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Evaluation of Motiv-ARCHE in the Santa Clara Museum

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Abstract: Currently, heritage sites, such as museums, have focused on the preservation and conservation of heritage elements for present and future generations. However, when displaying their content, they often do not consider different types of visitors, their preferences regarding the type and format of content, their interests, or their information needs (the same content is always presented). All of this can reduce the number of visits and the motivation of visitors. To address this issue, Motiv-ARCHE was developed as an application designed to enhance motivation in learning about cultural and natural heritage using augmented reality (AR). Motiv-ARCHE was implemented using the design-based research (DBR) methodology, an iterative approach that allows user feedback. In this article, we concentrate on presenting an experiment conducted at the Santa Clara Museum (Bogotá) in which a group of 44 participants used Motiv-ARCHE to access content associated with 10 cultural heritage elements that had been previously co-created with heritage experts from the museum itself. To evaluate the experiment, motivation and technology acceptance tests were applied, along with a demographic questionnaire, to statistically analyze whether the examined variables influence motivation for learning about cultural and natural heritage. Among the results, it is noteworthy that users with greater knowledge of AR, cultural and natural heritage, and a higher frequency of using this type of application felt more motivated to learn about heritage elements.

Keywords: information adaptation; augmented reality; co-creation; cultural and natural heritage; motivation

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Academic Editor: Andrea Sanna

Received: 5 February 2025
Revised: 15 February 2025
Accepted: 17 February 2025
Published: 21 February 2025

Citation: González Vargas, J.C.; Fabregat, R.; Carrillo-Ramos, A.; Jové, T. Evaluation of Motiv-ARCHE in the Santa Clara Museum. *Information* **2025**, *16*, 165. https://doi.org/10.3390/info16030165

1. Introduction

Nowadays, users have greater ease in accessing and utilizing immersive technologies such as augmented reality, virtual reality, and mixed reality [1]. However, in heritage environments, motivation for learning is becoming increasingly challenging, as traditional methods fail to adequately engage or motivate users [2]. The implementation of these technologies, such as augmented reality, in cultural and natural heritage learning environments generates greater interest compared to on-site learning using traditional methods. This is because users can explore and learn about the real world with virtual objects displaying different types of media, such as audio, text, images, and videos [3].

Previously, the main objective of museums was to preserve collections and present them to the public so that they would be available for current and future generations [4]. Today, heritage institutions such as UNESCO are dedicated to the identification, protection, and preservation of heritage elements. With the use of information and communication technologies, access to these collections is easier, so heritage sites must now focus on the visitor experience and their motivation to visit them [4].

A survey conducted within the framework of the European ORION project [5] shows that 35% of museums are using the presentation of three-dimensional models through immersive technologies, such as augmented reality. This technology allows museums to present their collections in an innovative way, attracting users to visit heritage elements. Furthermore, this survey reveals that around 65% of archaeological museums use three-dimensional models to present tangible heritage elements. In Hein's article [6], it is highlighted that museums primarily focus on their exhibitions rather than their visitors, so they are increasingly aware of the need to identify who their audiences are and why they visit their exhibitions [7].

Wojciechowski [8] mentions that, despite the use of immersive technologies, one of the persistent issues is that the implementation of these technologies to create augmented content must be carried out by a technology expert, which restricts the ability of heritage experts to modify the content. On the other hand, Keawalla [2] points out that in educational environments, teachers recognize the benefits of augmented reality but wish to have control over the content, as some applications do not allow for the modification of existing materials.

Another problem identified in the literature [9,10] is that heritage sites, by not considering the characteristics of the users who will visit the exhibitions, do not adequately address the users' motivations for visiting the heritage element. Falk mentions that, to attract users to visit these heritage sites, it is necessary to understand their motivations for learning and visiting these sites, considering aspects such as needs, interests, emotions, and experiences.

The literature also indicates that another way to motivate users to visit heritage sites is by allowing the co-creation of content. This encourages users to take ownership of what they create collaboratively with other users and act as promoters for others to visit the content they have developed to explain heritage elements [11]. An example described in Connolly [12] shows how users created different types of content about heritage elements, exceeding initial expectations, and how the same community collaborated to complement the information.

Based on the identified challenges, applications designed to facilitate learning about cultural and natural heritage should incorporate features such as co-creation and motivation.

This article examines an experiment conducted with Motiv-ARCHE, a learning application for cultural and natural heritage, in the Santa Clara Museum located in Bogotá, Colombia. The application leverages augmented reality as an immersive technology to visualize content associated with heritage elements. It has been developed as both a web and mobile application, ensuring ease of use so that users do not need expertise in augmented reality. Additionally, it enables users to collaboratively co-create content with others. Moreover, a literature review is presented to examine how similar applications evaluate technology acceptance, motivation, content co-creation, and information adaptation. This review also explores the outcomes of experiments focused on content co-creation and accessibility.

Section 2 presents the fundamental concepts necessary to understand the functioning of Motiv-ARCHE. Section 3 describes the related works identified in the literature review on the access to different types of content used for learning about cultural and natural heritage. Section 4 describes what Motiv-ARCHE is and how it operates. Section 5 analyzes the evaluation models identified through a literature review. Section 6 provides details of the experiment conducted at the Santa Clara Museum. Section 7 offers an analysis of the results obtained from the experiment on content visualization, and finally, Section 8 presents the conclusions.

2. Fundamental Concepts

This section introduces the fundamental concepts (cultural and natural heritage, extended reality, motivation, co-creation, and information adaptation) necessary to understand the function of the Motiv-ARCHE application. These concepts are derived from a previous literature review conducted in [13] aimed at identifying articles focused on motivation in learning cultural and natural heritage using immersive technologies (see Figure 1). Based on the results of this review, a classification of applications was carried out using the criteria proposed by [14–18]. These criteria include the following: type of device, level of immersion, activation methodology, execution environment, usage context, motivation, content co-creation, and types of adaptation.

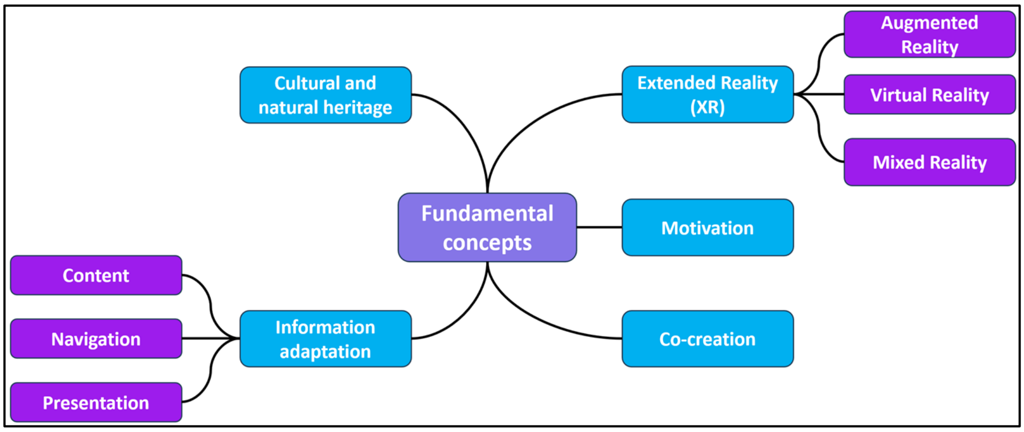

Figure 1. Fundamental concepts (authors' elaboration).

It is important to highlight that motivation, content co-creation, and types of adaptation were not initially considered in the literature review, as they represented missing features in existing applications. However, their implementation was identified as a key necessity for enhancing motivation in the learning of cultural and natural heritage, a topic explored in detail in [13].

2.1. Cultural and Natural Heritage

According to UNESCO, cultural and natural heritage is defined as the "cultural legacy we receive from the past, live within the present, and will pass on to future generations" [19]. It is classified into tangible heritage, which includes physical elements such as monuments, and intangible heritage, which encompasses aspects like oral traditions. Additionally, this classification includes natural heritage, referring to elements created by nature without human intervention [20,21].

In [22], it is emphasized that information and communication technologies (ICTs) are fundamental tools for strengthening the global economy, as they generate social value, promote knowledge, and contribute to the preservation and conservation of heritage elements [23]. However, in current applications that use some type of technology to display information about heritage elements, we encounter the problem that they do not consider the interests or needs of users. This especially occurs when it comes to young people [24,25].

2.2. Extended Reality

Milgram and Kishino [18] introduced the concept of the reality–virtuality continuum to differentiate between various types of immersive technologies, such as augmented reality (AR), virtual reality (VR), and mixed reality (MR). According to these authors, AR is a technology that complements the user's perception of the real world by adding virtual content without replacing it. In contrast, VR fully immerses the user in a digital environment, eliminating the perception of the real world. Lastly, MR combines features of both AR and VR by integrating and enabling real-time interaction between elements of the physical and digital worlds. Currently, the term extended reality (XR) [26] is used to encompass all these immersive technologies. They are also known as spatial computing or immersive computing [27], as all of them use virtual content to simulate or imitate elements of the real world.

XR has been applied in various fields, such as marketing, medicine, education, entertainment, and advertising, among others, providing innovative experiences by engaging users with virtual content [28]. In the field of cultural and natural heritage, these technologies are gaining increasing relevance. Currently, there are multiple applications in heritage and educational fields that use XR, demonstrating significant advantages compared to traditional learning methods, such as improved spatial reasoning and learning performance [20,26,29]. These technologies also provide tools that enrich the educational process by allowing the extension of knowledge about real-world elements through the integration of virtual content, enhancing the learning experience [30].

2.3. Motivation

All human beings engage in activities motivated by personal recognition or a reward [31]. In the literature, two main types of motivation are identified: intrinsic and extrinsic. Intrinsic motivation arises when an activity is performed for personal satisfaction or an internal benefit, without the need for external rewards. In contrast, extrinsic motivation occurs when an activity is carried out with the aim of obtaining an external reward. In learning, motivation is a fundamental characteristic for students to retain the information acquired [32].

From the perspective of learning about cultural and natural heritage, ref. [33] mentions that adults, professionals, and successful scientists often find motivation when visiting museums, particularly when discovering novel elements that stimulate their intellectual, emotional, and sensory aspects. Museum visits generally not only expand visitors' experiences beyond what they observe in the exhibits but also strengthen family and personal bonds. Additionally, museums are valued as key tools for understanding the past and transferring this knowledge to future generations.

In [9], a study is presented on what people remember when visiting a museum and the factors that influence their experiences. The study classifies visitors into five categories:

1. Explorers: They have no specific objective for the visit. Their interest lies in discovering elements that they find interesting.
2. Facilitators: They seek to share their experience with others. They act as guides within the museum.
3. Experience seekers: They are interested in new experiences, investing time and energy to enjoy the exhibits. They often take photographs.
4. Professional or Hobbyist: They visit the museum because they have prior knowledge of the subject matter and wish to deepen their learning.
5. Rechargers: They consider the museum visit a relaxing activity. They limit themselves to observing without reading all the available information.

2.4. Co-Creation

The term co-creation, also known as "collaborative creation" [34], refers to a practice in which all stakeholders actively participate in the joint development of a product or service. This approach aims to incorporate the characteristics and needs of users into the design and creation process. For this reason, co-creation views customers not only as end consumers but also as active participants in the construction of the product or service.

By enabling co-creation, user participation becomes more active, fostering open and collaborative environments in which users can contribute ideas about what they would like to use. This process ensures that the specific characteristics and needs of users are met when delivering the product or service that has been developed [34].

In the context of learning about cultural and natural heritage, some examples of the use of co-creation are described in [35,36], where, within museums, the community and students, in collaboration with heritage experts, contribute ideas on which elements should be exhibited. This allows them to share their knowledge about heritage and participate in the creation of related content.

2.5. Information Adaptation

From a technological standpoint, information adaptation refers to a system that modifies its properties based on the specific characteristics and needs of an individual user or group of users [37].

Like XR, information adaptation has been applied in various fields, such as education, business, and healthcare. These systems use a variety of methods and techniques to collect information from the user and their context. For example, data can be obtained through forms or questionnaires that gather basic information, sensors integrated into devices such as GPS, interactions with digital content, internet search history, and others [38–40].

In the educational field, the implementation of information adaptation systems is particularly relevant, as it has been shown to provide significant pedagogical benefits [41]. These benefits include the following:

1. Immediate feedback: The systems can respond quickly to the user's actions.
2. Domain-based learning: The content is adjusted to reinforce specific areas of knowledge.
3. Interactive learning: The presentation of the content dynamically adapts to the user's preferences, facilitating better understanding and learning.

To implement information adaptation, it is essential to develop a user model that defines which specific characteristics will be considered to personalize the content [13,39,42]. However, in addition to the user's attributes, it is important to consider external factors, such as the context in which the user is situated. For this, the sensors on the device used by the user are often a key tool [37].

A specific example of this approach is presented in [43], where an augmented reality application for the learning of cultural and natural heritage is developed. In this application, the content is adapted to the user's emotional states, using the device's camera to analyze their emotions while interacting with heritage elements. This approach not only enhances the user's experience but also strengthens their understanding and emotional connection with the presented content.

3. Related Works

Based on the literature review presented in [44], various studies related to the learning of cultural and natural heritage are analyzed. The submodels considered for adapting the information, the types of media reproduced, immersive technology, AR activation methods, the system in which the application has been developed, the execution environment, and the incorporation of co-creation are examined.

From the analysis of these studies, the types of media used to represent heritage content in augmented reality were identified, as presented in Table 1. The analysis reveals that none of these studies use PDF files, while the most-employed media are texts. For example, the related works [45,46] use 3D models to reconstruct elements that have disappeared or are degraded, complementing information that would not be possible to visualize with other types of media. In the case of videos, the related works [47–49] use them to provide details about artworks displayed in museums.

Table 1. Related works.

	[50]	[47]	[51]	[52]	[53]	[48]	[54]	[55]	[56]	[49]	[45]	[46]	[57]	Total
Audio			X			X								2
Image			X	X		X			X		X			5
Video		X				X				X				3
3D model											X	X		2
Website					X			X		X			X	4
PDF file														0
Text	X		X				X	X	X		X			8

For this reason, in Motiv-ARCHE, with the aim of enhancing motivation in learning about cultural and natural heritage, additional types of media have been incorporated beyond texts, images, and videos. These include audio, 3D models, websites, and videos, which can also present content associated with a heritage element in augmented reality. The following section briefly describes how Motiv-ARCHE works.

4. Motiv-ARCHE

Motiv-ARCHE is an application that uses augmented reality, content co-creation, and information adaptation to facilitate users' acquisition of knowledge about cultural and natural heritage. It employs AR as an immersive technology to display co-created content and considers the user's characteristics, the context, and the heritage element to suggest heritage items, content associated with these elements (such as audio, images, videos, 3D models, PDFs, websites, and texts), and routes.

This application has been implemented to be used both by users and heritage experts, who collaboratively create content for various heritage elements and, with this, routes. The application functions as both a web application and a mobile application, allowing users to associate content with heritage elements and visualize these virtual contents associated with the heritage elements through AR. In the application, AR is activated either by image recognition or by geographic location.

For the development of the application, the design-based research methodology (DBR) [58] was used, which is divided into three phases: design, implementation, and analysis. In [44], each of the mentioned phases are detailed.

To use the web application, go to the link https://motivarch.online/index.php (accessed on 10 January 2025) from any browser. To use the mobile application, it can be downloaded from the Google Play Store by searching for Motiv-ARCHE.

Through the web application, all services related to the creation, editing, deletion, and consultation of associated content, as well as heritage elements and routes, can be executed. Some of these services require the user to be registered to perform them. In [44], each of the services that can be executed within the application is described in detail.

The mobile application has been designed for users who are already registered in the system and is specifically used for the visualization of both the associated content of heritage elements in AR and the routes, although it can also be used to co-create content.

Motiv-ARCHE has been implemented to function on any device (mobile or desktop), utilizing a client/server architecture that allows access through a web browser or from a mobile device (see Figure 2).

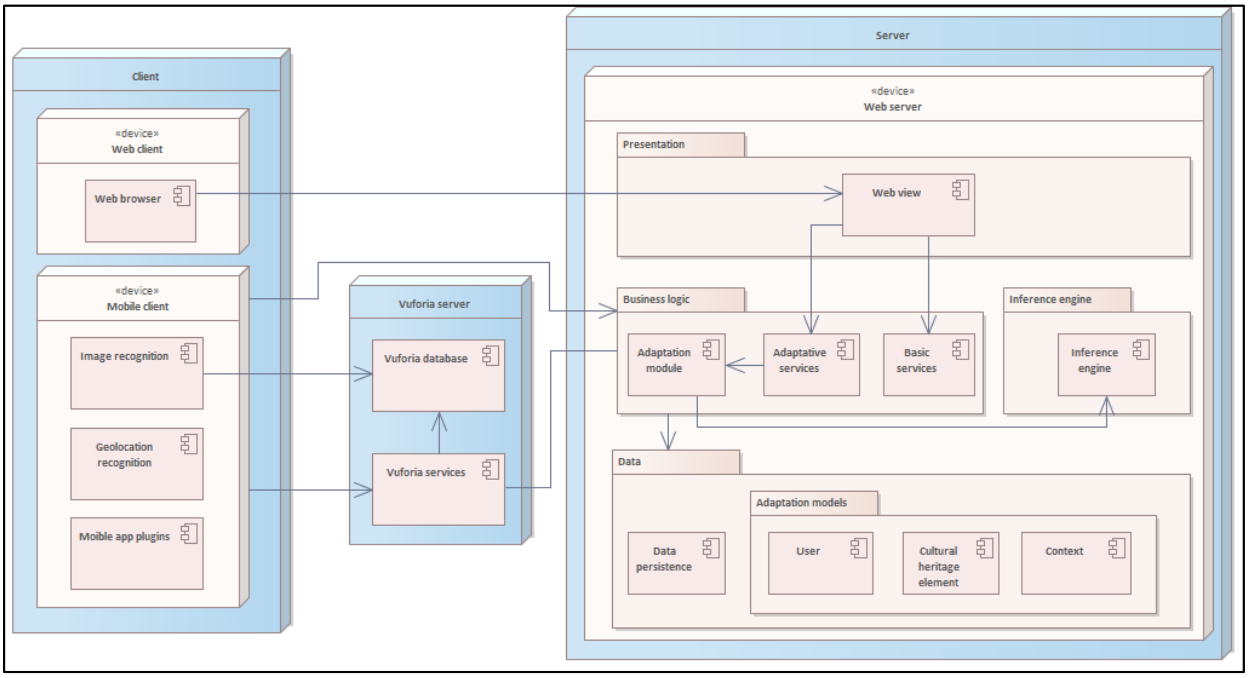

Figure 2. Motiv-ARCHE architecture (authors' elaboration).

- The client node consists of two types of devices: the web client and the mobile client. Both clients enable the co-creation of heritage elements, the associated content of each heritage element, and routes, as well as access and visualization of all of them in Motiv-ARCHE.
  - Web Client: This refers to the browser used by the user to access the web application.
  - Mobile Client: This represents the mobile device from which the user accesses the mobile application. For content visualization through image recognition, it communicates with an external server called Vuforia, a tool used to display augmented content. Regarding geolocation and content visualization, proprietary plugins developed in Unity's Asset Store are used.
- The Vuforia Server node contains the necessary tools for activating augmented reality through image recognition. This node stores the images used for recognition and retrieves their details:

- Vuforia Database: A database where the images used for recognition and augmented reality activation are stored.
- Vuforia Services: An API that enables communication between the mobile application and the Motiv-ARCHE server. This facilitates the creation, editing, deletion, and querying of details of the images used for augmented reality activation.

Finally, the server node hosts all the business logic of the Motiv-ARCHE. This node consists of four subcomponents—presentation, business logic, data, and inference engine—which are described as follows:

- Presentation: Contains the web view, which refers to all the code implemented for the web application interface.
- Business Logic: Includes the implementation of basic services, adaptive services, and the adaptation module. The adaptation module queries the adaptation submodels stored in the data. Then, it communicates with the inference engine to determine the rules that should be applied in generating suggestions about associated content, heritage elements, and routes.
- Data: These are contained in the database that stores information about users, heritage elements, content, and routes. Additionally, they hold the adaptation submodels (user, heritage element, and context), which record the characteristics of each of these elements.
- Inference Engine: This is responsible for defining the rules for generating suggestions on associated content, heritage elements, and routes. It communicates with the adaptation module to process, and it offers these suggestions.

5. Evaluation Models

To identify how applications like Motiv-ARCHE evaluate technological acceptance, motivation, co-creation, and information adaptation, a literature review was conducted to determine which tests are used. The following subsections explain these tests.

5.1. Technology Acceptance Test

To evaluate perceived usability, ref. [59] developed the System Usability Scale (SUS), a reliable and free psychometric test that has been used in various applications. This test consists of a questionnaire with 10 questions (odd-numbered questions are phrased positively and even-numbered questions negatively) and is answered using a Likert scale from 1 to 5. The test result is calculated based on the responses. For odd-numbered questions, 1 is subtracted from the selected value, and for even-numbered questions, the selected value is subtracted from 5. The scores of each question are then summed, and the total is multiplied by 2.5 to obtain a value between 0 and 100. If the result is greater than 51, the usability is considered acceptable; if greater than 72, it is considered good; and if greater than 85, it is considered excellent.

On the other hand, the TAM (Technology Acceptance Model) test was developed in [60]. It aims to explain how and why users adopt certain technologies. This test focuses on perceived usefulness, which refers to how the use of technology improves performance in specific activities, and perceived ease of use, which is related to the ease of use of the technology (see Figure 3). However, this model has been updated with additional variables. The most recent version of this model is TAM3, which was defined in 2008.

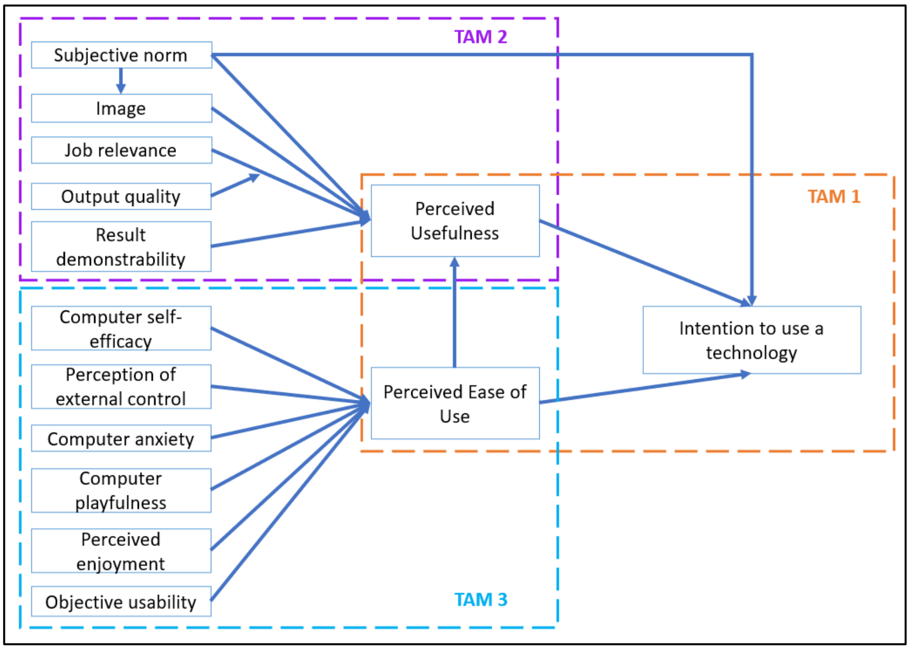

Figure 3. TAM, TAM2, TAM3 test. Taken and adapted from [61].

Although the TAM test has been used in many applications to evaluate system usability [62,63], one of the issues with this test is that it does not include variables that assess the user's intention to use a new technology, which are included in the UTAUT (Unified Theory of Acceptance and Use of Technology) test, nor does it consider variables that explore the consumer's context of use, which are addressed in UTAUT2 [64].

The UTAUT and UTAUT2 tests [62] aim to understand and predict user acceptance of technology by evaluating four variables in UTAUT and three additional variables in UTAUT2 related to intention and usage behavior: (1) performance expectancy, (2) effort expectancy, (3) social influence, (4) facilitating conditions, (5) hedonic motivation, (6) price value, and (7) habit (see Figure 4). This test has been used in learning management systems (LMSs). However, one variable used to measure usability is the price paid for the system, which may be irrelevant in educational contexts, as the most valuable aspects are the time and effort required to learn the subject being taught.

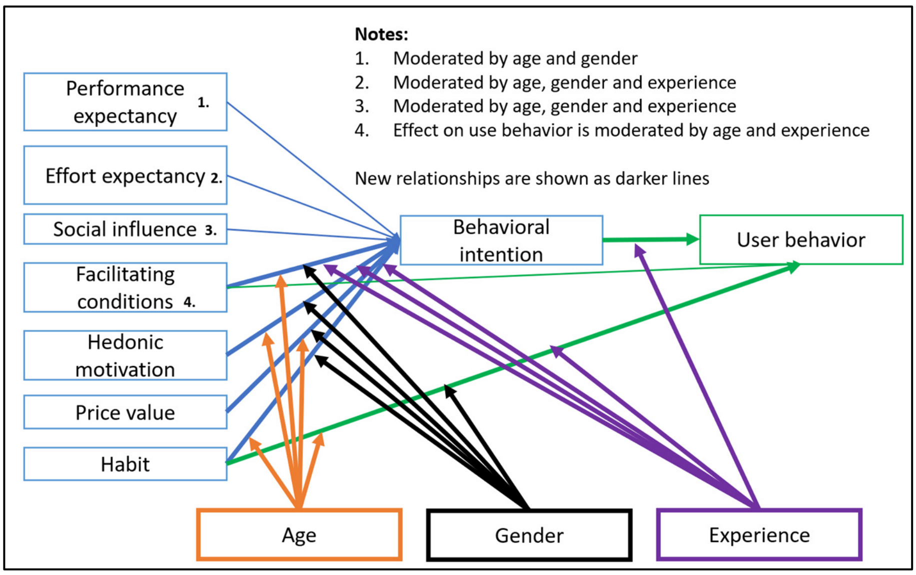

Figure 4. UTAUT2 test. Taken and adapted from [62].

In [63], a systematic review of different technology acceptance tests was conducted, and a new test was proposed to evaluate the intention to use augmented reality specifically for heritage sites called the ARAM (Augmented Reality Acceptance Model). This test is based on UTAUT to measure performance expectancy, effort expectancy, social influence, and facilitating conditions, and it adds computer anxiety and hedonic motivation.

- PE—Performance Expectancy: The degree to which the user can benefit from using the technological system. In the case of ARAM, this refers to the amount of information, the speed of obtaining it, the interest, and the exploration. Four questions are used to evaluate this variable.
- EE—Effort Expectancy: The degree of ease associated with using the system. In ARAM, it considers ease of use, clarity in interaction, and ease of becoming skilled. Three questions are used to evaluate this variable.
- SI—Social Influence: The degree to which a person perceives that all important people to them believe they should use the system. In ARAM, it considers the opinions of friends and family, their influence, and the influence of those around them. Three questions are used to evaluate this variable.
- FC—Facilitating Conditions: The degree to which a person believes they have the necessary conditions to access the technology. In ARAM, it includes the availability of adequate resources, appropriate knowledge, compatibility with other technologies, and available assistance. Four questions are used to evaluate this variable.
- CA—Computer Anxiety: The degree of apprehension or fear a person has when considering the possibility of using a new technological system. This variable has been added to this model, and it is evaluated through nervousness, insecurity, and fear. Three questions are used to evaluate this variable.
- HM—Hedonic Motivation: The degree of pleasure and mastery a person experiences while interacting with the system. This variable has been added to this model, and it is evaluated through fun, stimulation, and mastery. Three questions are used to evaluate this variable.
- TE—Trust Expectancy: The degree to which a person trusts the information they perceive while using the technological system. It assesses the credibility, reliability, and trustworthiness perceived when viewing augmented content. Three questions are used to evaluate this variable.
- TI—Technological Innovation: The degree of desirable innovative characteristics that will be introduced in the technological system. In this case, it is focused on auditory, olfactory, and haptic stimuli. Three questions are used to evaluate this variable.
- BI—Behavioral Intention: The user's willingness or intention to use augmented reality technology in the future. This includes their intention to use augmented reality in heritage environments frequently, as soon as possible, and in the future. Three questions are used to evaluate this variable.

The ARAM test consists of 28 questions, which are evaluated using a Likert scale ranging from 1 to 7, where 1 indicates strong disagreement, and 7 indicates strong agreement. The test was validated with 528 participants, and the results confirm its reliability in assessing the use of augmented reality in heritage environments [63]. In this case, it measures the behavioral intention of users when utilizing augmented reality while visiting a heritage site.

Eight hypotheses were proposed (see Figure 5) to identify which variables are influenced in the use of the system:

- $H1_0$: Technological innovation (TI) will influence performance expectancy (PE).
- $H2_0$: Trust expectancy (TE) will influence performance expectancy (PE).
- $H3_0$: Effort expectancy (EE) will influence hedonic motivation (HM).

- $H4_0$: Computer anxiety (CA) will influence hedonic motivation (HM).
- $H5_0$: Performance expectancy (PE) will influence behavioral intention (BI).
- $H6_0$: Social influence (SI) will influence behavioral intention (BI).
- $H7_0$: Facilitating conditions (FC) will influence behavioral intention (BI).
- $H8_0$: Hedonic motivation (HM) will influence behavioral intention (BI).

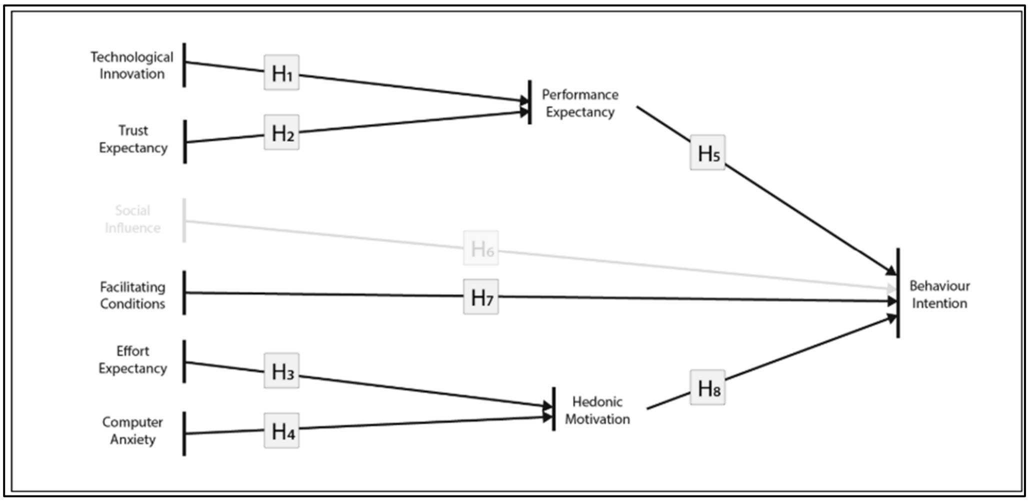

Figure 5. ARAM test. Taken from [63].

To validate the hypotheses, the average variance extracted (AVE) must be greater than 0.5, the composite reliability (CR) must be greater than 0.7, and Cronbach's alpha (CA) must be greater than 0.7. The results show that all the hypotheses meet the evaluation criteria (represented in Figure 5 with black color) except for H6, which does not meet the criteria (represented in gray color).

In [65], the HARUS (Handheld Augmented Reality Usability Scale) test is mentioned, which has been developed to evaluate the comprehension and manipulation of mobile augmented reality applications. The comprehension variable refers to the ease of understanding the information presented, and manipulation refers to the ease of handling the system to perform activities. To create the test, they based it on the SUS, using a Likert scale from 1 to 7. It consists of 16 questions. The first eight measure manipulation, and the remaining ones assess comprehension. Like the SUS, for positive questions, 1 is subtracted from the selected response, and for negative ones, the selected response is subtracted from 7. The results obtained from each question are summed and divided by 0.96 to obtain a score between 0 and 100.

5.2. Motivation Test

In [66–71], the IMMS (Instructional Materials Motivation Survey) test was used to assess motivation in educational settings, and in [51,72,73], it was used for learning about cultural and natural heritage. The IMMS test, developed by Keller [32,74], is based on the ARCS model (Attention, Relevance, Confidence, Satisfaction):

1. Attention: Assesses whether the materials generated maintain the student's interest.
2. Relevance: Evaluates whether users feel that the content is important to their life and interests.
3. Confidence: Assesses whether users feel confident when performing the proposed activities.
4. Satisfaction: Evaluates whether users feel satisfied when completing the activities and achieving their goals.

The test consists of 36 questions that assess the four factors mentioned earlier (9 questions for each factor). Each question is evaluated on a Likert scale from 1 to 5, where 1 means strongly disagree, and 5 means strongly agree. Once the responses for each question are collected, the scores for each factor are summed, and the average is calculated. A high score indicates that the material used meets the aforementioned factors. The results can help identify which elements need to be retained or modified in the content created to motivate users in their learning process. This test has been applied in various educational settings, both in traditional learning and in computer-assisted learning. In [74], a literature review of the use of this test in educational settings was conducted, showing that it has been utilized for over 30 years in primary, secondary, and university education across different areas and countries.

Another test found is the RIMMS (Reduced Instructional Materials Motivation Survey), which is based on the same factors of the ARCS model but uses fewer questions to measure motivation in educational materials [68]. In this case, the test contains only 12 questions instead of 36, which helps prevent overwhelming the student with too many questions.

5.3. Co-Creation Test

In the literature, there is not a specific test designed to evaluate content co-creation. In related works, what is typically done is the creation of a questionnaire where users are asked for their opinion about the co-creation process [12,56,75,76], and in [77], the quality of the content generated by users is evaluated.

5.4. Adaptation of Information Test

In the literature, no specific test was found to evaluate the adaptation of information, as it depends on the characteristics considered of the user and their context. To assess whether the adaptation is correct, the suggestions provided by a system are compared to what it would show if no adaptation were applied [45,47,49,52,54,56,57,78–86]. Additionally, some articles [48,50,53,55,64,87,88] use a technological acceptance test on both adapted and non-adapted versions to compare the differences between them.

5.5. Tests Used

In [44], a more detailed analysis of the tests previously mentioned has been presented. Based on this analysis, the tests used in Motiv-ARCHE have been selected to analyze the results obtained from the co-creation experiment and the visualization of content conducted at the Santa Clara Museum located in the city of Bogotá.

To evaluate acceptance technology, the ARAM test has been used because it is one of the most recent tests—it has been used by 528 users—and it is based on other tests. To evaluate motivation, the IMMS test was employed because it is the most widely used in the analyzed studies. To assess co-creation, the IMMS test questions were adapted to analyze motivation in co-creation. Finally, to evaluate adaptation of information, a test was conducted to compare what happens with and without adaptation when suggesting associated content, heritage elements, and routes.

6. Experiment

To evaluate the Motiv-ARCHE application, an experiment was conducted at the Santa Clara Museum in Bogotá (Colombia), where, in collaboration with museum experts, content co-creation was carried out, and museum visitors accessed the co-created content.

Before starting the content co-creation process, three heritage experts from the museum were instructed on how to create heritage elements, associated content, and routes in the Motiv-ARCHE application.

Together with these three heritage experts from the museum, 10 representative elements of the museum were selected, including paintings and sculptures. Figure 6 details these 10 elements and, for each of them, the number of associated contents of each type.

Cultural heritage element	Image recognition	Audio	Image	Video	3D model	Web	Text	PDF file
Adoration of the Magi (painting)	2	0	3	0	0	0	1	0
Annunciation (painting)	2	0	0	1	0	0	2	0
Mystical Marriage of Saint Catherine of Alexandria (painting)	2	0	2	1	0	0	3	0
Saint William of Aquitaine (painting)	2	0	1	0	0	2	1	0
Saint Vincent Ferrer (sculpture)	2	0	1	1	0	1	1	0
Saint Clare of Assisi (painting)	2	0	1	1	0	2	1	0
Saint Rose of Lima (painting)	2	0	2	1	0	1	2	0
Saint Teresa of Jesus (painting)	2	0	2	1	0	2	2	0
Lord of Humility (sculpture)	2	4	1	1	1	1	5	1
Vision of Saint Ignatius of Loyola in the Cave of Storia (painting)	2	0	1	1	0	2	3	0

Figure 6. Cultural heritage elements co-created in Museum Santa Clara.

Figure 7 shows how Motiv-ARCHE displays some of the types of content (for example, audio, image, website, and 3D model) co-created by heritage experts associated with the heritage element called Lord of Humility, which are displayed in augmented reality through activation by image recognition.

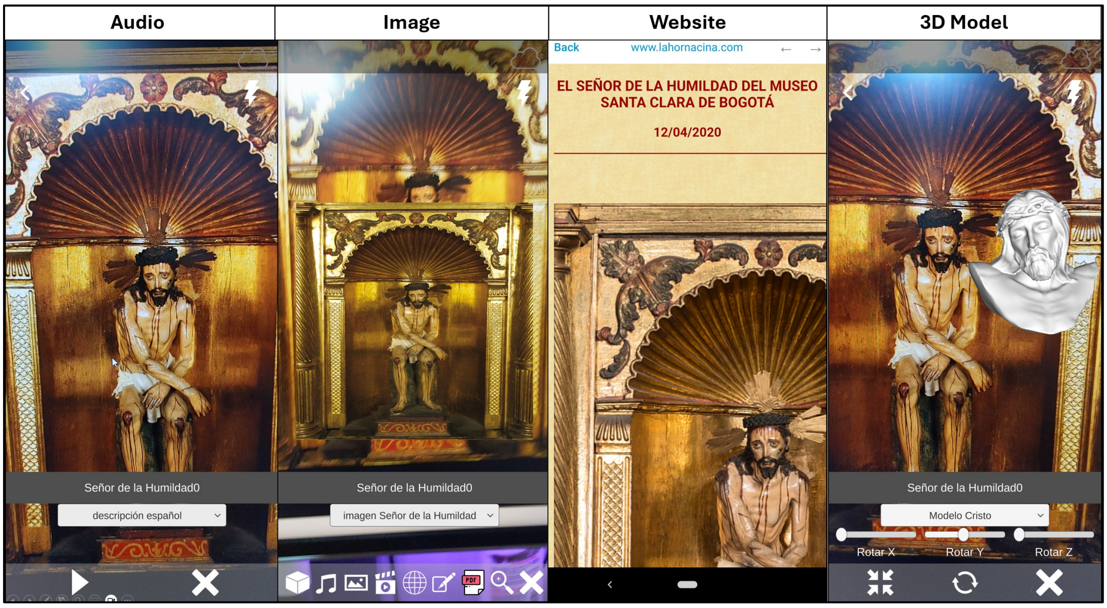

Figure 7. Media associated with the heritage element (Lord of Humility).

Based on the heritage elements and generated contents, 44 visitors accessed the contents using Motiv-ARCHE. For this experiment, each user downloaded the mobile application on their device and viewed the different contents associated with the 10 heritage elements (see Figure 6).

The age of the participating users ranged from 18 to 93 years. Although the application is primarily aimed at young people, the experiment was conducted with museum visitors of all ages to broaden the sample and compare the results between young and adult audiences. In this research, young people are considered individuals under 26 years old, and adults are those 27 years and older. Of the 44 users, 7 reported that they had not used augmented reality applications, while 37 had.

To determine whether the user's characteristics influence motivation toward learning about cultural and natural heritage, the experiment included a demographic questionnaire with the following eight questions:

1. Level of knowledge about cultural heritage: The knowledge the user believes they have regarding cultural heritage. A Likert scale from 1 to 7 is used, where 1 indicates very little knowledge, and 7 indicates a lot of knowledge.
2. Level of knowledge about augmented reality: The knowledge the user believes they have regarding augmented reality. A Likert scale from 1 to 7 is also used, where 1 indicates very little knowledge, and 7 indicates a lot of knowledge.
3. Previous experience with augmented reality: Whether the user has previously used augmented reality applications, with response options "yes" or "no".
4. Frequency of augmented reality use: How often the user uses augmented reality applications. This question is only answered by those who answered "yes" to the previous question. It is evaluated on a scale from 1 to 7, where 1 indicates rarely, and 7 indicates frequently.
5. Gender: The gender with which the user identifies, offering options of "male" or "female".
6. Education level: The level of education attained or currently in progress. Options include: "currently in primary/secondary school", "primary/secondary school", "currently in university", "university", "currently in master's degree/specialization", "master's degree/specialization", "currently in doctoral studies," and "doctoral degree".
7. Age: The user's current age.
8. Comments and/or suggestions: An open space for the user to share their opinions and suggestions about the application.

A questionnaire was also answered to evaluate whether the recognition images used for each of the heritage elements worked correctly to trigger the AR content. As previously mentioned, the ARAM test was used to evaluate the technological acceptance of the mobile application, and the IMMS test was used to assess motivation.

The average duration of the experiment was 40 min, during which users installed the app, performed the recognition of the 10 images, viewed the content associated with each heritage element, and completed the demographic questionnaire, the recognition image questionnaire, and the IMMS and ARAM tests.

The results obtained from the IMMS test, the ARAM test, and the demographic questionnaire were analyzed using the SPSS statistical program to identify correlations between quantitative variables and significant differences in qualitative variables for each value of the quantitative variables. Table 2 shows the variables from the IMMS test, the ARAM test, and the demographic questionnaire are shown, indicating the type of each variable.

Table 2. Variables for the experiment.

Questionnaire/Test	Acronym	Variables	Type of Variable
Demographic questionnaire	C_P	Level of knowledge about cultural heritage	Quantitative
	C_RA	Level of knowledge about augmented reality	Quantitative
	Fre_us	Frequency of use of augmented reality	Quantitative
	Gender	Gender	Qualitative
	Age	Age	Quantitative
	Educational level	Educational level	Qualitative
ARAM	PE	Performance expectancy	Quantitative
	EE	Effort expectancy	Quantitative
	SI	Social influence	Quantitative
	FC	Facilitating conditions	Quantitative
	CA	Computer anxiety	Quantitative
	HM	Hedonic motivation	Quantitative
	TE	Trust expectancy	Quantitative
	TI	Technological innovation	Quantitative
	BI	Behavioral intention	Quantitative
IMMS	A	Attention	Quantitative
	R	Relevance	Quantitative
	C	Confidence	Quantitative
	S	Satisfaction	Quantitative

7. Analysis Visualization of Contents Experiment

This section explains the statistical tests used to analyze the variables in Table 2 and the results obtained.

7.1. Statistical Test

The statistical tests in Table 3 show the type of test used depending on the number of participants in the experiment to identify whether the quantitative variables follow a normal distribution (when the significance is greater than 0.05).

Table 3. Statistical tests for normality of quantitative variables.

Kolmogorov Test	Shapiro–Wilk Test
Used when the population size is greater than 50 (N > 50)	Used when the population size is equal to or less than 50 (N ≤ 50)
If the significance is greater than 0.05, the variable follows a normal distribution, and parametric test should be applied (Sig. > 0.05) If the significance is less than or equal to 0.05, the variable does not follow a normal distribution, and non-parametric test should be applied (Sig. ≤ 0.05)	

The statistical tests in Table 4 were applied to verify if there is a correlation between quantitative variables and were used to check if there is a relationship between one variable and another. The significance result is a value between −1 and 1. If the significance is equal to 1, there is a perfect positive correlation; if it is equal to 0, there is no correlation; and if it is equal to −1, there is a perfect negative correlation.

Table 4. Statistical correlation tests for quantitative variables.

Type of Variables	Parametric Test	Non-Parametric Test
Quantitative + quantitative (independent variables)	Pearson Correlation	Spearman Correlation

The statistical tests in Table 5 were applied to determine the significant difference between quantitative and qualitative variables. In these tests, the statistical test is selected based on the number of options the qualitative variable has. A significant difference is considered when the significance is less than or equal to 0.05.

Table 5. Statistical tests for significant differences between quantitative and qualitative variables.

Type of Variables	Parametric Test	Non-Parametric Test
Quantitative + qualitative (2 groups)	T student for independent variables	Mann–Whitney U test
Quantitative + qualitative (More than 2 groups)	ANOVA	Kuskral–Wallis test
If the significance is greater than 0.05, there is no relationship between the variables (Sig > 0.05) If the significance is less than or equal to 0.05, there is relationship between the variables (Sig ≤ 0.05)		

7.2. Analysis of the Experiment

To determine if the variables have any kind of relationship, it is first necessary to assess whether the results follow a normal distribution. Since the population consists of 44 users, the Shapiro–Wilk test is performed to evaluate this (see Table 3). The results show that none of the quantitative variables follow a normal distribution (view Table 6).

Table 6. Shapiro–Wilk normality test.

	Shapiro–Wilk		
	Statistic	**gl**	**Significance.**
A (IMMS)	0.842	44	0.000
R (IMMS)	0.846	44	0.000
C (IMMS)	0.836	44	0.000
S (IMMS)	0.855	44	0.000
PE (ARAM)	0.850	44	0.000
EE (ARAM)	0.796	44	0.000
SI (ARAM)	0.879	44	0.000
FC (ARAM)	0.907	44	0.002
HM (ARAM)	0.746	44	0.000
CA (ARAM)	0.743	44	0.000
TE (ARAM)	0.799	44	0.000
TI (ARAM)	0.908	44	0.002
BI (ARAM)	0.805	44	0.000
Age (demographic)	0.837	44	0.000
C_RA (demographic)	0.922	44	0.006
C_P (demographic)	0.912	44	0.003
Fre_us (demographic)	0.947	44	0.042

To verify whether there are significant differences based on users' age, they have been divided into two groups (young and adult). In this study, a young person is considered anyone between 14 and 26 years old, while an adult is anyone aged 27 and older. The following sections present the results of the different analyses conducted. In all cases, the results for the 44 users (general population) are presented first, followed by results when considering separately the 21 young users (young population) and the 23 adult users (adult population).

In [44], the analysis performed and the results obtained have been presented in detail. The following sections provide a summary of these.

7.2.1. Correlation Between Quantitative Variables

This section presents the correlations obtained from the statistical tests conducted on the quantitative variables from the demographic questionnaire (C_RA, C_P, Age, and Fre_us) and the ARAM and IMMS tests.

Based on the results obtained from the correlations of the variables for the general, young, and adult populations, a diagram was created for each to show the variables that are correlated. The notation used for the diagram is that a thick, solid green line represents a direct correlation (if one variable increases, the other increases) between quantitative variables within the same test or questionnaire, while a thick, dashed green line represents a direct correlation with a variable from another test or questionnaire. Inverse relationships (if one variable increases, the other decreases) are represented in red, with a thick, solid line for relationships between quantitative variables within the same test or questionnaire, and a thick, dashed red line for relationships between quantitative variables and variables from another test or questionnaire. In the case of the ARAM test, the number of hypotheses proposed by the test's authors, mentioned in Section 5.1, is included to indicate which ones are fulfilled in each experiment (see Figure 8).

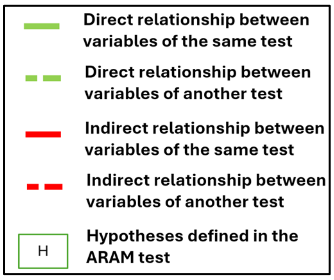

Figure 8. Notation for variable correlation diagrams.

As shown in Table 6, the variables from the IMMS test and the ARAM test do not follow a normal distribution. For this reason, the most appropriate test to evaluate the correlations between the quantitative variables is Spearman's correlation (see Table 4).

This statistical test allows for analysis of the relationship between two variables. In this case, it is used to determine whether the use of augmented reality contributes to improving motivation in cultural heritage learning. Additionally, it examines whether certain user characteristics such as their knowledge of augmented reality, their familiarity with cultural and natural heritage, their age, and the frequency with which they use this type of application influence cultural and natural heritage learning.

For example, Table 7 shows the correlations between the quantitative variables from the IMMS test and those from the demographic questionnaire, which considers age, level of knowledge about augmented reality, level of knowledge about cultural heritage, and frequency of use of augmented reality.

The test results indicate positive correlations between attention and age; relevance with age and knowledge of cultural heritage; confidence with knowledge of cultural heritage; and satisfaction with age and knowledge of cultural heritage. These results indicate that as age increases, users tend to perceive a higher level of attention, relevance, and satisfaction in learning about cultural and natural heritage. Likewise, as knowledge of cultural heritage increases, relevance, confidence, and satisfaction also improve.

For a more detailed explanation of the test results and the correlations performed, see [44].

Figure 9 shows the correlation of the quantitative variables from the IMMS test, ARAM, and demographic questionnaire for the 44 users (general population).

From the correlations obtained for the general population, in the IMMS test, all the variables of this test (attention, relevance, confidence, and satisfaction) were correlated with each other.

As for the ARAM test, variables such as trust expectancy, social influence, facilitating condition, effort expectancy, hedonic motivation, performance expectancy, and behavioral intention were correlated.

In the demographic questionnaire, the variable knowledge about augmented reality was correlated with the user's age and the frequency of use of this type of application.

The variables knowledge about cultural heritage and age from the demographic questionnaire were correlated with some of the variables from the IMMS test.

All the variables from the IMMS test were correlated with the variable's hedonic motivation, performance expectancy, and behavioral intention. Additionally, the variables from the IMMS test (except for satisfaction) were correlated with the variables social influence, facilitating condition, and effort expectancy from the ARAM test.

Table 7. Correlation between the variables of the IMMS test and the demographic questionnaire (general).

		Age	**C_RA**	**C_P**	**Fre_us**
A	Correlation coefficient	0.438 **	−0.199	0.200	−0.138
	Sig. (two-tailed)	0.003	0.195	0.194	0.370
	N	44	44	44	44
R	Correlation coefficient	0.340 *	0.075	0.346 *	0.102
	Sig. (two-tailed)	0.024	0.628	0.021	0.510
	N	44	44	44	44
C	Correlation coefficient	0.149	0.225	0.385 **	0.072
	Sig. (two-tailed)	0.335	0.142	0.010	0.642
	N	44	44	44	44
S	Correlation coefficient	0.337 *	−0.026	0.317 *	0.063
	Sig. (two-tailed)	0.025	0.864	0.036	0.686
	N	44	44	44	44

**. The correlation is significant at the 0.01 level (two-tailed); *. The correlation is significant at the 0.05 level (two-tailed).

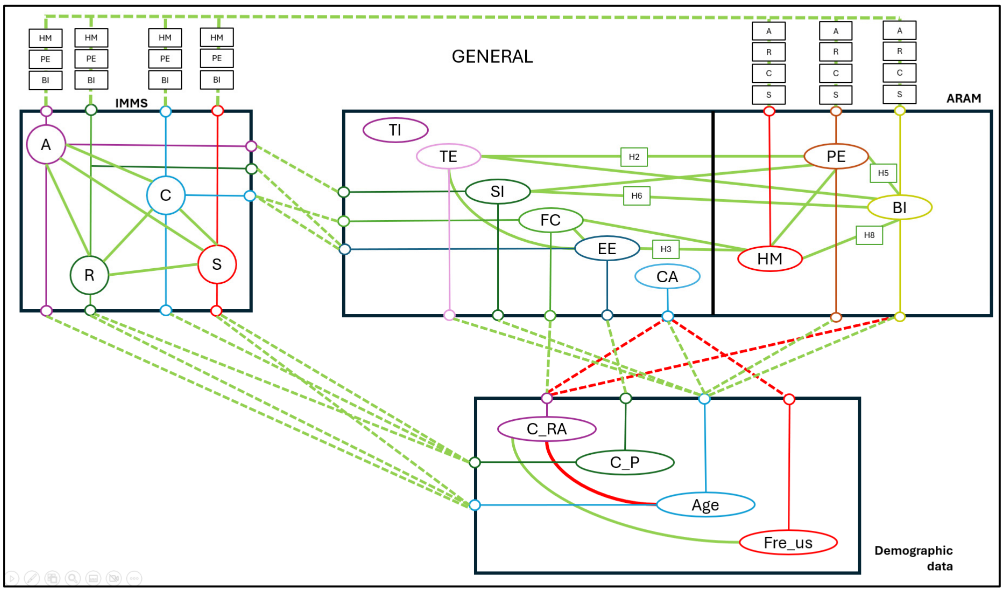

Figure 9. Correlation of quantitative variables with quantitative variables from the tests and questionnaire (general).

Finally, the age from the demographic questionnaire was correlated with the variables trust expectancy, social influence, facilitating condition, computer anxiety, performance expectancy, and behavioral intention from the ARAM test. Additionally, users with lower values for knowledge about augmented reality and frequency of use showed higher computer anxiety and, consequently, lower intention to use the application in the future.

Figure 10 shows the correlation of the quantitative variables from the IMMS test, ARAM, and demographic questionnaire for the young population.

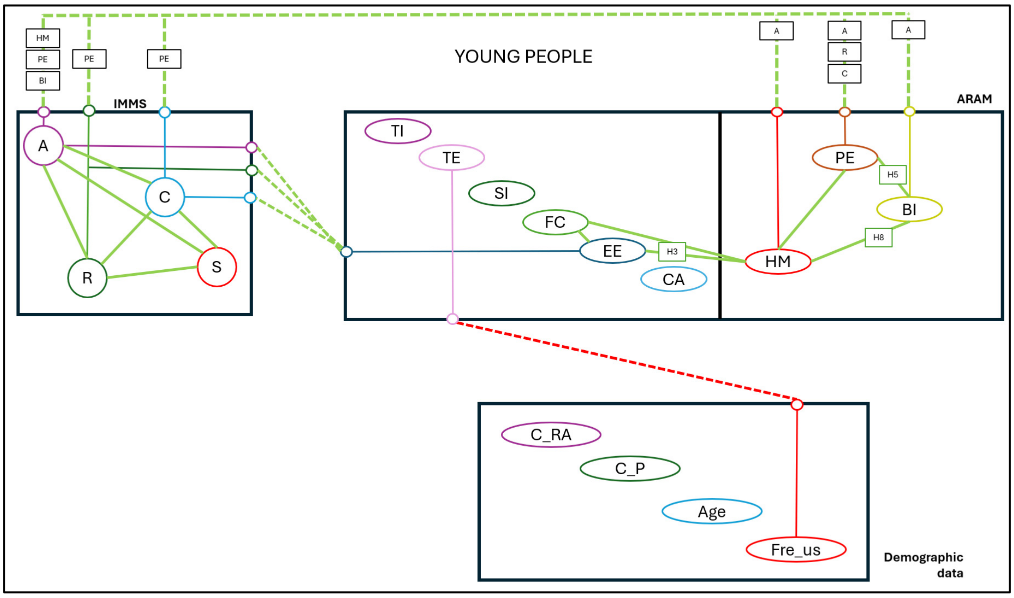

Figure 10. Correlation of quantitative variables with quantitative variables from the tests and questionnaire (young).

When considering only the young population, the same correlations from the IMMS test were found. Regarding the ARAM test, some of the correlations that existed in the ARAM test when compared to the general population also appeared. However, for this population, the characteristics that were found to most influence the intention to use the application were correlated with facilitating condition, effort expectancy, hedonic motivation, performance expectancy, and behavioral intention.

Regarding the demographic questionnaire, no correlations were found when considering only the young population. As for the correlations between the IMMS test and ARAM, it was found that effort expectancy and performance expectancy were correlated with attention, relevance, and confidence. Additionally, hedonic motivation and behavioral intention were correlated with attention.

Regarding the demographic questionnaire, there was only an inverse correlation between frequency of use and trust expectancy, meaning that those who use augmented reality applications the most have the least trust expectancy when using the application.

Figure 11 shows the correlation of the quantitative variables from the IMMS test, ARAM, and demographic questionnaire for the adult population.

When considering only the adult population, all the correlations between the variables of the IMMS test were found, except for the correlation between attention and confidence. Regarding the ARAM test, when compared to the general population, all correlations were present, although new ones emerged, such as technological innovation with performance expectancy and behavioral intention, where both were inversely correlated. There were also correlations between the ARAM test variables: trust expectancy with facilitating condition and effort expectancy with performance expectancy, behavioral intention, and hedonic motivation. Finally, computer anxiety had an inverse correlation with hedonic motivation, showing that, for adults, technologies added to the application increase computer anxiety and, consequently, decrease motivation, performance expectancy, and the intention to use it in the future.

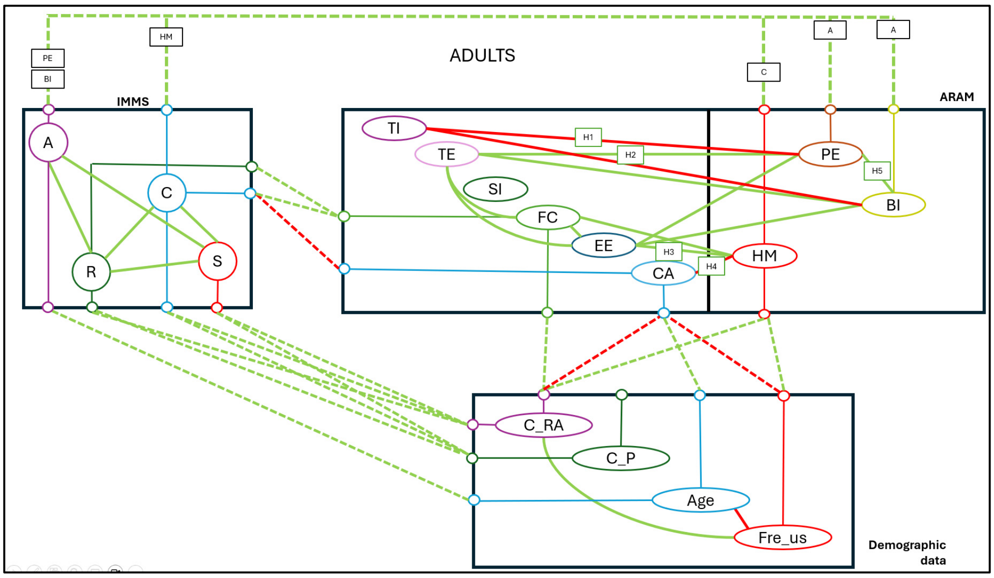

Figure 11. Correlation of variables from the tests and questionnaire (adults).

Regarding the correlations between the variables of the demographic questionnaire, users with more knowledge of augmented reality are those who use this type of application the most. Additionally, correlations between the IMMS test and the ARAM test show that they correlated with age. The correlations between the variables of the IMMS test and the variables of the ARAM test included facilitating condition, performance expectancy, behavioral intention, and computer anxiety. The latter shows that users with greater confidence in the application and in the conditions that facilitate its use have a higher interest in using the application, thus reducing computer anxiety.

The correlations found between the variables of the IMMS test and the demographic questionnaire show that users with higher computer anxiety are those who have insufficient knowledge of augmented reality, are older, or have low frequency of use of this type of application. In contrast, those who have knowledge consider it a condition that facilitates and motivates the use of the application.

Finally, the correlations between the IMMS test and the demographic questionnaire show that users who feel more motivated to use the application are those with greater knowledge of augmented reality and cultural heritage, and older users are the ones most drawn to the application.

7.2.2. Significant Differences Between Qualitative and Quantitative Variables

This section presents some of the results of the tests used to find significant differences between the qualitative variables gender and educational level in relation to the quantitative variables of the IMMS and ARAM tests, as well as the demographic questionnaire for the different populations.

A. Gender variable

For the qualitative variable gender, the Mann–Whitney U test was used because the quantitative variables do not follow a normal distribution, and the gender variable has only two groups: male and female (see Table 5). The results show that for the general population and adults, there were no significant differences. However, for young people, a significant difference was found in the quantitative variable facilitating condition from the ARAM test, where users who identify as male had greater ease compared to those who identify as female.

B. Educational level variable

For the qualitative variable educational level, the Kruskal–Wallis H test was used because all the quantitative variables from the IMMS and ARAM tests, as well as the demographic questionnaire, do not follow a normal distribution, and the educational level is divided into more than two groups (currently attending primary/secondary school, primary/secondary school, currently attending university, university, currently attending master's/doctoral programs, master's/doctoral, currently attending doctoral studies, and doctoral). The results show that for the general population, there were significant differences in the variables performance expectancy, social influence, computer anxiety, trust expectancy, and behavioral intention from the ARAM test. It was found that users with higher anxiety about using the application were those with primary education and university education. As for the other variables, the differences varied between each educational level, although the educational levels that did not show variation in the other variables were university, master's, and doctoral. This is because most of these users were familiar with technology. For both young people and adults, no significant differences were found for this variable.

C. Population variable

To evaluate if there are significant differences in the means of the qualitative variable population with respect to the quantitative variables from the IMMS test, ARAM, and the demographic questionnaire (level of knowledge about augmented reality, level of knowledge about cultural heritage, and frequency of use of augmented reality), the Mann–Whitney U test is used. This test was chosen because the quantitative variables do not follow a normal distribution, and the qualitative variable population has two groups (young and adult). In the following sections, the results of the statistical tests are presented.

C.1 IMMS test

To check for significant differences in the quantitative variables from the IMMS test (attention, relevance, confidence, and satisfaction) with respect to the qualitative variable population (young or adult), the result is shown in Table 8.

Table 8. Mann–Whitney U test with the population variables regarding the IMMS test variables.

	A	**R**	**C**	**S**
Mann–Whitney U	126.500	137.500	177.000	127.500
Wilcoxon W	357.500	368.500	408.000	358.500
Z	−2.710	−2.452	−1.523	−2.692
Sig. asin. (two-tailed)	0.007	0.014	0.128	0.007

From Table 8, it can be seen that the quantitative variables that yielded significant differences with respect to the qualitative variable population are attention, relevance, and satisfaction. Table 9 displays the significant differences found for each of these variables according to the population.

Table 9. Significant variance of population with respect to the quantitative variables of the IMMS test.

Ranks				
Population		N	Average Rank	Sum of Ranks
A	Young people	21	17.02	357.50
	Adult	23	27.50	632.50
	Total	44		
R	Young people	21	17.55	368.50
	Adult	23	27.02	621.50
	Total	44		
S	Young people	21	17.07	358.50
	Adult	23	27.46	631.50
	Total	44		

C.2 ARAM test

To check for significant differences in the quantitative variables from the ARAM test (performance expectancy, effort expectancy, social influence, facilitating condition, hedonic motivation, computer anxiety, trust expectancy, technological innovation, and behavioral intention) with respect to the qualitative variable population (young or adult), the result is shown in Table 10.

Table 10. Mann-Whitney U test with the population variables regarding the ARAM test variables.

	PE	EE	SI	FC	HM	CA	TE	TI	BI
Mann–Whitney U	70.000	231.500	123.000	235.500	172.000	148.000	135.500	217.500	77.000
Wilcoxon W	301.000	507.500	354.000	511.500	403.000	379.000	366.500	448.500	308.000
Z	−4.118	−0.240	−2.804	−0.142	−1.653	−2.353	−2.623	−0.570	−3.938
Sig. asin. (two-tailed)	0.000	0.810	0.005	0.887	0.098	0.019	0.009	0.569	0.000

From Table 10, it can be seen that the quantitative variables that yielded a significant difference with respect to the qualitative variable population are performance expectancy, social influence, computer anxiety, trust expectancy, and behavioral intention. Table 11 displays the significant differences found for each of these variables according to the population.

C.3 Demographic questionnaire

To check for significant differences in the quantitative variables from the demographic questionnaire (knowledge of augmented reality, knowledge of cultural heritage, and frequency of use) with respect to the qualitative variable population (young or adult), the result is shown in Table 12.

Table 11. Significant variance of population with respect to the quantitative variables of the ARAM test.

Population		N	Average Rank	Sum of Ranks
PE	Young people	21	14.33	301.00
	Adult	23	29.96	689.00
	Total	44		
SI	Young people	21	16.86	354.00
	Adult	23	27.65	636.00
	Total	44		
CA	Young people	21	18.05	379.00
	Adult	23	26.57	611.00
	Total	44		
TE	Young people	21	17.45	366.50
	Adult	23	27.11	623.50
	Total	44		
BI	Young people	21	14.67	308.00
	Adult	23	29.65	682.00
	Total	44		

Table 12. Mann–Whitney U test with the population variables regarding the demographic questionnaire variables.

	C_RA	C_P	Fre_us
Mann–Whitney U	109.500	194.500	189.500
Wilcoxon W	385.500	470.500	465.500
Z	−3.157	−1.139	−1.237
Sig. asin. (two-tailed)	0.002	0.255	0.216

From Table 12, it can be seen that the quantitative variables that yielded a significant difference with respect to the qualitative variable population are performance expectancy, social influence, computer anxiety, trust expectancy, and behavioral intention. Table 13 displays the significant differences found for each of these variables according to the population.

Table 13. Significant variance of population with respect to the quantitative variables of the demographic questionnaire.

Ranks				
Population		**N**	**Average Rank**	**Sum of Ranks**
C_RA	Young people	21	28.79	604.50
	Adult	23	16.76	385.50
	Total	44		

7.2.3. Image Recognition

To evaluate the functioning of the recognition images for each of the heritage elements in the museum, a questionnaire was designed which includes the name of the heritage element, the recognition image used to activate augmented reality, a QR code that was used in case the recognition image did not work, and data about the device used to view the content (operating system, operating system version, and device brand).

In the image recognition questionnaire, participants were instructed to mark "yes" if the associated content for the heritage element appeared or "no" if it did not work. If it did not work, they were asked to try viewing the content using a QR code and indicate "yes" or "no" depending on whether they were able to view the content associated with that heritage element. At the end, they were asked to record the characteristics of the device they used to test the application.

Participants were then asked to install the Motiv-ARCHE app. Once installed, the app's functionality is explained to them through a brief tutorial, where they are shown how to view the content associated with the heritage elements displayed in the museum. It is clarified that not all displayed elements have associated information, so they are provided with the questionnaire containing the images of the 10 elements that do have such information.

In this same questionnaire, users were able to write comments regarding image recognition. In some cases, especially with paintings, they indicated that the augmented reality activation was achieved by directly using the heritage element, the printed images within the museum, and the questionnaire, and they therefore did not need to use the QR codes. Users pointed out that the heritage elements that activated augmented reality directly through image recognition were Santa Teresa de Jesús, Vision of St. Ignatius of Loyola in the Storia Cave, and St. William of Aquitaine. In cases where they had to rely on the printed image from the museum or the questionnaire, it was because the augmented reality activation was complicated by external factors such as lighting, the angle of the device during recognition, and the height at which the heritage element was located.

In the case of sculptures, recognition could not be performed directly on the heritage element, as it was necessary to match the angle at which the recognition image had been taken to activate the augmented reality. However, by using the printed images available in the museum or in the questionnaire, the activation worked correctly.

In none of the cases did users have to resort to the QR code to view the augmented reality content for the 10 heritage elements. This indicates that the image used for each of these elements worked correctly and displayed the associated content for the heritage element.

8. Conclusions

Motiv-ARCHE is an augmented reality application designed to facilitate learning about cultural and natural heritage by displaying content associated with each heritage element (such as audio, images, videos, 3D models, PDF files, websites, and texts) based on the user's characteristics, their context, and the heritage element itself. This document focused on the visualization and access to content associated with heritage elements.

To evaluate access to the content, an experiment was conducted with users who visited the Santa Clara Museum in Bogotá. A total of 44 users participated, exploring 10 heritage elements previously created in collaboration with heritage experts. To access the content, a questionnaire was designed that included the 10 heritage elements and their respective recognition images to activate the associated AR content.

In addition, the IMMS motivation test, the ARAM technology acceptance test, and a demographic questionnaire were administered with the aim of analyzing whether there are correlations between the quantitative variables of the tests and whether there would be significant differences between the quantitative and qualitative variables to identify whether motivation, technology acceptance, and demographic variables influence learning about cultural and natural heritage.

The demographic questionnaire included questions about age, level of knowledge in cultural and natural heritage, level of knowledge in augmented reality, education level, gender, and frequency of use of augmented reality applications. Regarding the qualitative variables from the demographic questionnaire, gender did not show significant differences when considering all 44 users, indicating that all users had a similar perception of the application. However, when analyzing the results for young users, it was observed that male users found the application easier to use compared to female users. For the adult population, no significant differences were found in terms of motivation and technological acceptance of application.

Regarding educational level, when considering all 44 users, it was observed that those with a doctorate, master's degree, bachelor's degree, or those currently enrolled in a university program perceived Motiv-ARCHE as a slightly more useful tool. Additionally, it was found that social influence was one of the variables that defined the use of the application, meaning that university students would be more likely to use the application if it is recommended by someone who has already used it.

It was also found that, for users who were pursuing university studies, there was no fear in using the application. This is because, due to the studies they are undertaking, they are more familiar with this type of technology. Regarding knowledge of augmented reality, it was observed that users with a PhD and those currently pursuing university studies had the most knowledge of this technology, although this is also due to the previously mentioned reason. When reviewing the results of the young population with respect to educational level, no significant differences were found in any of the quantitative variables considered. The same happened when evaluating the adult population, so the differences mentioned earlier regarding educational level are due to the perception each group had regarding the Motiv-ARCHE application.

Based on the results, a statistical analysis was conducted to examine whether there would be a relationship between the considered variables. This analysis was carried out for the 44 users and was later analyzed by considering the 21 young users (aged 14 to 26) and the 23 adult users (aged 27 and above).

Additionally, the correlations show that older users tend to have less knowledge about augmented reality, which may increase their fear of using the application. On the other hand, younger users, who are more familiar with this type of application, find it easier to use and are not afraid of making mistakes. The statistical analysis results for young users show that those with a higher level of knowledge about cultural heritage consider the content more important and feel more confident in understanding what is being explained to them. Therefore, motivation depends not only on the content provided but also on how easily technology presents the augmented reality content, the required resources, how fun it is to interact with the application, and how useful it is for learning.

By including the qualitative variable population, the results for young and adult users were analyzed, showing significant differences for some of the variables in the IMMS test, the ARAM test, and the demographic questionnaire. From the analysis of the significant differences, it was found that for the IMMS and ARAM test variables, the results for young users compared to adults showed lower performance expectancy, social influence, computer anxiety, effort expectancy, and behavior intention. This is because, in the correlation analysis, it was found that this group of users is more accustomed to using augmented reality applications and has a greater knowledge compared to adult users.

The results of the statistical analysis for adult users show that motivation is higher when users have a strong knowledge of augmented reality and cultural heritage. Furthermore, as age increases, the frequency with which they use augmented reality applications decreases, which leads to less knowledge about how augmented reality works. Therefore, the more knowledge they have about augmented reality, the more motivated they feel and the more confident they are when using the application.

From a technological perspective, to motivate the adult population, it is important to offer a reliable and easy-to-use tool, as this reduces the fear of using it, improves the user experience, increases the intention to use it in the future at other heritage sites, and is perceived as useful for learning. However, care should be taken when adding more technological features, as more functionalities are implemented, the users perceive less utility, and their intention to use it decreases.

The overall results show that older age and greater knowledge of cultural heritage make users more motivated to view the contents of the heritage elements. This motivation is also influenced by factors such as social influence, ease of use of technology, interest in visiting heritage sites, and the intention to use the application in the future.

Although this article focused on a content visualization experiment to determine whether Motiv-ARCHE enhances user motivation in learning about cultural and natural heritage, during the content co-creation process with museum experts, they expressed that its use would allow them to manage heritage elements through the tagging of both heritage elements and their associated content. Additionally, they noted that the application would enable them to adapt the content provided to users.

As future work, we will consider implementing improvements to the application based on user suggestions (found in the demographic questionnaire and the ARAM test) and their activity within the platform, such as allowing users to edit and delete heritage elements to facilitate the co-creation of elements and content, as well as enriching the experience with more graphical elements. Additionally, we aim to provide detailed information about heritage elements, specifying the types of associated content and any access restrictions users may encounter during their visit. Furthermore, we plan to enhance co-creation modules to enable collaborative content generation between heritage experts and users, as well as refine the adaptation module, particularly in the development of personalized routes that consider user preferences, interests, and contextual characteristics. Finally, we aim to conduct tests in other museums to compare this experiment with others and validate the correlations found in this study. With more data, we could develop an analytical component that records user interactions and activity within the application, allowing us to incorporate additional factors such as user habits and trends into the adaptation module.

Author Contributions: Software, J.C.G.V.; Investigation, J.C.G.V., R.F., A.C.-R. and T.J.; Writing—original draft, J.C.G.V.; Writing—review & editing, R.F., A.C.-R. and T.J.; Supervision, R.F., A.C.-R. and T.J.; Project administration, J.C.G.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were waived for this study because all the information provided by the experiment's users was anonymized.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

AR	Augmented Reality
ARAM	Augmented Reality Acceptance Model
GPS	Global Positioning System
ICT	Information and Communication Technologies
IMMS	Instructional Materials Motivation Survey
LMSs	Learning Management Systems
MR	Mixed Reality
PDF	Portable Document Format
RIMMS	Reduced Instructional Materials Motivation Survey
SUS	System Usability Scale
TAM	Test Acceptance Model
UTAUT	Unified Theory of Acceptance and Use Technology
VR	Virtual Reality
XR	Extended reality

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