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The Use of Mixed, Augmented and Virtual Reality in History of Art Teaching: A Case Study

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Abstract: The incorporation of mixed, virtual, and augmented reality into the educational context takes place in this study through the development of a 3D object shaped by the artistic expressions of the Church of the Annunciation in Seville. In a study of an experimental and exploratory nature with a single group, we worked with a total of 20 students enrolled in a Master's degree, taught at Seville University, under the title of "Arte: idea y producción" (Art: idea and production). A questionnaire based on the "Technology Acceptance Model" (TAM) was used to ascertain the degree of acceptance that the utilized technology had created among students after their participation in the experience. Likewise, the questionnaire permitted understanding of the assessment made by students concerning the presented objects. Among the results obtained, it is noticeable that the participating students show a high level of acceptance of augmented and virtual reality technologies, alongside favorable attitudes towards their utilization and the intention to use them. It is worth highlighting as a significant conclusion that the exploratory study was performed within a real classroom situation, suggesting that both technologies can be applied in formal training environments.

Keywords: augmented reality; virtual reality; higher education; emergent technologies

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1. Introduction

The use of digital technology in training processes has been making unstoppable progress for years [1–3]. Educational experiences that integrate the use of digital resources in the teaching–learning process are being developed at all educational levels; however, some have been used to a far greater extent than others. Consequently, there are a wide variety of digital-technology-assisted training experiences which have already been adopted as standard practice in numerous educational settings [4]. We are referring to activities based on informative use of the Internet, multimedia resources, e-learning and b-learning, and so on [5–7]. In addition to being used quite often in educational centers, they have been the subject of research with regard to how they can be utilized [8]. Nevertheless, other innovative resources are less known and harnessed [9,10], including those associated with augmented reality (AR) and virtual reality (VR).

These are usually prototypes and experimental tests which progressively become rather significant, although they are not too detailed. Thus, we can find experiences in academic fields such as psychology [11], engineering [12], the humanities [13], as well as education [14], among others. In this broad field, applications aimed at academic disciplines related to the representation of space, such as geography and cartography, deserve special mention. In these fields, the possibilities of AR and VR as a resource for contextualized, place-based learning are manifold. In this sense, Klippel et al. [15] have experimented with educational experiences based on the design of immersive virtual field trips (iVFT) as substitutes for real trips, which are often impossible to carry out due to lack of resources. This experience with iVFTs demonstrated positive learning outcomes and served as preparation for actual field site visits. The introduction of pseudo-aerial images, as well as improved image resolution, made a new spatial situation model possible, which contributed to the acquisition of new knowledge.

Of course, to achieve good results, it is necessary to have the right hardware and software, as Kersten et al. [16] concluded in their study. They used different digital 3D models of a specific site, such as the Al Zubarah fortress in Qatar, at various resolutions. They demonstrated the influence of the amount of data and the hardware equipment on ensuring a smooth real-time visualization in a VR situation, and concluded that CAD models offer a better performance than mesh models. In the same vein, Dickman et al. [17] concluded, but this time with respect to AR, that different techniques influence the visualization and perception of AR elements in 3D space.

When it comes to mixed reality (MR), experiences and investigations are scarcer [18,19]. In this case, mixed reality can generate a user experience with great—though little known—educational possibilities.

Additionally, it must be remembered that the current pandemic context has favored a rethinking of face-to-face teaching owing to healthcare limitations. Faced with such a situation, the use of new educational resources that are able to foster spatial diversification is an issue that needs to be dealt with [19,20]. As for this specific study, our intention consists of addressing the articulation of innovative digital technologies that make it easier to create "spaces" in the educational context, and more precisely, in the university environment.

In light of all the above, this study aims to facilitate knowledge acquisition and to develop university students' competences through the use of MR. For that purpose, we examine an innovative proposal within post-graduate learning related to art. Its main contribution lies in the proposal of a not often used resource linked to digital transformation—namely MR—in relation to university training.

This study is structured as follows: Section 2 deals with the theoretical background about MR via the concepts of AR and VR. Section 3 provides the materials and methods: an in-depth description of the created objects, upon which the development of this research relies; and the data collection methods and analysis applied to those objects. Section 4 explains the results obtained, both the direct ones and those derived from the posed hypotheses. Finally, Section 5 includes the discussion and conclusions, along with the limitations and prospects for future research.

2. The State of the Art

2.1. Augmented Reality and Virtual Reality as Emergent Technologies for Education

The different technologies which have been recently presented as emergent and with real possibilities for training include AR and VR [21–25]. These digital technologies offer a variety of opportunities for their implementation in training: promoting mobile and ubiquitous learning; eliminating unnecessary information which is likely to prevent us from observing meaningful information; enriching information about reality to facilitate its understanding; favoring the perception of the most relevant elements; offering accuracy in the representation of objects; creating multimedia training scenarios; establishing active and interactive environments for learning; increasing student motivation; looking at objects from different points of view; enhancing the information supplied to students; and making it possible for the latter to become involved in a special, totally-controlled training context.

Over the last few years, the incorporation of low-cost hardware in designing and producing AR and VR, as well as all the breakthroughs achieved regarding creation software aimed at developing applications for a wide range of devices, has resulted in growing interest in these resources in the educational context [26]. On most occasions, both technologies have enjoyed great success [27–31]. This means being able to develop educational experiences with emerging technologies in a wide variety of educational contexts, regardless of economic or training constraints, for example.

2.2. What Do We Understand by AR and VR?

A way to define AR and VR consists of placing both technologies on the reality-virtuality continuum [32]. In this case, AR would lie closer to the real context, whereas VR would be located at the other end, with "Mixed Reality" being situated halfway. It is this digital technology, which incorporates both AR and VR features, that we are going to use in this study.

These techniques, linked to the possibility of creating new non-physical scenarios (totally or partially) offer computerized simulations, but require physical devices. For ex-ample, immersive VR can be perceived by using devices such as data gloves, special clothing, or a special pair of glasses [33].

Generally speaking, VR applications in education can be classified, according to visualization and interaction devices [34], into two broad categories: (i) non-immersive (the known window in the world), where the user's worldview is channeled through the flat screen of a computer which serves as a "window"; and (ii) immersive, which fully introduces the user to a virtual world through the use of lenses with two small screens placed before that user's eyes. Concerning AR, Cabero and García [35] point out that it is a technology that permits the combination of digital and physical information in real time by means of various technological devices, such as tablets or smartphones to quote but two, thus creating a new enriched reality.

Regarding VR, this is the most advanced way to connect a person with a computer system. This connection allows for a direct interaction between the user and the artificially generated environment. The latter serves to stimulate one or all of the human senses and is mainly characterized by creating in the user an illusion of direct participation at the brain level. In turn, Cañellas [35] clarifies that VR is the technology that makes it possible for any user to immerse themselves, firsthand and in 360°, in virtual scenarios by means of a VR viewer. This makes it easier for users to immerse themselves in such scenarios, even enabling them to interact with the elements which they are made up of. Users stop seeing the place where they find themselves physically and start visualizing "another reality" and interacting with it. As can be seen, AR and VR put forward ways to interact with reality in various ways: whereas VR takes users to an unreal world so that they can feel immersed, AR adds information to the real world.

On another note, it deserves to be highlighted that we can distinguish different levels within AR based on diverse elements such as: a black-and-white artificial pattern (N1); an image (N2); a 3D entity (N3); a location on the planet determined by its GPS coordinates (N4); and a thermal footprint (N5) [36]. According to Flores, Camarena, and Avalos [37], these levels do not exist in VR, as they are replaced by various virtual reality systems: desktop or non-immersive; semi-immersive; and totally immersive. In this regard, some authors reduce them to only two types [35]: immersive (based on the simulation of 2D or 3D scenarios where a user perceives such scenarios with a feeling of "being present" in the first person, as though they were really there); and non-immersive (based on the visualization of virtual scenarios through a screen, giving users the impression that they are looking at that virtual scenario from a "window").

2.3. Human Interaction and Technology with AR, VR and MRI Experiences with AR, VR, and MRI

One of the fundamental challenges around the use of 'realities' linked to the digital world is the search for maximum similarities between the real and the non-real. In this search, Palma et al. [38] found that the mapping of real objects in virtual reality situations, coupled with haptic feedback, resulted in a significantly more real and participatory experience for the user, and could establish "augmented virtuality". The same conclusion is drawn by Bouzbib et al. [39] These authors consider that the possibilities provided by touch-related feedback are crucial to enhance user experiences, which they experimented with in a study they conducted on the use of haptic devices in VR experiences. Similarly, Palma [38] considered a virtual reality experience using sensorized, physical copies of real artefacts, achieving a faithful reproduction of the appearance. More specifically, the user could change the virtual appearance of the object with their hands from a personal physical palette printed in 3D.

It is worth noting that the possibilities are manifold. Monteiro et al. [40] studied over 80 VR studies in which interfaces were used, the tasks associated with them, and the analysis of the evaluation performed. The voice, the eye, and the head were the most studied interfaces, in order of most to least, although brain interfaces and facial expressions were also used. Of these, voice proved to be the most versatile in terms of interface usability.

In any case, progress in terms of experimenting with new possibilities must go hand in hand with their evaluation [40]. It is necessary, in this sense, to establish standardized protocols and scales for this, although it may also be interesting to establish surveys aimed at the specific use of the technological solution employed, especially in the field of cultural heritage [41].

In some cases, the absence of an evaluation associated with the experience carried out makes it difficult to improve human interaction with the "machine" in future experiments [42]. There is a need for evaluation, especially regarding user testing, with the aim of understanding how stimuli can change people's perceptions. The variables to be analyzed could include aspects already addressed in previous studies [42]: (a) usability, from questions about interaction, ease of use, ease of understanding, manipulability; (b) satisfaction, which encompasses excitement, likability, enjoyment, frustration/excellence, boredom/excitement, rigidity/flexibility; (c) quality of experience ("QoE"), which may include analyzing the sense of touch (for haptic experiences), quality of content and realism issues; (d) sense of presence, referring to engagement and immersion. Based on the variables mentioned above, it is considered that the adoption of certain evaluation models, such as the TAM model [14] can be beneficial to systematize the evaluation process.

2.4. The Integration of AR, VR and MR into Educational Settings

AR has been developed to a greater extent than VR in the educational environment [43]. The main reason for this is that AR does not require special devices to observe information. Even so, both have actually been used in different areas of knowledge. Some of these uses are collected in the systematic review carried out by Ibáñez and Delgado-Kloos [44] on research studies focused on STEM disciplines, and the meta-analysis about applications in different contexts undertaken by Suh and Prophet [45]. It is also worth highlighting the review work by Akçayır and Akçayır [46], in which several variables related to the application of AR in education are studied. More specifically, it is also worth mentioning other studies referring to teaching modalities, such as distance education [47], or training in specific areas of knowledge: mathematics [48], medicine [49] and engineering [37], among others.

Likewise, some interesting studies have addressed the world of art and cultural heritage, among them, those that are presented in the work by Lin et al. [50] which provides a detailed account of experiences referring to both with regard to VR. In this respect, special attention needs to be paid to aspects directly linked to didactic issues, such as co-creation, which enables the user to contribute to the generated content, or intrinsic as well as extrinsic motivation. The study of Margetis et al. [51] concerning realistic virtual museums deserves to be highlighted here as well. In this case, augmented, virtual, and mixed reality technologies are combined to deliver unified extended reality. The new space created is a "realistic virtual museum" where visitors access the interactive fusion of a physical and a virtual world, where there are virtual agents to interact with.

Nevertheless, three clear aspects limit the utilization of AR and VR in training: the lack of learning models and theories to justify their incorporation into teaching–learning processes; the non-existence of educational materials; and the low number of research studies [36,52]. These aspects suffice to stress the need for this paper.

3. Materials and Methods

3.1. Description of the MR Objects Used

The combination of art with AR, VR, and MR opens up a whole range of possibilities for the user. In this sense, as explained by Portalés [53], artists and experts in computer technology have been collaborating in recent years with the purpose of creating new experiences that revolve around art from various fields. By way of example, Aldridge and Bethel [54] investigated the feasibility of patients with brain injuries participating in virtual art therapies. On another note, Chih-Long et al. [55] analyzed an experience of appreciating artistic painting through several VR types and compared it with the appreciation of a physical painting. Panciroli et al. [56] directly focused on AR-assisted education about art. On this occasion, as with other similar ones, the aim consists of integrating these digital technologies into non-formal contexts, although there are also experiences in formal contexts—as illustrated by our case study.

In our research, the objects produced in MR relate to the Church of the Annunciation in Seville, a building which belongs to the University of Seville. It was initially known as "Casa Profesa de la Compañía de Jesús" (Professed House of the Society of Jesu) and dates back to 1565. Its façade is one of the masterpieces of Sevillian Mannerism. The MR application developed allows the user to view, on a scoreboard, the 3D models of the carvings of St. Ignatius of Loyola and Saint Francis Borgia made by the sculptor Martínez Montañés between 1610 and 1624, which are located at the main altarpiece of this church. Additionally, users can access a gigapixel photograph of that altarpiece which, by means of an extreme zoom, they will be able to see each and every one of its details. Furthermore, it will be possible for any user to not only to experience a 360° viewing of the central nave, the entrance, and the crossing, but to also visualize a video of the central nave interior, recorded with the help of a drone (Figure 1).

Figure 1. Images of the object produced to study art in the Church of the Annunciation in Seville. Source: developed by the authors.

The images were taken using an automatic stitching system using the Roundshot VR robot in conjunction with a Canon EOS 6D camera. This system allows a multitude of high-resolution photographs to be taken, which are then unified into a super zoomable image. The glasses used for the VR viewing were of the 3D virtual reality type from Celexon. The created digital material incorporates a set of questions meant to ascertain whether students have paid attention during their interaction (Figure 2). The results achieved by each student can be found at the end of the questionnaire.

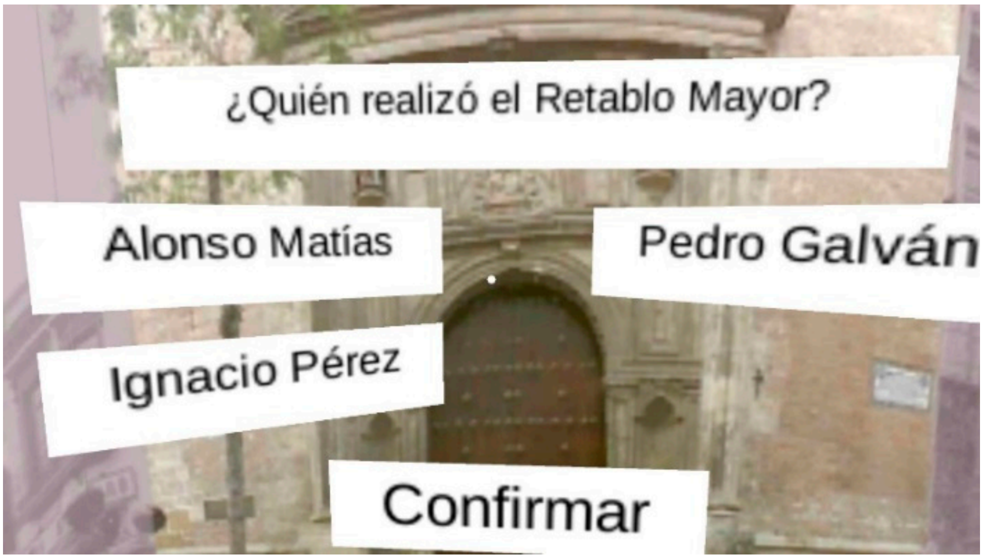

Figure 2. An example of the questions appearing in the produced software. Source: developed by the authors.

The produced material can be classified as Level-2 AR, immersive VR, 360 vision, and 3D modeling, with the incorporation of audio and gigapixels which makes it easier to enlarge the image so that details can subsequently be observed (Figure 3).

Figure 3. Image of the gigapixel of the artistic figure from the Annunciation. Source: developed by the authors.

Different software programs—listed in Table 1—were used to build both objects.

Seeking to facilitate the utilization of the elaborated digital product by students, the objects were designed using an app compatible with IOS and Android devices.

3.2. Methods

Among the different strategies which can be used to evaluate information and communication technologies is an "assessment by and from users" [57], where the users/addressees of these technologies are explicitly requested to offer their views about the quality of them. This work is organized from this perspective.

Table 1. Software used for the production of AR and VR objects. Source: elaborated by the authors.

Agmented Reality	
Software	What it is used for
Zappar	Launcher
Android Studio	Java development environment. APK export for Android.
Sketchfab	A platform permitting the visualization and downloading of 3D objects. Some applications for AR and VR make it possible to directly link with that platform to embed 3D resources.
Blender	3D retouching.
GigaPan Stitch	Gigapixel creation.
Adobe Photoshop	Equirectangular creation. Graphics.
Virtual Reality	
Unity 3D	Virtual reality programming. APK export for Android.
Krpano	Making reality via web images and video.
Sketchfab	A platform permitting visualization and downloading of 3D objects. Some applications for AR and VR make it possible to directly link with that platform to embed 3D resources.
Adobe Photoshop	Equirectangular creation. Graphics.

The research was performed with students enrolled in a Master's degree in "Art: idea and production" at Seville University. The total number of participants amounted to 20—the number of students registered for that Master's degree; therefore, no sampling whatsoever was carried out; all the students belonging to the addressee population took part in the initiative. The type of study developed can be categorized as one of an experimental and exploratory nature with a single group.

We developed an ad hoc information collection instrument structured in two separate parts. The first one aimed to ascertain the degree of acceptance that both AR and VR had created in the subjects after their participation in the experience; as for the second, it sought to ascertain the assessment that students made of the presented objects. We diagnosed the extent to which AR and VR technologies were accepted from the "Technology Acceptance Model" (TAM). It is a robust and powerful theoretical framework of users' acceptance and usage of technology [58,59]. It is considered appropriate to use this model, which is based on the theoretical foundation of social psychology theories, including the theory of reasoned action and the theory of planned behavior. In addition to this theoretical basis, it is worth highlighting the numerous studies that have been carried out using this model. This is an added value, as it has been sufficiently tested. This model, originally formulated by Davis [60], collects information from five dimensions (see Figure 4): perceived usefulness (PU); perceived ease of use (PEU); perceived enjoyment (PE); attitude towards its use (AU); and intention to use it (IU). Davis's proposal suggests that our predisposition towards the use of any technology depends on our attitude towards it, which in turn is influenced by the "perceived ease of use", the "perceived usefulness" and the "perceived enjoyment". This model has been utilized to analyze the degree of acceptance of various technologies, and more specifically for AR [14,59–66]. It is likewise worth stressing that the TAM model proved to be truly robust when evaluated by means of structural equations [67].

This first instrument consisted of 14 items with a Likert-type construction (4 for perceived usefulness; 3 for perceived ease of use; 3 for perceived enjoyment; 2 for the attitude towards its use; and 2 for the intention to use it), with seven response options, ranging from "Extremely unlikely/I totally disagree" (1) to "Extremely likely/I totally agree" (7).

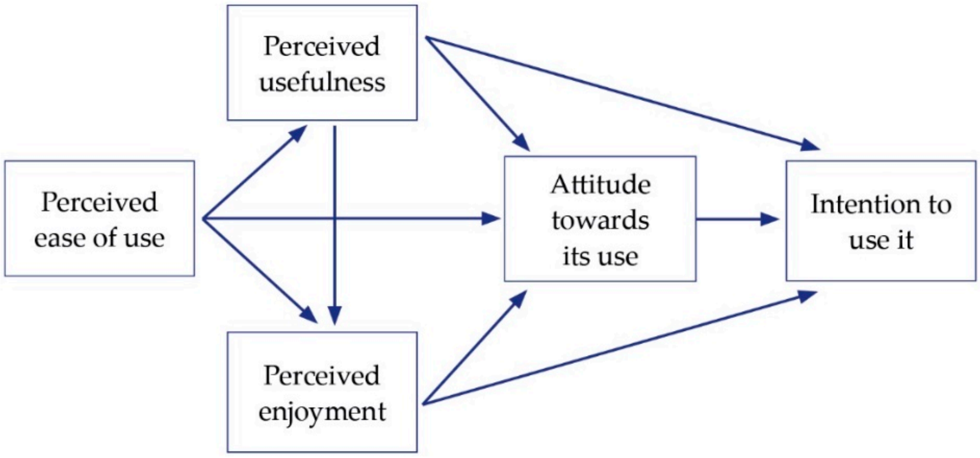

Figure 4. TAM's graphic representation [58]. Source: developed by the authors from Davis [58].

A second instrument based on tools already created in other similar studies for the assessment of learning instruments in AR formats was added to evaluate the produced objects [68–70]. This was an 11-item Likert-type tool with six response options that ranged from "Very negative/I totally disagree" to "Very positive/I totally agree". These items gathered information about two dimensions: technical and aesthetic aspects of the object produced in AR and VR (4 items); and ease of use (7 items).

Due to the small number of students involved in the exploratory study, the joint instrument was administered by means of a printed document. So as to obtain the reliability index, we followed the advice of O'Dwyer and Bernauer [71], according to whom Cronbach's alpha is best suited for Likert-type tests. Table 2 provides the different values reached for both sub-instruments, as well for the various dimensions shaping them. The scores achieved allow us to state that the instruments, both globally and in the different dimensions that they are made up of, show high or very high reliability levels, according to O'Dwyer and Bernauer [71].

Table 2. Cronbach's alpha of the respective questionnaires and sections used.

TAM		Object Quality Assessment	
Dimension	**Alpha Value**	**Dimension**	**Alpha Value**
Instrument total	0.901	Instrument total	0.951
Perceived usefulness	0.878	Technical aspects	0.893
Perceived ease of use	0.888	Ease of navigation	0.900
Perceived enjoyment	0.834	Software program tutorial	0.882
Attitude towards its use	0.817	-	-
Intention to use it	0.850	-	-

The procedure implemented to assess the different learning objects occupied a three-hour session during which a four-step sequence was followed: (1) introductory explanation about AR and VR (Figure 5a); (2) presentation of the information incorporated into each of the objects, the procedure selected for the utilization of AR and VR from an ad hoc elaborated guide, and the downloading of the app; (3) students' interaction with the objects (Figure 5b); and (4) completion of the evaluation tools (Figure 5c).

(a) (b) (c)

Figure 5. Screenshots of the work process (**a**–**c**). Source: developed by the authors.

4. Results

In order for the outcomes to be more easily understood, we will firstly present those obtained through the application of the first part of the instrument relating to the TAM model, subsequently showing those corresponding to students' assessment of the objects, and finally carrying out an analysis of the correlations between both of them.

As for the TAM model, Table 3 lists the means and standard deviations obtained for the two used objects. It also offers the results referring to: (a) the instrument globally; (b) each of the dimensions shaping it; and (c) each of the items.

Table 3. Means and standard deviations reached with the instrument related to the TAM model. Source: developed by the authors.

		AR		VR	
		m	**s.d.**	**m**	**s.d.**
(1)	Perceived usefulness (PU)				
1.1.	Using this system could improve my learning in the classroom. (PU1)	6.20	1.20	6.40	1.14
1.2.	Using this system during classes will make it easier for me to understand certain concepts. (PU2)	6.60	0.60	6.70	0.57
1.3.	I think the system is useful when learning. (PU3)	6.40	1.14	6.35	1.18
1.4.	Using this system would increase my learning. (PU4)	6.40	1.14	6.40	1.14
(2)	Perceived ease of use (PEU)				
2.1.	I think the system is user-friendly. (PEU1)	5.35	1.27	5.11	1.05
2.2.	Learning to use and manage the system was not a problem for me. (PEU2)	5.15	1.63	5.20	1.58
2.3.	The information received to use and manage the system seemed clear and understandable to me. (PEU3)	5.70	1.49	5.70	1.38
(3)	Perceived enjoyment (PE)				
3.1.	Using the system was fun for me (PE1)	6.85	0.37	6.80	0.41
3.2.	I enjoyed using the system (PE2)	6.50	0.95	6.65	0.67
3.3.	I think the system permits learning by playing. (PE3)	6.60	0.75	6.75	0.64
(4)	Attitude towards its use (AU)				
4.1.	Using the system makes learning more interesting. (AU1)	6.60	0.60	6.65	0.49
4.2.	In my opinion, using this system in the classroom is a good idea. (AU2)	6.30	0.98	6.30	0.98
(5)	Intention to use it (IU)				
5.1.	I would like to use this system in the future if I had the chance. (IU1)	6.60	0.75	6.70	0.66
5.2.	I would like to use the system to learn both the topics dealt with and others (IU2).	6.65	0.59	6.65	0.59
	Perceived usefulness (PU)	6.40	0.97	6.46	0.95
	Perceived ease of use (PEU)	5.40	1.27	5.36	1.16
	Perceived enjoyment (PE)	6.65	0.58	6.73	0.48
	Attitude towards its use (AU)	6.45	0.71	6.48	0.64
	Intention to use it (IU)	6.63	0.60	6.68	0.52
	TAM globality	6.28	0.67	6.32	0.62

The values obtained allow us to point out that the students showed a high degree of acceptance of AR and VR technologies, revealing a highly favorable attitude towards their use (AR = 6.45 and VR = 6.48), and a strong agreement regarding their intention to use them (AR = 6.63 and VR = 6.68). Likewise, it was deemed appropriate to verify a set of hypotheses that we formulated as follows:

- H1-H2-H3. The perceived ease of use may positively and significantly influence perceived enjoyment and perceived usefulness, as well as the attitude towards the use of learning objects produced in AR and VR.
- H4-H5-H6. The perceived usefulness of learning objects produced in AR and VR is likely to positively and significantly affect perceived enjoyment and the intention to use them, as well as the attitude towards the use of learning objects in AR and VR.
- H7-H8. Perceived enjoyment may positively and significantly influence both the attitude towards their use and the intention to use learning objects produced in AR and VR.
- H9. The attitude towards their use is likely to positively and significantly affect the intention to use learning objects made in AR and VR.

These hypotheses also make it possible to check the validity of the model put forward by Davis [58], for which Pearson's correlation coefficient was applied, obtaining the values collected in Table 4 below.

Table 4. Correlations between the different TAM dimensions. Source: developed by the authors.

Dimension	Object	PEU	PE	AU	IU
Perceived usefulness (PU)	AR	0.494	0.529	0.550	0.752
	VR	0.460	0.671	0.530	0.680
Perceived ease of use (PEU)	AR	-	0.209	0.386	0.539
	VR	-	0.288	0.429	0.565
Perceived enjoyment (PE)	AR	-	-	0.558	0.434
	VR	-	-	0.465	0.479
Attitude towards its use (AU)	AR	-	-	-	0.787
	VR	-	-	-	0.807

The values achieved provide evidence of positive correlations; thus, when one of them increases in a specific direction, the other one does so in the same direction, going from "low" levels ($0.2 < r < 0.4$) to "high" ($0.6 < r < 0.8$) or "very high" ones ($0.8 < r < 1$) [72]. A special mention must be made of the relationship between "attitude towards their use" and "intention to use them" (AR = 0.787 and VR = 0.807).

The following hypotheses were posed in order to ascertain whether significant differences existed between the scores assigned by students to the objects produced in AR and VR:

Hypothesis 0 (null hypothesis): no significant differences exist between the scores assigned by students to the objects produced in AR and VR in the various dimensions that shape the TAM model, with a 0.05 or lower alpha risk of our being wrong.

Hypothesis 1 (alternative hypothesis): significant differences exist between the scores assigned by students to the objects produced in AR and VR in the various dimensions that shape the TAM model, with a 0.05 or lower alpha risk of our being wrong.

To that end, we applied the Student's t-test and obtained the results offered in Table 5.

Table 5. Results referred to the Student's t-test. Source: developed by the authors.

Contrast Dimension	t	df	Sig.
Perceived usefulness (PU)	−1.157	19	0.262
Perceived ease of use (PEU)	0.431	19	0.671
Perceived enjoyment (PE)	−1.561	19	0.135
Attitude towards its use (AU)	−0.370	19	0.716
Intention to use it (IU)	−1.453	19	0.163
Instrument globality	−0.863	19	0.399

The values obtained do not allow us to reject either of the formulated null hypotheses; we can consequently state that students show similar degrees of acceptance for both technologies, with no differences being perceived between them.

Seeking to delve deeper into the results achieved, we paid attention to the correlations established between the assessments given to the different objects in each dimension. For this purpose, we applied Pearson's correlation coefficient and obtained the scores provided in Table 6.

Table 6. Correlations between the scores achieved by the two objects in each dimension. Source: developed by the authors.

Contrast Dimension	Correlation
Perceived usefulness (PU)	0.955
Perceived ease of use (PEU)	0.969
Perceived enjoyment (PE)	0.941
Attitude towards its use (AU)	0.914
Intention to use it (IU)	0.903
Instrument globality	0.974

As can be seen, the correlations reached between both objects in each one of the dimensions can be considered "very high" and positive [72], which would suggest a high level of similarity in the scores given by students to each one of the objects.

Regarding students' assessments of the objects, Table 7 provides the mean values and the standard deviations obtained in each instrument item, in the instrument globally, and in the three dimensions shaping it, for each of the utilized objects.

Table 7. Mean scores and standard deviations for each of the dimensions. Source: developed by the authors.

		AR		VR	
		m	s.d.	m	s.d.
(1)	Technical and aesthetic aspects				
1.1.	The operation of the resource that we have presented to you is:	5.05	0.85	5.35	0.75
1.2.	On the whole, you consider the aesthetics of the resource produced:	5.00	1.15	5.15	0.88
1.3.	In general, you would describe the technical functioning of the resource as:	5.11	0.99	5.20	0.77
1.4.	Broadly speaking, how would you assess the presentation of information on the screen?	5.37	1.01	5.20	0.89
(2)	Ease of use				
2.1.	How would you describe the user-friendliness and handling of the resource that we have presented to you?	5.05	0.91	5.05	0.97
2.2.	How would you describe the extent to which it is easy to understand the technical functioning of the resource that we have presented to you?	5.37	0.83	5.26	0.99
2.3.	How would you assess the overall design of the AR resource produced?	4.95	1.03	5.16	1.07
2.4.	How would you assess the overall design of the resource that we have presented to you?	4.65	1.50	4.79	1.23
2.5.	How would you assess the flexibility in the utilization of the material that we have presented to you?	5.21	1.13	5.21	0.98
2.6.	Using the resource produced was fun for you:	5.95	0.52	6.00	0.49
	Technical aspects	5.13	0.88	5.23	0.61
	Ease of use	5.02	1.18	5.22	0.79
	Instrument total	4.98	1.17	5.23	0.63

An initial analysis of the collected data leads us to emphasize the high score given by students to the different learning objects produced. More precisely, the mean scores were situated at 4.98 (AR) and 5.23 (VR) for the instrument total; at 5.13 (AR) and 5.23 (VR) for the dimension about technical aspects; and at 5.02 (AR) and 5.22 (VR) regarding ease of use. The best valued item in both objects was "using the produced resource was fun for you" (AR = 5.95 and VR = 6.0). It is additionally worth highlighting that the standard deviations achieved were not very high, which suggests a certain level of agreement in students' assessments.

The following hypotheses were put forward in order to ascertain whether significant differences existed in students' assessments of both objects:

Hypothesis 0 (Null hypothesis): No significant differences exist in students' assessments of the objects produced in AR and those produced in VR, with a 0.05 alpha risk of our being wrong, as both regard the scores assigned to the object globally, to its technical aspects, and to ease of navigation.

Hypothesis 1 (Alternative hypothesis): significant differences exist in students' assessments of the objects produced in AR and those produced in VR, with a 0.05 alpha risk of our being wrong, as both regard the scores assigned to the object globally, to its technical aspects, and to ease of navigation.

To that end, we once again applied the Student's t-test and obtained the values offered in Table 8.

Table 8. Student's t-test values. Source: developed by the authors.

Contrast Dimension	t	df	Sig.
Technical aspects	−0.952	18	0.354
Ease of use	−1.179	17	0.255
Globality	−1.145	18	0.267

The obtained values do not allow us to reject either of the formulated null hypotheses. We can thus point out that no significant differences exist, with a $p \leq 0.05$ alpha risk in students' assessments of the different objects produced in AR and VR. Furthermore, as we had done previously, we paid attention to the correlations established between the assessments given to the different objects in each dimension. For this purpose, we applied Pearson's correlation coefficient and obtained the scores provided in Table 9.

Once more, as could be expected from the abovementioned results, the correlation between the scores assigned to the different objects can be considered very high [72]. So as to check the existence of relationships between the different dimensions analyzed in the instrument, and between them in the two objects, we performed a Pearson's correlation coefficient test (Table 10).

Table 9. Pearson's correlation coefficient. Source: developed by the authors.

Contrast Dimension	Correlation
Technical aspects	0.862
Ease of use	0.793
Instrument globality	0.874

Table 10. Pearson's correlation coefficient. Source: developed by the authors.

	Object	Ease of Use	Technical Aspects
Globality	AR	0.936	0.899
	VR	0.953	0.829
Ease of use	AR	-	0.689
	VR	-	0.620

As shown above, the obtained scores can be regarded as "very high", which would suggest "very high" correlations between the instrument globally and the different dimensions shaping it, and between the dimensions themselves. The relationships found were very similar for both objects.

Finally, we present the results referring to the relationships which exist between the two broad dimensions examined in our study: degree of acceptance of the utilized technology; and assessment made by students about the two produced objects. Pearson's correlation coefficient was used for that purpose, obtaining the scores corresponding to the globality of both instruments, which are collected in Table 11.

Table 11. Pearson's correlation coefficient between the scores achieved for both instruments. Source: developed by the authors.

Contrast	Correlation Coefficient
Augmented Reality Object	0.561
Virtual Reality Object	0.335

The correlations found, which can be considered moderate, were weaker when they referred to the VR object. As for the specific dimensions, their correlations appear in Table 12 below.

Table 12. Pearson's correlation coefficient between the scores achieved for both instruments. Source: developed by the authors.

Dimension	Object	Correlations		
		Total	Ease of Use	Technical Aspects
Perceived usefulness (PU)	AR	0.348	0.297	0.349
	VR	0.186	0.190	0.124
Perceived ease of use (PEU)	AR	0.429	0.439	0.339
	VR	0.341	0.367	0.201
Perceived enjoyment (PE)	AR	0.520	0.387	0.593
	VR	0.268	0.283	0.172
Attitude towards its use (AU)	AR	0.567	0.525	0.516
	VR	0.288	0.268	0.236
Intention to use it (IU)	AR	0.463	0.418	0.436
	VR	0.224	0.212	0.182

Moreover, in this case, the achieved scores resemble those for the instrument in its totality that were presented above.

5. Discussion

Our results follow other authors' findings regarding the positive acceptance of AR and VR by our students [17,32,63–65,73–75]. Nevertheless, it is necessary for us to recognize that more coincidences were obtained with results that referred to AR than with those corresponding to VR, where research studies are less abundant, although their number has been growing lately [76].

Regarding the technical and aesthetic aspects of the design of AR and VR objects and their link to user-friendliness, the results match those achieved in other studies on AR subjects [69,70]. In these studies, the assessments made by the students were also very positive, rating the objects as very attractive to them; thus, we concur with the results obtained by Jung et al. [16]—although their work referred to the commercial context in art galleries—that the attitude towards AR was positive. Our research has also been linked to improved motivation, as have other similar studies [77].

The findings concerning the absence of significant differences between AR and VR matches those few available studies where both technologies are compared [78]. This leads us to stress, in accordance with Makransky, Petersen, and Klingenberg [79], the need for further research on the investigation of VR objects.

The two sub-instruments used—both that of TAM and the one associated with object assessment—proved to have good reliability levels, which is in keeping with those obtained in other studies [68,80]. Moreover, their simplicity and quick administration makes the resulting instrument easy to use for students to assess the produced resources, and thus to ascertain the degree of acceptance created by the utilization of these technologies.

As explained above, AR and VR technologies are highly valued by experts for their incorporation into training [81]; they are equally appreciated by students [74] and are very significant, both when students become object producers [82] and as Smart Learning Environments [83]. Along these lines, it is worth stressing that the exploratory study was carried out in a real classroom situation, which allows us to state that both technologies can be implemented in formal training contexts. This is also indicated by Allcoat et al. [84], where VR and MR are presented as suitable alternatives to traditional learning methods.

We researched certain artistic works located in an enclosed space in line with the work of Bekele et al. [85] who addressed museum cultural heritage. Despite this limited space, our work process was analogous to others in terms of where open VR environments were constructed. An example of this is the interactive mapping approach to explore open urban landscapes by Edler et al. [86] or the work of Giachero et al. [87] on virtual gardening and intellectual disability.

In keeping with the results obtained by Lin et al. [50] in a study where users chose the physical artistic form, our findings likewise suggest that these new realities reduce the gap between face-to-face and non-face-to-face formats; however, we need to improve the design of digitized objects, so that a stronger impact on the user's experience can be achieved. In this sense, we concur with several studies [16,17], where the need to comply with certain technical requirements for software and hardware to offer quality immersive experiences was confirmed.

6. Conclusions and Limitations

We have used the TAM model [60]. As indicated above, this model is based on theories of social psychology, including the theory of reasoned action and the theory of planned behavior. In general, these theories argue that human beings act rationally, so an analysis that studies these behaviors is possible. In our case, we proposed an experience based on AR and VR. These are emerging technologies, and it is necessary to establish what behaviors derive from their use. In this sense, we will ultimately be able to define new learning scenarios contextualized in today's society.

As shown in the preceding pages, the use of AR and VR objects—i.e., MR objects—in university teaching aroused great interest among the students who took part in the study, and they also expressed a high degree of acceptance of the utilized technologies. All this leads us to conclude that the technology acceptance model developed by Davis [60] proved effective in ascertaining the extent to which AR and VR technologies were accepted and as a tool to determine students' future intention to use them.

More specifically, and with regard to the degree of acceptance, we must point out that no significant differences were found between the two objects, which suggests that students perceived that they were participating in a mixed reality experience, drawing no distinctions whatsoever between both resources and viewing the experience globally.

The importance of the design of AR and VR objects and its link to aspects such as the usability of these objects was also noted.

Although the scores given to the VR object were slightly better than those for the AR object, the differences were not statistically significant; hence our similar and positive assessment of both types of objects.

The limitations of our research are linked to the small sample size of the study and the absence of a control group. All respondents were in the same Master's program and worked in groups; moreover, this is likely to be an incredibly biased source population. We would need to replicate the research in a larger group in order to reach definitive conclusions. We also consider it a limitation that we did not compare the results with a previously trained group; however, despite these limitations, this research provides results that can be used to promote the use of MR in learning.

The last reflections in this paper aim to promote possible future lines of research. Among those that stand out: replicating the research with students enrolled in the Degree in Fine Arts; adding a test to analyze academic performance among the information collection instruments; and extending object production to other areas of knowledge.

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