the specific variables of the model (perceived usefulness, perceived ease of use, perceived enjoyment and attitude towards immersive VR) and incorporating as external variables the students' prior knowledge and perceived attention.

The research model proposed for the analysis of TAM offers a high level of reliability, which coincides with most known studies in which TAM is identified as a valid and robust model with wide applicability (King & He, 2006; Marangunić & Granić, 2015). This study provides evidence of the suitability of applying TAM to measure the acceptance of immersive VR in primary education. To evaluate the proposed hypothetical model, the six research variables have been linked through 13 causal paths. Four out of the thirteen hypotheses under study were supported by the data gathered. After an exploratory factor analysis, five constructs were identified that are in turn related to each other: attention to the instructional material, perceived enjoyment, perceived usefulness, perceived ease of use and attitude to immersive VR use. Our results indicated that prior knowledge is not a prerequisite for behavioural intention to use immersive VR. Thus, the students' prior knowledge of the subject does not have a significant effect on attention towards immersive VR, perceived enjoyment, perceived ease of use and perceived usefulness. As a result of this, the hypotheses H_{01}, H_{02}, H_{03} and H_{04} were not supported. In this sense, these results are novel, since no studies have been found that have included prior knowledge as an external variable in the TAM model. Despite the strong relationship that has been observed in other studies between prior knowledge and other learning variables (performance, motivation, understanding. . .) (Dochy et al., 1999; Lin et al., 2011; Moos & Azevedo, 2008), the results of this research suggest that the intention to use immersive VR technology does not require prior knowledge so that users are attentive, enjoy it, consider it easy to use or perceive that it is useful.

On the contrary, the second of the external variables included in the model – perceived attention – has a medium effect on the students' behavioural intention to use immersive VR. Perceived attention shows a large direct and significant effect on perceived usefulness (H_{05}), which provides this construct with an important role as an external predictor of perceived usefulness, demonstrating its influence on students' beliefs towards the system. In addition, although not statistically significant, attention also shows a medium effect on perceived enjoyment. One of the main contributions of this study lies in the validation of the effect of attention as an external variable to increase the predictive validity of TAM. Indeed, this study answers some of the demands stated in reviews of the TAM literature which focus on the need to incorporate additional variables into the model (Marangunić & Granić, 2015). In particular, it contributes to responding to the need to incorporate other motivational variables and theories (Sanchez-Franco, 2010). From our results, it is plausible to infer that when students show positive attention, they are likely to consider immersive VR as a useful tool and become more involved in its use. Therefore, when designing VR tools or using VR as a learning tool, those content or human characteristics (e.g. curiosity) should be taken into consideration which place important value to attention as an element of motivation and a prerequisite for learning (Keller, 1987).

Another dimension that has shown a total effect of medium size on the intention to use is perceived enjoyment. The results greatly support the important role of perceived enjoyment in determining the actual use of the system. Enjoyment has a direct significant influence on perceived utility. These interactions coincide with what has been provided in other studies (Teo & Noyes, 2011; Tokel & İsler, 2015; Wojciechowski & Cellary, 2013) in which it has been found that perceived enjoyment has a significant influence on the core constructs of TAM: perceived utility, perceived ease of use and intention to use the technology. In fact, in studies on virtual reality or virtual environments it has been found that enjoyment usually appears together with the perceived usefulness as one of the main factors in predicting the acceptance and use of this technology (Sun & Cheng, 2009; Tokel & İsler, 2015), such as in our study, in which the effects of perceived enjoyment and perceived utility add up to a total effect of .443. In some of these studies (Huang et al., 2013; van der Heijden, 2004), the important role of enjoyment has been related to hedonic qualities and its influence on the use of VR when experimenting with content in the first person. According to Sagnier et al. (2020), 'virtual environments are perceived as hedonic technologies, as evidenced by studies that integrate both hedonic variables and utilitarian variables to explain user acceptance'. In this regard, our results indicate that the greater the enjoyment derived from the use of virtual reality, the greater the intention to use it.

The results also indicate that perceived ease of use makes it possible to predict perceived usefulness (H_{11}). Therefore, if students perceive that the use of virtual reality is easy, their perception of the usefulness of immersive VR will be higher. The findings are aligned with those provided by previous studies (Al-Gahtani, 2016; Davis et al., 1992; Lin & Yeh, 2019; Liu et al., 2009; Sun & Cheng, 2009; Tokel & İsler, 2015). However, unlike other studies in which ease of use has been the most influential construct that directly affects intention to use (Cabero et al., 2018; Chow et al., 2012), in our study, perceived ease of use did not have a significant direct effect on the intention to use immersive virtual reality. This lack of importance of perceived ease of use, according to King and He (2006), could be explained by the instability of the effect of this variable or by the sample size, but also by the reduced number of tasks or duration of the intervention (Sagnier et al., 2020). It is striking how perceived ease of use is the only dimension of the TAM model that shows a null effect on the intention to use. This fact may be explained because immersive VR is not yet as widespread in our daily lives as believed, and less so in educational centres. Most likely, as the use of immersive VR spreads in all areas and, specifically, in educational contexts, the perceived ease of use will increase with daily practice and will cause perceptions of usefulness to increase. From the point of view of the design of technological resources for teaching, these results have important implications, since they suggest that those tools that are perceived as easy to use are also associated with a higher level of utility.

Finally, the perceived utility of immersive VR is the essential and the main determinant that explains the students' acceptance and use of immersive VR by students (H_{09}) with a medium-sized direct effect. The intention to use immersive VR is robustly determined by its perceived usefulness, which suggests that students who consider immersive VR useful have the intention of using it. This is consistent with previous studies in which the influence of perceived utility on the intention to use has also been pointed out (Cheung & Vogel, 2013; Chow et al., 2012; Davis, 1989; Davis et al., 1992; Mohammadi, 2015; Venkatesh, 2000). Furthermore, perceived usefulness has been highlighted as the strongest predictor of intention to use in a good number of studies (Chen & Tseng, 2012; Chow et al., 2012; Sagnier et al., 2020; Wojciechowski & Cellary, 2013) and can capture much of the influence of perceived ease of use (King & He, 2006). According to Sagnier et al. (2020), these results fit with the utilitarian nature of the technology employed in this study. Our results clearly support that students who view immersive VR as a useful tool will show a positive attitude towards its use. These data corroborate the importance of the correct design and integration of technology in learning contexts, starting from effective instructional design environments in which the use of technology is clearly defined according to the interests and needs of the educational process.

4.1. Limitations and future directions

In this study, some limitations have been identified that should be addressed in future research. First, the sample size could be increased. The study analysed data gathered from 111 fourth-grade students. Although this size, according to Bentler and Chou (1987), allowed us to build a valid structural equation model, a larger sample will provide more information on student acceptance of immersive VR and will allow us to introduce additional external variables into the model. Furthermore, as previously mentioned, a larger sample would also allow us to better understand the effect of some variables on the model, such as perceived ease of use. In addition, the limitation to a specific course (fourth grade) also makes it necessary to consider other ages to obtain a broader and more balanced vision that takes into account all the grades of this educational stage to generate a more holistic vision of VR acceptance.

Another limitation of our study is the effect of the duration and design of the task. It would be convenient to replicate this study with a greater number of sessions dedicated to the intervention, as well as with a more complex task design, to obtain a more complete view of the effects of internal and external variables on the intention to use. In addition, as mentioned above, expanding the number of sessions can allow students to become familiar with the operation of the immersive VR devices used, and modify their opinions on the ease of use, its usefulness and their intention to use it.

Regarding the technological tool, an immersive virtual reality system has been used through head-mounted display and a specific application. Future research should continue to provide knowledge on the use of this and other immersive devices and interventions that allow students to broaden their sensory and emotional experiences in these learning environments.

The use of VR technology in education offers the possibility of providing meaningful learning experiences in the teaching of social sciences. Our findings provided direct and significant implications for the acceptance of immersive VR technology by students in an educational stage that has been little studied so far. This study contributes to supporting the positive results obtained by the inclusion of VR technology in primary education classrooms from the analysis of students' perceptions of their intention to use it, one additional dimension that should be taken into account for the development and implementation of effective interventions mediated by technologies in the classrooms.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the University of Castilla-La Mancha and by the European Regional Development Fund (ERDF) [grant number 2022-GRIN-34039], by the Castilla-La Mancha Regional Administration [grant number SBPLY/19/180501/000278], and by MCIN/AEI/10.13039/501100011033 and by the "European Union NextGenerationEU/PRTR [grant number TED2021-131557B-100].

Notes on contributors

Rafael Villena-Taranilla is a primary teacher in San Cristóbal school (Albacete), where he is the Coordinator of the Longlife Learning Programme and digital transformation. He is also a part-time lecturer at University of Camilo José Cela (Spain). His research interests include virtual reality, augmented reality, gamification and educational robotics.

Ramón Cózar-Gutiérrez is a lecturer of the Department of History at the University of Castilla-La Mancha. He is co-leader of the research group LabinTic at the Faculty of Education of Albacete. His research fields in education address the teaching and learning of social sciences, teacher training and educational technology.

José Antonio González-Calero is currently a lecturer at the University of Castilla-La Mancha. He is co-leader of the research group LabinTic at the Faculty of Education of Albacete. His research interests include educational technology and the development and implementation of interactive learning environments.

Pascual D. Diago is a lecturer at the University of València. He is currently teaching on the degree courses of Early Childhood Education and Primary Education and on the master's degree in research in Specific Didactics. His research focuses on problem-solving and the use of new technologies in the teaching-learning processes of school mathematics.

ORCID

Rafael Villena-Taranilla http://orcid.org/0000-0002-7665-775X
Ramón Cózar-Gutiérrez http://orcid.org/0000-0001-8255-6376
José Antonio González-Calero http://orcid.org/0000-0003-0842-8151
Pascual D. Diago http://orcid.org/0000-0002-0900-8098

References

Abd Majid, F., & Mohd Shamsudin, N. (2019). Identifying factors affecting acceptance of virtual reality in classrooms based on technology acceptance model (TAM). *Asian Journal of University Education*, *15*(2), 51. https://doi.org/10.24191/ajue.v15i2.7556

Adov, L., Pedaste, M., Leijen, A., & Raniikmäe, M. (2020). Does it have to be easy, useful, or do we need something else? STEM teachers' attitudes towards mobile device use in teaching. *Technology, Pedagogy and Education*, *29*(4), 511–526. https://doi.org/10.1080/1475939X.2020.1785928

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Al-Gahtani, S. S. (2016). Empirical investigation of e-learning acceptance and assimilation: A structural equation model. *Applied Computing and Informatics*, *12*(1), 27–50. https://doi.org/10.1016/j.aci.2014.09.001

Alharbi, S., & Drew, S. (2014). Using the technology acceptance model in understanding academics' behavioural intention to use learning management systems. *International Journal of Advanced Computer Science and Applications*, *5*(1). https://doi.org/10.14569/IJACSA.2014.050120

Armenteros, M., Liaw, S. S., Fernández, M., Díaz, R. F., & Sánchez, R. A. (2013). Surveying FIFA instructors' behavioral intention toward the multimedia teaching materials. *Computers & Education*, *61*, 91–104. https://doi.org/10.1016/j.compedu.2012.09.010

Bailenson, J. N., Yee, N., Blascovich, J., Beall, A. C., Lundblad, N., & Jin, M. (2008). The use of immersive virtual reality in the learning sciences: Digital transformations of teachers, students, and social context. *Journal of the Learning Sciences*, *17*(1), 102–141. https://doi.org/10.1080/10508400701793141

Barclay, D., Thompson, R., & Dan Higgins, C. (1995). The partial least squares (PLS) approach to causal modeling: Personal computer adoption and use as an illustration. *Technology Studies*, *2*(2), 285–309.

Barton, K., & Levstik, L. (2004). *Teaching history for the common good*. Lawrence Erlbaum.

Bentler, P. M., & Chou, C. H. (1987). Practical issues in structural modeling. *Sociological Methods & Research*, *16*(1), 78–117. https://doi.org/10.1177/0049124187016001004

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*(2), 103–124. https://doi.org/10.1207/S15327965PLI1302_01

Brown, M., McCormack, M., Reeves, J., Brooks, C., & Grajek, S. (2020). *2020 EDUCAUSE horizon report. Teaching and learning edition*. Educause.

Burdea, G., & Coiffet, P. (2003). Virtual reality technology. *Presence Teleoperators and Virtual Environments*, *12*(6), 663–664. https://doi.org/10.1162/105474603322955950

Cabero, J., Gallego, O., Puentes, Á. D. J., & Jiménez, T. (2018). La 'Aceptación de la Tecnología de la Formación Virtual' y su relación con la capacitación docente en formación virtual. *EDMETIC*, *7*(1), 225. https://doi.org/10.21071/edmetic.v7i1.10028

Cabero, J., & Pérez, J. L. (2018). Validación del modelo TAM de adopción de la Realidad Aumentada mediante ecuaciones estructurales. *Estudios Sobre Educación*, *34*, 129–153. https://doi.org/10.15581/004.34.129-153

Carretero, M. (2005). *Construir y enseñar las Ciencias Sociales y la Historia*. Aique.

Carretero, M., & Voss, J. (2004). *Aprender y pensar la historia*. Amorrortu.

Chang, H. Y., Liang, J. C., & Tsai, C. C. (2020). Students' context-specific epistemic justifications, prior knowledge, engagement, and socioscientific reasoning in a mobile augmented reality learning environment. *Journal of Science Education and Technology*, *29*(3), 399–408. https://doi.org/10.1007/s10956-020-09825-9

Chang, C. C., Yan, C. F., & Tseng, J. S. (2012). Perceived convenience in an extended technology acceptance model: Mobile technology and English learning for college students. *Australasian Journal of Educational Technology*, *28*(5). https://doi.org/10.14742/ajet.818

Chen, E. W. L. (2019). Choosing between the theory of planned behavior (TPB) and the technology acceptance model (TAM). *Educational Technology Research and Development*, *67*(1), 21–37. https://doi.org/10.1007/s11423-018-9598-6

Chen, Y. H., & Chengalur, I. (2015). Factors influencing students' use of a library web portal: Applying course-integrated information literacy instruction as an intervention. *The Internet and Higher Education*, *26*, 42–55. https://doi.org/10.1016/j.iheduc.2015.04.005

Cheng, K. H. (2017). Reading an augmented reality book: An exploration of learners' cognitive load, motivation, and attitudes. *Australasian Journal of Educational Technology*, *33*(4). https://doi.org/10.14742/ajet.2820

Cheng, Y. M., Lou, S. J., Kuo, S. H., & Shih, R. C. (2013). Investigating elementary school students' technology acceptance by applying digital game-based learning to environmental education. *Australasian Journal of Educational Technology*, *29*(1). https://doi.org/10.14742/ajet.65

Cheng, K. H., & Tsai, C. C. (2019). A case study of immersive virtual field trips in an elementary classroom: Students' learning experience and teacher-student interaction behaviors. *Computers & Education*, *140*, 103600. https://doi.org/10.1016/j.compedu.2019.103600

Cheng, M., & Yuen, A. H. K. (2019). Cultural divides in acceptance and continuance of learning management system use: A longitudinal study of teenagers. *Education Technology Research and Development*, *67*(6), 1613–1637. https://doi.org/10.1007/s11423-019-09680-5

Chen, S. Y., & Huang, P. R. (2013). The comparisons of the influences of prior knowledge on two game-based learning systems. *Computers & Education*, *68*, 177–186. https://doi.org/10.1016/j.compedu.2013.05.005

Chen, H. R., & Lin, Y. S. (2016). An examination of digital game-based situated learning applied to Chinese language poetry education. *Technology, Pedagogy and Education*, *25*(2), 171–186. https://doi.org/10.1080/1475939X.2015.1007077

Chen, B., Sivo, S., Seilhamer, R., Sugar, A., & Mao, J. (2013). User acceptance of mobile technology: A campus-wide implementation of Blackboard's mobileTM learn application. *Journal of Educational Computing Research*, *49*(3), 327–343. https://doi.org/10.2190/EC.49.3.c

Chen, H. R., & Tseng, H. F. (2012). Factors that influence acceptance of web-based e-learning systems for the in-service education of junior high school teachers in Taiwan. *Evaluation and Program Planning*, *35*(3), 398–406. https://doi.org/10.1016/j.evalprogplan.2011.11.007

Cheung, R., & Vogel, D. (2013). Predicting user acceptance of collaborative technologies: An extension of the technology acceptance model for e-learning. *Computers & Education*, *63*, 160–175. https://doi.org/10.1016/j.compedu.2012.12.003

Chow, M., Herold, D. K., Choo, T. M., & Chan, K. (2012). Extending the technology acceptance model to explore the intention to use second life for enhancing healthcare education. *Computers & Education*, *59*(4), 1136–1144. https://doi.org/10.1016/j.compedu.2012.05.011

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *The Journal of Applied Psychology*, *78*(1), 98–104. https://doi.org/10.1037/0021-9010.78.1.98

Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*, *41*(1), 10–32. https://doi.org/10.1111/j.1467-8535.2009.01038.x

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of Applied Social Psychology*, *22*(14), 1111–1132. https://doi.org/10.1111/j.1559-1816.1992.tb00945.x

Dede, C. (2012). *Interweaving assessments into immersive authentic simulations: Design strategies for diagnostic and instructional (Commissioned white paper for the ETS invitational research symposium on technology enhanced assessments) insights*. Educational Testing Service.

Delgado-Algarra, E. J. (2020). *ICTs and innovation for didactics of social sciences*. ISI Global.

Di Natale, A. F., Repetto, C., Riva, G., & Villani, D. (2020). Immersive virtual reality in K-12 and higher education: A 10 year systematic review of empirical research. *British Journal of Educational Technology*, *51*(6), 2006–2033. https://doi.org/10.1111/bjet.13030

Dochy, F., Segers, M., & Buehl, M. M. (1999). The relation between assessment practices and outcomes of studies: The case of research on prior knowledge. *Review of Educational Research*, *69*(2), 145–186. https://doi.org/10.3102/00346543069002145

El-Tamini, A., Abidi, M. H., & Al-Ahmari, A. M. (2017). Challenges for technology innovation: An agenda for the future. In *Challenges for technology innovation: An agenda for the future* (pp. 121–126). Routledge. https://doi.org/10.1201/9781315198101

Fabola, A., & Miller, A. (2016). Virtual reality for early education: A study. In C. Allison, L. Morgado, J. Pirker, D. Beck, J. Richter, & C. Gütl (Eds.), *Immersive learning research network (iLRN 2016). Communications in computer and information science* (pp. 59–72). Springer.

Fan, X., Thompson, B., & Wang, L. (1999). Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes. *Structural Equation Modeling*, *6*(1), 56–83.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Addison-Wesley.

Fontal, O., & Ibañez, A. (2017). La investigación en Educación Patrimonial. Evolución y estado actual a través del análisis de indicadores de alto impacto. *Revista de Educación*, *375*, 184–214. https://doi.org/10.4438/1988-592X-RE-2016-375-340

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50.

Fornell, C., Tellis, G. J., & Zinkhan, G. M. (1982). Validity assessment: A structural equations approach using partial least squares. In B. J. Walker, W. O. Bearden, W. R. Darden, P. E. Murphy, J. R. Nevin, J. C. Olson, & B. A. Weitz (Eds.), *An assessment of marketing thought & practice* (pp. 405–409). American Marketing Association.

Freina, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: State of the art and perspectives. In *Proceedings of ELearning and Software for Education*. Bucharest.

Gaitatzes, A., Christopoulos, D., & Roussou, M. (2001). Reviving the past: Cultural heritage meets virtual reality. In D. B. Arnold, A. Chalmers, & D. W. Fellner (Eds.), *Proceedings of the 2001 conference on virtual reality, archeology, and cultural heritage - VAST '01* (p. 103). ACM Press. https://doi.org/10.1145/584993.585011

Galbis-Córdoba, A., Martí-Parreño, J., & Currás-Pérez, R. (2017). Education students' attitude towards the use of gamification for competencies development. *Journal of E-Learning and Knowledge Society*, *13*, 1. https://doi.org/10.20368/1971-8829/158

Gavish, N., Gutiérrez, T., Webel, S., Rodríguez, J., Peveri, M., Bockholt, U., & Tecchia, F. (2015). Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks. *Interactive Learning Environments*, *23*(6), 778–798. https://doi.org/10.1080/10494820.2013.815221

Getchell, K., Miller, A., Allison, C., & Sweetman, R. (2009). Exploring the second life of a byzantine basilica. In O. Petrovic & A. Brand (Eds.), *Serious games on the move* (pp. 165–180). Springer.

Gómez Carrasco, C. J., Chaparro Sainz, Á., Felices de la Fuente, M., & Cózar Gutiérrez, R. (2020). Estrategias metodológicas y uso de recursos digitales para la enseñanza de la historia. Análisis de recuerdos y opiniones del profesorado en formación inicial. *Aula Abierta*, *49*(1), 65–74. https://doi.org/10.17811/rifie.49.1.2020.65-74

Gómez-Carrasco, C. J., & Miralles-Martínez, P. (2017). *Los espejos de Clío. Usos y abusos de la Historia en el ámbito escolar*. Silex.

Grotzer, T. A., Powell, M. M., Derbiszewska, M., Courter, K., Kamarainen, A. M., Metcalf, S. J., & Dede, C. J. (2015). Turning transfer inside out: The affordances of virtual worlds and mobile devices in real world contexts for teaching about causality across time and distance in ecosystems. *Technology, Knowledge and Learning*, *20*(1), 43–69. https://doi.org/10.1007/s10758-014-9241-5

Hedberg, J., & Alexander, S. (1994). Virtual reality in education: Defining researchable issues. *Educational Media International*, *31*(4), 214–220. https://doi.org/10.1080/0952398940310402

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology*, *41*(1), 33–55. https://doi.org/10.1111/j.1467-8535.2008.00900.x

Huang, Y. C., Backman, S. J., Backman, K. F., & Moore, D. (2013). Exploring user acceptance of 3D virtual worlds in travel and tourism marketing. *Tourism Management*, *36*, 490–501. https://doi.org/10.1016/j.tourman.2012.09.009

Huang, H. M., Rauch, U., & Liaw, S. S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers & Education*, *55*(3), 1171–1182. https://doi.org/10.1016/j.compedu.2010.05.014

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Ibañez-Etxeberria, A., Gómez-Carrasco, C. J., Fontal, O., & García-Ceballos, S. (2020). Virtual environments and augmented reality applied to heritage education. An evaluative study. *Applied Sciences*, *10*(7), 2352. https://doi.org/10.3390/app10072352

Ibáñez-Etxeberria, A., Kortabitarte, A., De Castro, P., & Gillate, I. (2019). Digital competence using heritage theme apps in the DigComp framework. *Revista Electronica Interuniversitaria de Formacion Del Profesorado*, *22*(1), 13–27. https://doi.org/10.6018/reifop.22.1.356231

Islamoglu, H., Kabakci Yurdakul, I., & Ursavas, O. F. (2021). Pre-service teachers' acceptance of mobile-technology-supported learning activities. *Education Technology Research and Development*, *69*, 1025–1054. https://doi.org/10.1007/s11423-021-09973-8

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, *23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, *39*, 31–36.

Kalyvioti, K., & Mikropoulos, T. A. (2014). Virtual environments and dyslexia: A literature review. *Procedia computer science*, *27*, 138–147. https://doi.org/10.1016/j.procs.2014.02.017

Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of virtual reality in education. *Themes in Science & Technology Education*, *10*(2), 85–119.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, *10*(3), 2–10.

Keller, J. M. (2010). *Motivational design for learning and performance*. Springer US. https://doi.org/10.1007/978-1-4419-1250-3

Kelly, H. (2014). A path analysis of educator perceptions of open educational resources using the technology acceptance model. *International Review of Research in Open and Distributed Learning*, *15*(2). https://doi.org/10.19173/irrodl.v15i2.1715

Kilmon, C. A., Brown, L., Ghosh, S., & Mikitiuk, A. (2010). Immersive virtual reality simulations in nursing education. *Nursing Education Perspectives*, *31*(5), 314–317.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management*, *43*(6), 740–755. https://doi.org/10.1016/j.im.2006.05.003

Kline, R. B. (2010). *Principles and practice of structural equation modeling* (3rd ed.). Guilford Press.

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta-analysis. *International Journal of Instructional Media*, *26*(1), 71–85.

Lee, A. E., Wong, K. W., & Fung, C. C. (2010). How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach. *Computers & Education*, *55*(4), 1424–1442. https://doi.org/10.1016/j.compedu.2010.06.006

Li, L. Y. (2019). Effect of prior knowledge on attitudes, behavior, and learning performance in video lecture viewing. *International Journal of Human–Computer Interaction*, *35*(4–5), 415–426. https://doi.org/10.1080/10447318.2018.1543086

Liceras, A. (2000). *Tratamiento de las dificultades de aprendizaje en ciencias sociales*. Grupo editorial universitario.

Lin, Y. C., Lin, Y. T., & Huang, Y. M. (2011). Development of a diagnostic system using a testing-based approach for strengthening student prior knowledge. *Computers & Education*, *57*(2), 1557–1570. https://doi.org/10.1016/j.compedu.2011.03.004

Lin, P. H., & Yeh, S. C. (2019). How motion-control influences a VR-supported technology for mental rotation learning: From the perspectives of playfulness, gender difference and technology acceptance model. *International Journal of Human–Computer Interaction*, *35*(18), 1736–1746. https://doi.org/10.1080/10447318.2019.1571784

Liu, S. H., Liao, H. L., & Pratt, J. A. (2009). Impact of media richness and flow on e-learning technology acceptance. *Computers & Education*, *52*(3), 599–607. https://doi.org/10.1016/j.compedu.2008.11.002

Ludlow, B. L. (2015). Virtual reality: Emerging applications and future directions. *Rural Special Education Quarterly*, *34*(3), 3–10. https://doi.org/10.1177/875687051503400302

Maas, M., & Hughes, J. (2020). Virtual, augmented and mixed reality in K–12 education: A review of the literature. *Technology, Pedagogy and Education*, *29*(2), 231–249. https://doi.org/10.1080/1475939X.2020.1737210

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods*, *1*(2), 130–149. https://doi.org/10.1037/1082-989X.1.2.130

Mantziou, O., Papachristos, N. M., & Mikropoulos, T. A. (2018). Learning activities as enactments of learning affordances in MUVEs: A review-based classification. *Education and Information Technologies*, *23*(4), 1737–1765. https://doi.org/10.1007/s10639-018-9690-x

Marangunić, N., & Granić, A. (2015). Technology acceptance model: A literature review from 1986 to 2013. *Universal Access in the Information Society*, *14*(1), 81–95. https://doi.org/10.1007/s10209-014-0348-1

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education*, *70*, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769–780. https://doi.org/10.1016/j.compedu.2010.10.020

Mikropoulos, T. A., & Strouboulis, V. (2004). Factors that influence presence in educational virtual environments. *CyberPsychology & Behavior*, *7*(5), 582–591. https://doi.org/10.1089/cpb.2004.7.582

Miralles, P., Gómez, C. J., & Arias, L. (2013). Social sciences teaching and information processing. An experience using WebQuests in primary education teacher training. *RUSC Universities and Knowledge Society Journal*, *10*(2), 98. https://doi.org/10.7238/rusc.v10i2.1536

Miralles, P., Gómez, C. J., & Monteagudo, J. (2019). Percepciones sobre el uso de recursos TIC y «MASS-MEDIA» Para la enseñanza de la historia. Un estudio comparativo en futuros docentes de España-Inglaterra. *Educación XX1*, *22*(2). https://doi.org/10.5944/educxx1.21377

Mohammadi, H. (2015). Investigating users' perspectives on e-learning: An integration of TAM and IS success model. *Computers in Human Behavior*, *45*, 359–374. https://doi.org/10.1016/j.chb.2014.07.044

Molina-Carmona, R., Pertegal-Felices, M., Jimeno-Morenilla, A., & Mora-Mora, H. (2018). Virtual reality learning activities for multimedia students to enhance spatial ability. *Sustainability*, *10*(4), 1074. https://doi.org/10.3390/su10041074

Moos, D. C., & Azevedo, R. (2008). Self-regulated learning with hypermedia: The role of prior domain knowledge. *Contemporary Educational Psychology*, *33*(2), 270–298. https://doi.org/10.1016/j.cedpsych.2007.03.001

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. McGraw-Hill Inc.

Padilla-Meléndez, A., Del Aguila-Obra, A. R., & Garrido-Moreno, A. (2013). Perceived playfulness, gender differences and technology acceptance model in a blended learning scenario. *Computers & Education*, *63*, 306–317. https://doi.org/10.1016/j.compedu.2012.12.014

Pagès, J. (2009). Enseñar y aprender ciencias sociales en el siglo XXI: reflexiones casi al final de una década. In *Investigación en Educación, Pedagogía y Formación Docente, II Congreso Internacional* (pp. 140–154). Universidad Pedagógica Nacional, Universidad de Antioquia, Corporación interuniversitaria de servicios.

Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Educational Technology & Society*, *12*(3), 150–162.

Pedhazur, E. J., & Schmelkin, L. P. (1991). *Measurement, design, and analysis: An integrated approach*. Lawrence Erlbaum Associates.

Pellas, N., Mystakidis, S., & Kazanidis, I. (2021). Immersive virtual reality in K-12 and higher education: A systematic review of the last decade scientific literature. *Virtual Reality*, *25*, 835–861. https://doi.org/10.1007/s10055-020-00489-9

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, *95*, 309–327. https://doi.org/10.1016/j.compedu.2016.02.002

Redondo, J. D. (2012). Patrimonio universitario, patrimonio virtual. *Educación y Futuro: Revista de Investigación Aplicada y Experiencias Educativas*, *27*, 121–137.

Rivero, P., & Feliu, M. (2017). Aplicaciones de la arqueología virtual para la Educación Patrimonial: análisis de tendencias e investigaciones. *Estudios Pedagógicos*, *43*(4), 319–330. https://doi.org/10.4067/S0718-07052017000400017

Sagnier, C., Loup-Escande, E., Lourdeaux, D., Thouvenin, I., & Valléry, G. (2020). User acceptance of virtual reality: An extended technology acceptance model. *International Journal of Human–Computer Interaction*, *36*(11), 993–1007. https://doi.org/10.1080/10447318.2019.1708612

Salzman, M. C., Dede, C., Loftin, R. B., & Chen, J. (1999). A model for understanding how virtual reality aids complex conceptual learning. *Presence Teleoperators and Virtual Environments*, *8*(3), 293–316. https://doi.org/10.1162/105474699566242

Sanchez-Franco, M. J. (2010). WebCT – The quasimoderating effect of perceived affective quality on an extending technology acceptance model. *Computers & Education*, *54*(1), 37–46. https://doi.org/10.1016/j.compedu.2009.07.005

Schoonenboom, J. (2014). Using an adapted, task-level technology acceptance model to explain why instructors in higher education intend to use some learning management system tools more than others. *Computers & Education*, *71*, 247–256. https://doi.org/10.1016/j.compedu.2013.09.016

Schumacker, R. E., & Lomax, R. G. (2010). *A beginner's guide to structural equation modeling* (3rd ed.). Routledge.

Scott, E., Soria, A., & Campo, M. (2017). Adaptive 3D virtual learning environments – A review of the literature. *IEEE Transactions on Learning Technologies*, *10*(3), 262–276. https://doi.org/10.1109/TLT.2016.2609910

Segars, A. H. (1997). Assessing the unidimensionality of measurement: A paradigm and illustration within the context of information systems research. *Omega*, *25*(1), 107–121. https://doi.org/10.1016/S0305-0483(96)00051-5

Shroff, R. H., Deneen, C. C., & Ng, E. M. W. (2011). Analysis of the technology acceptance model in examining students' behavioural intention to use an e-portfolio system. *Australasian Journal of Educational Technology*, *27*(4). https://doi.org/10.14742/ajet.940

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, *64*(2), 489–528. https://doi.org/10.1111/j.1744-6570.2011.01190.x

Stevens, J. P. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Lawrence Erlbaum Associates.

Sun, H. M., & Cheng, W. L. (2009). The input-interface of webcam applied in 3D virtual reality systems. *Computers & Education*, *53*(4), 1231–1240. https://doi.org/10.1016/j.compedu.2009.06.006

Tabachnick, B. G., & Fidell, L. S. (2007). Using multivariate statistics. In *Studies in nonlinear dynamics and econometrics* (Vol. 20, Issue 1, 5th ed.). Pearson Education. https://doi.org/10.1515/snde-2014-0102

Tarhini, A., Hone, K., & Liu, X. (2014). Measuring the moderating effect of gender and age on E-learning acceptance in England: A structural equation modeling approach for an extended technology acceptance model. *Journal of Educational Computing Research*, *51*(2), 163–184. https://doi.org/10.2190/EC.51.2.b

Teo, T. (2010). Examining the influence of subjective norm and facilitating conditions on the intention to use technology among pre-service teachers: A structural equation modeling of an extended technology acceptance model. *Asia Pacific Education Review*, *11*(2), 253–262. https://doi.org/10.1007/s12564-009-9066-4

Teo, T., Lee, C. B., & Chai, C. S. (2007). Understanding pre-service teachers' computer attitudes: Applying and extending the technology acceptance model. *Journal of Computer Assisted Learning*, *24*(2), 128–143. https://doi.org/10.1111/j.1365-2729.2007.00247.x

Teo, T., & Noyes, J. (2011). An assessment of the influence of perceived enjoyment and attitude on the intention to use technology among pre-service teachers: A structural equation modeling approach. *Computers & Education*, *57*(2), 1645–1653. https://doi.org/10.1016/j.compedu.2011.03.002

Teo, T., Zhou, M., Fan, A. C. W., & Huan, F. (2019). Factors that influence university students' intention to use Moodle: A study in Macau. *Education Technology Research and Development*, *67*, 749–766. https://doi.org/10.1007/s11423-019-09650-x

Tilhou, R., Taylor, V., & Crompton, H. (2020). 3D virtual reality in K-12 education: A thematic systematic review. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum. Bridging human and machine: Future education with intelligence*. Springer. https://doi.org/10.1007/978-981-15-0618-5_10

Tokel, S. T., & İsler, V. (2015). Acceptance of virtual worlds as learning space. *Innovations in Education and Teaching International*, *52*(3), 254–264. https://doi.org/10.1080/14703297.2013.820139

van der Heijden, H. (2004). User acceptance of hedonic information systems. *MIS Quarterly*, *28*(4), 695. https://doi.org/10.2307/25148660

VanSledright, B. A. (2011). *The challenge of rethinking history education. On practice, theories, and policy*. Routledge.

Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information System Research*, *11*(4), 342–365.

Venkatesh, V., Morris, M., Davis, G., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*(3), 425. https://doi.org/10.2307/30036540

Vicent, N., Rivero Gracia, M. P., & Feliu Torruella, M. (2015). Arqueología y tecnologías digitales en Educación Patrimonial. *Educatio Siglo XXI*, *33*(1), 83. https://doi.org/10.6018/j/222511

Villena-Taranilla, R., Cózar-Gutiérrez, R., González-Calero, J. A., & López-Cirugeda, I. (2022). Strolling through a city of the roman empire: An analysis of the potential of virtual reality to teach history in primary education. *Interactive Learning Environments*, *30*(4), 608–618. https://doi.org/10.1080/10494820.2019.1674886

Villena-Taranilla, R., Tirado-Olivares, S., Cózar-Gutiérrez, R., & González-Calero, J. A. (2022). Effects of virtual reality on learning outcomes in K-6 education: A meta-analysis. *Education Research Review*, *35*, 100434. https://doi.org/10.1016/j.edurev.2022.100434

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research*, *34*(3), 229–243. https://doi.org/10.2190/FLHV-K4WA-WPVQ-H0YM

Webster, R. (2016). Declarative knowledge acquisition in immersive virtual learning environments. *Interactive Learning Environments*, *24*(6), 1319–1333. https://doi.org/10.1080/10494820.2014.994533

Wheaton, B., Muthén, B. O., Alwin, D. F., & Summers, G. F. (1977). Assessing reliability and stability in panel models. *Sociological Methodology*, *8*(1), 84–136.

Wiederhold, B. K., & Bouchard, S. (2014). *Advances in virtual reality and anxiety disorders*. Springer.

Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers & Education*, *68*, 570–585. https://doi.org/10.1016/j.compedu.2013.02.014

Ye, Y. (2016). Design and implementation of digital art teaching system based on interactive virtual technology. *International Journal of Emerging Technologies in Learning (iJET)*, *11*(11), 49. https://doi.org/10.3991/ijet.v11i11.6254

Yildirim, G., Elban, M., & Yildirim, S. (2018). Analysis of use of virtual reality technologies in history education: A case study. *Asian Journal of Education and Training*, *4*(2), 62–69. https://doi.org/10.20448/journal.522.2018.42.62.69

Yim, J. S., Moses, P., & Azalea, A. (2019). Predicting teachers' continuance in a virtual learning environment with psychological ownership and the TAM: A perspective from Malaysia. *Education Technology Research and Development*, *67*, 691–709. https://doi.org/10.1007/s11423-019-09661-8

Zhu, Y., Zhang, J. H., Au, W., & Yates, G. (2020). University students' online learning attitudes and continuous intention to undertake online courses: A self-regulated learning perspective. *Education Technology Research and Development*, *68*, 1485–1519. https://doi.org/10.1007/s11423-020-09753-w