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Vav ni Dharohar: An Interactive Mobile App with AR Experience of UNESCO World Heritage Site "Rani-ki-Vav”

ABSTRACT

Digital technology and artificial intelligence are powerful tools for documenting and modeling historic architecture. Yet there remains a substantial need to present information about symbolism, construction, and purpose in accessible, standardized, and engaging forms, especially on-site. This paper presents the design and development of a mobile application that leverages Augmented Reality (AR) to enable visitors to scan sculptures at the UNESCO World Heritage Site, Rani-ki-Vav, and receive detailed breakdowns of iconography, construction techniques, and cultural symbolism. We adapted the original kiosk-based system to enable portable, personalized engagement via smartphone, retaining all research stakeholders, methodology, and content strategies. Human-centered design guided app development, and extensive stakeholder engagement ensured cultural and linguistic inclusivity. This approach demonstrates how AR mobile technology enhances heritage interpretation, accessibility, and visitor satisfaction.

Keywords - Augmented Reality, Interaction Design, historical monument, Rani-ki-Vav, UX Research, Human-Centred Design, UNESCO World Heritage Site.

1. Introduction

A stepwell serves the community by acting as a shared social space as well as a functional water source, it is intentionally designed as cool retreats where people could rest, interact, and carry out daily activities around the well (Mungona & Thakre, 2025). Stepwells can also be found next to main roadways, inside a village, or on its outskirts. They are located approximately at distances that a caravan could march in a day, making them the perfect spots to stop throughout the lengthy voyage. The majority of them have been discovered along the ancient trade routes that connect the coastal towns of Gujarat to the great capitals of northern India. The protracted lean season in Gujarat's arid climate results in very little water in the rivers and lakes. These subterranean wells were once the primary source of water for the home and for the farm (Neubauer, 1999).

The "Rani-ki-Vav" or Queen's Stepwell in Patan, Gujarat, is an intact stepwell that was commissioned and built during the Chaulukya or Solanki dynasty in the eleventh century CE. The region was formerly known as Anhilwara Patan, the Chalukya capital. The Chaulukya period, also known as the Golden period in Gujarati history, saw the construction of many public welfare projects, such as stepwells, ponds, lakes, vidyapeeth (ancient universities), chhatravas (dormitories), temples, and other similar establishments that enhanced society and culture (Prajapati & Kava, 2022).

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The designation of a location as a World Heritage Site by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) brings international recognition and respect. This certification serves as a permanent instrument for promoting the place, adding value to tourists, and ensuring the standard quality of cultural experiences (Marcotte & Bourdeau, 2006). Museums at heritage sites conserve, guard, and shape a significant portion of our cultural history. Museums are increasingly being viewed as leisure centers, emphasizing the importance of user experience and interaction. The museum sector focuses on audience research, marketing, and consumer profiling. The 'primacy of the guest' phenomenon has led museums to prioritize visitors while developing new strategies (Løvlie, et al., 2022).

According to visitor studies, technology can be used successfully in a personal tour of museum programs because visitors are willing to try new gadgets to learn about exhibitions. Furthermore, as the use of handheld devices increases, so does the comfort of users with digital technology. A museum visit should be looked back upon as a good memory of a pleasurable learning experience, not as a bad memory of a battle with a troublesome gadget (Lydens, Saito, & Inoue, 2007). Studies also demonstrate that museum visitors prefer technologies that allow them to access information on demand, navigate exhibits easily, and engage with content at their own pace, which helps build comfort and eliminates barriers to learning (Rhee, Pianzola , & Seo, 2025).

While perceptions about archaeology and cultural heritage are typically developed at a young age through exposure to mass media and official and informal education, the quality of these exposures varies greatly and frequently fails to engage young people in meaningful ways. Although digital tools may appear to be an appealing means of intervening in this meaning-making process, their application to archaeological pedagogy in primary and secondary schools is limited. Using historical empathy and the Arc of Dialogue as guides, we created a digital resource for archaeology that emphasises collective, embodied, and affective learning. This resource includes 3D prints, a chatbot, webpages, and virtual walkthroughs (McKinney, Perry, Katifori, & Kourtis, 2020). Adaptive resources, such as virtual worlds or games, require continual input from the user, and because of their nature, they are becoming more frequent as archaeogaming and VR/AR technology gain traction. Finally, communicative resources include tasks that rely on interaction between individuals and groups, such as social media or texting. Archaeological sites and museums often use social media to share digital educational resources with the public (McKinney, Perry, Katifori, & Kourtis, 2020).cl

Adapting AR in cultural heritage organisations needs more than just having the appropriate gear or software. It also depends on the readiness of both museums and their audiences to participate in new experiences. Satisfaction of visitor with AR in heritage museums is mainly driven by the novelty of the technology, their trust in it, and how well the AR experience delivers aesthetics, education, and authenticity, which in turn strongly increases both their intention to keep using AR and to revisit the

destination. The intentions of tourists to use AR in a cultural heritage museum are strongly shaped by how useful and easy to use they perceive the AR to be, as well as by personality traits such as innovativeness, discomfort, and concerns about security, which together influence their attitudes and their willingness to revisit the destination (Xu W. , Ismail, Shahruddin, Quan, & Li, 2025). Museums are urged to prioritise human-centred design, strong privacy safeguards, and adjust AR material for a range of audiences while taking cultural variances and practical difficulties into account in order to maintain audience engagement (Xu W. , Ismail, Shahruddin, Quan, & Li, 2025).

1.1 Literature Review

A stepped-well is an underground well with steps that lead to the water level. Step-wells were generally excavated near rivers. Creating reservoirs, lakes, wells, and other watering sites was considered a noble act in India, especially to honour the dead, leading to the excavation of several stepped-wells in Gujarat and Rajasthan over centuries. Subterranean structures with exquisite interiors stand out amid the Western desolate landscape of India. The stepped-well of India is a unique contribution to the architectural heritage of the world (Mankodi, 2012). The semi-arid climate of Gujarat necessitated the construction of stepwells to suit drinking water requirements. They provided a comfortable space for women to gather and, in some cases, were used for worship. These step wells are also known for their intricate sculptures and carvings (Amirthalingam, 2015).

Rani-ki-Vav (23° 51'N; 72° 11'E) is located 2 km northwest of the old town of Patan. Rani-ki-Vav faces east and has a well-built stepped-well. Among the step-wells, Rani-ki-Vav is the most magnificent, not only in Gujarat but throughout the entire country (Mankodi, 2012). Book of Merutuṅga "Prabandha Cintamani", written in the 14th century, states: During the reign of King Bhimadeva I, Queen Udayamati planned to build a stepwell (Sadani, 1998).

It is a stunning example of the Jal Dharohar, which makes India one of the only countries in the world with such intricate yet publicly accessible water supply systems (Prajapati & Kava, 2022). UNESCO selects World Heritage Sites based on their historical, cultural, natural, or other significance and their importance to humanity. As of July 2018, UNESCO has listed Rani-ki-Vav as a World Heritage Site along with 1092 other monuments (Riley, 2018).

Heritage sites and museums are no longer solely about displaying things in isolation. They are adopting new technology to engage visitors through various modalities, promoting discovery, comprehension, and personalised learning. Since the mid-1990s, interactive devices (ID) have been utilised in museum exhibitions to provide visitors with graphic and contextualised information, facilitating multi-generational learning. Interactive devices, such as digital kiosks, provide powerful learning experiences in museum galleries (Harvey, 2014).

Museums/Exhibitions use various technologies, such as interactive information panels, audio/multimedia guides, installations, and VR headgear. According to Hornecker and Ciolfi, technology in museums can be categorized into three types of interactions: standalone installations, mobile interactions, and 'assemblies' that combine digital technology across several displays. Stand-alone installations emphasize technology above the actual collection. A common example is the digital information kiosk. Adding digital content to the physical display via a visitor-portable device is a popular approach to incorporating technology into museums. Virtual Reality, Augmented Reality, Artificial intelligence are technological trends that go through cycles of hype and bust, and in practice, it is often more complicated to apply new technologies into real-world settings than the hype suggests. This is also the case in the museum domain, where the promises and challenges of digital technologies have permeated the field for decades (Løvlie, et al., 2022).

Digital knowledge solutions that make the assumption that everyone approaches information in the same way and with the same skills run the danger of leaving out a significant portion of the population. Actually, by keeping people from using digital resources at all, these applications work to disable them. Our knowledge of how individuals use digital resources has to be expanded (Williams, 2012).

In museum settings, AR has been shown to significantly improve educational opportunities, stimulate the curiosity of visitor, and boost their level of engagement. By superimposing digital material on actual objects, these technologies give displays life and create multimodal learning environments. When combined with devices that are easy to use and comfortable, the richness and depth of augmented reality material optimise learning outcomes and psychological immersion. Efficient design and ergonomic equipment are essential for maintaining the comfort and interest of guests. The Information Systems Success Model is one theoretical framework that links these benefits to careful hardware design and content strategy. Researchers recommend expanding creative uses of AR across museum exhibits, always refining the user experience and keeping cultural contexts in mind to achieve optimal educational impact (Chen & Lai , 2021).

Museum practice is being further revolutionised by extended reality (XR) technologies. This includes AR, virtual reality, and mixed reality, which together offer interactive, customised, and engaging experiences. XR is shown to deepen visitor satisfaction, enhance learning, and encourage more meaningful connections with cultural heritage, especially among younger audiences. Museums are experimenting with gamified exhibits, virtual field trips, and immersive narrative forms to open up new ways of inquiry and interaction. Despite these improvements, institutions nevertheless have to deal with technological difficulties, investment costs, and legitimacy issues. Museums are setting the standard for visitor-centred strategies that benefit the whole museum industry as they embrace XR and develop into dynamic venues for intercultural communication, personal discovery, and creative educational programs (Avlonitou & Papadaki, 2025).

2. The Proposed Method

The project was also an exercise in combining secondary literature review with primary ethnographic research.

The timeboxing four-phase model: A development model for interactive installations consisting of four phases, each with a set of deliverables as illustrated in (Figure 1).

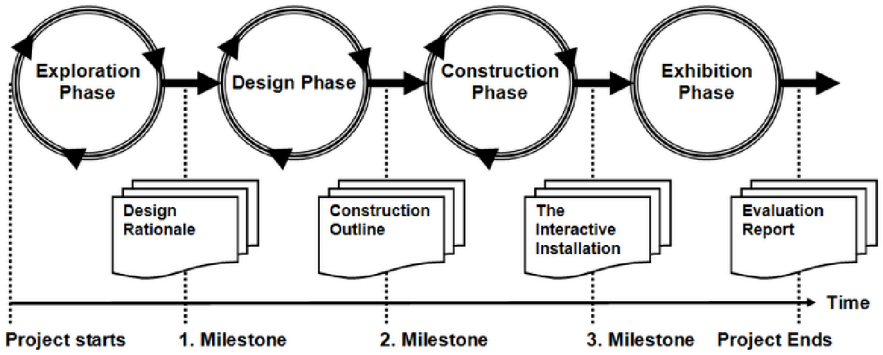

Fig 1 The time boxing four-phase model. Source: Situated Design Methods (Troels, Andreasen; Juul, Niels Christian; Rosendahl, Mads; 2014:276)

It focuses on the time-boxing of the deliverables during the process rather than on the activities. These elements are especially important when the interactive installation is to be used at an

exhibition or at an event with a fixed deadline (Troels, Juul, & Rosendahl, 2014).

- Exploration Phase: This stage aims to determine the best technology choice and elucidate the overall behaviour of the installation.
- Design Phase: During this stage, the architecture of the software and the surrounding area should be made clear.
- Construction Phase: The scanning functionality of the app was developed utilising AR libraries that work with common devices. Based on user feedback, wireframes, high-fidelity screens, and UX prototypes were continuously improved. Additionally, a QR code for scanning sculptures was created.
- Exhibition Phase: On-site user testing and feedback analysis are part of the deployment. Cycles of continuous improvement are used to address issues with ergonomics, accessibility, and interpretation.

Fig 2: Rani-ki-Vav, a world heritage site

Fig 3 SAPTI - Stone Artisan Park Training Institute, Ambaji

Fig 4: Lalbhai Dalpatbhai Museum, Ahmedabad

According to the timeboxing four-phase model, research work has been done in the exploration phase as follows:

1. Interviews were conducted on the world heritage site, Rani-ki-Vav, with local tourists, international tourists, students, teachers, professors, residents of Patan, tourist guides, elderly people and staff of the world heritage site, Rani-ki-Vav.
2. In order to collect all the information about the contents, visual gallery, and historical values used in the design of kiosk and augmented reality experiences, the author visited the following locations: Adalaj-ni-Vav, Gandhinagar; SAPTI - Stone Artisan Park Training Institute, Ambaji (Figure 3); Hemchandracharya North Gujarat University, Patan; Lalbhai Dalpatbhai Museum, Ahmedabad (Figure 4); Baroda Museum and Picture Gallery, Vadodara; Lakshmi Vilas Palace, Vadodara; Sun Temple, Modhera; Chhatrapati Shivaji Maharaj Vastu Sangrahalaya, Mumbai; Rani-ki-Vav, a world heritage site (Figure 2); and the Patan Patola Heritage Museum, Patan.

2.1 User Journey Mapping

The Rani-ki-Vav experience prior to the development of mobile app is depicted in the User Journey Map (Table 1). It describes every phase of the user's engagement, from organising the trip to exploring the website, and pinpoints their requirements, behaviours, problems, and feelings. This journey's mapping assisted in identifying user experience gaps and significant design intervention opportunities. It gave a basic understanding of how the mobile app may improve education and participation at the historical site.

By visualising these touchpoints together, the journey map exposes critical UX gaps, including scattered pre-visit information, minimal interpretive signage on-site, inconsistent guide narratives, and the absence of tools to identify deities, mudras, and symbolism.

Table1: User Journey Map

Steps	**Planning Visit**	**Arrival**	**Looking for Information**	**Hires a guide**	**Exploring Site**	**Identifying Sculptures**	**Engaging with space**	**Leaving the site**
User Actions	Searches online, reads blogs or Wikipedia	Reaches the site, buys ticket, enters premises	Reads ASI information board	Hires a guide by paying ₹500	Observes sculptures and carvings	Tries to recognize deities such as Vishnu, Shiva, etc. from mythology	Walks around, click photos, chat with others	Exits without full understanding
Feelings	Curious but underinformed	Confused /Overwhelmed	Under whelmed	Misinformed / Misled	Curious / Lost	Frustrated / Guessing	Visually pleased	Mixed feelings
User Needs	Want to understand site's significations	Needs direction and overview of site layout	Expert historical and cultural insights	Seeks accurate interpretation of sculptures and architecture	Wants to understand their identity and symbolism	Visual reference to identify divine figures	Desires a deeper emotional or spiritual connection	Would like to take something meaningful away
Touch points	Google, Social media, Tourist ;./sites	Ticket counter, Entry gate	One ASI board	Verbal interaction	Carvings, stairs, levels	Deity Sculptures	Garden, platforms, staircases	Exit gate
Pain points/ Gaps	Limited verified sources, scattered or outdated information	No Information center, No site map, unclear where to begin exploration	Only basic history is given, no mention of sculpture's meaning or mudras	Guides often provide incorrect or superficial information, especially about apsaras sculptures	Can't differentiate deities or interpret poses, no signboards or labels	Sculptures lack labels or identifier, myths not contextualized	Visual beauty present, but deeper meaning missing	Leaves with photos but many questions, unanswered, especially on symbolism & mudras

2.2 User Interface Designing

Now in the second phase of the model, the author has designed a system, content and AR experiences as follows:

The design of mobile app at Rani-ki-Vav follows the principles of People, Place, and Perspective. The insights from various stakeholders were incorporated to provide balanced information about the heritage of the site.

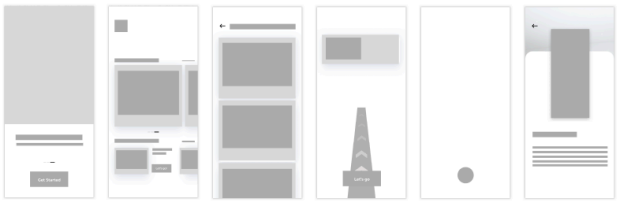

Fig 5: Wireframe of Mobile App

Wireframes (Figure 5) are low-fidelity representations of the mobile app interface, visualising layout, content flow, and functionality. They facilitate iterative refinement through user feedback, ensuring a user-centred design.

High-fidelity screens (Figure 6) showcase the final version of the mobile app interface with all visual elements.

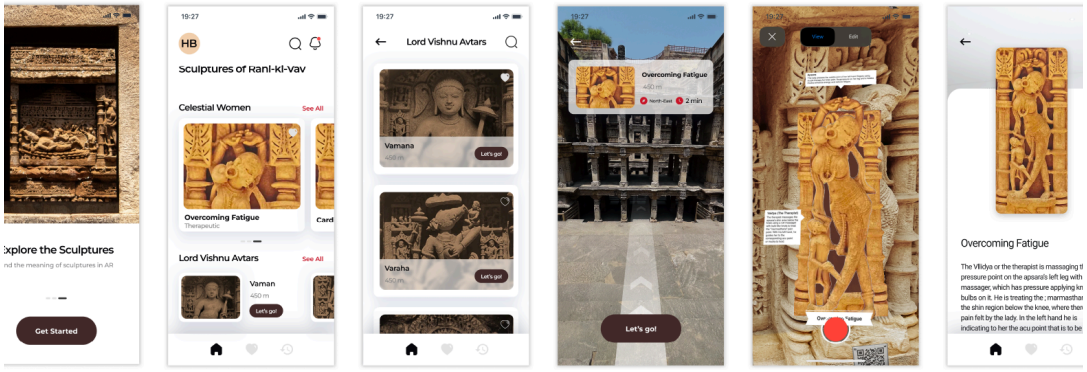

Fig 6: High-fidelity User Interface of Mobile App

3. Result

The Vav ni Dharohar mobile AR app demonstrably improved how visitors engaged with Rani-ki-Vav's sculptures and narratives. Grounded in a human-centred design process, the app allowed users to scan sculptures with their own smartphones, receive layered AR explanations of iconography and mythology, and navigate the site through guided routes, accessible text, and audio support. This shifted the experience from visually driven but partial understanding to a more informed, self-paced, and inclusive exploration of the stepwell's cultural and historical significance.

Field observations and on-site feedback indicated that visitors using the app spent more time at individual sculptures, asked more content-specific questions, and reported greater confidence in interpreting deities, mudras, and narrative scenes compared with the pre-app journey dominated by sparse signage and inconsistent guide information. These behaviours align with wider museum studies that link interactive, handheld interpretation to deeper learning, higher satisfaction, and stronger intention to revisit or recommend heritage sites.

3.1. Functionality:

- Users start by launching the app and selecting preferred language/voice narration mode.
- Using their phone's camera, they scan any sculpture; the app identifies its meaning in AR.
- An AR overlay appears, breaking down the sculpture into iconography, mythological context, and symbolic attributes (mudras, postures, associated stories).
- The app provides navigation routes, highlights must-see sculptures, and suggests further reading or audio tours.

4. Implementation and Technical Overview

To ensure compatibility and scalability across widely used smartphone devices, the Vav ni Dharohar mobile app was developed using cross-platform augmented reality libraries and modern mobile frameworks, such as Flutter and React Native. The AR vision pipeline utilises object identification models that have been trained to recognise specific sculptures; these models are triggered by scanning QR codes positioned next to important artefacts. Real-time AR overlays provide low latency feedback to maintain user engagement while exploring the site. To optimize usability, the team conducted iterative usability tests with diverse age groups and incorporated feedback to refine wireframes, high-fidelity interfaces, and core app interactions. Models for object detection are trained to identify

specific sculptures by scanning the QR code. Real-time AR overlays are implemented with low latency to maintain user interest.

5. Conclusion and Discussion

Fig 7: AR Scanning in Mobile App

The Vav ni Dharohar mobile app (Figure 7) aims to enhance heritage interpretation by integrating advanced technology with user-centered design. The app promotes research on heritage digitisation, tourist engagement, and cultural education by offering a captivating, easily accessible, and interactive experience with the sculptures of Rani-ki-Vav. It demonstrates a scalable approach for enhancing visitor understanding of complex architectural sites, supporting conservation education, and fostering deeper cultural connections through the use of immersive technology. By providing immersive and accessible digital experiences, the app facilitates deeper engagement with cultural heritage, promoting learning, empathy, and emotional connections.

It also provides some scholarly contributions which includes:

- Supporting heritage preservation by digitally highlighting intricate details and narratives of sculptural art that may be inaccessible or overlooked in physical visits, thus enhancing heritage appreciation and scholarly documentation.
- Providing a model for integrating AR into historical site interpretation, which can be extended to other monuments worldwide, creating new research opportunities in heritage technology, digital humanities, and participatory culture.
- Strengthening cultural identity by visually and experientially connecting visitors to the historical, religious, and artistic significance of Rani-ki-Vav and similar stepwells. It strengthens cultural identity and promotes both local pride and a broader scholarly conversation on water architecture and sacred landscapes.

This strategy aligns with the acknowledged architectural and cultural value of Rani-ki-Vav, an 11th-century stepwell that has been conserved by heritage organisations such as UNESCO and the Archaeological Survey of India, and is renowned for its extraordinary artistry and technological expertise. As a result, the Virasat app enhances academic discussions about the application of immersive digital tools for conservation education and heritage interpretation.

By offering evidence-based strategies for developing historical technologies that encourage participation, care, and ongoing interest, the Vav ni Dharohar mobile app enhances the design domain and contributes to broader conversations about digital heritage, experience design, and cultural preservation practices.

Future Scope

- Integration of animated reconstructions to visualize lost features of the sculpture.
- Audio storytelling and voice guides in more languages/dialects.

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