Journal of Positive Psychology & Wellbeing http://journalppw.com
2023, Vol. 7, No. 2, 481 – 499 ISSN 2587-0130

MOBILE APPLICATION WITH AUGMENTED REALITY FOR THE TOURIST EXPERIENCE: A CASE STUDY IN THE DISTRICT OF CASA GRANDE, PERUVIAN NORTH COAST

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Summary

When visiting the Casa Grande District, tourists arrive at the Main Square, from where they see around them many buildings to which they only take pictures and then leave, but they do not know about the history and value that each of them represents. Thus, the objective of this research is to value the diverse architectural heritage that the Casa Grande District has and at the same time improve the tourist experience, through the use of a Mobile Application with Augmented Reality. To carry out the experimental research, the agile Mobile-D methodology was used, which has 5 phases: Exploration, Initiation, Production, Stabilization and Testing; in the Research Design, two groups were used: Experimental Group (Ge) and Control Group (Gc), while Student's t-test was used to validate the hypotheses. Finally, the results revealed that the Mobile Application with augmented reality presented better results in the Ge with respect to the Gc in each of the indicators: time and cost of access to information, the number of visits and the satisfaction of tourists.

Keywords - Mobile Application, Augmented Reality, Mobile-D, Tourist Experience, Geolocation, Access to Information.

I. INTRODUCTION

Tourism is one of the most emerging and widespread economic and socio-cultural activities worldwide (Raj Sharma et al., 2022). But in the case of tourism of historical heritage or archaeological sites, it usually happens that the deterioration caused by the passage of centuries leads some tourists to feel some disappointment

at the state of conservation in which they are (Mañas Viniegra, 2018). And although some countries have used augmented reality to promote culture and urban tourism in heritage sites; however, it is still a tool with little exploration (Agüero-Bravo, 2021). Since current implementations of augmented reality (AR) in tourism still lack effective engagement by the tourist (Cibilić et al., 2021). It also happens that heritage virtualization can be affected by the difficulties of obtaining accurate historical documentation for content creation (Challenor & Ma, 2019). With the above in mind, Xian and Shen designed a graphic AR travel system, which stimulated the learning of cultural heritage to the tourist (Xian & Shen, 2020). Similarly, Jiang et al. (2022) improved the memorability of tourist experiences at heritage sites for visitors to the Great Wall of China. On the other hand, Shin & Choi (2021) designed an app called Seoul AR, which increased user satisfaction by gaining information about the main places in Seoul. So too Han *et al.* obtained positive effects on destination authenticity and satisfaction from using AR as a support tool (Han et al., 2021).

Thus, this research is of great social relevance since it positively affects the intention of tourists to use a mobile application with AR (Siang et al., 2019). At the same time, it has great scientific relevance, given that little research has explored the effects of AR on the experiences of tourists (He et al., 2018). It also obtains an important relevance in environmental immersion, this means that being physically in front of heritage provides the user with a sense of historical empathy that cannot be achieved from a classroom with a textbook (Challenor & Ma, 2019). As specific objectives were considered: reduce the time it takes tourists to access information, also reduce the cost they normally spend on accessing information, consequently, it will be possible to increase the number of tourist visits, in the same way it will be possible to increase the satisfaction of tourists. The present research is organized as follows: in section II the theories of each variable are presented as Background. Section III details the methods and materials used in applying each phase of the Mobile-D methodology. Section IV presents a detailed case study. Section V presents the Results and Discussions. Finally, Section VI presents the Conclusions and Future Research.

II. BACKGROUND

2.1. Mobile Application with Augmented Reality

In recent years the proliferation of smart mobile devices that has allowed a demand for mobile applications for smartphones and tablets has increased enormously, including augmented reality (Ahmad et al., 2018; Do et al., 2020) . AR is a fusion between the virtual world and the real world that is projected in 2D or 3D form, used for entertainment, engineering design or as a means of learning (Adnan et al., 2020). Unlike virtual reality, augmented reality is designed for constant use on the move (Arena et al., 2022). It is a technology that significantly facilitates the execution of complex operations (Leksono et al., 2022). Thanks to the different augmented reality techniques, free and easily implemented on mobile devices, they allow anyone to know the value of places in a simple and interactive way (González-Delgado et al., 2020). In this way, users will have more consistent information about their destination location (Demir & Karaarslan, 2018). AR in tourism has contributed to revolutionizing the way tourists and visitors access information, acquire knowledge and integrate physical spaces and destinations visited (Azevedo & Alturas, 2019).

2.2. Tourist Experience

It is the result of multisensory stimuli and perception, positive emotions, elevated emotional states, surprising events, extraordinary moments and pleasant and positive memories (Pedro, 2021). Experience is influenced by the interaction between a user, product characteristics, system properties, and context (Potdevin et al., 2021). Memorable experiences must be provided to the tourist, that is, he must take a good memory of his visit; which generates a source of competitive advantage (Spadoni et al., 2022). In the context of heritage tourism, the basic composition that determines the success or failure of the entire tourism experience is the

perceived experiential value (Han et al., 2021). The heritage tourism experience is actually a process of coding symbols and allowing emotional satisfaction in tourists to evolve (Zhao, 2021).

III. RESEARCH METHOD

3.1. Mobile-D Methodology

It is one of the most suitable methods for mobile application development because it is agile and flexible (Purwanto et al., 2020). Since it does not require a large amount of equipment and the processing time is shorter than the others (Ependi et al., 2019). See Figure 1.

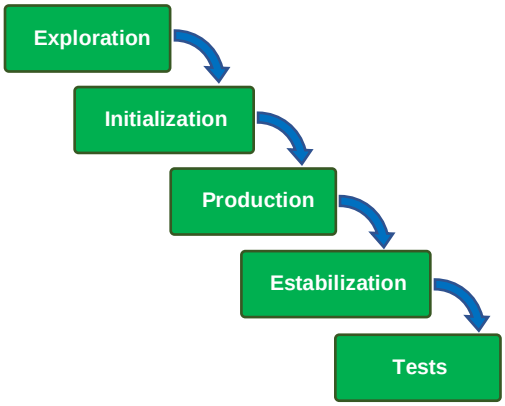

Figure 1. Mobile-D Methodology

a. Exploration: A plan must be developed and the characteristics of the project established.
b. Initialization: All critical development issues are prepared and verified to ensure that issues are addressed in the final phase when customer-selected requirements are implemented.
c. Production: This phase consists mainly of implementation activities. When this phase is performed, most of the deployment must be completed.
d. Stabilization: This phase is the integration of the system. Large products can be divided into smaller subsystems. When multiple teams work together, the subsystems, which are generated into a single product, must be integrated.
e. Testing: The tasks of this phase are to verify whether or not the system produces what the customer wants, get feedback from the project team on the functionality of the system, and correct defects.

3.2. Applied Research Methodology

A. Operationalization of Variables

The indicators considered in the research to be optimized through the Mobile Application are presented in Table I.

Table I. Indicators of the Dependent Variable

Indicator	Index	Unit of Measure
Time of access to information	[10 - 20]	Minutes

Cost of access to information	[20 - 50]	Soles
Number of visits by tourists	[1 - 10]	Tourists
Tourist satisfaction	Strongly agree, I agree Neither agree nor disagree, Disagree, Strongly disagree.	Likert scale

B. Research Design

For this research, the Applied and Pure Experimental Research type with Post-test only and control group was used.

RG_{and} X O_1
RG_c- - O_2

Where:

A: Random choice of the elements of the Sample (Ge or Gc).

Ge: Experimental group: Study group to which the stimulus will be applied (Mobile Application with Augmented Reality).

Gc: Control group: Study group to which the stimulus will not be applied (Mobile Application with Augmented Reality).

X: Stimulus: Mobile Application with Augmented Reality.

--: Absence of Stimulus.

Data are taken from the control group (Gc), the independent variable is applied and data is taken from the experimental group (Ge). The elements of the sample are chosen randomly (R) to which a Stimulus (X) is applied.

C. Universe and Sample

For the universe, all the processes of tourist experience in natural and cultural heritage of Latin America were taken: N = Indeterminate.
For the sample, the processes of tourist experience in the Casa Grande district were considered. n = 30

D. Data Collection Procedures

In this research the data collection instrument was the observation sheet, the techniques used were direct observation and indirect observation through document review.

E. Statement of Hypotheses

H1: The use of a Mobile Application with Augmented Reality, based on the Mobile-D Methodology, decreases the time of access to information for the Tourist Experience in the District of Casa Grande.
H2: The use of a Mobile Application with Augmented Reality, based on the Mobile-D Methodology, reduces the cost of access to information for the Tourist Experience in the Casa Grande District.
H3: The use of a Mobile Application with Augmented Reality, based on the Mobile-D Methodology, increases the number of visits by tourists in the Casa Grande District.
H4: The use of a Mobile Application with Augmented Reality, based on the Mobile-D Methodology, increases the satisfaction of tourists in the Casa Grande District.

For the testing of the hypotheses, the following solution was proposed for each of the indicators.
μ1: Population mean (H1, H2) for the Gc Posttest.
μ2: Population mean (H1, H2) for the Ge Posttest.
Where:

Ho: m1 ≤ m2

Ha: m1 > m2

In addition:

μ1: Population mean (H3, H4) for Posttest of Gc.
μ2: Population mean (H3, H4) for Ge Posttest.
Where:

Ho: m1 > m2

Ha: m1 ≤ m2

Finally, the data normality test, descriptive statistical analysis (See Table VI), and the hypotheses were validated using Student's t-test with specialized Minitab software (See Table VII and Table VIII) were performed.

IV. CASE STUDY

For the development of the Mobile Application with Augmented Reality, the methodology was used Mobile-D, which consists of 5 phases: Scanning, Initialization, Production, Stabilization and System Testing.

4.1. Exploration

A. Establishment of Interest Groups or Stakeholders:

- **Interest Groups:** District or Provincial Municipalities with natural and/or cultural heritage, sites of tourist interest.
- **Potential Clients:** Places with historical and cultural potential that require support to be considered a tourist center within their region and effectively make their history known to tourists.
- **App users:** Tourists visiting the Casa Grande District.
- **Sponsor:** The District Municipality of Casa Grande, Trujillo, Peru.
- **Developer:** Author of the research.

B. Scope Definition:

- Available to all tourists visiting the Casa Grande District, through the use of smartphones or tablets, in which they can follow a geolocated tourist route.
- Establishhistorical content of tourist attractions where a marker is available.

C. Identification of modules and requirements:

The Modules developed are presented below in Table II.

Table II. Application Modules

Code	Module
M001	Main Menu
M002	Geolocated Route
M003	Marker Recognition
M004	Augmented reality
M005	Services Menu

D. Establishment of the project:

This section determines the physical and technical resources necessary for the development of the project. The tools to be used are the following:

- Technology: Unity 2021.
- Library: Vuforia Engine 10.5.5
- Operating system: Windows 10 (64-bit).
- Computer: 1 Laptop with 4-core processor plus, 16 GB of RAM and with minimum available space on 50GB disk.
- Development methodology: Mobile-D.

4.2. Initialization

A. Solution Architecture

One of the most important sections, since it allows defining the way in which current architectures (information, technological services and information systems) should be adjusted, see Figure 2.

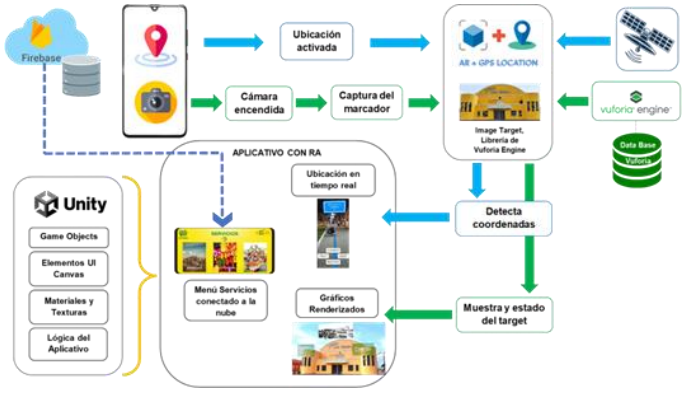

Figure 2. Solution Architecture

B. Preparation of the environment

You must have the following:

- Core i7 laptop with 16GB of RAM.
- Unity 2021.2.16f1 installation.
- Download and install the SDK to Unity.
- Download and install the JDK to Unity.
- Download and install the Visual Studio 2019 code editor.
- Download and install Vuforia to Unity.
- Upload the predefined bookmarks in Vuforia to Unity.
- Sort the Unity environment by folders (scripts, folders, packages, etc.).

C. Mobile Application Requirements

- Android: 8.0 the top.
- Camera: 8mp or higher.
- Processor: 2 cores (minimum).
- RAM: 3 GB (minimum).
- FHD (1920 x 1080) resolution screen or preferably 4K resolution (3840 pixels).
- Screen preferably 6 or 7 inches.

D. Prototypes

This section shows the prototypes developed (See Figure 3, Figure 4, Figure 5 and Figure 6):

Figure 3. Home of the Mobile Application

Figure 4. Services Menu

Figure 5. Geolocated Route

Figure 6. Augmented reality

4.3. Production

- **Database**

At this stage, the application data model, shown in Figure 7, has been developed.

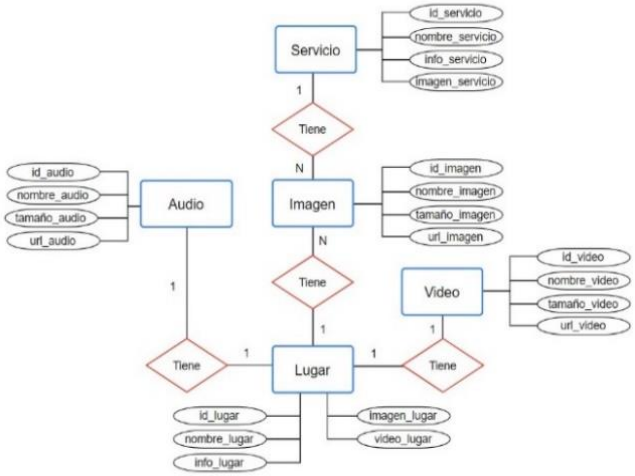

Figure 7. Entity–Relationship Model

4.4. Stabilization

In this phase, the functionalities described in the Production phase are integrated, as shown in Figure 8.

- **Scene Change**

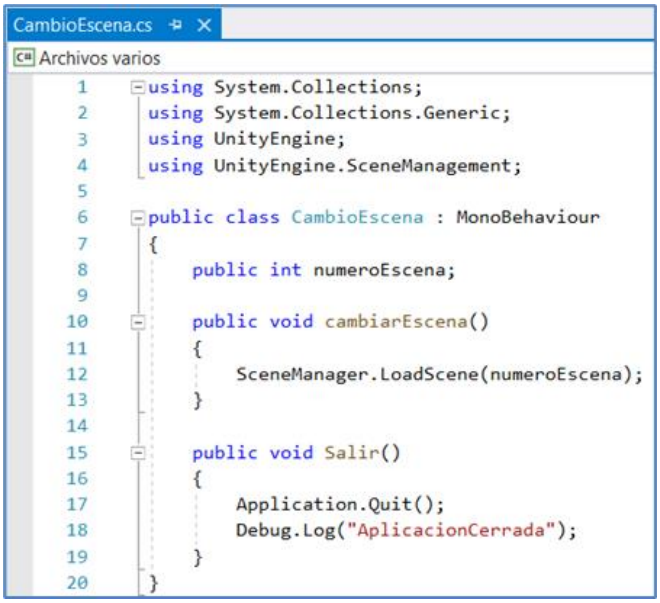

Figure 8. Scene Change Code

4.5. Tests

In this phase, the functionalities of the mobile application are validated and the errors found are corrected using the following guidelines:

- Test Cases.
- Testing strategy.
- Availability and performance.
- Monitoring and verification of corrections.
- Summary sheet of corrections and modifications.

V. RESULTS AND DISCUSSION

5.1. Results: After application de the solution has obtained real values for: Time of access to information, Cost of access to information, Number of visits of tourists, Satisfaction of tourists.

A. Experimental Results

30 values were obtained for each indicator using different statistical techniques, which are shown in Table III and Table IV.

Table III. Gc Posttest and Ge Posttest Results for I1 and I2

	I1: Information access time (minutes)		**I2: Cost of access to information (soles)**	
No.	**PosPrueba del Gc**	**PosPrueba del Ge**	**PosPrueba del Gc**	**PosPrueba del Ge**
1	14.4	1.2	20.0	7.0
2	11.2	2.4	30.0	3.0
3	13.1	2.8	20.0	6.0
4	12.4	1.7	20.0	0.0

5	11.6	0.5	15.0	10.0
6	10.4	1.3	25.0	0.0
7	12.4	2.7	40.0	5.0
8	10.1	1.1	30.0	0.0
9	12.5	2.6	20.0	3.0
10	15.6	1.7	25.0	7.0
11	14.1	2.4	59.9	7.0
12	13.2	1.0	45.0	0.0
13	13.6	0.4	45.0	5.0
14	10.5	2.5	35.0	4.0
15	12.8	2.1	60.0	0.0
16	11.1	1.1	55.0	3.0
17	12.2	1.6	40.0	6.0
18	13.4	0.4	70.0	10.0
19	15.3	2.1	60.0	3.0
20	10.1	1.0	55.0	7.0
21	12.4	1.6	45.0	6.0
22	14.5	1.7	40.0	4.0
23	16.3	1.6	60.0	5.0
24	15.4	3.4	70.0	5.0
25	11.3	1.8	85.0	6.0
26	12.5	1.6	49.9	10.0
27	14.4	1.7	53.0	0.0
28	15.6	1.6	41.0	3.0
29	14.3	2.4	20.5	7.0
30	13.4	0.5	34.0	10.0

Table IV. Gc Posttest and Ge Posttest Results for I 3 and I4

	I3: Number of visits by tourists	**I4: Sglimpse of the Tonists(Likert scale)**

No.	PosPrueba of Gc	PosPrueba de Ge	PosPrueba of Gc	PosPrueba de Ge
1	2	3	2	3
2	0	2	0	2
3	1	4	1	4
4	3	5	3	5
5	2	5	2	5
6	2	6	2	6
7	3	2	3	2
8	2	8	2	8
9	1	3	1	3
10	2	9	2	9
11	0	3	0	3
12	3	4	3	4
13	0	3	0	3
14	3	5	3	5
15	5	4	5	4
16	6	7	6	7
17	3	4	3	4
18	4	5	4	5
19	0	7	0	7
20	1	4	1	4
21	1	2	1	2
22	3	8	3	8
23	4	6	4	6
24	2	9	2	9
25	0	3	0	3
26	2	6	2	6
27	0	8	0	8
28	4	7	4	7
29	1	7	1	7

30	4	5	4	5

B. Normality Test

This test has made it possible to compare the empirical cumulative distribution function (ECDF) of the sample data with the distribution expected if the data were normal. Evidence for three indicators is presented. (See Figure 9, Figure 10 and Figure 11)

I1: Time of Access to Information

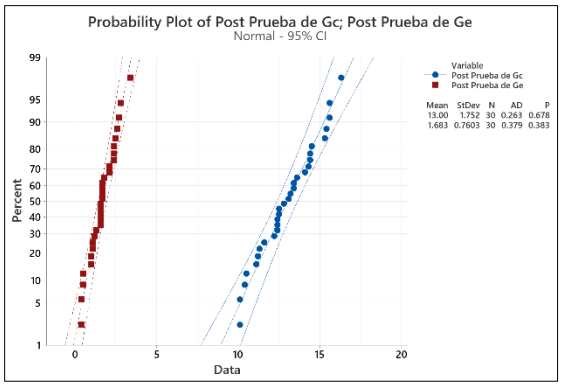

Figure 9. Normality Test for Indicator 1

It is observed that, for Gc and Ge, the value of p (0.678 and 0.383) > α (0.05). Demonstrating that the values of the indicator have a normal behavior.

I2: Cost of Access to Information

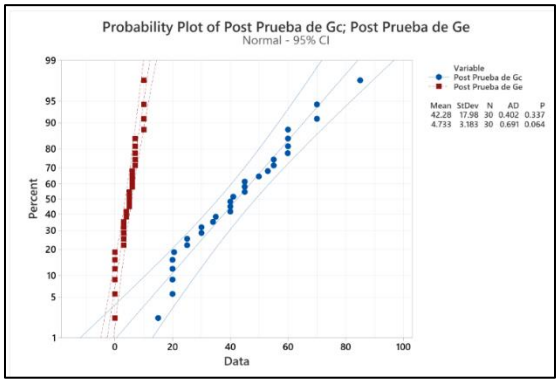

Figure 10. Normality Test Indicator 2

Thus, for Gc and Ge, the value of p (0.337 and 0.064) > α (0.05). Demonstrating that the values of the indicator have a normal behavior.

I3: Number of Tourist Visits

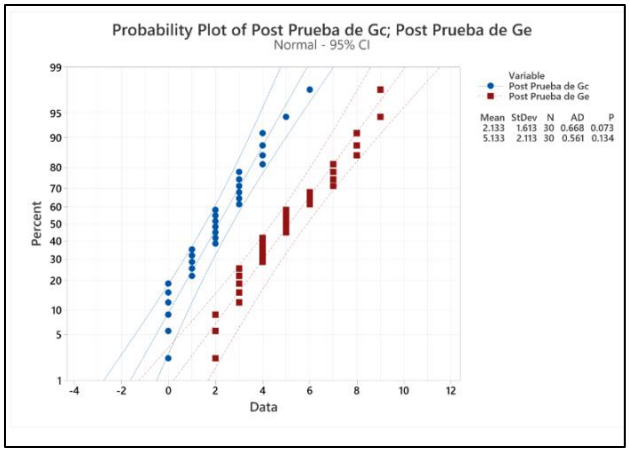

Figure 11. Normality Test for Indicator 3

You can visualize r that, for Gc and Ge, the value of p(0.073 and 0.134) > α(0.05). Demonstrating that the values of the indicator have a normal behavior.

5.2 Discussion of Results

The discussion of the results has been carried out through a critical and honest position of the researchers respecting the results as they are, without altering or distortingthem. In addition, practical and theoretical implications are presented for each result obtained.

A. With descriptive statistics

An initial descriptive analysis of the data allows to determine patterns and trends in them. This is shown in Table V and Table VI.

Table V. Results with Descriptive Statistics

Indicator	n	Media	StDev	TO	p-value
I1: PosPrueba (Gc)	30	13.00	1.752	0.263	0.678
I1: PostTest (Give)		1.683	0.7603	0.379	0.383
I2: PosPrueba (Gc)	30	42.28	17.98	0.402	0.337
I2: PosPrueba (Give)		4.733	3.183	0.691	0.064
I3: PosPrueba (Gc)	30	2.133	1.613	0.668	0.073

I3: PosPrueba (Give)		5.133	2.113	0.561	0.134

Regarding the results of the "Anderson Darling" normality test, the AD and p-value are greater than α (0.05); therefore, the normality of the data for analysis was confirmed. It was observed that, with a confidence level of 95%, the mean and standard deviation revealed normal results in the data of the research indicators .

Tabla VI. Resumen de Resultados para lparametric indicators

Indicator	**n**	**95% confidence intervals for mean**	**Kurtosis**	**Asymmetry**	**Q3**
I1: PosPrueba (Ge)	30	1.3994 - 1.9672 min	-0.365926	0.110919	2.4
I2: PosPrueba (Ge)	30	3.5447 - 5.9220 soles	-0.744127	-0.014131	7
I3: PosPrueba (Ge)	30	4.3444 - 5.9223 tourists	-0.994190	0.259062	7

According to the details shown in the Table, about 95% of the values are within 2 standard deviations from the mean, Kurtosis indicates that there are values with very low peaks, Asymmetry indicates that most values are low, the 3rd Quartile (Q3) indicates that 75% of the values are lessthan or equal to this value.

For indicator I1: The results were similar to those of Davari et al. (2022), who in their research "Validation of the benefits of visible and context-sensitive augmented reality for daily tasks of access to information", expressed that the time of access to information in the Ge (2.83 minutes) was significantly lower than the Gc (7.31 minutes). In the same way, these results were similar to those of Purnomo et al. (2018), which improved the time to obtain information by 97%. So also Rezaee et al. (2021) obtained a 73.75% decrease in the time for the price ofthe type of tourist attraction. These results were greater than those of Zhang et al. (2022) that could decrease by 53% of the time for access to information. Likewise, Muñoz Sajama et al. (2018) decreased the time to access information on each estate.

There is no doubt that thanks to the mobile application with augmented reality, a decrease in the times to access information was obtained, so it is inferred that it can also favor different processes that require the shortest possible time such as: location of boats, find routes and trails; In the same way to be able to access information about hotels, restaurants, local businesses, etc.

For indicator I2: The results were similar to those of Xian & Shen (2020) who determined a 17.5% decrease in the cost to access tourist information. Theseresults were lower than those of Condeixa Venancio et al. (2019) whois determined a significant decrease of 84% for the cost of access to information. It was also better rum is that theauthoris Zhang et al. (2022) that obtained a decrease of 51. 6% of the perceived value of the tourist experience. They are also better than the results obtained by Shen et al. (2022) whois achievedreduced 64.5% dthe cost of access to information. Similarly, Schofield et al. (2021)

decreased by 83% the average cost to access historical information of buildings and rooms.

Sin doubt for any place it is important to provide an excellent tourist service so this research used augmented reality, as an innovative method that can reducecosts to access heritage information, so it can also help to economize information on: biology, botany, archeology, location of routes and trails, etc. in order to provide more affordable services in the world.

For indicator I3: Theresults obtained were similar to those of Kato & Yamamoto (2020) whodetermined a significant increase of 77% in the number of tourist visits. The results were also superior to those of Shin & Choi (2021) who determined an 83.3% increase in tourist visits. These results are greater thanthose of Llerena et al. (2018) whois managed to increase the tourist flow by 50.74%. Similarly Falomo Bernarduzzi et al. (2021) obtained similar results, and achieved an increase of 456 tourists who downloaded the application used by the Museum of History of the University of Pavia. Aothers Jiang et al. (2022) increased the number of visitors by 81.1%.

It follows that using augmented reality achieves an immersive experience helping to capture the interest of tourists, this allows the number of tourists to increase considerably; so it can also be integrated into: cultural events, art galleries, museums, local historic centers, aquariums, zoos and many other places that want to attractmore people.

For indicator I4: The results were similar to those of the authorShin & Choi (2021) who in their research "SEOUL AR: Designing a Mobile AR Tour Application for Seoul Sky Observatory in South Korea", expressed that the satisfaction of tourists in the Ge (M = 3.59) was higher than the Gc (M = 3.18). Similarly, these results were similar to those of Phithak & Kamollimsakul (2020) who in their research "Korat Historical Explorer: The Augmented Reality Mobile Application to Promote Historical Tourism in Korat" expressed that the satisfaction of tourists in the Ge (4.30) was higher than the Gc (3.67). Likewise, in her research Tsai (2020) obtainedor 77% in the degree of tourist satisfaction. These results were similar to those of Leksono et al. (2022) whois determined a satisfaction of 72.3% of tourists regarding the use of their application for Innovation with Augmented Reality. Very similar to the results of Zainal Abidin et al. (2018) which obtained that 75.83% of respondents are satisfied with the application of augmented reality.

In this sense, the present study covered the main needs of tourists, since the mobile application with augmented reality, allowed to increase their satisfaction; In the same way, it could also satisfy visitors in any country in the world who participate in tourist routes, guided tours, art exhibitions, etc.

B. With Inferential Statistics: Hypothesis Testing

Tables VII and VIII show the values obtained after the application of the statistical tests of contrast of the hypotheses.

Table VII. Hypothesis Testing for Parametric Indicators

Indicator	**n**	**I have**	**t-value**	**p-value**
I1: PosPrueba (Gc)	30	m1 < m2	32.46	0.000
I1: PostTest (Give)				
I2: PosPrueba	30	m1 < m2	11.26	0.000

(Gc)				
I2: PosPrueba (Give)				
I3: PosPrueba (Gc)	30	m1 > m2	-6.18	0.000
I3: PosPrueba (Give)				

Table VIII. Contrast of Hipótesis for non-P arametric indicators

Indicator	**n**	**I have**	**t-value**	**p-value**
I4: PosPrueba (Gc)	30	m1 > m2	465.0	0.000
I4: PosPrueba (Give)				

Since all p values are less than α (0.05), the results provide enough evidence to reject null hypotheses (Ho), and the alternate hypotheses were true. For this reason the evidence turned out to be significant.

VI. CONCLUSIONS AND FUTURE RESEARCH

The Tourist Experience through a mobile application with augmented reality showed positive results, achieving an increase in the number of visits from tourists, therefore, the use of mobile applications to solve the complications of tourists in accessing information is efficient. That is why thispublication describesconcepts about mobile applications, and methodologies for the development of this, such as Mobile-D, methodology used in this research, which provides 5 important phases: Exploration, Initiation, Production, Stabilization and Testing. Likewise, the solution of this research is based on the Unity development platform, the Vuforia development kit and the AR+GPS geolocation package etc. In order to measure the results of the application, the search for information was made, identifying dimensions of time, cost, quantity and satisfaction with four indicators, for this reason the research is applied, with a pure experimental design. Finally, the hypotheses were validated using Student's t-test and specialized Minitab software.

For future research it is recommended to implement 3D objects, in this way to make the visit of the tourist more interactive and encourage their curiosity to know more places.

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