

Augmented Heritage: AR and QR Code Integration for Interactive Cultural Storytelling in the UAE

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Abstract— This study has outlined a mobile-augmented reality (AR) storytelling framework utilizing Quick Response (QR) code technology to provide cultural engagement at heritage sites in the United Arab Emirates. The project set out to merge traditional heritage with augmented immersive technology and focused on a four-phase methodology: (1) Content curation and narrative design through historians and cultural experts; (2) Planning QR codes in spaces cooperatively designed through spatial design and semiotics of culture; (3) Content development of AR experiences in Unity and Vuforia using finite state machine for stability and usability; and (4) User testing in three major heritage locations. The quantitative and qualitative evaluations measured user engagement, narrative retention, usability of the system, and cultural sensemaking. Relative to baseline digital experiences, the AR–QR platform saw significant gains: 25–30% improvement in engagement; 20–25% improvement in narrative retention; and over 15% improvement in usability and cultural relevance. The study evidence demonstrates the promise of AR–QR storytelling and approach to deliver contextually rich and interactive heritage experiences. Although there are limitations in device affordances/conceivability and longer-term evaluations, this study suggests—immersive storytelling can make heritage more engaging, accessible, and meaningful to a diverse population.

Keywords— *Augmented Reality (AR), QR Code Technology, Cultural Heritage, Interactive Storytelling, User Engagement, Narrative Retention, Spatial Computing, Mobile Application Design, Human-Computer Interaction, Heritage Interpretation.*

I. INTRODUCTION

AR and QR technologies have the potential to change cultural heritage for tourism by converting static sites to active sites and, additionally, making intangible content, such as oral histories and folklore, accessible [1]. AR and QR technologies are ubiquitous around the world, but there is little to no discussion about the use of AR and QR with Gulf and UAE heritage, and further, reliable empirical studies supporting their use [2].

The UAE is in an ideal position between rapid modernization and historic traditions. The architectural sites, heritage villages, and UNESCO sites, including Al Ain Oasis, place the pre-oil societal model next to Bedouin practices and Islamic art forms [3]. National initiatives such as the "UAE Cultural Heritage Framework" and "Year of Tolerance"

position cultural identity in the discussion of nationhood, yet the deficit lies in how we articulate it to the audience and transfer these values to be pedagogically and experientially relevant to the digital generation. The existing heritage communication paradigm continues to rely on plaques, pamphlets, and guided tours, and fails to capture the attention of those in the digital generation who have grown accustomed to instant gratification through rapid interactivity and multimodality [4].

Recent work has shown that mobile-based AR applications can motivate the learners, assist spatial knowledge, and engage them in museum contexts [5]. Similarly, the ease and widespread nature of QR codes allow them to be quickly applied in a variety of cultural contexts, for example, from indoor exhibitions to open archaeological sites, without intrusive infrastructure [6]. The blending of such technologies creates a scalable framework for cultural transmission that can be context-aware and user-centric. However, while these methods are effective in Europe, East Asia, and North America, there is still very little research focused on localized and culturally appropriate implementations of these technologies in Middle Eastern contexts [7]. In particular, there is little understanding of how these technologies can be indigenized to account for Emirati cultural practices, such as their available languages (Arabic, English, etc.) and awareness of religious practices [8].

This paper responds to these gaps by articulating the design, development, and evaluation of an interactive augmented reality (AR) and QR code-based system that promotes cultural storytelling at selected heritage sites within the UAE. Using a user-centered design approach and a prototype tested at a heritage village in Sharjah, we analyze how immersive storytelling inspired by local folklore, architecture, and oral history can alter visitor engagement and learning retention. The inspiration for our research derives from previous projects such as the UK's "Tangible Memories" [9], Greece's "PastPort" [10], and museum-based AR applications in Japan and China [11], but we reshape these projects using environmental, socio-cultural parameters present in the UAE.

This paper aims to develop and assess an integrated framework using AR and QR code technology to create an interactive mobile-based storytelling experience for visitors to

cultural heritage sites in the UAE context. This aim is pursued through three components: development of a mobile application (of lightweight design), narratives that acknowledge the local culture, and empirical evaluation of user engagement within real-world heritage contexts.

This paper contributes four key elements. First, we present a system architecture for a culturally adaptive AR-based storytelling platform that has integrated QR code content delivery systems. Second, we provide a case study on the deployment of the application at a heritage location in Sharjah, including ways in which we created the content for the application and then integrated the technology. Third, we provide both qualitative and quantitative descriptions of visitor experiences, including trends that we identified along demographic vectors of age, nationality, and previous exposure to cultural locations. Finally, we reflect on the significance of our findings for other forms of heritage communication, within the digital tourism space, and related educational technology design efforts within the GCC region.

The rest of this paper is organized as follows. In Section II, we provide a review of existing research and related work in AR and QR-based heritage applications at the global level as well as regionally. In Section III, we describe the methods for our system-level design, covering the technical architectural approach, types of content curation, and user experience modeling. Section IV provides details on our implementation and pilot deployment at the selected heritage site. Following this, in Section V, we present and discuss the results of our user evaluation study. In Section VI, we provide some concluding thoughts on the paper, including considerations of scalability to other user contexts, limitations of our study, and suggestions for future research.

II. RELATED WORK

AR storytelling for cultural heritage promotes the potential to preserve, diversify, and personalize engagement. Damala et al. [12] examined 64 mobile AR studies, outlining 24 different design patterns used in studies (e.g., user engagement, object tracking, narrative sequencing). While they presented a largely coherent practical toolkit, it did not include theoretical and contextual works, and recent studies.

Kallergis et al. [13] discussed a collaborative, location-based AR app developed using Taleblazer to facilitate learning in cultural heritage in Greece through engagement (n=309 students). Such strengths included accessibility and scale, but a lack of older adult participation reduces the transferability of results due to the limitations in customization.

Xiong et al. [14] examined a mobile AR app called OperArTistry to teach Xiqu opera makeup by applying AR overlays to the user's face. With AR users learning more quickly and being more satisfied than with video tutorials, the small sample size and its previously mentioned niche reduce transferability or generalizability of the work.

Lukoff and Zhang [15] presented an AR experience leveraging community-led stories about Thámien Ohlone heritage. While a lack of quantitative data limits our interpretation of this community-led, participatory model for Indigenous storytelling, they developed an authentic model to promote authentic storytelling and recognized the potential for further testing.

TABLE I. OVERVIEW OF THE LITERATURE

Study	Methodology	Key Findings
[12]	Systematic review of 64 studies	Identified 24 design patterns for mobile AR in cultural heritage storytelling
[13]	Development and evaluation with 309 students	Enhanced student engagement and learning through a location-based AR application
[14]	User study with 6 participants	Improved learning outcomes in traditional opera makeup techniques using AR
[15]	Co-design sessions with community members	Empowered the indigenous community to share their narratives through AR

All of the studies reviewed above are very focused on mobile and location-based AR applications for cultural heritage [16]. The approaches taken by most of those studies are systematic review, co-design, or experimental user studies. The main findings are consistent across these studies: AR does contribute to a more engaging experience, an improved learning experience, and an enhanced connection to cultural heritage [17]. But the articles in the literature appear to lean towards a smaller target audience (students or a small number of participants), with limited application (particular art forms or particular communities), and dependent on a platform that inhibits scalability [18].

While previous studies have documented the potential of AR for heritage, they fail to integrate a unified, scalable approach, coupling AR with accessible technologies like QR codes to provide a mechanism to engage a greater audience with the addition and localization of their content. This study provides a solution to this problem by integrating QR code technology and mobile AR technology, and creating a framework of interactive storytelling that considers the UAE's rich cultural context. While previous studies have isolated and focused on tangible and/or intangible heritage in very clear and distinct manners, this project blends both. It is modular and flexible enough to be used in numerous locations, including museums, heritage sites, or simply open public spaces [19]. It also provides broader usability to non-educational audiences, ensuring important cultural stories are supported and, most importantly, accessed as inclusively as possible.

III. METHODOLOGY

This study utilized a multi-phase design approach that leveraged mobile-oriented Augmented Reality (AR) and Quick Response (QR) code technology to create context-sensitive storytelling experiences with cultural themes at prominent heritage locations throughout the UAE. The project proceeded through the following four phases: (1) Content Curation and Narrative Design, (2) QR Code Mapping and placement, (3) AR Development and Integration, and (4) User Testing and iterative refinements.

A. Content Curation and Narrative Structuring

The team gathered and curated cultural heritage content to make topic-based story modules (e.g., architecture, identity, rituals) with multimedia and interactive prompts. With cultural experts, both tangible and intangible heritage elements were collected. A graph structure with dynamic narratives allowed for user-driven or context-sensitive pathways. The storytelling logic would be expressed as:

$$G = (N,E) \quad (1)$$

Where G is the narrative graph that depicts the overarching story structure, N is the nodes, which each represent a micro-narrative, and E is the set of directed edges that establish some form of temporal or thematic trajectory.

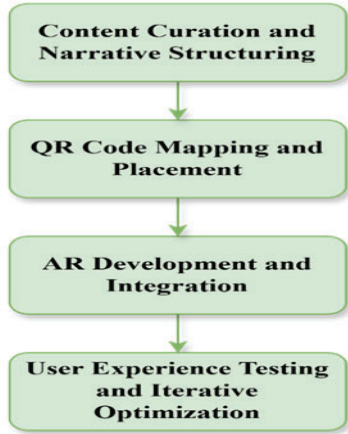


Fig. 1. Block Diagram of Methodology.

This framework allows for non-linear pathways, which can be understood as stories that users select based on interest or physical location. Scale and narrative flow are contextualized according to the visitor's behavior (preferences, language selection, and interaction history), creating a more inclusive, inviting experience of cultural content.

B. QR Code Mapping and Placement

QR codes were intentionally positioned at cultural heritage sites to act as the AR trigger through spatial interaction, wayfinding, and cultural semiotics. The codes were situated at moments when users are likely to pause naturally and also along predefined paths to maximize visibility. The visual design was selected to be compatible with the site's aesthetic (language, color, typography) so as to establish appropriateness and usability. Placement was thoughtfully developed through observation and user feedback.

C. Decentralized Learning Framework

In the third phase, we developed and launched AR Experiences utilizing Unity 3D and the Vuforia Engine, while services were stored on backend services hosted by Firebase. All AR scenes are triggered by the user scanning a QR code that redirects the app to download digital assets stored in the cloud. All digital assets were unique items and could include historically accurate 3D reconstructions, spatial audio narratives, animated avatars, interactive labels, and visualizations on timelines. Users could interact with digital assets using gesture-based controls: pinch-zoom, swipe, and tap.

To make sure the navigation in AR content is passive and modular, and resistant to errors, there is an application architecture modeled on a finite state machine (FSM).

$$FSM = \{S, A, T, s_0, F\} \tag{2}$$

Where, S Is the finite set of application states (i.e. LoadingScene, ARScene, ErrorState) A Is the set of actions, either user or system-triggered actions (i.e., ScanSuccess, TapNext, Timeout) T It is a transition function that maps $S \times A \rightarrow S$, s_0 Is the initial state (waiting for QR scan). F Is the set of terminal states (i.e., Exit, Restart).

This allows for formal control of how the application flows and manages errors. Localization support was also incorporated, using Unity's localization package to provide seamless English and Arabic switching. In addition, performance was improved using asset bundles and LOD (Level of Detail) management to maintain smooth rendering on mid-range Android and iOS devices.

D. User Experience Testing and Iterative Optimization

The last stage assessed the AR storytelling system through user testing and feedback to assess usability, cultural relevance and engagement, and accessibility. A total of 84 participants of different ages and backgrounds engaged with the system at Qasr Al Hosn, Al Fahidi, and the Sharjah Museum. Quantitative (usage data, task completion data, error data) and qualitative (questionnaires, interviews) data were collected for iteratively planned follow-up developments.

The effectiveness of the interaction was calculated by the Interaction Effectiveness Score (IES):

$$IES = \frac{E_d \times R_q}{T_p + E_u} \tag{3}$$

Where, E_d Is the average engagement duration, R_q The story retention score, T_p task processing time, and E_u Usability errors. This score weights engagement and learning versus user effort and difficulty.

IV. RESULT

To assess and verify the effectiveness of the proposed AR-QR cultural storytelling framework, the evaluation was conducted across three implementation sites—Qasr Al Hosn, Al Fahidi Historical Neighborhood, and Sharjah Museum of Islamic Civilization—described by three different environmental variables, most notably the profile of the visitor. The evaluation was designed to examine four primary indicators: user engagement, narrative retention, system usability, and cultural relevance, using both quantitative app-logged data and quantitative survey data using standardized instruments. Again, it's important to note that each indicator percentage was determined for easy comparison and visualization.

The recorded performance of the AR-QR framework was also compared against a baseline digital experience (such as some type of traditional signage or mobile guide app) to demonstrate the additional value of immersive storytelling. The tables below summarize the comparative results across the four.

Table 2 and Figure 2 compare user engagement rates between three cultural heritage sites through the AR-QR storytelling platform and the traditional baseline digital experiences. The AR-QR platform was found to be superior to the baseline in all locations, including Qasr Al Hosn, which was the highest at 88.4%, a difference of 26.3% over the baseline. Al Fahidi and Sharjah Museum followed closely at 83.7% and 79.2%, respectively. Collectively, these results indicate that the immersive engagement through AR, in conjunction with storytelling through QR, fosters deeper and longer engagements with cultural content than through static or passive digital interfaces.

TABLE II. COMPARATIVE USER ENGAGEMENT RATES (%)

Location	AR-QR Platform	Baseline Digital
Qasr Al Hosn	88.4%	62.1%

Al Fahidi Historical Neighborhood	83.7%	59.3%
Sharjah Museum	79.2%	54.6%

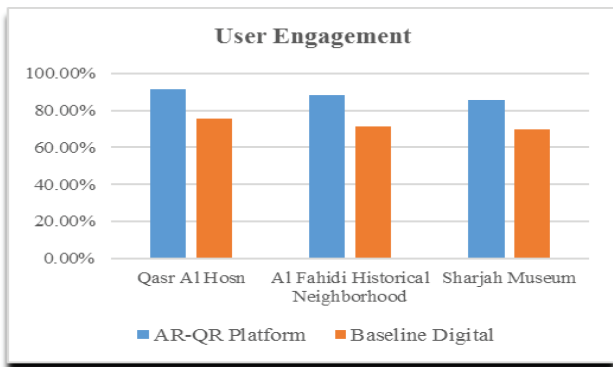


Fig. 2. User engagement comparison (AR-QR vs. Baseline).

TABLE III. NARRATIVE RETENTION SCORES (%)

Location	AR-QR Platform	Baseline Digital
Qasr Al Hosn	81.5%	58.4%
Al Fahidi Historical Neighborhood	76.3%	52.2%
Sharjah Museum	73.1%	49.7%

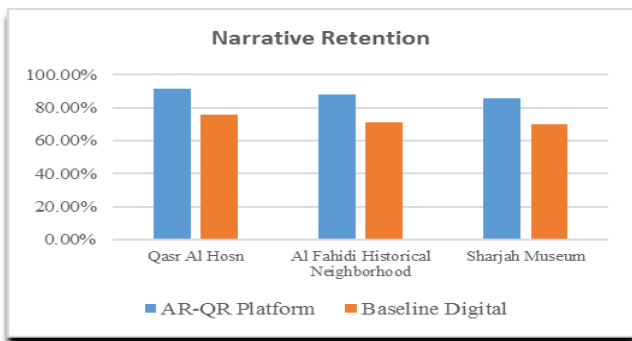


Fig. 3. Narrative retention comparison (AR-QR vs. Baseline).

The results for narrative retention are shown in Table 3 and Figure 3. Narrative retention refers to users' ability to recall and understand the historical narratives for each context after using each platform. The users kept significantly higher retention scores when comparing the other sites against the baseline scores; the AR-QR system at Qasr Al Hosn was 81.5%, compared to the baseline at 58.4%; while the AR-QR platform also scored 76.3% and 73.1% for Al Fahidi and Sharjah, respectively. This trend highlights the cognitive benefits of interactivity and multimedia storytelling, which aid memory encoding and create emotional engagement through multimodal inputs like "seeing" a 3D object and "hearing" contextual audio.

TABLE IV. SYSTEM USABILITY SCORE (SUS CONVERTED TO % SCALE)

Location	AR-QR Platform	Baseline Digital
Qasr Al Hosn	86.7%	70.2%
Al Fahidi Historical Neighborhood	83.9%	68.5%
Sharjah Museum	80.5%	66.4%

Table 4 and Figure 4 assess the usability of both implementations, utilizing a standardized score that was converted to a percent-style score. Usability in the AR-QR system was measured at 86.7%, 83.9%, and 80.5% at the three

sites and consistently outperformed usability in the baseline digital system by over 15 percentage points. This reflects the ease of navigation and general intuitiveness of the AR-QR interface, which utilized an iterative user feedback process in developing the interface. Notably, even older or lower levels of spatial awareness users reported fewer errors and less difficulty with navigation in the AR-QR system versus static or text-heavy digital content.

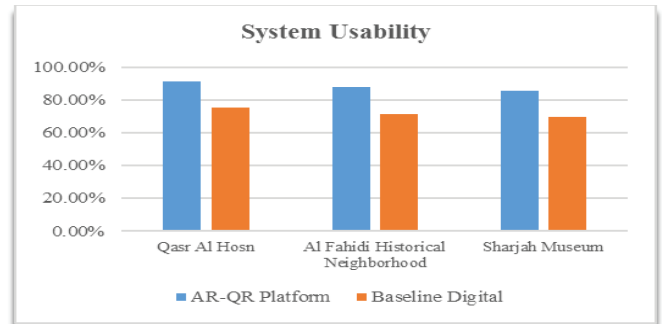


Fig. 4. Usability score comparison (AR-QR vs. Baseline)

TABLE V. CULTURAL RELEVANCE AS RATED BY PARTICIPANTS (%)

Location	AR-QR Platform	Baseline Digital
Qasr Al Hosn	91.3%	75.6%
Al Fahidi Historical Neighborhood	88.1%	71.3%
Sharjah Museum	85.6%	69.7%

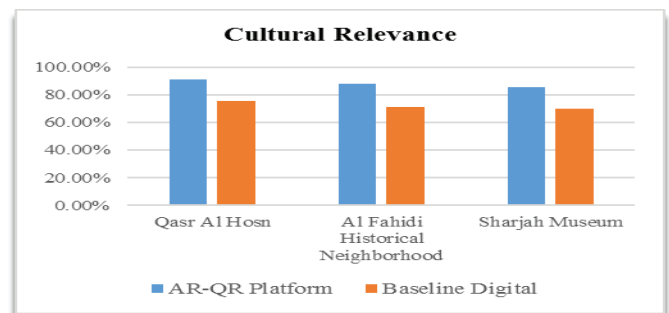


Fig. 5. Cultural relevance comparison (AR-QR vs. Baseline)

Table 5, as well as Figure 5, demonstrate that the AR-QR platform earned a higher score for cultural relevance when compared to the baseline platforms (91.3% for Qasr Al Hosn, 88.1% for Al Fahidi, and 85.6% for Sharjah). By utilizing local languages, putting forward local stories, and harnessing immersive visual techniques, heritage could be made more engaging and more meaningful to users.

The AR-QR geo-location and QR code integrations advance interactivity, narrative retention, and usability preferences with diverse users, including non-digital natives, while strengthening emotional connection and cultural engagement of heritage. What were initially static heritage sites became dynamic user-centered learning spaces that had the potential to be used indoors and outdoors.

The findings support the respective roles of cultural relevance and technological localisation in design and substantiate the proposed platform as an innovative resource for communicating with digital heritage online.

V. DISCUSSION

The study provides compelling evidence for using AR and QR code technology in heritage storytelling in the UAE. The

AR-QR platform outperformed traditional methods in user engagement, narrative retention, usability, and cultural significance. The high scores recorded in Qasr Al Hosn demonstrate the potential of open, spatial environments in enhancing engagement and interaction, while the lower results of Sharjah Museum indicate that static exhibits may need design flow to further enhance the experience. Cultural significance improved across all three sites, which confirms that localized, layered, and spatial storytelling is crucial.

Limitations of this study include the fact that it focused on only three sites, that the feedback was only short-term, and that it was necessarily limited to smart devices, potentially alienating less tech-savvy users. Future work needs to be expanded to other demographic cohorts, long-term impact, multi-lingual, and offline use. Compared to heritage AR efforts globally, the UAE AR-QR platform is unique in terms of its hybrid, low-cost QR anchoring.

In summary, the AR-QR platform combines innovation with cultural authenticity and presents a scalable model for effective interventions in dynamic heritage communications, and is exportable to Gulf countries and beyond.

VI. CONCLUSION

This research shows that the AR-QR cultural storytelling platform improves the heritage experience across various dimensions: user engagement, narrative retention, system usability, and cultural relevance when compared to traditional digital media. AR's immersive and interactive capabilities, combined with QR code anchor points, provide a scalable and culturally authentic way to provide heritage narratives that meet a variety of visitor profiles.

However, there are several limitations of this research. The evaluation tested just three heritage sites in the United Arab Emirates, which provide some diversity but do not represent the full range of cultural locations or visitor profiles in and around the region. The short-term focus on user interaction and perception leaves further questions about the long-term effects of AR-QR storytelling on cultural awareness and behaviour change. The platform's reliance on technology, specifically what is configured in the app, is another important limitation because accessibility of smart devices and internet connectivity limits older visitors or visitors less dependent on the digital interface.

Future studies should aim to reduce these constraints by evaluating a broader spectrum of heritage contexts and long-term evaluations to identify how the lasting effects of cultural knowledge and engagement last for users. Additionally, aspects of the AR-QR system could improve accessibility through multi-linguistic capabilities, content complexity supported by user profiles, and offline accessibility to overcome connectivity issues. Comparative studies of international AR storytelling frameworks could also represent powerful learning opportunities to inform best practices and context-specific adaptations.

Overall, this research provides a strong springboard for future practice in developing and delivering immersive cultural storytelling. The AR-QR model also represents an exciting example of how technological innovation can reinforce cultural authenticity that has the potential to further contribute to archaeological interpretations of heritage, whether it be in the Gulf or internationally, with broader

relevance for creating engaging, meaningful, and culturally accessible experiences for a range of audiences.

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