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User Experience of Virtual Heritage Tours with 360° Photos: A Study of the Chapel of Dolores in Icod de los Vinos

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Abstract: Virtual tours with 360 photos present a quick, easy and accessible way to create immersive experiences. The visualization on diverse devices provides a user experience that can be different. A virtual tour with 360 photos of the Chapel of Dolores (Tenerife) has been created. Access is limited to specific days, so the creation of a virtual tour allows you to visit it at any time; in addition, a pilot test has been carried out with students of the degree of restoration and conservation of cultural heritage in order to measure the user experience of the virtual tour, depending on the device used. The participants took a virtual tour of the Dolores Chapel, first with a cell phone and then with the virtual reality headset, and then completed a user experience questionnaire. The results obtained comparing both visualization technologies are detailed, highlighting the fact that when using the virtual reality headset no better results are obtained on the immersion subscale; in addition, the visualization on a smartphone is more comfortable and obtains better results for consequences such as dizziness and vertigo. Therefore, it may be an interesting strategy to have simple versions that work quickly on cell phones.

Keywords: virtual tour; 360° photos; user experience; Chapel of Dolores

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1. Introduction

For this work, we created a virtual tour with 360 photos of the Chapel of Nuestra Señora de los Dolores, also known as Capilla de la Huerta, located in the municipality of Icod de los Vinos, on the island of Tenerife (Spain). This property is annexed to the dependencies of the former Convento Franciscano del Espíritu Santo, being considered part of the convent complex, which has had the denomination of an Asset of Cultural Interest, in the category of Monument since 2013 [1].

It was the family of Hurtado de Mendoza who promoted the construction of the chapel in the late eighteenth century at the request of Captain Hurtado de Mendoza, who wanted to dedicate it to the Virgin of Dolores. The chapel was finished in 1770, although it underwent modifications until 1774 [2]. Focusing on its interior, the temple has a single nave, rectangular floor plan and a roof of pair and knuckle, with suspenders that present an ornamentation of crosses and stars, being one of the few structures of these characteristics that are preserved on the archipelago (Figure 1).

Occupying the front of the chapel is the main altarpiece, which belongs to the second half of the 18th century and is catalogued as a Rococo–Chinesque altarpiece [3]. It can be said that this altarpiece is registrable, which means it is allowed to be transited through several accesses which at the time were created for functional reasons (extraction and placement of niches and images, modification of the altar table, etc.) and this has allowed the identification and analysis of its construction system, of architectural box or sheet, which is hidden behind the facade of the altarpiece [4].

Figure 1. Interior of a single nave. In the background, the main altarpiece that presides over the chapel.

The interest aroused by this altarpiece has led to different technical studies and interventions on it [5]. The last of these works took place in 2021, within the framework of the Final Degree Project in Conservation and Restoration of Cultural Property, where the study and conservation–restoration of the central niche of the main altarpiece was carried out [6].

Although the chapel is still open for worship, its access is limited to specific days of the month and festivities, so the creation of a virtual tour provides the possibility of being able to visit it at any time. This chapel, as described above, is of historical–artistic interest and justifies its dissemination, encouraged by the good state of preservation in which it is found and the amount of documentation available thanks to the studies and interventions carried out. In short, this project aims to enhance the value of the Chapel of Dolores, also revealing rooms and spaces which, even on the days it is open, are not accessible to the public.

In any case, virtual reality, to be effective as an element of communication in the dissemination of heritage, must be accepted by the user. This means that the user of this technology must feel comfortable with the interface used and perceive that the scenario he or she visualizes is valid. Although virtual environments are considered a powerful tool for learning and communication [7,8], some authors have started to study the user experience (UX), i.e., the overall perception a person has when interacting with a product, in this case a virtual tour. This includes all aspects of the interaction, such as usability, accessibility, aesthetics, usefulness and satisfaction experienced by the user [9,10].

In this sense, one of the ways to evaluate user experience are surveys with specialized questionnaires. The first user experience questionnaire (UEQ) was created in 2005 [11] and consisted of eighty questions and six scales (Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty). This questionnaire allows for an efficient quantitative measurement of a product's characteristics. The questionnaire is available in multiple languages and was validated several times [12,13]. User experience questionnaires can be used to test new versions of a product, compare one product to another, and validate a new product to see if it is good enough for the user, as well as to determine where improvements need to be made [14].

Research on virtual tours has been conducted, for example at Princess Norah University in Saudi Arabia. The results revealed that the virtual tour lacked interest and adequate visualization options. Improvements in the graphic design were needed to make it more visible, as images of campus buildings and features requested by users were missing [15]. In another research study, forty virtual museum tours were analyzed, and the study found a noticeable difference with user experience. With the results obtained, they offer specific recommendations to improve the creation of 360-degree virtual tours, making them more accessible and user-friendly [16]. Li and Huang [17] analyzed a virtual tour of the Palace Museum, concluding that, although virtual reality does not replace the real experience, it can enhance the understanding of artifacts and allows for a better understanding of their stories. In another study they compare the navigation of a virtual tour on the one hand with a mouse and on the other hand a navigation based on hand gestures with a user experience questionnaire. The study concludes that although the mouse is easier and faster to use, the gesture navigation gave better results for Interest/Enjoyment [18]. In other studies they compare the user experience of different virtual environments made on the one hand with 360 photos and on the other hand 3D modeling [19].

The aim of this work is to know the user experience provided by this virtual tour when visualized by different technologies in order to determine the validity as an element of dissemination of this historical–artistic space and to make a comparison of user perception when using different visualization technologies. The main research hypothesis is that the use of virtual reality headsets significantly improves the immersion in the virtual tour compared to the visualization on mobile devices. As a secondary hypothesis, we consider that the virtual tour is an effective tool for the dissemination and learning of cultural heritage, regardless of the technology used.

To carry out this research, a pilot test was conducted with students into the degree of restoration and conservation of cultural property. The participants took a virtual tour of the Chapel of Dolores, first with a smartphone and then with a virtual reality headset (a Cardboard type), and then completed a user experience questionnaire. Specifically, the students were given the "Questionnaire on User Experience in Immersive Virtual Environments (QUXiVE)", which follows the ISO 9241-210 standard [20] and is composed of nine subscales: presence, engagement, immersion, flow, usability, emotion, skill, judgment, experience consequence and technology adoption. An assessment of the virtual tour as a tool for learning is also conducted. This paper details the results obtained by comparing both visualization technologies, highlighting the fact that when using virtual reality headset, results obtained in the immersion subscale are similar to those with the smartphone, but worse results are obtained in usability and consequences such as nausea and vertigo.

2. Background

A virtual tour is a recreation of an entirely virtual environment in which you can move freely and interact using a digital device. Virtual tours can be a copy of a reality or a fictitious space and even a mixture of both [21], where the user can walk through or examine the place. To create these tours there are a variety of programs and applications, on the one hand advanced, expensive technologies that require specialized knowledge for their use, and on the other hand simple and free technologies available to anyone [22].

One type of technology that makes it possible to create a virtual tour is 3D modeling using CAD (Computer Aided Design) tools [23]. With these programs it is possible to model, texture, illuminate and animate any scene or element. They are commonly used in video games and other entertainment media; however, they require a large investment of time. In these cases, the environments can be faithful copies of reality or invented scenarios, as well as mixed. In order to turn these 3D models into virtual tours, video game engines such as Unity or Unreal Engine, among others, are usually used. A first-person controller (FPC), i.e., an element that moves through the space, is usually incorporated to traverse these environments, thus allowing the entire environment to be visited [24]. In addition, video game engines allow for the addition of all kinds of interactivity; however, it takes time to achieve realistic scenarios.

In order to create virtual tours that are an exact copy of reality, technologies other than 3D modeling can be used. For example, two suitable technologies for this process would be photogrammetry and 3D scanning of the environment [25]. Photogrammetry uses multiple photographic images taken from different angles to perform a three-dimensional reconstruction of the space. Three-dimensional scanners, on the other hand, allow for obtaining point clouds (x, y, z) of the existing space. Both techniques can be combined to optimize the workflow and improve the appearance of the 3D models. The use of 3D scanners and/or photogrammetry in complex environments such as the Chapel of Dolores requires knowledge of advanced software to be able to process, visualize or edit the tours. Despite this, these technologies are frequently used in the industry [26]. These tours are usually exact copies of reality and in some cases they are referred to as digital twin, since this represents with maximum possible detail the real environment in a virtual model [27].

However, there is another technology for virtual tours, based on 360 photos, which also captures the environment in a completely realistic way, but it is much simpler and faster to create, manipulate and visualize. To perform this type of tour, it is necessary to use a 360 camera. Such cameras record or take spherical 360-degree photographs. Although there are cameras aimed at professional sectors that require a very high resolution, there are also models aimed at the general public that are small, easy to handle and affordable. To create the virtual tour from the 360 photos, it is necessary to use specific software such as Matterport, Cloudpano, 3DVista, etc., which allows for the linking of each of the photos, to be able to move through the tour [22]. Virtual tours made with 360 cameras do not allow a completely free movement of the user as happens with other technologies. In this case, the movement is performed as teleportation between one scene and the next. Normally, these type of virtual tours are also conceived as digital twins, since they are faithful to reality.

Once the virtual tour has been created, the form and technology to be used for its visualization must be taken into account. The types of visualizations of a virtual tour are classified into three levels of immersion (low immersion, semi-immersive and high immersion). Virtual tours on screens and controlled by a mouse or touch screen are considered as low immersion [28]. Virtual reality booths (CAVEs) with projections on the floor and walls are considered semi-immersive, and finally, virtual reality headsets are considered fully immersive [29,30]. On the other hand, virtual tours can be generated as an installable application on devices (computers, phones, virtual reality headsets, etc.) or as a web link that allows for the viewing the tour from the browser of our device.

In general, tours created with CAD programs and video game engines usually require a high level of processing, so they can only be viewed on a computer or video game console. Likewise, point clouds or elements created with scanners require a device with high processing capacity to be displayed. Virtual tours made with 360 photographs usually require little processing and therefore are habitually accessible [22].

Due to the ease of creation and visualization of virtual tours created with 360 cameras, they are used in many areas, ss for example to disseminate tourist attractions such as Puerto Bajaña in the Buena Fe canton [31]. In another case, the Teotihuacán Valley is shown in its antiquity and today in order to offer new experiences for tourists, as well as to raise awareness about the value of and care for the conservation of heritage [32]. Another use is the design and implementation of virtual tours for university campuses, so that the navigation limitations of the map application can be replaced by the application of virtual tours [33]. Likewise, in the real estate market, 360 virtual tours have become the most relevant marketing strategy to sell the property [34]. The 360 virtual tours are implemented in hotels as a digital differentiation tool in the local hotel industry. These tours would allow customers to explore the facilities remotely, improving visibility and user experience, increasing bookings, customer satisfaction and long-term profitability [35]. In addition, virtual tours are used for marketing purposes, achieving user engagement through a multisensory virtual tour of the actual production site [36]. In other research, virtual tours are developed for places associated with famous personalities (e.g., the birthplace of an artist), presenting current photos of the place together with historical recreations using computer media, allowing visitors to travel back in time during the virtual tour [37]. A project was also carried out to raise students' awareness of environmental culture, through an interactive tour with 360 technology through ecosystems such as moorlands and Andean forests [38]. Another study investigates how the use of 360-degree virtual tours of mountains can motivate audiences to take real hikes in the mountains [39].

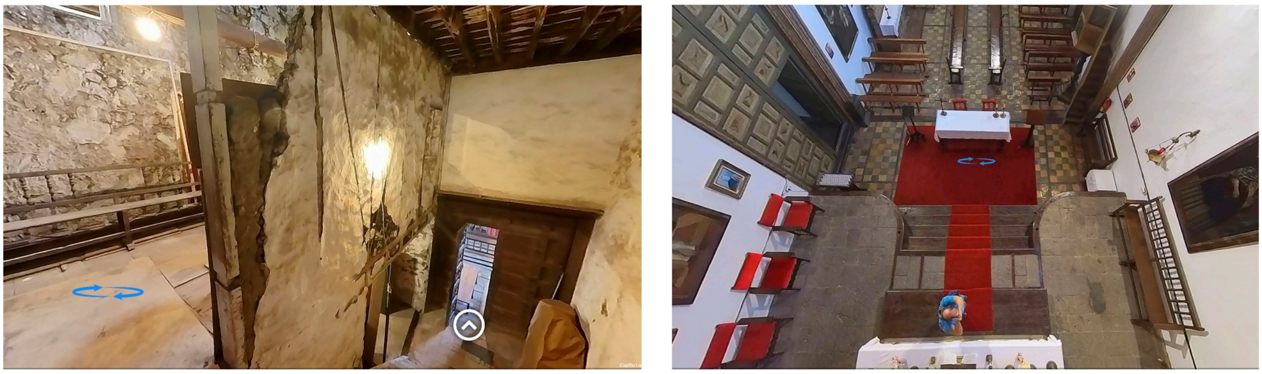
As mentioned above, virtual reality, in order to be effective as a communication element in the dissemination of heritage, must be accepted by the user. In other fields (architecture, engineering, landscaping, etc.) the measurement of user experience in virtual environments is very common [40–42]. This implies that the user experience of virtual content created for cultural heritage should be studied [43]. For example, Škola et al. [44] measure presence, engagement, and immersion in virtual reality with 360-video for cultural heritage. Verhulst et al. compare different types of virtual and augmented reality technologies around cultural heritage, with a result of high enjoyment for all devices, and similar cognitive and emotional engagement levels, although with the presence higher in one of the devices [45]. Other studies compare a large number of virtual heritage resources, visible on screen, and review different ways to evaluate the performance of such applications with surveys of workload, usability, flow, and potential VR symptoms. They conclude that there is a need to access materials in easily accessible formats and with great detail. Low-resolution textures and rough 3D models can deteriorate immersion, user experience and overall application quality [46]. In other cases, they study accessibility enhancement and intangible heritage preservation, and also compare desktop media and virtual reality. The conclusions show that the virtual reality experience did not affect the effort expectancy for the desktop application, but the same experience significantly influenced the performance expectancy construct [47].

One of the uses of virtual tours created with 360 photos is the dissemination and enhancement of the historical and cultural heritage of cities. Many local entities, which have a limited budget, choose virtual tours based on 360 photos for their dissemination tasks. For example, the tourist office of Alicante has tours of some of its monuments and historic buildings, such as the castle of Santa Barbara [48] or the Cathedral of Santiago de Compostela [49]. Other cultural institutions, such as museums or exhibition halls also use this type of virtual tour to disseminate their exhibitions [50]. It is interesting to note that in the field of heritage, chapels or hermitages in small towns do not usually use this type of technology.

3. Materials and Methods

In this work, we have made a virtual tour based on 360 photos of the Chapel of Dolores in Icod de los Vinos in Tenerife. It is a chapel in a small town, which does not have many resources for the dissemination of its heritage. A 360 camera was used, specifically the Insta 360 X3 model of Arashi Vision Inc. located in Shenzhen, China (cost approximately EUR 500). Subsequently, a pilot test was carried out with students studying the degree of conservation and restoration of cultural heritage, to measure the user experience of the virtual tour. An evaluation of the virtual tour as a learning tool was also carried out.

A total of 27 spheric photographs were taken with the Insta 360 X3 camera. Both the exterior, i.e., the entrance door, and the visitable interior were photographed, as well as parts that are not normally visited due to their poor condition (Figure 2a). Due to the great height of the central nave and the altarpiece, photos were taken at a height of 5 m, allowing a close-up view of the details of the ceiling and the altarpiece. An extendable monopod was used for the high-altitude photos to avoid the use of drones inside the chapel (Figure 2b). Since the altarpiece is accessible on foot, we entered into the interior to capture 360 images that are very difficult to access and that allow a much more complete visualization.



(**a**) (**b**)

Figure 2. (**a**) Parts not passable due to their poor condition; (**b**) photo from 5 m above the ground.

The photographs are then entered into the online program Cloudpano to generate the virtual tour (Figure 3). The main task is to organize the photographs and to create the link points between one scene and the next. These links then allow the user to move within the virtual tour. The virtual tour can be accessed at the following URL: https://capilladoloresvr.cultimerse.com (accessed on 3 April 2024).

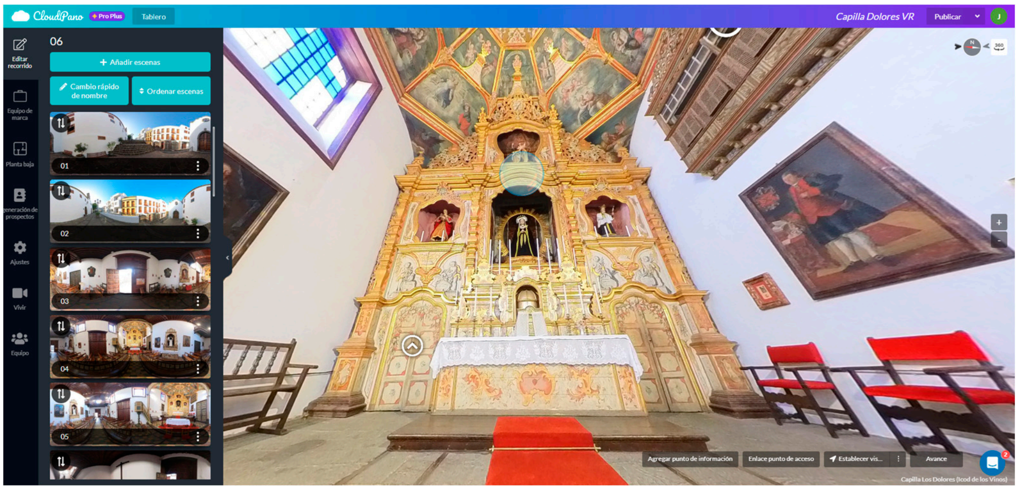


Figure 3. Detail of the Cloudpano program used for the virtual tour.

3.1. Participants

The pilot test was carried out with 18 students of the fourth year course, Conservation and Restoration of Altarpieces, of the degree of conservation and restoration of cultural goods of the University of La Laguna (Tenerife, Spain). The participants were selected on the basis of their accessibility and willingness to participate, i.e., an ad hoc sampling.

3.2. Measurement Tool

The tool used to determine the user experience in a virtual environment is the Questionnaire on User Experience in Immersive Virtual Environments (QUXiVE) [51]. According to ISO 9241-210 [20], User Experience (UX) is defined as "User perceptions and responses resulting from the use of a system or service". This questionnaire has been developed using a selection of components from different existing standardized tests to measure each of the ten subscales of the test. It is the only questionnaire that assesses 10 subscales of virtual environments: presence, engagement, immersion, fluency, usability, skill, emotion, experience consequence, judgment, and technology adoption of virtual tours distributed in 82 questions. The authors indicate that it should be adapted to each practical case. For this case, 27 questions have been selected from 9 of the 10 subscales of the original questionnaire. Each of the questions can be answered on a Likert scale from 1 to 10, where one is completely disagree and ten is completely agree.

In the QUXiVE (Questionnaire on User Experience in Immersive Virtual Environments) questionnaire used in this work, and the subscales are defined as follows.

- Presence: the sense of being there, of the user in the virtual environment.
- Engagement: the energy in action, the connection between a person and their activity in a behavioral, emotional and cognitive form.
- Immersion: the illusion that the virtual environment technology replaces the user's sensory stimuli by the virtual sensory stimuli.
- Flow: defined as "a pleasant psychological state of sense of control, fun and joy".
- Skill: the knowledge the user gains in mastering his activity in the virtual environment.
- Emotion: defined as the feelings (of joy, pleasure, satisfaction, frustration, disappointment, anxiety...) of the user in the VE.
- Usability: the ease of learning (learnability and memorizing) and the ease of
- Using (efficiency, effectiveness and satisfaction) the VE.
- Judgement: defined as the overall judgement of the experience in the virtual environment.
- Experience consequence: defined as the symptoms (e.g., the "simulator sickness", stress, dizziness, headache...) the user can experience.
- Technology adoption: defined as the actions and decisions taken by the user for a future use of, or intention to use, the VE.

Of the 82 total questions that make up the questionnaire, the following 27 have been selected as shown in Table 1:

Table 1. Questions of the user experience questionnaire.

Subscale	N°	Question
Presence	1	I was able to actively survey the virtual environment using vision.
	2	My interactions with the virtual environment seemed natural.
	3	I could examine objects from multiple viewpoints.
	4	The devices (gamepad or keyboard) which controlled my movement in the virtual environment seemed natural.
Engagement	5	The visual aspects of the virtual environment involved me.
	6	The sense of moving around inside the virtual environment was compelling.
Immersion	7	I felt stimulated by the virtual environment.
	8	I become so involved in the virtual environment that I was not aware of things happening around me.
	9	I become so involved in the virtual environment that it was as if I was inside the game rather than manipulating a gamepad and watching a screen.
	10	I become so involved in the virtual environment that I lost all track of time.
Flow	11	At each step, I knew what to do.
	12	Time seemed to flow differently than usual.
	13	I felt I was experiencing an exciting moment.
Usability	14	I thought the interaction devices were easy to use.
	15	I found the interaction devices very cumbersome to use.

Table 1. *Cont.*

Subscale	N°	Question
Emotion	16	I enjoyed being in this virtual environment
	17	I found my mind wandering while I was in the virtual environment.
	18	I enjoyed dealing with the interaction devices.
Judgement	19	Personally, I would say the virtual environment is practical.
	20	Personally, I would say the virtual environment is clear (not confusing).
	21	I found this virtual environment amateurish (1) professional (10).
	22	I found that this virtual environment is ugly (1) beautiful (10).
Experience Consequence	23	I suffered from fatigue during my interaction with the virtual environment.
	24	I suffered from dizziness with eyes open during my interaction with the virtual environment.
	25	I suffered from nausea during my interaction with the virtual environment.
Technology adoption	26	The interaction devices would make work more interesting.
	27	I would like to work with the interaction devices.

An additional statement was used to assess the extent to which these types of virtual environments can serve as a learning tool. The statement is as follows: I believe that this type of VR environment serves to disseminate and learn practical content.

3.3. Pilot Test

The participants first visualized the virtual tour on their cell phone (Figure 4). An expert in conservation, restoration and architecture who has carried out numerous studies on the Chapel of Dolores guided them, simulating a real visit. The tour lasted approximately twenty minutes and they received an explanation of the chapel and its significant elements. Once the tour was over, the participants filled out the user experience questionnaire.

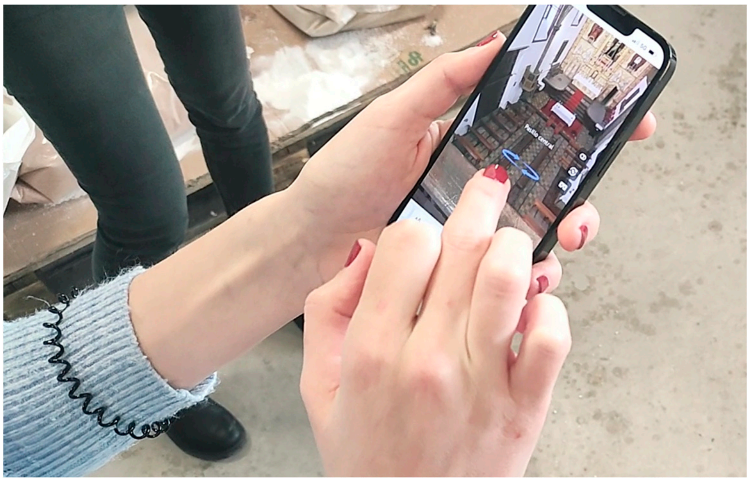


Figure 4. Visualization of the virtual tour on a smartphone.

The second part of the pilot test consisted of performing the virtual tour again, using Woxter Neo Vr1 Cardboard virtual reality headsets (Figure 5a), which allow the visualization of stereoscopic images (Figure 5b). Navigation within this type of device works as follows: if you fix your gaze for a few seconds on a point in the image where there is a link to change scenes, it automatically advances to the next location. Therefore, these headsets do not need any external controller.

(**a**) (**b**)

Figure 5. (**a**) Visualization of the virtual tour on a smartphone using the Woxter Neo Vr1 virtual reality headset; (**b**) visualization in stereoscopic mode for viewing in virtual reality headsets.

When using the headsets it is important to create a safety space around the user or to have a swivel chair, as it is necessary to move and turn the head 360 degrees to be able to perform the virtual tour (Figure 6). Finally, the participants filled out a new user experience questionnaire.

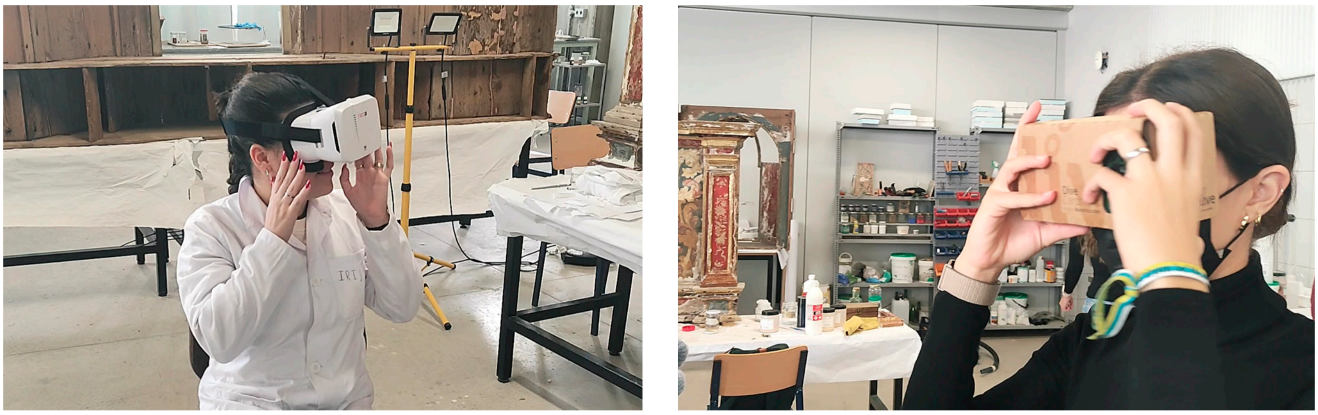


Figure 6. Students during the virtual tour session using virtual reality headsets.

4. Results

The results obtained and the media and standard deviation for each of the questions on the questionnaire can be seen in Table 2.

In the additional question on learning, a score of 9.44 (1.10) was obtained for the route taken on the cell phone and 9.06 (1.63) for the route viewed in the virtual reality headsets.

The results obtained, grouped by the subscales of the questionnaire used, are listed in Table 3.

Table 2. Results obtained from the Questionnaire on User Experience in Immersive Virtual Environments (QUXiVE).

Subscale	N°	Statement	360 Smartphone (Des. Vest.)	360 VR Cardboard (Des. Vest.)
Presence	1	I was able to actively survey the virtual environment using vision.	9.98 (0.32)	9.56 (0.78)
	2	My interactions with the virtual environment seemed natural.	8.94 (0.87)	8.89 (1.32)
	3	I could examine objects from multiple viewpoints.	9.56 (0.7)	9.50 (0.71)
	4	The devices (gamepad or keyboard) which controlled my movement in the virtual environment seemed natural.	9.28 (0.83)	9.06 (1.21)
Engagement	5	The visual aspects of the virtual environment involved me.	9.67 (0.49)	9.17 (1.10)
	6	The sense of moving around inside the virtual environment was compelling.	9.56 (0.70)	8.56 (1.50)
Immersion	7	I felt stimulated by the virtual environment.	9.28 (0.75)	8.72 (1.45)
	8	I become so involved in the virtual environment that I was not aware of things happening around me.	7.89 (1.45)	8.67 (1.46)
	9	I become so involved in the virtual environment that it was as if I was inside the game rather than manipulating a gamepad and watching a screen.	8.39 (1.91)	8.56 (1.72)
	10	I become so involved in the virtual environment that I lost all track of time.	7.44 (1.79)	8.17 (1.82)
Flow	11	At each step, I knew what to do.	9.00 (1.41)	8.78 (1.83)
	12	Time seemed to flow differently than usual.	8.00 (1.68)	7.78 (1.99)
	13	I felt I was experiencing an exciting moment.	8.61 (1.50)	8.72 (1.36)
Usability	14	I thought the interaction devices were easy to use.	9.61 (0.70)	8.83 (1.63)
	15	I found the interaction devices very cumbersome to use.	9.17 (2.07)	6.83 (3.31)
Emotion	16	I enjoyed being in this virtual environment	9.00 (1.03)	8.22 (3.37)
	17	I found my mind wandering while I was in the virtual environment.	5.06 (2.69)	6.56 (2.85)
	18	I enjoyed dealing with the interaction devices.	9.22 (1.73)	8.78 (2.18)
Judgement	19	Personally, I would say the virtual environment is practical.	9.44 (0.86)	8.94 (2.15)
	20	Personally, I would say the virtual environment is clear (not confusing).	9.50 (0.79)	8.83 (2.15)
	21	I found this virtual environment amateurish (1) professional (10).	7.50 (3.19)	7.67 (3.05)
	22	I found that this virtual environment is ugly (1) beautiful (10).	7.33 (3.27)	7.24 (3.44)
Experience Consequence	23	I suffered from fatigue during my interaction with the virtual environment.	1.56 (1.69)	4.56 (3.18)
	24	I suffered from dizziness with eyes open during my interaction with the virtual environment.	1.17 (0.51)	4.28 (3.37)
	25	I suffered from nausea during my interaction with the virtual environment.	1.17 (0.51)	3.22 (3.08)
Technology adoption	26	The interaction devices would make work more interesting.	9.17 (1.20)	9.33 (0.84)
	27	I would like to work with the interaction devices.	9.17 (1.15)	9.00 (1.71)

Table 3. Results grouped into subscales of the Questionnaire on User Experience in Immersive Virtual Environments (QUXiVE).

Subscale	Fotos 360 (Smartphone)	Fotos 360 (VR Headset)
Presence	9.42 (0.68)	9.25 (1.01)
Engagement	9.61 (0.59)	8.86 (1.30)
Immersion	8.25 (1.48)	8.53 (1.61)
Flow	8.61 (1.50)	8.72 (1.36)
Usability	9.39 (1.38)	7.83 (2.47)
Emotion	7.76 (1.82)	7.85 (2.47)
Judgement	8.09 (2.44)	7.95 (2.88)
Experience Consequence	1.30 (9.91)	4.02 (3.21)
Technology adoption	9.17 (1.18)	9.17 (1.28)

5. Conclusions

Once the research has been carried out, we can affirm that it is possible to create virtual tours with a high level of detail and a high level of user acceptance through low-cost technologies. This methodology would allow local entities, with a limited budget, to disseminate their heritage through the use of virtual tours, accessible from any device. The need to access materials in easily accessible formats and high detail is recommended by H. Cecotti [46]. The Cloudpano program has been selected to create virtual tours; it has been one of the best rated applications by Nieva García [22], who analyzes several programs to create virtual tours. Our development also confirms the study by Rahaman et al., which demonstrates visualizations of virtual tours without the requirement for expensive virtual reality headsets [52].

Regarding immersion, the results indicate that the main research hypothesis is not fulfilled, i.e., that the use of virtual reality headsets significantly improves immersion in the virtual tour compared to visualization on mobile devices. The results obtained in the corresponding subscale (immersion) are very similar (8.25/10 smartphone and 8.53/10 in VR headsets). Despite the fact that smartphone screens are considered low-immersion devices and VR headsets are considered high-immersion devices [28,30], similar results were obtained. Ideally, immersion also includes a simulation of the acoustic, haptic, smell, taste, and motion senses. However, immersion in user experience is defined as the illusion that the virtual environment technology replaces the user's sensory stimuli by the virtual sensory stimuli. Therefore, in the virtual tours presented in this article made with 360 photos and without any other haptic device, there is only the visual sensation of immersion. Our conclusion is that in our case study without any haptic device and only visual immersion, it is not necessary to have virtual reality headsets for visualization.

On the other hand, the secondary hypothesis, that the virtual tour is an effective tool for the dissemination and learning of cultural heritage, regardless of the technology used, is considered valid. The participants rated the virtual tour very positively as a tool for learning and dissemination of heritage (9.44/10 for mobile devices and 9.06/10 for virtual reality glasses). No major differences are observed between the use of screens or headsets for learning objectives. Therefore, it may be an interesting strategy to have simple versions that work quickly on the smartphones of potential users.

Additionally, we can see that the virtual tour created with 360 photos generates a user experience in both viewing alternatives that is very positive. We can highlight the fact that on the subscale of presence, commitment and adoption of technologies, the valuation is higher than 9 out of 10. Therefore, we can conclude that the virtual tour will be very well accepted by potential users. On the other hand, fluency, emotion and judgment also obtain very positive values, but close to 8 out of 10. No notable differences are observed in these subscales in the comparison between cell phones and virtual reality headsets.

It should be noted that virtual tours can have negative consequences, such as dizziness or vertigo, described by other studies like [28,44]. In our study, it was found that when participants use virtual reality headsets, the consequence subscale increases significantly (4.02 out of 10 vs. 1.02 out of 10). Due to the use of stereoscopic images, it is difficult to improve the negative sensations of dizziness because the user floats above the scene. In other virtual reality headsets, environments such as cabins, visible paths, or the user's hands and body parts can be visualized, thus mitigating some of the negative effects [53].

Interestingly, the usability of the two devices is significantly different. For the specific question about the comfort of the device used, the participants rated cell phones with 9.17/10 compared to 6.83/10 for virtual reality headsets. This indicates that virtual reality headsets would be necessary only for very specific cases. As a future study, we propose the analysis of scenarios where the use of virtual reality headsets is necessary, compared to other types of visualizations. In addition, we propose to extend this research with a larger and more diverse number of participants, in order to obtain more conclusive results.

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