JOURNAL OF THE FACULTY OF TOURISM AND HOTELS
UNIVERSITY OF SADAT CITY
Journal homepage:
https://mfth.journals.ekb.eg/

New Digital Interpretation Tools for Enhancing the Visitor Experience at the Royal Jewelry Museum

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Printed ISSN: 2537-0952
Online ISSN: 3062-5262
DOI: 10.21608/MFTH.2025.454444

ABSTRACT

Digital technologies have revolutionized the way museums provide intellectual access, enabling highly personalized pathways for learning and exploration. Visitors can now engage with content in their preferred format such as text, video, or audio and at a pace that suits them best. Features such as multilingual support, interactive storytelling, and intuitive user interfaces empower individuals to connect with collections on their own terms, resulting in a more inclusive, immersive, and meaningful museum experience. In this way, the visitor becomes not merely a passive observer but an active participant in the interpretation process. Moreover, digital interpretation complements and enhances the museum's audience development strategies. By leveraging social media platforms, mobile applications, and official websites, museums can reach and engage previously untapped audiences, including those who may never have considered a visit. Creative narratives combined with interactive features invite people of all genders, ages, and cultural backgrounds to explore the museum both virtually and onsite. This study explores a diverse range of digital interpretation tools that could be implemented at the Royal Jewelry Museum to enrich visitor engagement and broaden its cultural reach.

KEYWORDS

Royal Jewelry Museum, Digital Interpretation Tools, Visitor Engagement, Digital Heritage.

أدوات تفسير رقمية جديدة لتعزيز تجربة الزائر في متحف المجوهرات الملكية

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الترقيم الدولى الموحد للطباعة:
2537–0952
الترقيم الدولى الموحد الإلكترونى:
3062–2562
DOI:
10.21608/MFTH.2025.454444

الملخص

يهدف هذا البحث إلى دراسة دور التفسير الرقمي في تعزيز تجربة الزوار في متحف المجوهرات الملكية، من خلال تمكين الوصول الفكري للمحتوى المتحفي وتوفير مسارات فردية للتعلم والاستكشاف. تعزز التقنيات الرقمية قدرة الزوار على التفاعل مع المحتوى عبر أشكال متعددة، سواء كانت نصية أو مرئية أو صوتية، وبالشكل الذي يتناسب مع احتياجاتهم، مع توفير الإمكانيات متعددة اللغات، والسرد القصصي التفاعلي، والواجهات سهلة الاستخدام. هذا يسهم في خلق تجربة أكثر شمولية وذات قيمة معرفية عالية اثناء زيارة المتحف، ويحوّل الزائر من متلق سلبي إلى مشارك نشط في عملية التفسير. كما يدعم التفسير الرقمي استراتيجيات المتحف لتنمية الجمهور، حيث يمكن من خلال منصات التواصل الاجتماعي، وتطبيقات الهواتف المحمولة، والمواقع الإلكترونية الرسمية، جذب جماهير جديدة والتواصل معهم، بما في ذلك الأفراد الذين لم يفكروا سبقًا في زيارة المتحف. ويشجع السرد الجذاب والمبتكر، إلى جانب الميزات التفاعلية، الزوار من مختلف الأعمار والجنس والخلفيات الثقافية على استكشاف المتحف افتراضيًا وشخصيًا.
تبحث الدراسة مجموعة من أدوات التفسير الرقمي الممكن تطبيقها في المتحف، بهدف تعزيز مشاركة الزوار، وزيادة فهمهم للمجموعات الفريدة من المجوهرات الملكية، وتحقيق تجربة معرفية تفاعلية ثرية .

الكلمات الدالة

متحف المجوهرات الملكية، ادوات التفسير الرقمية، تفاعل الزوار، التراث الرقمي.

1. Introduction

The Jewelry Museum houses an exceptional collection of royal jewelry belonging to the family of Muhammad Ali Pasha. Renowned for their deep appreciation of artificial and artistic opulence, the family considered the acquisition of precious antiques and rare jewelry an essential practice, serving as prominent symbols during feasts, public events, coronations, weddings, and official celebrations. The museum was established under Presidential Decree No. 173 of 1986, which stipulated the allocation and conversion of the palace of Princess Fatima Haidar Fadel[1] into a museum.

The palace of Princess Fatima Al-Zahra was converted into a museum to display part of the Muhammad Ali family's remarkable jewelry collection. Following the July 23, 1952 Revolution, the Egyptian government nationalized and confiscated the jewelry and treasures of the Muhammad Ali dynasty, which were subsequently stored in bank vaults, particularly at the Central Bank of Egypt. These items remained locked away until 1986, when they were occasionally subject to tampering and even theft. Presidential Decree No. 173 of that year officially designated the palace as a museum to safeguard and exhibit artifacts considered integral to Egypt's national heritage.[2]

The selection of Princess Fatima Al-Zahra's palace in Alexandria was deliberate: the palace's owner was a member of the same royal lineage, and the palace itself stands as an architectural masterpiece, aesthetically harmonizing with the treasures it now houses. Jewelry museums hold a distinct allure for audiences worldwide. Each piece of jewelry encapsulates a story, not only about its wearer, but also about its creator or giver. These objects serve as tangible links to personal memories, significant events, cultural traditions, and historical epochs. As reflections of the artistic and social values of their time, such pieces offer profound insights into the civilization and heritage they represent[3].

Despite the Royal Jewelry Museum's magnificent and historically significant collection, it remains underrepresented in global rankings and listings of leading jewelry museums. This lack of visibility represents a missed opportunity for international recognition. The adoption of advanced digital interpretation strategies could play a pivotal role in reshaping this narrative by enhancing global awareness and appreciation of the museum's distinctive offerings.[4]

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[1] Princess Fatima Al-Zahraa was born in 1903. Her mother is Zainab Hanim Fahmy, the sister of the architect Ali Fahmy, who participated in the design of this palace. Her father is Prince Ali Haidar, son of Prince Ahmed Rushdi, son of Prince Mustafa Bahjat, son of Prince Ali Haidar, son of Prince Ahmed Rushdi, son of Prince Mustafa Bahgat, son of Prince Fadel Pasha, son of Ibrahim Pasha, son of Muhammad Ali Pasha, the ruler of Egypt and the founder of its modern renaissance, meaning that Muhammad Ali Pasha is the Fifth grandfather of Princess Fatima Al-Zahraa. She married to Mohamed Fayeq Yaken in 1930, and she has three children, Fadel, Fayez and Faiza.

صلاح أحمد البهنسي، *المتاحف علم وفن* (الإسكندرية: دار الوفاء لدنيا الطباعة والنشر، 2019)، 136.

[2] محمود عباس احمد عبد الرحمن، *القصور الملكية في مصر: تاريخ وحضارة* (الجيزة: دار العالمية للنشر والتوزيع، 2005)، 151

[3] ابراهيم عبد السلام النواوي. *علم المتاحف* .القاهرة: مطابع المجلس الأعلى للآثار، 2010، 2.

[4] 91Victoria and Albert Museum, London; British Museum, London; Galerie des Bijoux, Musée des Arts Décoratifs, Paris; Schmuckmuseum Pforzheim, Germany; and The Metropolitan Museum of Art, New York. "Five Great Museums to See Jewellery." The Life of Jewels. Accessed August 5, 2025. https://thelifeofjewels.com/five-great-museums-to-see-jewellery/

In recent years, museums and galleries have increasingly embraced digital technologies as a means of enriching the visitor experience. Numerous studies have evaluated the effectiveness of exhibition design and patterns of visitor engagement, underscoring the need for cultural institutions to create more inclusive, stimulating, and meaningful experiences. While digital tools possess significant potential to advance this objective, their implementation must be approached thoughtfully to ensure that they enhance the overall museum experience.

This research explores key digital tools currently utilized within museum contexts, aiming to assess their role in fostering visitor engagement before, during, and after a museum visit. The focus is placed not on the technical specifications of these technologies, but on their capacity to deepen audience connection and enrich cultural participation[5].

The integration of digital technology has become an essential element of the contemporary museum experience, which can be conceptualized in three interconnected phases: before the visit, during the visit, and after the visit. Across each phase, a range of technological tools is utilized to enhance visitor engagement and enrich the cultural encounter.

Before the visit, digital platforms play a pivotal role in preparing visitors and providing essential information. Official museum websites, cultural heritage portals, and user-generated review platforms offer practical details such as opening hours, ticket prices, exhibition highlights, and accessibility features. Mobile applications enable users to plan itineraries, preview exhibitions, and tailor visits to personal interests. This preparatory stage fosters anticipation and ensures visitors approach the experience with clarity and purpose.

During the visit, advanced technologies facilitate interpretation and interaction within the museum space. Augmented reality (AR), virtual reality (VR), and mixed reality (MR) create immersive environments that reconstruct historical contexts and animate artifacts. Hologram technology presents three-dimensional visualizations of historical figures or objects, bringing history to life. QR codes placed near exhibits provide instant access to multimedia resources, while Personal Digital Assistants (PDAs) and in-ear translators deliver real-time, multilingual interpretation, accommodating diverse audiences.

After the visit, digital tools extend and deepen engagement. Mobile apps and virtual museum platforms allow visitors to revisit exhibition content, explore specific topics in greater depth, and share experiences on social media. Online surveys and feedback mechanisms enable institutions to gather insights, refine offerings, and cultivate lasting relationships with audiences. This phase plays a crucial role in reinforcing knowledge, encouraging reflection, and sustaining meaningful connections between museums and their visitors.

This paper argues that the Royal Jewelry Museum has to strategically integrate a multi-layered digital environment, which includes immersive, interactive, and accessible technology, rather than just upgrading it for aesthetic reasons. In order to accomplish its educational objective and maintain its relevance in a competitive global

[5] Anthony Cassar, *Digital Interpretation Tools for Heritage* (Master's thesis, University of Malta, 2019), 35.

cultural landscape, such integration is necessary to transform the visitor experience from passive observation to active interaction.

Research Problem

Although the Royal Jewelry Museum in Alexandria houses unique heritage and artistic collections, their presentation continues to rely largely on traditional display methods. This approach may restrict visitor engagement and limit the depth of understanding regarding the historical and cultural significance of the exhibits. With the rapid advancement of digital interpretation technologies, there is a pressing need to examine their potential in enhancing the museum experience. The core research problem lies in the absence of a systematic assessment of the effectiveness of these tools in fostering interaction, increasing visitor participation, and improving comprehension and knowledge. Furthermore, there is a need to identify the challenges associated with implementing such technologies within the context of a heritage museum.

Research Objectives

This research aims to

1. Highlight the critical role of interpretive strategies in enhancing the overall visitor experience at the Royal Jewelry Museum.
2. Support the preservation, documentation, and promotion of the museum's distinctive jewelry collections.
3. Investigate the differences in visitor engagement and interaction with artifacts within traditional physical settings versus digitally mediated environments, emphasizing the potential of advanced technologies to create immersive and realistic virtual experiences.
4. Propose innovative digital interpretation solutions specifically designed to align with the cultural and historical significance of the museum's collections, aiming to deepen visitor understanding and engagement.
5. Explore the role of modern digital interpretation tools (such as augmented reality, virtual reality, mobile applications, and holograms) in developing display methods and enhancing interaction between the visitor and the exhibits.
6. To determine the extent to which digital technology improves visitor experience in terms of understanding, participation, satisfaction, and increased engagement with museum content.

Research Methodology

Based on a thorough analysis of recent research on digital heritage and museum technology, this study employs a qualitative approach. The potential for immersive storytelling, accessibility improvement, and alignment with the Museum's collection type were among the criteria used to identify and assess a set of important digital interpretation tools. After that, a conceptual framework for their use at the Museum is suggested.

Theoretical Framework

2. Digital interpretation tools used before and after the visit

2.1 Museum website

Museum websites have become a central component of digital strategy, serving a dual role both before and after the physical visit. Prior to the visit, they function as powerful tools for attracting potential visitors by presenting collections and exhibitions in an informative and engaging manner. After the visit, they enable continued learning and interaction, allowing users to revisit content, explore related topics, and maintain a connection with the museum. Rather than replacing the physical museum experience, these websites are designed to complement it, reinforcing the relationship between the visitor and the institution.[6]

To effectively fulfill this role, museum websites must be user-friendly, visually appealing, and responsive to visitors' expectations. This includes intuitive navigation, personalized features, and access to rich, regularly updated content. Moreover, ensuring that the website is easily discoverable through search engines is critical, and this largely depends on the quality, relevance, and structure of the digital content provided.

In this way, a successful museum website functions not merely as an informational platform, but as a continuous intellectual bridge connecting the museum with its audience throughout the entire visitor experience, before, during, and after the physical visit[7].

2.2 Social media platforms

Utilizing social media platforms such as Facebook, Twitter, Instagram, and Pinterest have significantly redefined the ways in which museums engage with their audiences. These platforms facilitate the dissemination of digital heritage and promote interaction with diverse communities by encouraging dialogue, user participation, and content sharing. By utilizing a variety of applications and networks, including RSS feeds, Flickr, and YouTube, museums can cultivate online communities that facilitate the exchange of ideas, broaden the accessibility of cultural content, and strengthen visitor engagement through innovative and interactive modes of communication.[8]

Establishing a consistent and recognizable digital voice that reflects the museum's brand identity is also crucial for maintaining visibility and credibility across platforms. Museums must avoid publishing misleading, irrelevant, or low-value content and should closely monitor audience interactions to assess the effectiveness of various types of content. Planning and scheduling posts in advance helps ensure consistency and continuity, while the development of clear community guidelines helps regulate user behavior and maintain a respectful and constructive digital environment on the museum's social media pages.[9]

2.3 User-generated content (UGC)

User-Generated Content (UGC) refers to photos, videos, texts, and audio recordings created and shared by visitors on social media platforms or review websites. This form of content plays a significant role in shaping the museum's public image, as it offers

[6] Anna Lushnikova et al., "Self-Determination Theory Applied to Museum Website Experiences," *Proceedings of ECCE '23: European Conference on Cognitive Ergonomics* (September 2023): 1.

[7] Cassar, *Digital Interpretation Tools for Heritage*, 71–74.

[8] Aml Abd El-Wareth Mohamed, "Integrating Digital Techniques/Technologies in Developing Egyptian Museums (Case Study: Alexandria Library Museums - Alexandria City)," Sohag Engineering Journal (SEJ) 4, no. 1 (March 2024): 40.

[9] Cassar, Digital Interpretation Tools for Heritage, 74–76.

authentic reflections of real visitor experiences that others can relate to and trust. Platforms such as TripAdvisor, Booking.com, and Google Reviews heavily rely on UGC to rank and evaluate services, thereby creating a democratic and transparent feedback system from which museums can greatly benefit.

Moreover, visitor reviews and shared images offer valuable insights into the museum experience by providing feedback on practical aspects such as ticket pricing, waiting times, the quality of exhibits, and the availability of visitor amenities. This feedback can be instrumental in identifying areas for improvement and enhancing overall visitor satisfaction. However, despite the advantages of UGC, some museums remain hesitant to fully embrace it. In many cases, strict photography restrictions are still in place, limiting the potential for visitors to share their experiences online. While concerns over artifact preservation and intellectual property are valid, overly restrictive policies may hinder a museum's digital presence and reduce opportunities for broader audience engagement.[10]

2.4 The Mobile Application Technologies in Museum Interpretation

Smartphone applications play a key role in enriching the museum experience by providing visitors with additional information and improved accessibility to exhibits. These applications enable the use of audio guides and multimedia content, including text, videos, audio recordings, animations, and 3D digital models, through mobile devices. They support interactive and personalized engagement, particularly for individuals with disabilities, and assist in navigation through visual guidance tools. Acting as virtual museums, such applications utilize image recognition and QR codes to deliver targeted information. They also offer safe, extended access to artifacts, allowing users to store and revisit content for personal or educational use.[11]

Smartphones, due to their widespread adoption and integration into daily life, have the potential to significantly enhance the museum visitor experience.[12]

Museums and tourist attractions are increasingly encouraging visitors to use their own smartphones rather than renting audio devices. This shift is driven by cost efficiency, as institutions are no longer required to invest in dedicated equipment. Additionally, allowing tourists to use familiar personal devices enhances user convenience and eliminates the need for learning how to operate unfamiliar tools.[13]

The British Museum application, as illustrated in Fig. 1, offers an audio guide designed to support visitors in exploring the museum at their own pace, whether they have a limited time or an entire day. The app allows users to view a selection of the museum's most popular objects, browse images of the exhibits, and save their favorite items for a more personalized experience.

[10] Cassar, Digital Interpretation Tools for Heritage, 74–76.

[11] Sahar Ibrahim Mohamed El Sayed, "The Use of Digital Technology in Museum Display," *Scientific Journal of Education* 24, no. 6 (2023): 39–40.

[12] Dan Wang, Sangwon Park, and Daniel R. Fesenmaier, "The Role of Smartphones in Mediating the Touristic Experience," *Journal of Travel Research* 51, no. 4 (2012): 372.

[13] Michelle de la Harpe and Karina Sevenhuysen, "New Technologies in Tourist Guiding," *Journal of Tourismology* 6, no. 1 (2020): 5.

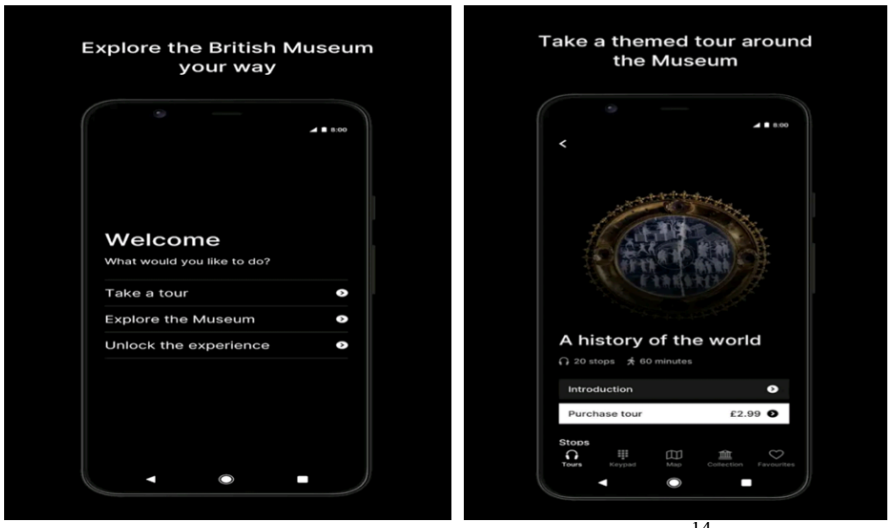

Fig. 1: The British Museum application.[14]

The study proposes the development of a bilingual mobile application for the Royal Jewelry Museum, as shown in Fig. 2, designed to enhance visitor engagement and accessibility through an intuitive and user-friendly interface. The application would prominently feature the official museum logo and offer complete functionality in both Arabic and English, with a seamless toggle option to switch between the two languages. This design ensures inclusivity and caters to both local and international audiences.

Key features of the proposed mobile application include a Collections section, which showcases the museum's exhibition items along with comprehensive details such as descriptions, origins, and current locations, accompanied by high-quality images. A Timeline function would visually narrate the history of the museum, tracing its development from inception to the present day. Notifications would keep users informed of new developments, announcements, and exhibit updates.

To provide an immersive preview of the museum, a Panorama feature would offer 360-degree views of the museum's interior spaces, allowing users to virtually navigate the halls. The Library section would grant online access to the museum's scientific journals and digital publications, supporting academic research and public education. A dedicated News tab would highlight recent events and institutional updates, ensuring users remain informed about museum activities.

The Scan QR functionality would enable users to scan codes placed near exhibits to retrieve detailed information and supplementary images directly on their devices. Additionally, an interactive Maps tool would display the museum's structural layout, including gallery locations and numbers, assisting in physical navigation. The Location feature, integrated with GPS, would help users identify their current position and guide them to the museum's physical site.

The Contact function would facilitate communication between users and museum staff, offering access to email services, general contact details, and information

[14] British Museum, "Audio App," accessed February 4, 2024, https://www.britishmuseum.org/visit/audio-app.

regarding exhibition schedules and visitor hours. Finally, the Settings menu would allow users to customize their language preferences, enabling fluid switching between Arabic and English while using the application. Collectively, these features aim to enhance the museum experience, making information more accessible, fostering educational engagement, and supporting the institution's outreach goals in a digitally connected world.

Fig. 2: A conceptual visualization of the Mobile Application at the Royal Jewelry Museum.[15]
(AI-Generated Developed by the Researcher)

3. Digital interpretation tools used during the visit

3.1 Augmented, Virtual and Mixed Reality's Function in Heritage Interpretation

Advancements in Information and Communication Technologies (ICT), particularly Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), are transforming the tourism and heritage sectors. These technologies enable the integration of physical and virtual environments, offering immersive experiences that enhance heritage interpretation. AR and VR facilitate multi-sensory engagement by overlaying digital content onto real-world settings or simulating entirely virtual environments. Such tools allow tourists to experience cultural sites in new dimensions, thereby deepening understanding and enriching visitor experiences.[16]

3.1.1 Augmented reality

Augmented Reality (AR) is a modern technological innovation that merges virtual elements with the real-world environment, offering immersive and interactive experiences. In recent years, the swift advancement of AR technologies has drawn significant interest, highlighting the dynamic and evolving nature of this field. AR facilitates the integration of physical and digital realities through multimedia, 3D modeling, real-time tracking, and multiple sensory inputs.[17]

These components work together to enhance users' perception and interaction with their environment, often providing guided and intelligent experiences. At its core, augmented reality (AR) functions by overlaying computer-generated content,

[15] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.
[16] Julia Beck, Mattia Rainoldi, and Roman Egger, "Virtual Reality in Tourism," *Tourism Review* 74, no. 3 (2019): 586–587.
[17] Mark Billinghurst et al., "A Survey of Augmented Reality," *Foundations and Trends in Human-Computer Interaction* 8, no. 2–3 (2015): 75.

including text, images, and three-dimensional models, onto the physical world in real time. This digital layer enhances users' understanding of their surroundings and assists them in performing tasks by delivering relevant, contextual virtual information. By seamlessly integrating real and virtual elements, AR enriches the overall user experience, creating a cohesive environment in which both dimensions coexist and complement one another[18].

AR systems ensure precise alignment and registration between virtual objects and the physical environment, allowing digital elements to appear naturally integrated within the user's surroundings. Together, these features create a seamless and immersive experience that enhances both perception and interaction[19].

Augmented reality extends beyond mere visual enhancement, offering the potential to improve perception and compensate for sensory deficits through sensory substitution. For example, AR can provide auditory cues to assist blind or low-vision users, or deliver visual signals to support individuals who are deaf or hard of hearing. These capabilities make AR a powerful tool for enhancing accessibility and promoting more inclusive experiences across diverse environments[20].

Augmented Reality at the Acropolis Museum

The CHESS project explores how personalized and interactive storytelling, delivered through mobile devices, can enrich the museum visitor experience. Unlike conventional linear narratives, CHESS offers tailored content that adapts to various aspects such as themes, language, depth of information, preferred visit style, and selected activities. These activities integrate a range of multimedia components, including audio narration, images, 2D and 3D reconstructions, videos, games, and augmented reality, all embedded within multiple storylines. The experience is initially customized based on visitor profiles and further evolves in real time, responding to the user's behavior, location, and interactions throughout the museum visit, as illustrated in Fig. 3, which shows an AR application at the Archaic gallery in the Acropolis Museum.[21]

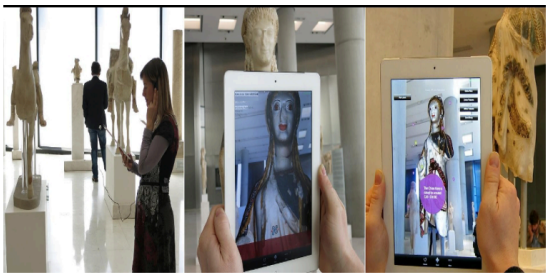

Fig. 3: AR at the Archaic gallery at the Acropolis Museum.[22]

[18] Aditi Banerjee, Priya Vij, and Gagandeep Kaur Nagra, "Augmented and Virtual Reality in Tourism Industry – An Empirical Study," *International Journal of Innovation Studies* 8, no. 2 (2024): 1.

[19] Ronald T. Azuma, "A Survey of Augmented Reality," *Presence: Teleoperators and Virtual Environments* 6, no. 4 (1997): 356.

[20] Julie Carmigniani and Borko Furht, "Augmented Reality: An Overview," in *Handbook of Augmented Reality* (New York: Springer, 2011), 3.

[21] CHESS (Cultural Heritage Experiences)," Acropolis Museum, accessed August 8, 2025, https://www.theacropolismuseum.gr/en/research-programs/chess.

[22] "A Digital Look at Physical Museum Exhibits," *Digital Heritage International Congress* 2 (2013): 1–2, https://doi.org/10.1109/DigitalHeritage.2013.6744836.

The study introduces Jewel AR, a proposed immersive augmented reality (AR) mobile application designed to enhance the visitor experience at the Royal Jewelry Museum, as illustrated in Fig. 4. This innovative application aims to shift the traditional museum experience from passive observation to active participation, enabling users to interact with virtual exhibits, access historical and cultural narratives, and virtually try on displayed jewelry pieces in real-time.

The proposed application includes a set of integrated features to support engagement and education. Key among these is the presentation of highly detailed 3D models of the museum's most iconic jewelry, allowing users to examine artifacts from multiple angles and appreciate their craftsmanship. Interactive tours led by virtual guides will narrate the historical background, artistic techniques, and cultural significance of each item. The try-on feature uses smartphone cameras to allow users to visualize themselves wearing selected jewelry, enhancing personalization and enjoyment. Additionally, social media sharing tools are embedded to encourage visitors to document and distribute their experiences, thereby expanding the museum's digital footprint.

The research further highlights the broader potential of a dedicated AR-based application in enriching museum interpretation. Through personal smartphones or museum-provided tablets, users can interact with specific artifacts by scanning or pointing at them, triggering digital overlays and multimedia enhancements. The application would feature high-resolution 3D reconstructions of jewelry items, enabling visitors to closely observe intricate details and restoration-informed renderings of the original appearance.

One of the application's most distinctive components is the "X-ray View" functionality, which reveals internal structures, layered gemstone cuts, and hidden engravings or inscriptions, offering deeper insight into the complexity of jewelry design. Rich historical storytelling is integrated, supplemented with archival visuals and contextual information, including the provenance, creators, and historical use of the artifacts. An optional virtual try-on module uses AR to simulate the experience of wearing selected items. To ensure accessibility and inclusivity, the app supports multiple languages and includes audio descriptions for visually impaired users.

To further encourage engagement and learning, the inclusion of gamified elements, such as quizzes, interactive AR treasure hunts, and educational challenges, is recommended. Practical extensions, including bookmarking favorite items, exploring a digital catalog and integrating with the museum shop for AR-inspired souvenir purchases are also envisioned.

Ultimately, the proposed Jewel AR application has the potential to revolutionize the museum experience by making it more immersive, interactive, and accessible. It enhances storytelling, supports inclusive engagement, appeals to younger and tech-savvy audiences, and leverages user-generated content to increase visibility and connection beyond the physical space of the museum.

Fig. 4: A conceptual visualization of Augmented Reality at the Royal Jewelry Museum (AI-generated by the researcher)[23]

3.1.2 Virtual reality

Virtual Reality (VR) has emerged as a transformative innovation in the museum sector, enabling the creation of immersive, interactive environments that transcend the conventional physical and spatial boundaries of exhibition spaces. By simulating realistic and engaging experiences, VR allows museums to extend their reach to wider audiences, enhance educational outcomes, and align with the evolving expectations of digitally oriented visitors. This technology not only enriches the interpretive potential of exhibits but also fosters deeper emotional and cognitive engagement with cultural content.[24]

The Naples National Archaeological Museum in Italy has embraced virtual reality technologies to enhance visitor engagement through interactive educational tools. One notable example is the "Father and Son" game, categorized as an educational game, as illustrated in Fig. 5. This two-dimensional game was developed and released by the museum in 2017. The narrative centers on a young American named Michael, who travels to Naples in search of memories of his father, a former employee at the museum. Through the storyline, players are introduced to various artifacts and exhibitions, while simultaneously exploring different historical eras, including ancient Pompeii, Pharaonic Egypt, and the Baroque period in Naples.[25]

This innovative approach not only deepens the emotional connection between users and the museum's collections but also extends the museum's reach beyond its physical boundaries. As a result, the "Father and Son" game has significantly contributed to attracting a global audience, showcasing how digital storytelling and virtual interactivity can serve as powerful tools for cultural dissemination and educational outreach.

[23] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.

[24] Mohamed A. Mohamed Hassan, Henar Abo El-Magd Ahmed Kalefa, and Mohamed Hosny Sabet Mohamed, "Enhancing Museum Engagement through Virtual Reality: A Case Study of the Egyptian Museum in Cairo," International Journal of Engineering and Applied Sciences – October 6 University 2, no. 1 (January 2025): 111.

[25] Mario A. Gutiérrez, Frédéric Vexo, and Daniel Thalmann, Stepping into Virtual Reality (London: Springer, 2008), 2–3.

Fig. 5: Son and Father Game.[26]

The present research advocates for the development of JewelVR, a virtual reality (VR) application specifically designed to immerse users in the unique cultural and historical heritage housed within the Royal Jewelry Museum. Utilizing VR headsets, this application would allow visitors to engage with meticulously crafted digital replicas of the museum's most significant artifacts, offering an experience that closely mirrors physical presence. As illustrated in Fig. 6, the envisioned application provides an immersive and interactive platform where users can explore reconstructed virtual galleries, manipulate highly detailed 3D jewelry models, and access contextual narratives that highlight the artistry, craftsmanship, and symbolic significance of each piece.

JewelVR would comprise several core functionalities: realistic navigation through a digitally reconstructed museum environment, close-up interaction with digitally modeled jewelry, and enriched educational content. Visitors could experience a personalized and exploratory journey, accessing multimedia historical data, high-resolution object details, and contextual storytelling. Of particular note is the incorporation of a virtual try-on tool, which enables users to wear royal jewelry in real time using integrated VR or AR technologies, thereby bridging the gap between observation and personal interaction. To extend its reach, the application would be accessible both within the museum through on-site VR headsets and globally via compatible mobile VR platforms.

Furthermore, the study proposes the implementation of a premium online VR museum tour, offering a high-resolution, interactive 3D experience that allows remote access to both the jewelry collection and the museum's architectural interiors. This virtual walkthrough would feature a click-to-explore interface, a 360-degree spatial immersion system, and a comprehensive set of interpretive tools, including narrated stories, historical reenactments, and augmented reality animations demonstrating the ceremonial uses of the artifacts. Users would be able to attend simulated events such as royal weddings or banquets, interact with AI-generated historical figures, and virtually explore iconic locations, including Abdeen Palace and Montaza Palace.

To further deepen engagement, the platform would include educational and gamified components such as interactive quizzes, treasure hunts, and challenges related to identifying jewelry or deciphering historical clues, designed for both general audiences and educational institutions. An interactive storytelling module would allow users to be guided by avatars of historical royal figures, including Queen Nazli and

[26] "Digital Invasion of the Museums," *Mirador de les Arts*, March 12, 2019, https://www.miradorarts.com/digital-invasion-of-the-museums/.

Princess Fawzia, providing first-person accounts and perspectives that humanize and contextualize the museum's collection.

Accessibility and inclusivity remain central to the proposed model. The VR experience would support multiple languages (e.g., Arabic, English, and French) and integrate features for users with disabilities, including audio guides for the visually impaired and text descriptions for the hearing impaired. Additional proposed elements include a virtual museum shop, where users can purchase souvenirs or jewelry-inspired replicas based on their virtual try-on experiences.

From an operational and economic perspective, the research suggests various monetization models to sustain the platform: single-entry passes, tiered membership subscriptions, VIP packages with exclusive content (e.g., expert interviews), and live VR-guided tours suitable for academic use. The proposed implementation pathways include in-museum VR stations (see Fig. 6), mobile-based VR applications for remote visitors, and immersive projection screens for group experiences in classrooms or exhibition spaces.

Ultimately, the JewelVR initiative aims to transform the traditional museum visit into a multi-sensory, interactive, and globally accessible experience. It seeks to enhance the appreciation of Egypt's royal heritage, particularly from the Muhammad Ali Dynasty (1805–1952), by leveraging advanced VR technologies to reconstruct historical events, revive cultural practices, and digitally preserve artifacts. This integration of historical accuracy and digital innovation is expected to expand the museum's reach, engage younger audiences, and contribute to the sustainable preservation and interpretation of national cultural assets.

Fig. 6: A conceptual visualization of Virtual Reality at the Royal Jewelry Museum (AI-generated by the researcher).[27]

3.1.3 Mixed Reality

Mixed Reality (MR) is an advanced form of immersive technology that merges the physical and digital worlds to create interactive environments. It can be accessed through specialized devices such as Microsoft HoloLens or mobile applications, as illustrated in Fig. 7. MR enables users to engage with both real and virtual elements simultaneously, offering new opportunities for interactive experiences. This technology allows individuals to manipulate virtual objects within the physical space, thereby facilitating the creation of dynamic and customizable scenarios. As such, MR

[27] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.

has the potential to transform various sectors by redefining how individuals interact with digital content in real-world settings.[28]

Fig. 7: Microsoft Hololen.[29]

The Museum Eye project at the Egyptian Museum exemplifies the potential of mixed reality (MR) technology by offering visitors an immersive glimpse into ancient Egyptian life. Through the integration of virtual characters, objects, background music, and sound effects, the project creates a highly engaging and interactive MR experience, as illustrated in Figs. 8 and 9. One of the most innovative features of Museum Eye is its virtual guide, an avatar that interacts with visitors by engaging in dialogue and presenting a variety of visual content, including films, images, and three-dimensional visualisations of artefacts.

This virtual interaction allows for a more personalised and informative tour, enriching the visitor's understanding of the exhibits. A key advantage of digitally generated artefacts over traditional tangible artefacts is that they enable visitors to observe objects closely, without the restrictions of protective glass displays. Users can examine items from multiple angles and gain a more comprehensive understanding of their design and historical significance. The MR application specifically reconstructs eleven artefacts from the Tutankhamun collection, incorporating three narrative-driven scenes. Throughout the 30–40-minute guided experience, the MR avatar accompanies the visitor, offering detailed explanations and maintaining an engaging tour from start to finish.[30]

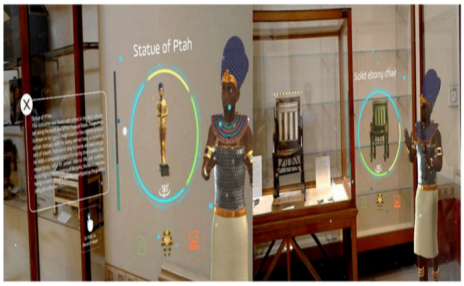

Fig. 8: MR Museum Eye guide and levels of interaction.[31]

[28] Dipesh Gyawali, "Mixed Reality: The Interface of the Future," *arXiv preprint* arXiv:2309.00819 (2023): 1.

[29] Microsoft, "HoloLens 2," accessed February 6, 2024, https://www.microsoft.com/en-us/hololens.

[30] Ramy Hammady, Minhua Ma, Carl Strathearn, and Mostafa Mohamad, "Design and Development of a Spatial Mixed Reality Touring Guide to the Egyptian Museum," *Multimedia Tools and Applications* 79, no. 1 (2019): 4.

[31] Ramy Hammady, Minhua Ma, Carl Strathearn, and Mostafa Mohamad, "Design and Development of a Spatial Mixed Reality Touring Guide to the Egyptian Museum," *Multimedia Tools and Applications* 79, no. 1 (2019): 1–24.

Fig. 9: Visitor in the Egyptian museum while testing MR Museum Eye guide.[32]

In line with global trends in museum innovation, this study proposes the integration of Mixed Reality (MR) technology at the Royal Jewelry Museum through the use of Microsoft HoloLens. This cutting-edge approach aims to enhance the visitor experience by providing an interactive and emotionally engaging tour led by a virtual guide modeled after Fatma Hedar, the founder of the museum.

The use of MR via HoloLens (Fig. 10) would allow visitors to receive a personalized welcome and a 30- to 40-minute guided tour that combines verbal narration with diverse visual elements, including videos, images, and 3D visualizations of jewelry artifacts. This multimedia approach is expected to increase engagement, facilitate better knowledge retention, and provide a deeper understanding of the historical and artistic context of the exhibits.

One of the key advantages of this technology is the freedom it grants to visitors. Users can explore the museum at their own pace, choosing areas of personal interest and interacting with the guide when needed. The HoloLens enables closer inspection of items typically protected by glass, offering a 360-degree view and zoom capabilities that reveal intricate details of craftsmanship and design.

Moreover, the proposed MR application could incorporate interactive elements such as quizzes, historical timelines, and AR overlays, adding layers of educational and entertaining content. These features would appeal to a broad audience, including tech-savvy visitors, students, and international tourists seeking immersive learning experiences.

The implementation of MR at the Royal Jewelry Museum would not only modernize its interpretation strategies but also position it as a leader in adopting innovative technology within Egypt's museum sector. This could significantly boost its public image, attract new visitor segments, and increase media attention.

Fig. 10: A conceptual visualization of Mixed Reality at the Royal Jewelry Museum[33] (AI-generated by the researcher)

[32] Hammady et al., Design and Development of a Spatial Mixed Reality Touring Guide to the Egyptian Museum, 5.

[33] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.

3.2 Hologram Technology and the Visiting Experience

The term "hologram" is derived from the Greek roots "holos" (meaning whole or entire) and "gramma" (meaning something written or recorded), reflecting the concept of recording a complete three-dimensional image of an object.[34]

A hologram is a three-dimensional image created through the positive interference of laser light waves. This process captures both the intensity and the phase of light, allowing for the reconstruction of a complete visual representation of an object. The technical term for this process is wavefront reconstruction, as it involves recreating the light waves that would have been reflected from the original object.[35]

Holograms can be categorized into two main types: thin (plane) holograms and thick (volume) holograms, depending on their structure and the way they interact with light, either through absorption or phase modulation. All types of holograms rely on recording both the amplitude and phase information of light to reconstruct a three-dimensional image.[36]

Hologram technology has been widely adopted across various sectors, particularly in the display of archaeological artifacts in museums. Emerging virtual reality museum formats now include specialized rooms equipped with advanced display systems, integrated databases, communication networks and interactive tools. These components collectively enhance sensory engagement by simulating non-physical exhibits through virtual models. Such innovations play a crucial role in preserving cultural heritage, including antiquities, paintings and sculptures by transforming traditional displays into more open, dynamic and hybrid exhibition spaces. This shift not only broadens visual accessibility but also strengthens the visitor's experiential connection to the content. Furthermore, the spatial design of these systems reflects contemporary technological practices employed in both Egyptian and international museums[37].

The Heritage Documentation Center at the Library of Alexandria (CULTNAT) developed a three-dimensional holographic representation of King Tutankhamun's mask, as illustrated in Fig. 11. This hologram was installed in place of the original mask in the Egyptian Museum's exhibition hall after the original was transferred to the restoration laboratory. Holography represents one of the most advanced museum

[34] رانيا إمام،" تصور مقترح لمتحف تاريخي هولوجرامي وباستخدام تقنية التزييف العميق لإحياء الشخصيات التاريخية"، المجلة الدولية للتراث والسياحة والضيافة، المجلد15 ، العدد3(ديسمبر2021:416)

Also see: Husain Ghuloum, "3D Hologram Technology in Learning Environment," in Proceedings of Informing Science & IT Education Conference, Cassino, Italy, June 19–24, 2010 (Italy: InSITE, 2010), 695.

[35] Universal-Hologram, "What is Holography?," last modified February 7, 2024, http://universalhologram.com/what_is_holography.htm.

[36] Ahmed S. El Deen, and Fatma M. Hussein, "Using Hologram Technology in Constructing Virtual Scenes in Archaeological Sites to Support Tourism in Egypt," *Journal of Architecture, Arts and Humanities* 5, no. 20 (2019): 661.

[37] Ahmed Roshdy, "Studying the Possibility of Using Hologram Technology, a Virtual Reality Technique, in Museum Display," *Journal of the Faculty of Archaeology*, Cairo University 18, no. 28 (2025): 115.

display technologies globally, offering a modern alternative to traditional exhibition methods.[38]

Fig. 11: Hologram of King Tutankhamun's mask.[39]

This study proposes that the incorporation of hologram technology into the Royal Jewelry Museum marks a significant advancement in contemporary curatorial practices, introducing a futuristic and immersive approach to engaging with the museum's collection.

By projecting three-dimensional images of artifacts, as illustrated in Fig. 12, this technology facilitates enhanced visitor interaction, allowing for rotation, magnification, and detailed examination of intricate features that are typically imperceptible to the naked eye. This interactive medium captivates and engages diverse audiences while substantially enriching the museum's educational value. When combined with contextual historical information, analyses of craftsmanship, and narrative interpretations, holographic displays provide a multidimensional understanding of each artifact, thereby deepening visitors' appreciation of the cultural and artistic heritage represented in the jewelry collection.

Moreover, the application of hologram technology significantly enhances accessibility by incorporating features such as tactile feedback systems designed to assist visually impaired visitors, thereby fostering a more inclusive museum environment. This innovation positions the Royal Jewelry Museum at the forefront of digital transformation in the heritage sector, aligning with global trends in museum modernization and attracting a younger, technology-oriented audience. Ultimately, the strategic implementation of holographic tools would not only strengthen the museum's educational mission but also elevate its status as a dynamic and experiential cultural institution.

Fig. 12: A conceptual visualization of a Hologram display at the Royal Jewelry Museum (AI-generated by the researcher).[40]

[38] علياء عاطف عطية، "المتاحف الافتراضية ما بين التسويق الرقمي و رقمنة التراث"، *مجلة السياحة والفنادق والتراث* 5، عدد 3 (2022): 241.

[39] YouTube video, "هولوجرام - قناع توت عنخ أمون," uploaded by CULTANT, November 19, 2015, https://youtu.be/SvW2qwcK6G0

3.3 QR Codes as a Tool of Interpretation

Quick Response (QR) codes are a key component of mobile tagging, a technology that utilizes smartphones to link physical objects, such as museum antiquities, to digital content accessible through internet connectivity. These two-dimensional (2D) codes are typically placed near or directly on specific artifacts or exhibits. By using specialized applications, smartphone users can scan the QR code to be redirected to relevant web pages containing detailed information.

QR codes serve multiple functions, including marketing, delivering contextually relevant information, and attaching supplementary data to buildings and specific objects. Within the tourism sector, QR codes can be integrated into official tourism websites, museums, and souvenir shops situated near tourist attractions. In this context, QR codes can direct tourists to downloadable PDF documents that provide comprehensive details about artifacts, including their historical significance. Additionally, QR technology can utilize location-based services to deliver real-time, site-specific information to travelers, thereby enhancing their overall experience and engagement with the cultural or historical environment.[41]

The research advocates for the strategic implementation of QR codes adjacent to each artifact within the Royal Jewelry Museum, as illustrated in Fig. 13, to significantly enhance the overall visitor experience. This initiative proposes enabling visitors to scan QR codes using their personal mobile devices to instantly access a wealth of digital content, including high-resolution images, detailed descriptive texts, videos, and interactive media related to each exhibit.

One of the primary advantages of this approach is the enhancement of the visitor experience through interactive, self-guided exploration. By supplementing or replacing traditional physical labels, QR codes provide access to comprehensive information, including historical context, craftsmanship techniques, and cultural significance, thereby creating a more engaging and personalized learning environment. Furthermore, this strategy addresses spatial constraints often encountered in conventional exhibitions. By transferring detailed interpretive content to digital platforms, the museum can maintain a streamlined and visually uncluttered exhibition space while preserving the depth of interpretive material.

An additional benefit lies in enhancing accessibility for a diverse, international audience. QR codes can be linked to multilingual content, thereby accommodating non-native speakers and promoting inclusive educational engagement. This digital method also aligns with sustainability objectives by minimizing the use of printed materials, reducing paper waste, and lowering the operational costs associated with printing and maintenance.

Moreover, the use of QR codes introduces content flexibility and adaptability. Unlike static placards, digital content accessed through QR technology can be regularly

[40] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.

[41] Michelle de la Harpe and Karina Sevenhuysen, "New Technologies in the Field of Tourist Guiding: Threat or Tool?" *Journal of Tourismology* 6, no. 1 (2020): 17.

updated to reflect new scholarly research, curatorial insights, or changes in exhibition narratives. This dynamic capability ensures that the museum provides accurate and up-to-date information. The platform also supports a range of multimedia integrations, including audio guides, 3D visualizations, and augmented reality features, thereby accommodating diverse learning preferences and enhancing overall visitor immersion.

From an institutional perspective, QR codes offer valuable opportunities for data analytics. By monitoring user interaction and scan frequency, museum administrators can gain insights into visitor interests and engagement patterns, which can inform future decisions regarding curatorial planning, educational programming, and exhibition design.

Nonetheless, successful implementation requires consideration of several logistical challenges. Ensuring that visitors have access to smartphones and possess the digital literacy necessary to engage with QR technology is essential. Additionally, the museum must invest in a robust wireless infrastructure to support seamless content delivery and ensure that all digital resources are optimized for mobile use across various devices.

In conclusion, the integration of QR code technology into the Royal Jewelry Museum represents a progressive, cost-effective, and sustainable approach to enhancing educational value and visitor engagement. It bridges the gap between traditional curatorial practices and contemporary digital expectations, ultimately fostering a more inclusive, interactive, and accessible cultural heritage experience.

Fig. 13: A conceptual visualization of QR Code at the Royal Jewelry Museum[42] (AI-generated by the researcher)

3.4 Bluetooth Beacons

Beacons are compact, wireless devices designed for easy installation on a variety of surfaces, often equipped with adhesive backing for convenient placement. They address the limitations of GPS in indoor environments by functioning as localized signal transmitters that deliver cloud-based content including text, images, audio and video to nearby Bluetooth-enabled devices such as smartphones, tablets and smartwatches.

Each beacon transmits a unique identification code that allows surrounding devices to recognize and interact with it. This communication is facilitated through Bluetooth

[42] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.

Low Energy (BLE), a power-efficient variant of Bluetooth technology that was officially introduced in 2010, with origins tracing back to Nokia's Wibree technology developed in 2006. The use of BLE is integral to the functionality of beacons, as it enables continuous operation while maintaining minimal energy consumption.

Beacons are typically powered by small lithium batteries, which provide significantly longer operational lifespans compared to conventional AA batteries. This combination of energy efficiency, compact design, and effective indoor communication makes beacon technology an essential component in location-based services, particularly in settings such as museums, retail environments, and smart tourism applications.[43]

In response to evolving visitor expectations, museums are increasingly adopting advanced location-based technologies such as Near Field Communication (NFC), GPS geofencing, and Bluetooth Low Energy (BLE) beacons to enhance the visitor experience. NFC technology enables users to access exhibit-specific information by simply tapping their mobile devices on designated tags. However, its functionality is limited by the requirement for close physical proximity, which may restrict its broader applicability within large or crowded exhibition spaces.

By integrating such technologies, museums not only enhance the interactivity and personalization of the visitor experience but also improve their capacity for data-driven decision-making and operational efficiency.[44]

A prominent example of Bluetooth Low Energy (BLE) technology implementation is the ArtLens application, as illustrated in Fig. 14, developed by the Cleveland Museum of Art. This app utilizes a network of over 240 iBeacons strategically placed throughout the museum to deliver personalized tours and multimedia content aligned with each visitor's individual interests and preferences. By leveraging BLE technology, ArtLens enhances visitor engagement through location-aware experiences, increases accessibility to interpretive content, and fosters a high degree of personalization. This case highlights the transformative potential of BLE-based solutions in redefining how audiences interact with museum spaces and collections.

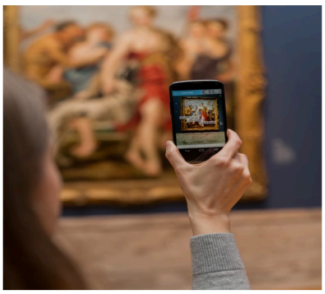

Fig. 14: Artlens app.[45]

[43] André R. Guedes, Ter o Museu na Mão: A Tecnologia Beacon no Museu Nacional dos Coches (Master's dissertation, Mestrado em Museologia e Museografia, 2018), 20.

[44] Rosen Ivanov and Victoria Velkova, "Enhancing Museum Experiences: A Multi-Institution Mobile Multimedia Delivery System Using BLE Beacons," in *Digital Presentation and Preservation of Cultural and Scientific Heritage. Conference Proceedings*, vol. 14 (Sofia, Bulgaria: Institute of Mathematics and Informatics, 2024), 188–189.

This study proposes the integration of Bluetooth Beacon technology within the Royal Jewelry Museum as an innovative approach to enhancing visitor engagement and delivering a personalized, interactive touring experience. Bluetooth Beacons are compact, low-energy wireless transmitters that can be strategically positioned near selected exhibits to automatically transmit context-specific notifications to a visitor's smartphone when in close proximity. This system would enable seamless access to supplementary digital content directly aligned with the artifact being observed, significantly enriching the overall museum experience.

Upon receiving a beacon-triggered notification, visitors would be able to access a range of interpretive materials, including concise historical narratives, high-resolution archival images of the jewelry in its original royal context, and immersive audio guides that detail the artifact's materials, craftsmanship techniques, and cultural significance. Additionally, the system could offer access to augmented reality (AR) features, enabling users to explore 360-degree reconstructions or virtual overlays that depict how the jewelry may have appeared when worn by historical figures.

Key functionalities of the proposed system include automatic proximity-based notifications, delivering real-time alerts as visitors approach each exhibit. These notifications could contain brief summaries, hyperlinks to extended multimedia content, and options to engage with corresponding audio or video guides. Moreover, the technology would support interactive digital experiences, including access to 3D models, layered gemstone visualizations, and virtual reconstructions that illustrate the ceremonial or symbolic use of the artifacts within royal settings.

To further personalize the visitor experience, the system would offer multilingual functionality, allowing users to select their preferred language (e.g., Arabic, English, French) and customize their notification settings through the museum's dedicated mobile application. The system could also track previously accessed exhibits, thereby avoiding redundancy and ensuring a coherent and non-repetitive information flow. Audio synchronization would enhance accessibility, particularly for visually impaired visitors, by providing narrated content as an alternative to on-screen text.

Additionally, the integration of QR codes and social media features would extend user engagement beyond the physical museum visit. Notifications could link to QR codes enabling visitors to bookmark favorite exhibits, share them on social platforms with educational captions, or revisit the digital archive at a later time. For premium or VIP users, exclusive content such as behind-the-scenes footage, expert interviews, or access to archival documents could be offered to provide a deeper scholarly insight into the collection.

The implementation process would follow a phased approach, starting with the installation of Bluetooth Beacons near key jewelry displays. This would be accompanied by the development or adaptation of a mobile application capable of receiving and displaying beacon triggered content. The initial phase would involve comprehensive testing to ensure accurate detection ranges and a seamless user interface. Subsequent phases would focus on developing multilingual content,

[45] ArtLens App, Cleveland Museum of Art, "Free Mobile Companion Guide Using Bluetooth iBeacons for Navigation and Personalized Tours," accessed August 8, 2025, https://www.clevelandart.org/digital-innovations/artlens-app.

implementing accessibility adaptations, and training museum staff. A targeted promotional campaign would support the launch, aiming to educate the public about the new feature and encourage its use.

In conclusion, the adoption of Bluetooth Beacon technology in the Royal Jewelry Museum aligns with global trends in digital transformation and museum innovation. It promotes inclusivity, experiential learning, and sustained visitor engagement while preserving the integrity and aesthetic elegance of the physical exhibits. This forward-thinking strategy positions the museum at the forefront of technologically enhanced cultural heritage interpretation.

3.5 Personal Digital Assistants

These portable digital devices, equipped with compact touchscreens, function as interactive tools for accessing and navigating a wide range of informational content within museum environments. They support the delivery of multimedia materials, including text, high-resolution images, audio, and video files. While visual content is displayed directly on the screen, auditory information is typically delivered through headphones, ensuring an immersive yet personalized experience.

Operating as digital personal assistants, these devices enable users to interact with images of exhibited artifacts, which serve as intuitive interfaces for retrieving contextual information related to the historical, artistic, and archaeological significance of each object. This interaction effectively simulates the presence of a knowledgeable museum curator, guiding visitors through the exhibition and offering enriched interpretive content. By promoting intuitive user engagement and seamless access to layered information, such technology enhances the educational and experiential dimensions of museum visits, aligning with contemporary approaches to digital heritage interpretation.[46]

The Los Angeles County Museum of Art has implemented the use of personal digital assistants (PDAs) for visitor engagement, as illustrated in Fig. 15.

Fig. 15: PDA used by Los Angeles County Museum of Art.[47]

Personal Digital Assistants (PDAs) can significantly enhance the museum visitor experience by delivering detailed information and interpretive content, sustaining

[46] Ahmed Roshdy ElSakhry, "Role of Digital Technologies in Enhancing Museum Interaction and Visitor Experience: Rijksmuseum in Amsterdam – A Case Study," *International Journal of Tourism, Archaeology, and Hospitality* 5, no. 2 (July 2025): 35; see also Seungjae Lee, "A Review of Audio Guides in the Era of Smart Tourism," *Information Systems Frontiers* 19, no. 4 (2017): 710.

[47] Rick Nelson, "The Art of Wireless: Testing Ensures WLAN Quality of Service," *EDN Network*, 2009, accessed August 8, 2025, https://www.edn.com/design/test-and-measurement/4380620/The-art-of-wireless-Testingensures-WLAN-quality-of.

visitor engagement throughout the exhibition, and promoting awareness of available museum amenities and services.[48]

One of the key features of Personal Digital Assistants (PDAs) used in museum settings is the ability for visitors to save selected artifacts as favorites on their devices and to receive email updates with related content or exhibition news. However, a notable limitation of PDAs and similar digital interpretation tools is their potential to reduce social interaction among visitors. The continuous and structured transmission of information often leaves little opportunity for spontaneous discussion, personal reflection, or the exchange of individual interpretations.

As a result, the technology may inadvertently create a more passive consumption of information, rather than encouraging collaborative or dialogic engagement with the exhibits.[49]

The research recommends equipping the Royal Jewelry Museum with Personal Digital Assistants (PDAs), as illustrated in Fig. 16, to enhance the overall visitor experience through the integration of advanced interactive features. These handheld devices would serve as personalized guides, directing visitors through various sections and exhibits within the museum. Each PDA would include an audio guide system, providing narrated tours that offer in-depth explanations and historical context for the displayed jewelry pieces, thereby enriching visitor understanding and appreciation. To further extend the museum's reach, the proposed system also incorporates the development of virtual tours, allowing remote users to access the museum's collections from home, which is particularly valuable for individuals unable to visit in person.

A central component of the recommendation is its emphasis on inclusivity and accessibility. The PDA system would incorporate features such as subtitles for hearing-impaired visitors, audio descriptions for those with visual impairments, and navigation routes optimized for wheelchair users. These elements collectively aim to ensure a more equitable, engaging, and inclusive museum experience for all audience segments.

Fig. 16: A conceptual visualization of Personal Digital Assistants at the Royal Jewelry Museum.[50] (AI-generated by the researcher)

[48] Daphne Economou, Savvas Varytimiadis, Myrsini Samaroudi, Katy Micha, and Damianos Gavalas, "The Effectiveness of Personal Digital Assistants (PDAs), Audio-Guides and Paper Leaflets to Enhance the Museum Visit Experience," in *Proceedings of the 3rd International Conference on Museology, ICOM-AVICOM Annual Conference: Audiovisuals as Cultural Heritage and Their Use in Museums* (Mytilene, Greece: WestminsterResearch, 2006), 3.

[49] Dirk vom Lehn and Christian Heath, "Accounting for New Technology in Museum Exhibitions," *International Journal of Arts Management* 7, no. 3 (2005): 6, 9.

3.6 In-s Function in Transforming Museum Experiences'Ear Translator

Waverly Labs, a U.S.-based company, has developed the 'Pilot' system—an advanced in-ear translation device, as illustrated in Fig. 17. Designed to translate spoken languages in real time, this compact device fits comfortably in the user's ears and enables seamless communication across language barriers. Although the device is currently available only through pre-order, its innovative functionality holds significant potential for transforming the tourism industry. By facilitating instant translation of any spoken language, the 'Pilot' system could greatly enhance the travel experience for international tourists, promoting cross-cultural interaction and reducing communication challenges in diverse settings such as museums, guided tours, and heritage sites.[51]

Fig. 17: Waverly Labs Pilot Earbuds Can Translate Languages in Real Time.[52]

An illustrative example of real-time translation technology in a museum setting can be seen at the Tenement Museum in New York, which employs the Ambassador Interpreter, an over-the-ear wearable device designed to enhance multilingual accessibility. This device uses advanced real-time audio and text translation technologies during guided tours. It captures the tour guide's spoken content and transmits it to visitors as both translated audio and synchronized on-screen text via a connected mobile application. Supporting more than 20 languages and 42 dialects, including Arabic, the device can be worn by either the visitor or the guide and operates through a Bluetooth connection. In the context of museum interpretation, this technology significantly improves accessibility for linguistically diverse audiences, enabling them to fully engage with the narrative and interpretive content. By providing live translation and transcription, the Ambassador Interpreter enhances inclusivity and enriches the overall visitor experience[53].

As illustrated in Fig. 18, the research proposes the adoption of In-Ear Translators as a strategic innovation to enhance the visitor experience at the Royal Jewelry Museum. These devices offer a wide range of benefits, starting with the delivery of a seamless multilingual experience. Through real-time translation, visitors of all linguistic backgrounds can understand the historical and cultural significance of each artifact, thereby eliminating language barriers and promoting meaningful engagement with the exhibits.

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[50] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create.

[51] J. Gould-Bourn, "In-Ear Device That Translates Foreign Languages in Real Time," *Bored Panda*, 2016, http://www.boredpanda.com/real-time-translator-ear-waverly-labs/.

[52] Sellmallsm. "In-Ear Translator Device." Accessed April 15, 2021.https://sellmallsm.pics/product_details/6697378.html.

[53] enement Museum, "Reserve a Language Translation Device," accessed August 4, 2025, https://www.tenement.org/reserve-language-translation-device/.

One of the key strengths of these translators lies in their ability to promote accessibility and inclusivity. By accommodating diverse linguistic needs, the museum becomes more welcoming to an international audience, ensuring equitable access to cultural knowledge. The devices also support personalization, allowing users to tailor the experience based on their preferences, including language selection, audio volume, and tour duration. Such customization enhances visitor satisfaction and deepens engagement by aligning with individual learning styles and interests.

Moreover, the educational value of the museum visit is significantly enriched. Real-time translation facilitates a deeper understanding of complex historical narratives and the intricate craftsmanship associated with the jewelry collection. The hands-free, discreet nature of the In-Ear Translators eliminates the need for traditional guidebooks or handheld devices, allowing visitors to explore the museum more comfortably and immersively.

From a strategic perspective, implementing this technology reinforces the Royal Jewelry Museum's image as a forward-thinking and technologically progressive institution. It not only appeals to tech-savvy audiences but also strengthens the museum's competitive position within the cultural tourism sector. Additionally, the system offers the potential to collect valuable data on visitor preferences and behavior, such as language usage patterns, which can inform future improvements in content delivery and exhibit design.

However, the integration of such advanced technology is not without challenges. The initial investment cost, ongoing maintenance, staff training, and hygiene considerations, particularly in a post-pandemic context, must be carefully managed. Despite these factors, the implementation of In-Ear Translators holds significant potential for transforming the museum experience. It facilitates inclusive communication, enhances educational impact, and aligns with contemporary expectations for interactivity and accessibility in cultural spaces.

Fig. 18: A conceptual visualization of In-Ear Translator at the Royal Jewelry Museum[54]
(AI-generated by the researcher)

Conclusion

The study concludes that the integration of advanced digital interpretation tools such as augmented, virtual, and mixed reality, hologram technology, QR codes, Bluetooth beacons, mobile applications, personal digital assistants, and in-ear translators provides a transformative pathway for the Royal Jewelry Museum into a more inclusive, interactive, and globally competitive cultural destination. These

[54] Bing Images, "AI-Generated Image," accessed February 4, 2024, https://www.bing.com/images/create

technologies go beyond their technical functions to play a vital role in supporting both intellectual and physical accessibility. For visitors with mobility limitations or those unable to access the museum's physical space, virtual tours and online platforms provide alternative means to experience the exhibits, ensuring inclusivity and expanding the museum's reach to broader audiences than ever before.

By offering richer, more immersive, and personalized experiences, digital interpretation tools bridge the gap between traditional exhibits and the expectations of contemporary audiences. They enrich storytelling, enhance accessibility, and foster deeper emotional and intellectual connections with the museum's heritage assets. Furthermore, they extend engagement before, during, and after the visit, attracting diverse visitor segments including younger and tech-savvy audiences, individuals with disabilities, and international tourists. These tools also contribute to sustainable cultural preservation by reducing reliance on physical materials, allowing continuous updates of interpretive content, and supporting data-driven decision-making for improved visitor experiences.

Ultimately, adopting innovative digital interpretation tools represents a valuable opportunity for the Royal Jewelry Museum to expand its audience reach, strengthen its global visibility, and safeguard its unique collections for future generations through the fusion of historical authenticity and cutting-edge technology.

Further study should adopt an empirical approach in order to build upon this conceptual framework. Surveying visitors on-site at the Museum to determine their current digital habits and demand for new technologies would be an essential next step. A prototype, like the suggested "Jewel AR" application, might then be developed and pilot-tested with focus groups to gather important information on user engagement and learning results.

Bibliography

Foreign References

Azuma, Ronald T. "A Survey of Augmented Reality." Presence: Teleoperators and Virtual Environments 6, no. 4 (August 1997): 355–385.

Banerjee, Aditi, Priya Vij, and Gagandeep Kaur Nagra. "Augmented and Virtual Reality in Tourism Industry — An Empirical Study." International Journal of Innovation Studies 8, no. 2 (2024): 1–15.

Beck, Julia, Mattia Rainoldi, and Roman Egger. "Virtual Reality in Tourism: A State-of-the-Art Review." Tourism Review 74, no. 3 (May 2019): 586–587.

Billinghurst, Mark, Adrian Clark, and Gun A. Lee. "A Survey of Augmented Reality." Foundations and Trends in Human-Computer Interaction 8, no. 2–3 (January 2015): 73–272.

Carmigniani, Julie, and Borko Furht. "Augmented Reality: An Overview." In Handbook of Augmented Reality, edited by Borko Furht, 3–46. New York: Springer, 2011.

Cassar, Anthony. *Digital Interpretation Tools for Heritage*. Master's thesis, University of Malta, 2019.

de la Harpe, Michelle, and Karina Sevenhuysen. "New Technologies in the Field of Tourist Guiding: Threat or Tool?" Journal of Tourismology 6, no. 1 (2020): 5–17.

Economou, Daphne, Savvas Varytimiadis, Myrsini Samaroudi, Katy Micha, and Damianos Gavalas. "The Effectiveness of Personal Digital Assistants (PDAs), Audio-Guides and Paper Leaflets to Enhance the Museum Visit Experience." In Proceedings of the 3rd International Conference on Museology, 1–12. Mytilene, Greece: WestminsterResearch, 2006.

El Deen, Ahmed S., and Fatma M. Hussein. "Using Hologram Technology in Constructing Virtual Scenes in Archaeological Sites to Support Tourism in Egypt." Journal of Architecture, Arts and Humanities 5, no. 20 (2019): 661–678.

ElSakhry, Ahmed Roshdy. "Role of Digital Technologies in Enhancing Museum Interaction and Visitor Experience: Rijksmuseum in Amsterdam — A Case Study." *International Journal of Tourism, Archaeology, and Hospitality* 5, no. 2 (July 2025): 35–54.

Ghuloum, Husain. "3D Hologram Technology in Learning Environment." In Proceedings of Informing Science & IT Education Conference, 693–704. Cassino, Italy: InSITE, 2010.

Guedes, André R. Ter o Museu na Mão: A Tecnologia Beacon no Museu Nacional dos Coches. Master's thesis, Universidade de Lisboa, 2018.

Gutiérrez, Mario A., Frédéric Vexo, and Daniel Thalmann. Stepping into Virtual Reality. London: Springer, 2008.

Gyawali, Dipesh. "Mixed Reality: The Interface of the Future." arXiv preprint arXiv:2309.00819 (September 2023): 1–15.

Hammady, Ramy, Minhua Ma, Carl Strathearn, and Mostafa Mohamad. "Design and Development of a Spatial Mixed Reality Touring Guide to the Egyptian Museum." Multimedia Tools and Applications 79, no. 1 (2019): 1–24.

Hassan, Mohamed A. Mohamed, Henar Abo El-Magd Ahmed Kalefa, and Mohamed Hosny Sabet Mohamed. "Enhancing Museum Engagement through Virtual Reality: A Case Study of the Egyptian Museum in Cairo." International Journal of Engineering and Applied Sciences — October 6 University 2, no. 1 (January 2025): 111–125.

Ivanov, Rosen, and Victoria Velkova. "Enhancing Museum Experiences: A Multi-Institution Mobile Multimedia Delivery System Using BLE Beacons." In Digital Presentation and Preservation of Cultural and Scientific Heritage, vol. 14, 188–199.

Lee, Seungjae. "A Review of Audio Guides in the Era of Smart Tourism." Information Systems Frontiers 19, no. 4 (2017): 705–717.

Lushnikova, Anna, Jannicke Baalsrud Hauge, Peter Weiss, and Matthias Lischke. "Self-Determination Theory Applied to Museum Website Experiences: Fulfill Visitor Needs, Increase Motivation, and Promote Engagement." Proceedings of ECCE '23: European Conference on Cognitive Ergonomics, September 2023, 1–8.

Mohamed, Aml Abd El-Wareth. "Integrating Digital Techniques/Technologies in Developing Egyptian Museums (Case Study: Alexandria Library Museums -

Alexandria City)." *Sohag Engineering Journal (SEJ)* 4, no. 1 (March 2024): 40–52.

Roshdy, Ahmed. "Studying the Possibility of Using Hologram Technology, a Virtual Reality Technique, in Museum Display." Journal of the Faculty of Archaeology, Cairo University 18, no. 28 (2025): 115–134.

Sofia, Bulgaria: Institute of Mathematics and Informatics, 2024.

vom Lehn, Dirk, and Christian Heath. "Accounting for New Technology in Museum Exhibitions." International Journal of Arts Management 7, no. 3 (2005): 6–18.

Wang, Dan, Sangwon Park, and Daniel R. Fesenmaier. "The Role of Smartphones in Mediating the Touristic Experience." *Journal of Travel Research* 51, no. 4 (2012): 371–387.

Arabic References

النواوي، إبراهيم عبد السلام. *علم المتاحف*. القاهرة: مطابع المجلس الأعلى للآثار، 2010.

البهنسي، صلاح أحمد. *المتاحف علم وفن*. الإسكندرية: دار الوفاء لدنيا الطباعة والنشر، 2019

إمام، رانيا. "تصور مقترح لمتحف تاريخي هولوجرامي وباستخدام تقنية التزييف العميق لإحياء الشخصيات التاريخية." المجلة الدولية للتراث والسياحة والضيافة 15، عدد 3 (ديسمبر 2021): 416–433.

عبد الرحمن، محمود عباس أحمد. القصور الملكية في مصر: تاريخ وحضارة. الجيزة: دار العالمية للنشر والتوزيع، 2005.

عطية، علياء عاطف. "المتاحف الافتراضية ما بين التسويق الرقمي ورقمنة التراث." *مجلة السياحة والفنادق والتراث* 5، عدد 3 (2022): 241–260.

Web Sources

ArtLens App. Cleveland Museum of Art. "Free Mobile Companion Guide Using Bluetooth iBeacons for Navigation and Personalized Tours." Accessed August 8, 2025. https://www.clevelandart.org/digital-innovations/artlens-app.

Bing Images. "AI-Generated Image." Accessed February 4, 2024. https://www.bing.com/images/create.

British Museum. "Audio App." Accessed February 4, 2024. https://www.britishmuseum.org/visit/audio-app.

CHESS (Cultural Heritage Experiences through Socio-Personal Interactions and Storytelling). Research Programme, Acropolis Museum (Athens). February 1, 2011–January 31, 2014. Accessed August 8, 2025. https://www.theacropolismuseum.gr/en/research-programs/chess.

"Digital Invasion of the Museums." *Mirador de les Arts*. March 12, 2019. Accessed February 6, 2024. https://www.miradorarts.com/digital-invasion-of-the-museums/.

Gould-Bourn, J. "In-Ear Device That Translates Foreign Languages in Real Time." *Bored Panda*, 2016. http://www.boredpanda.com/real-time-translator-ear-waverly-labs/.

Microsoft. "HoloLens 2." Accessed February 6, 2024. https://www.microsoft.com/en-us/hololens.

Nelson, Rick. "The Art of Wireless: Testing Ensures WLAN Quality of Service." *EDN Network*, 2009. Accessed August 8, 2025. https://www.edn.com/design/test-and-measurement/4380620/The-art-of-wireless-Testingensures-WLAN-quality-of/.

Sellmallsm. "In-Ear Translator Device." Accessed April 15, 2025. Tenement Museum. "Reserve a Language Translation Device." Accessed

August 4, 2025. https://www.tenement.org/reserve-language-translation-device/.

Universal-Hologram. "What is Holography? and, How to Light a Hologram." Last modified February 7, 2024. http://universalhologram.com/what_is_holography.htm.

YouTube video. "هولوجرام - قناع توت عنخ أمون." Uploaded by CULTANT, November 19, 2015. Accessed February 4, 2024. https://youtu.be/SvW2qwcK6G0.

91Victoria and Albert Museum, London; British Museum, London; Galerie des Bijoux, Musée des Arts Décoratifs, Paris; Schmuckmuseum Pforzheim, Germany; and The Metropolitan Museum of Art, New York. “Five Great Museums to See Jewellery.” The Life of Jewels. Accessed August 5, 2025. https://thelifeofjewels.com/five-great-museums-to-see-jewellery/