Role of Digital Technologies in Enhancing Museum Interaction and Visitor Experience: Rijksmuseum in Amsterdam A Case Study

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Abstract

Digital technologies significantly enhance visitor experiences in museums and facilitate access to cultural heritage. They include various tools and systems that enhance visitor understanding and interaction with the exhibits. For example, interactive display screens promote innovation and entertainment by engaging visitors in firsthand experiences more intelligently and creatively than traditional methods. Additionally, direct projection technology is a modern advancement in displaying artifacts. It creates unique and engaging visual experiences for visitors. It uses projection devices to transform various surfaces into interactive display screens. Augmented reality integrates digital information with the physical environment, providing supplementary information about the exhibited items helping visitors understand the historical and cultural context of the displayed artifacts. Mixed reality technology combines real and virtual elements, allowing users to interact with them in a single environment within the context of museums. This paper aims to shed light on the most significant outcomes of using digital technologies in museums, particularly in increasing museum attendance. According to the 2021 International Council of Museums (ICOM) report, elevating visitor experience and transforming a museum visit into an enjoyable and interactive educational experience enhances understanding, increases motivation for learning, and makes museums modern educational platforms that align with the aspirations of new generations. Hence, the integration of technology in our Egyptian museums, particularly the regional ones (Kafr el-Sheikh and Ismailia), becomes a priority to keep pace with the times and to fulfill their educational and cultural mission on a broader scale.

Keywords: Interactive Screen - Virtual Reality- Augmented Reality- Mixed Reality- Personal Digital Assistant- Rijksmuseum

STATEMENT OF THE PROBLEM

Across the museums sector since the turn of the twenty-first century, we have seen something of a colonization of the online environment, including increasingly VR, AR, MR, and laser projection. During the writing of this dissertation, I was interested in studying the way cultural organizations and specifically museums react to the digital shift and what are the steps leading to the implementation of a digital strategy. More specifically, by researching an exemplary case concerning digital innovation during the last decade in Europe, namely the digital strategy applied

in the Rijksmuseum. Therefore, this study seeks to address the following research problem: How do digital technologies enhance visitor experience in museums? Despite significant advancements in the field of digital technology, many museums, particularly in developing countries, still struggle to effectively utilize these technologies to enhance visitor experiences and improve the management of museum collections. Some museums lack digital infrastructure or suffer from a shortage of qualified personnel to operate and maintain these technologies, leading to a gap between the globally available technical capabilities and what is actually implemented within these cultural institutions. This raises the main issue: To what extent do digital technologies contribute to the development of museum performance and the enhancement of visitor experiences, and what challenges prevent their optimal application in Egyptian museums?

Introduction

Museum experience is essential for enhancing the cultural identity of communities. It promotes cultural and cognitive understanding among visitors by presenting historical stories innovatively and engagingly, thereby building a bridge between the past and the present. Technology and the information revolution have successfully attracted experiences and attention, contributing to the revitalization of renewal and innovation, the development of design thinking, and the creation of new means of expression and previously unfamiliar innovative ideas. Additionally, they have significantly impacted museum display methods and promoted interactivity. Innovative technologies have presented opportunities for developing techniques used in museums to showcase collections through the concept of participation, transitioning design from a two-dimensional to a more profound and interactive experience among visitors, one that is three-dimensional, to attract attention and convey the museum's message interactively[1].

The role of interactive methods in the communication process is highlighted in light of the significant and rapid developments in the field of information technology. Modern technologies are the foundation for producing, presenting, and retrieving information, relying on multimedia and interactive applications as a powerful and effective means of delivering the communication message, whose effectiveness increases[2]. The use of interactive methods in designing museum display techniques enhances the visitor's sense of participation and presents a wealth of information about the exhibits, which the visitor encounters voluntarily, allowing them to interact and become an active participant in the communication and presentation process[3]. Among the most important interactive digital technologies used in museums are the following:

1. Interactive Display Screens

These special display screens combine text designs, static and dynamic images, audio recordings, and linear graphics to present the museum message. They add dimensions, special effects, and distinctive programs that enhance user experiences, which facilitate concept building, stimulate user interest, and satisfy their information needs[4]. They could be operated through touch interfaces, allowing users to save, store, or send what has been displayed to their mobile devices or any device operating on IOS or Android technology. These screens serve as a means of interaction between

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[1] Roshdy, A., <u>Studying the Possibility of Using Hologram Technology, A Virtual Reality Technique, in Museum Display</u>. Journal of the Faculty of Archaeology, *18*(28), 2025, pp 109-125.

[2] Luo, Y., <u>On the Information Application of Multimedia Technology in Museum</u>. In 2020 5th International Conference on Communication, Image, and Signal Processing (CCISP), 2020, (pp. 299-303).

[3] Huang, J. & Li, W., <u>Research on Innovative Strategies of Museum Display Design to Improve User Experience.</u> In International Conference on Human-Computer Interaction, 2024, (pp. 343-358).

[4] Al-Awad, S., <u>The Use of Modern Technologies in Museum Exhibitions</u>, Masters' Thesis, College of Graduate Studies and Scientific Research, Shendi University (Sudan), 2019, pp. 114-155

the user and the museum content presented engagingly and enjoyably, thereby attracting the visitor's attention[5]. This technology adds a high degree of innovation, appeal, and entertainment due to the visitor's interaction and its ability to attract attention more smartly and creatively than traditional methods, whether through touch or remote interaction. Interactive screens include:

1.1 Interactive Touch Screens

Interactive touch screens are display panels equipped with touch-sensitive technology that allows users to interact directly with the content displayed. By recognizing finger movements or stylus inputs, these screens respond to gestures such as taps, swipes, and pinches, providing an intuitive and user-friendly experience. The touchscreen panel is designed with several layers, with the top layer being a separating glass, and the inner surface connected to a low electrical voltage. When a visitor touches the screen with their finger, the electrical voltage on the panel is slightly affected by the static electricity in the visitor's finger. In one way or another, the exact touch position is determined; then, the information is sent directly to the processor in the device for an immediate response to that touch [6] (**Fig 1**).

1.2 Interactive Screens (Gesture-Based):

These interactive screens operate with sensor devices. They can display dynamic, interactive multimedia content. This technology uses a body-tracking camera, sensors, and a technological system to recognize these gestures and interact directly with visitors' movements in real time[7].

1.3 Interactive Video Kiosks

Kiosks are positioned near the museum entrance and at key locations within the museum to convey introductory information, helping the visitors to familiarize themselves with the museum concepts and offering information about exhibits at the museum, their locations, and facilities[8]. The kiosk application may also include practical information to assist with orientation in the museum and planning the visit. Kiosks installed near the entrance to the exhibition can provide information about the different paths visitors can follow through the museum, depending on their interests and the planned time of the visit, as well as recommendations for visitors with children[9](**Fig 2**).

2. Personal Digital Assistant (PDA)

They are portable devices with small screens that display information and can be used to make selections via a touchscreen[10]. They enable the presentation of multimedia content, texts, and images, as well as audio and video files. Visual content is shown on the screen while audio information is delivered through headphones[11]. The digital personal assistant helps visitors use the displayed image of the exhibited artifact as an interface to invoke related historical, artistic, and archaeological facts and information as if the visitor were with the museum curator pointing to and

[5] Ibrahim, Z. A. & Ibrahim, S. B., Analytic Study for Interactive Museum Display Panels of Science and Technology Museum in Islam at Saudi Arabia. Journal of Architecture, Arts and Humanities, 2016, pp 163-177.

[6] Soboleva, I., Interactive elements: Interactive Screens in Helsinki Design Museum, 2016, pp 1-31.

[7] Abdel Moneim, H. et al, Employment of Interactivity in the Design of Museum Display Methods, Journal of Architecture, Arts and Humanities, 2018, pp 626-649.

[8] Burmistrov, I., Touchscreen kiosks in museums. Tallinn▪ interUX, 2015, pp 1-29.

[9] Apollonio, F. I., et al., Accurate Visualization and Interaction of 3D Models Belonging to Museums' Collection: From the Acquisition to the Digital Kiosk. ACM Journal on Computing and Cultural Heritage, 18(1), 2025, pp 1-25.

[10] Ziefle, M., Information Presentation in Small Screen Devices: The Trade-off Between Visual Density and Menu Foresight. Applied Ergonomics, 2010, Vol 41, Issue (6), pp 719-730.

[11] Yung, P. W. C. PDA Application for Museum, 2006.

explaining the artifact, but in a visually advanced and technological manner that provides the visitor with ease of use and freedom of navigation among the museum collections[12] **(Fig 3).**

2.1 Use of Digital Personal Assistants to Enhance the Museum Experience

The integration of PDAs in museum environments represents a significant shift from traditional, passive methods of exhibition toward more dynamic and user-centered experiences. By delivering information tailored to individual preferences, languages, and learning styles, PDAs not only improve accessibility but also foster deeper understanding and appreciation of cultural heritage. Moreover, the ability to track visitor pathways and engagement patterns allows museums to refine their services and better meet the needs of diverse audiences[13]. The importance of personal assistants in museums lies in the following:

- Digital personal assistants provide additional information about exhibits by directing the camera towards them to read their QR codes, allowing visitors to view interactive content, such as videos or animations that explain the history of the piece or how it is used[14].
- The museum can collect data on visitors' traffic, to create heat maps illustrating the most attractive areas. This information enables museum management to improve internal planning and distribution[15].
- Instant Translation: Personal assistant devices can provide instant translation services for visitors speaking different languages, facilitating their understanding of the exhibited content[16].
- Instant Assistance: Visitors can request help or obtain additional information through applications connected to personal assistant devices, making it easier for them to navigate the museum and receive support when needed.
- Personal assistant devices can empower visitors to share their museum experiences on social media, enhancing social interaction and attracting more visitors.
- They improve the booking and payment experience. Applications linked to personal assistant devices can facilitate the ticket booking and payment process, reducing wait times and increasing visitor comfort[17].

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[12] Hussein, S. & Mohamed E, A. The Role of Graphics in the Display Museum, Architecture and Humanities Magazine, 2021, pp 148-168.

[13] Tesoriero, R, et al., Revaluating the Users' Experience of a PDA-Based Software Applied in Art Museums. In WEBIST (2), 2007, pp. 351-358.

[14] Medic, S. & Pavlovic, N., Mobile Technologies in Museum Exhibitions. Tourism, 2014.

[15] Micha, K. & Economou, D., Using Personal Digital Assistants (PDAs) to Enhance the Museum Visit Experience. In Panhellenic conference on Informatics, 2005, pp. 188-198. Berlin, Heidelberg: Springer Berlin Heidelberg.

[16] De La Harpe, M. & Sevenhuysen, K., New technologies in the field of tourist guiding Threat or tool? Journal of Tourismology, 6(1), 2020, pp 13-33.

[17] Economou, D., et al. The Effectiveness of Personal Digital Assistants (PDAs), Audio-Guides or Paper Leaflets to Enhance the Museum Visit Experience. In 3rd International Conference on Museology, ICOM-AVICOM Annual Conference: audiovisuals as cultural heritage and their use in museums, 2006, pp 1-11.

2.2. Benefits of PDA in Comparison to Tourist Guides

Table 1: Difference between the roles of a digital personal assistant and a tour guide in the museum (Prepared by the Author)

Personal Digital Assistant (PDA)	Tourist Guides
The information provided is correct.	Tourist guides can offer a richer experience.
The user of the personal assistant lacks interaction with those around him while visiting the museum, due to his reliance on earphones.	Visitors can interact and ask questions to the tour guide.
It caters to a large number of visitors and can be presented in various languages.[18]	The tourist guides may only be proficient in one language.
Since opening times, tours are not time restricted.	Tours are time restricted.
The personal assistant makes it difficult for visitors to engage in a discussion due to the earphones[19].	They encourage interaction between group members.

3. Digital Light Projection

Information is displayed optically through projectors that reflect light on various surfaces (glass surfaces, walls, floors, or ceilings). The classification of optical display devices varies according to the light path[20], as follows:

3.1 Direct projection

It is the most common display system and includes projectors for animated films, still films, and slides. In these devices, light falls directly from the projection lamp through the lenses, then passes through the displayed materials, such as animated and still films and slides. After that, it moves through the projection lens until it falls on the projection screen. Behind the projection lamp, a reflector gathers the light and reduces its loss; consequently, only a small amount of light is lost during its path[21] **(Fig 4).**

3.2 Indirect projection

Indirect projection devices are used to display images and transparencies on a screen in front of an audience. Unlike direct projection, the light does not travel in a straight line from the lamp to the screen; instead, it changes its path through mirrors and lenses before reaching the screen[22].
These devices rely on an intense light source (usually a high-power lamp between 600 and 1000 watts) to produce a large amount of light. The light from the lamp is directed to the material to be displayed (such as a transparency or image) through a system of lenses and reflective mirrors.

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[18] Yung, P. W. C., PDA application for museum, 2006.
[19] Salim, J., et al, Mobile Tourism Directory, International Symposium on Information Technology, Vol. 1, 2010, pp. 1-5.
[20] Mohamed, U., Integrating Digital Techniques/Technologies in Developing Egyptian Museums (Case Study: Alexandria Library Museums-Alexandria City). Sohag Engineering Journal, 4(1), 2024, pp 34-47.
[21] Bani Hassan, N, et al. Ultrahigh Frame Rate Digital Light Projector Using chip-scale LED-on-CMOS technology. Photonics Research, 2022, pp 2434-2446.
[22] Hsu, S. H. Projection System with Auto-Project Portable Device for Displaying Images Automatically. U.S. Patent No 9,837,042, 2017, PP 1-16.

After passing through or reflecting off the material, the projection lens enlarges the image. Finally, an angled mirror reflects the image and directs it towards the display screen so that it appears in front of the audience[23].

3.3 Using Digital Projection in Museums

Museums are increasingly striving to integrate digital technology to enhance visitor experiences and enrich the educational value of their collections. By utilizing technologies such as 3D imaging and digital light displays, museums can offer immersive and interactive presentations that make culture and history more accessible and understandable. Notably, the Grand Egyptian Museum opened the interactive Tutankhamun exhibition on November 21, 2023, in partnership with the Spanish Foundation Madrid Arts Digitales. This exhibition was part of temporary exhibitions organized by the museum, aiming to provide visitors with a rich cultural experience through the use of the latest digital display technologies. Through interactive experience, utilizing the latest digital projection devices, visitors can see themselves in the life of the legendary king Tutankhamun. Additionally, they can embark on a magnificent audio-visual journey that spans over 3,400 years into the depths of history, discovering the wonders and secrets of the king's treasures, starting from the creation myths of Heliopolis to the treasures of his tomb. The complete experience includes a 30-minute interactive presentation and a 45-minute guided tour of the Great Hall and the Great Staircase. The experience is available in both English and Arabic. The exhibition attracted more than 300,000 visitors during the first eight months of its launch in November 2022 in various cities, denoting its significant success and popularity, as well as the effectiveness of technology in attracting visitors worldwide[24] **(Fig 5).**

3.4   Advantages of Using Direct Projection in Museums

- Projection technology enables museums to design interactive and immersive exhibitions that vividly animate historical and artistic content. For example, exhibitions such as "Van Gogh Alive" employ projection mapping to immerse visitors in the artist's world, thereby enriching both educational impact and visitor enjoyment. Such immersive experiences make exhibits more engaging and accessible, particularly for younger audiences who are accustomed to dynamic and visually stimulating media[25].

- Modern projection systems, particularly those equipped with 4K technology, deliver exceptional image clarity, rich colors, and intricate detail. This advanced visual capability enables museums to present artworks and historical artifacts in a highly realistic and visually captivating manner, closely reflecting their original appearance.

- Tourism Industry By leveraging demographic data of their visitors, museums can contribute to the development of targeted marketing strategies aimed at specific audience segments, such as families or students. These data-driven campaigns have demonstrated effectiveness in attracting new visitor groups and enhancing overall engagement. Notably, customized advertising efforts directed at youth have led to a 30% increase in attendance[26].

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[23] Brennesholtz, M. S. & Stupp, E. H., Projection displays, 2008.

[24] Mohammed, S. & Metwaly, H. K., Digitization, and the Collection Sustainability: Report on the Grand Egyptian Museum Project, Egypt. Studies in Digital Heritage, 7(2), 2023, 161-174.

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4. Augmented Reality (AR)

Augmented reality blends the physical world with digital enhancements, enriching actual environments with interactive and engaging elements. By overlaying digital content—such as images, videos, and 3D models—onto real-world settings, it transforms the user's experience into a more dynamic and immersive one.[27]. Augmented reality is characterized by:

- The combination of real and virtual worlds,

- Real-time interaction, and Inclusion of three-dimensional models[28]. There are two main steps for augmented reality application systems:

- The application must continuously assess both the real-world environment and the current state of the augmented virtual world. It then seamlessly integrates virtual elements with the real surroundings, creating an experience where visitors perceive the virtual components as naturally embedded in their physical environment. These processes occur simultaneously and in a continuous loop[29]. The main components of an augmented reality system are:
- Sensors determine the state of the real natural world, and sensors play their role when the visitor takes an active and effective role in the mixed reality experience[30].
- A processor evaluates the data received and ensures that the laws of nature are consistent with the virtual world to generate the required signals for operating the mixed reality display[31].
- An appropriate display to create the impression that the virtual world and the real natural world coexist in a way that stimulates the senses of the visitors and makes them feel the union of the natural world with the virtual world[32] **(Fig 6).**

4.1 Advantages of Augmented Reality

- It makes things memorable and eye-catching, sensory-oriented. This is a significant advantage employed in marketing, presentations, or revealing more details or specific qualities of the object that could not be done without augmenting reality[33].

- Augmented reality can create new values at cultural sites. Visitors can explore the unfamiliar environment enjoyably and thrillingly. This represents one of the most significant benefits from a supply perspective because an increasing number of tourists look for unique and memorable on-trip experiences[34].

- Highly specialized hardware is not required; devices can be operated in open and closed areas, presentation quality can be adapted to the device used, and full interaction is supported[35].

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[27] Yuen, S.; et al., Augmented reality: An overview and five directions for AR in education. Journal of Educational Technology Development and Exchange (JETDE). Vol 4(1), 2011, pp 119-140.

[28] Zhan, Tao, et al. "Augmented Reality and Virtual Reality Displays: Perspectives and Challenges." Iscience 23.8 (2020).

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[30] Arena, F., et al., An Overview of Augmented Reality. Computers, 11(2), 28, 2022. PP 1-15.

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[34] Buhalis, D., and Tscheu, F., Augmented Reality at Cultural Heritage sites. In: Inversini, A., and Schegg, R. (ed), Information and Communication in Tourism, Springer, 2016, pp.606-636.

[35] Deliyiannis, Ioannis, and Georgios Papaioannou. "Augmented reality for archaeological environments on mobile devices: A novel open framework." Mediterranean Archaeology and Archaeometry 14.4, 2014.

4.2 Disadvantages of Augmented Reality
4.2.1 High Costs
Expensive Hardware: The development and acquisition of AR devices, such as headsets or smartphones capable of running AR applications, often involve substantial financial investment, which can limit accessibility for many users and organizations.

Development Expenses: Creating AR applications requires advanced technology and skilled developers, leading to increased project costs. Estimates suggest that basic AR apps can range from $10,000 to $50,000, depending on complexity[36].

4.2.2 Health Concerns
- Physical Health Risks: Prolonged use of AR devices can cause eyestrain, discomfort, and other vision-related issues, often referred to as "computer vision syndrome". Users may also experience distractions that could lead to accidents while engaging with AR in real-world environments[37].
- Mental Health Implications: Excessive reliance on AR technology may foster social isolation and dependency.
Users may become engrossed in virtual experiences at the expense of real-life interactions, potentially leading to anxiety and depression[38].

4.3 Difference Between Virtual Reality (VR) and Augmented Reality (AR)
Despite their common features, AR and VR are not the same, as (table 1) illustrates. For instance, AR allows users to see the real world with two-dimensional (2D), or three-dimensional (3D) visuals superimposed over real-world photos or videos, but VR fully immerses users inside a virtual environment (VE), so they are unable to see the real world around them[39].

TECHNOLOGIES	AUGMENTED REALITY	VIRTUAL REALITY
LOCATION	On-site	Off-site
PLATFORM	IOS or Android	Website, IOS or Android
DEVICES	PC, HMDs, etc.	3G and 4G mobile devices
NATURE	Informative, interactive, and immersive	Informative, interactive, and immersive
VISITATION	During the museum's visit	Before and after the museum's actual visit
CONTENT	Bite site information (text, animation, video, audio, images of early years, and suggestions on where to go next, and what to do next)	Large information (text, animation, video, audio, and virtual tour featuring 360-degree panoramic images)
FUNCTIONS	Marketing tools to attract visitors, informative and educational, interactive, actual visits, and a virtual tour guide	Marketing tools to attract visitors, tour planning before the visit, informative and educational, virtual visits, and post-visit updates[40].

[36] https://bigohtech.com/advantages-and-disadvantages-of-ar-and-vr/ accessed on 29-9-2024.
[37] Alemayehu, A. M., & Alemayehu, M. M. Pathophysiologic mechanisms of computer vision syndrome and its prevention. World J Ophthalmol Vis Res, 2(5), 2019, pp 1-7.
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4.4 Use of Augmented Reality to Enhance the Museum Experience
4.4.1 Augmented Reality Apps in Natural History Museums
Natural history museums are increasingly using augmented reality to improve visitor interaction and educational opportunities. Through the integration of digital content into tangible exhibitions, museums may offer engaging and immersive educational experiences.

4.4.2 National Museum of Natural History, Paris
REVIVE Project: This pioneering project enables visitors to encounter 3D representations of extinct animals at their actual size. It creates a vivid connection between the past and present by allowing users to visualize species that no longer exist[41]**(Fig 7).**

4.4.3 Cleveland Museum of Art
Leading the way in AR integration, the Cleveland Museum of Art uses innovative technologies to improve visitor interaction and education. The Art Lens app is a cornerstone of the museum's AR offerings, launched in 2016. It employs image-recognition software to provide visitors with detailed information about artworks when pointing their smartphones at them.
Features: Interactive Content: Users can access videos and related artworks and participate in quizzes, enhancing their understanding of the exhibits.
Wayfinding: The app includes mapping and beacon technology to guide visitors through the museum, making it easier to navigate the collection.
User Engagement: Designed to spark conversations among visitors, it allows them to save artwork and photos during their visit, creating a personalized experience[42] **(Fig 8).**

5. Mixed Reality
Mixed reality (MR) is an innovative paradigm that merges real and virtual environments, allowing users to interact with both physical and digital elements simultaneously, which enhances user experiences across various applications, from gaming to collaborative technologies. The following sections elaborate on the key aspects of MR[43]. MR technologies transform museum experiences by enhancing visitor engagement and interaction. These technologies integrate digital content with physical exhibits, creating immersive environments that enrich cultural understanding and learning[44].

5.1 Advantages of Mixed Reality in Museums
-MR provides new ways to understand history and art by integrating digital elements with physical exhibits, making information more engaging and exciting.
-Global access is facilitated by these technologies, allowing individuals who may not be able to physically visit museums to access cultural content.

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[41] Allal-Chérif, O, Intelligent Cathedrals: Using Augmented Reality, Virtual Reality, and Artificial Intelligence to Provide an Intense Cultural, Historical, and Religious Visitor Experience. Technological Forecasting and Social Change, 2022, pp 121-604.
[42] Ding, M., Augmented Reality in Museums. Museums & Augmented Reality–A collection of Essays from the Arts Management and Technology Laboratory, 2017, pp1-15.
[43] Waheed, S. A., An effective role of Virtual Reality, Augmented Reality and Mixed Reality in Product Design. International Design Journal, 11(5)2021, pp 133-149.
[44] Trunfio, M., et al, Mixed Reality Experiences in Museums: Exploring the Impact of Functional Elements of the Devices on Visitors' Immersive Experiences and Post-Experience Behaviors. Information & Management, 59(8), 2022, 103698.

-It enhances the visitor experience by making visits more interactive and enjoyable, increasing the influx of visitors to museums[45].

5.2 Use of Mixed Reality to Enhance the Museum Experience
5.2.1 MR Museum in Kyoto
The MR Museum in Kyoto is an innovative MR experience located at Kennin-ji, Japan's oldest Zen temple. This project, developed by Hakuhodo-VR AR in collaboration with the Kyoto National Museum, aims to enhance the appreciation of traditional Japanese art through innovative technology. Visitors wear Microsoft HoloLens devices to experience a 10-minute interactive tour, which includes holographic narratives and 3D renditions of various artworks inspired by Sotatsu's original piece, allowing guests to see them side by side in high resolution[46] **(Fig 9)**.

5.2.2 Egyptian Museum
Visitors can interact with the displayed artifacts in a virtual dimension, exploring their secrets through firsthand experiences. This interactivity is a key element that distinguishes MR from traditional museum tours, as it allows guests to manipulate 3D models of artifacts, enhancing their understanding and appreciation. Observations have shown that visitors engage with holographic visuals four times longer than they would with standard displays, suggesting a significant increase in engagement levels.
The MR tour features a virtual guide, Tutankhamun, who narrates the history of the artifacts on display. This storytelling approach allows visitors to connect emotionally with the exhibits, making history feel alive and relevant. The use of Microsoft HoloLens enables users to see and interact with holographic representations of ancient figures and artifacts, creating a more engaging narrative experience [47] **(Fig 10)**.

5.3 Advantages of Using Mixed Reality in Museums
Research has shown that using MR technology significantly increases visitor engagement. For instance, visitors spend four times longer interacting with holographic visuals than traditional exhibits, demonstrating the effectiveness of MR in enhancing the museum experience[48]. The MR experience combines education with entertainment, making learning about ancient Egypt more enjoyable. Gamification elements, such as interactive challenges and treasure hunts, encourage visitors to explore and learn actively rather than passively observing. This method has been shown to improve educational outcomes from museum visits, making the experience both fun and informative[49].

6. Case Study: The Rijksmuseum, Amsterdam
The State Museum in Amsterdam, known as The Rijksmuseum, is the national museum of the Netherlands and is considered to be one of the most significant cultural institutions in terms of history, collection, and popularity, both in the Netherlands and in Europe as well. The museum was established in Amsterdam in 1808, initially as the Royal Art Museum and, eventually, as the

[45] Shehade, M., & Stylianou-Lambert, T. Virtual Reality in Museums: Exploring the Experiences of Museum professionals. Applied sciences, 10(11), 2020, 4031.
[46] Gadjeva, N., Japanese Digital Cultural Promotion: Online Experience of Kyoto. Routledge, 2023.
[47] Hammady, R., Virtual Guidance Using Mixed Reality in Historical Places and Museums. Diss. Staffordshire University, 2019.
[48] Hammady, R., & Ma, M. Interactive Mixed Reality Technology for Boosting the Level of Museum Engagement. In Augmented Reality and Virtual Reality: New Trends in Immersive Technology, 2021, (pp. 77-91). Cham: Springer International Publishing.
[49] Ravichandran, G. & Nam, S. Immersive Cross-Cultural Journeys: Enhancing Museum Experiences through Mixed Reality. TEM Journal, 2024.

home of the National Art collection. Since then, over one million physical items have been collected, while today the museum holds the finest collection of Dutch masterpieces in the world, including the work of seventeenth-century masters Rembrandt van Rijn and Johannes Vermeer[50]. The digitalization of the collection, its up-to-date online presentation, and the support of open content, allow the Rijksmuseum to appear very progressive," says Viola Ruhse. The digital and marketing departments of The Rijksmuseum declare that: "the open access strategy has greatly contributed to a rejuvenation of the museum's public perception or 'brand'. Moving away from a traditional and outdated reputation as a major European museum, where academic knowledge preceded full appreciation for works of art, the Rijksstudio has aligned itself with other digital content platforms, nearly putting the curatorial expertise in the hands of the public[51].

6.1 Digital Technologies at the Rijksmuseum

The Rijksmuseum launched its first application in 2013, when the museum reopened. The app included Multimedia tours to assist users during their visit to the museum, providing information on more than 300 exhibits[52]. The content was three-layered, since it consisted of an audio introduction, video, animations, and audio by an expert with in-depth information. The application could be downloaded via Google Play or Apple's App Store, without any charge. There was also a possibility to rent PDA, a device featuring the app, for visitors who preferred not to use their own, costing € 5. The user of the app could choose from 22 tours, with different lengths and routes, while more information was provided if the user typed the number of the artwork. The new app has three key features: the Rijksstudio, Multimedia Tours, and the ticketing service. The navigation to the app is kept significantly simple, visual, and user-friendly[53](Fig 11).

6.2 Results of Using Digital Technologies at the Rijksmuseum

After the opening of the new museum in 2013, Booz & Company completed research on the economic and social impact of the renovation. According to their report, the annual economic impact of the museum increases and contributes€90million per year to the Dutch economy. Their estimation was based on numerous factors, such as the employment opportunities the museum was able to provide after the renovation. As far as the social impact is concerned, it was examined at the local, national and international level. The key findings were that The Rijksmuseum promotes cultural activities and increases the appeal of the city for visitors and businesses, while at the national level, it is considered to be an iconic institution of the Dutch identity, having a leading role in conservation, restoration, scientific research as well as design innovation and product development[54]. The annual visitor numbers for the museum before the use of digital technologies (before 2013) ranged between 0.8 to 1.3 million visitors annually during the late 1990s and early 2000s. In 2013, after the reopening (April 13) equipped with internal wireless network technologies and digital information services (such as Wi-Fi in the halls, digital tours, rental devices, and technical support from Cisco), the museum achieved 2.246 million visitors; more than doubling the visitor numbers compared to previous years. Cisco's report indicates an increase of 188% when digital technologies were explicitly utilized within the museum[55].

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7. Challenges Facing the Implementation of Digital Technologies in Egyptian Museums

Although the application of digital technologies provides a rich educational experience for the visitor, it faces many financial, technological, and human resource challenges. Here is a breakdown of the key challenges:

Financial Challenges

Developing, implementing, and maintaining digital technologies (e.g., digitization of collections, interactive exhibits, virtual tours, sophisticated online platforms) can be extremely expensive. This includes hardware, software, specialized personnel, and ongoing updates[56].

Technological challenges

Digital technologies evolve quickly, meaning that investments can become outdated in a relatively fleeting period, requiring continuous upgrades and re-investment. In addition, many museums have vast amounts of analog information or data stored in outdated systems, making digitization and integration a complex and time-consuming task[57].

Human Resources

Museums often lack staff with the necessary digital skills, including expertise in IT, data management, web development, content creation for digital platforms, and experience design. Sometimes, Museum professionals, accustomed to traditional practices, may be resistant to adopting innovative technologies or changing established workflows. This can stem from a fear of the unknown, a belief that technology detracts from the "authentic" museum experience, or a lack of understanding of the benefits[58].

Conclusion

Digital technologies, such as VR, AR, and interactive screens, are cornerstones in the development of modern museums. They enhance interaction, expand access, support education, and protect cultural heritage. Thanks to these innovations, museums have become more capable of attracting visitors and creating rich and inspiring experiences that align with the aspirations of new generations and meet the demands of the digital age. Digital technologies have made museums more appealing to youth and children, as traditional display methods have struggled to engage this demographic or maintain their interest. Additionally, they boost children's self-confidence, foster independence, and enhance their ability to express their opinions and ideas clearly, especially when participating in interactive digital activities within the museum. Some of the most significant outcomes of using digital technologies in museums include:

Increase in Museum Visitors: According to the International Council of Museums (ICOM) report in 2021, museum digital activities experienced a 5.6% increase, with the Sharjah Museum welcoming 370,055 visitors over eight months, including 25,457 virtual visitors through digital programs and 344,598 physical visitors. The British Museum also reported that the use of AR applications increased visitor interaction time with exhibits by 41% and boosted the rate of repeat visits by 29% over six months.

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Improving Visitor Experience through Interactive Applications: A study conducted by the Cleveland Museum of Art in collaboration with Rockman et al., supported by the National Endowment for the Arts (NEA), evaluated the impact of digital technologies on visitor experience. The results showed that 76% of participants felt that their visit to the ARTLENS exhibition enhanced their overall experience at the museum. In comparison, 74% reported that the exhibition encouraged them to engage more deeply with the artworks and notice further details.

Transforming a museum visit into an enjoyable and interactive educational experience enhances understanding, increases motivation for learning, and makes museums modern educational platforms that align with the aspirations of new generations.

Recommendations

The use of digital technologies in museums has become indispensable for these cultural institutions to meet the aspirations of visitors, especially among youth and children, who are the most enthusiastic about technology compared to the traditional form of the museum. Museums are no longer places for displaying artifacts; they have transformed into interactive learning environments that contribute to enhancing understanding and engagingly delivering information, enriching the cognitive experience. This makes the integration of technology in Egyptian museums , particularly the regional ones (Kafr el-Sheikh and Ismailia), an urgent priority to keep pace with the times and to fulfill their educational and cultural mission on a broader scale. Therefore, it is recommended that the Supreme Council of Antiquities develop the infrastructure of Egyptian museums by incorporating all modern technologies of exhibition displays. It is essential to enhance Egyptian museums by establishing a specialized team for electronic museum management, including programmers, data developers, translators, and personnel responsible for general inquiries, promotional activities, and e-marketing. Additionally, obstacles must be removed for individuals with disabilities, ensuring that their experience when visiting the museum is enhanced using modern technologies, such as models, PDA, and guidance robots. Thus, the use of digital technologies is no longer an option but a strategic necessity to enhance communication with the public and provide an advanced visitor experience that aligns with the demands of the digital age.

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Figures

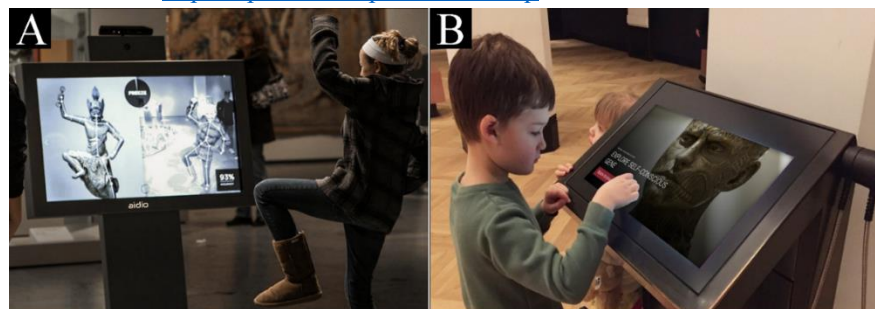**Fig 1: Use of Interactive Display Screens at the Qatar National Museum**
After https://spiral.co.uk/portfolio/nmoq/ accessed on 29-9-2024

Fig 2: Interactive Kiosks in museums
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Fig 3: Use of Digital Personal Assistants in Museums
After https://caramellaapp.com/aldriaan/B85WwDBAS/almtahf-althkyh accessed on 3-10-2024
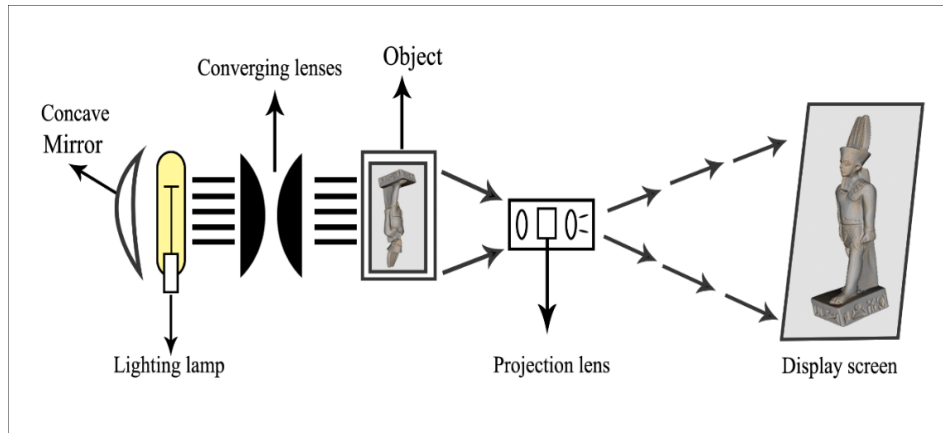
Fig 4: Using Digital Projection in Displaying Museum Artifacts
(Source: Designed by the Author)

Fig 5: Digital Projection at the Grand Egyptian Museum
After: https://www.shorouknews.com/news/view.aspx?cdate=20112023&id=a88c27e1-4baa-42ea-8204-ed1f068a01da (Accessed on 23-11-2024)
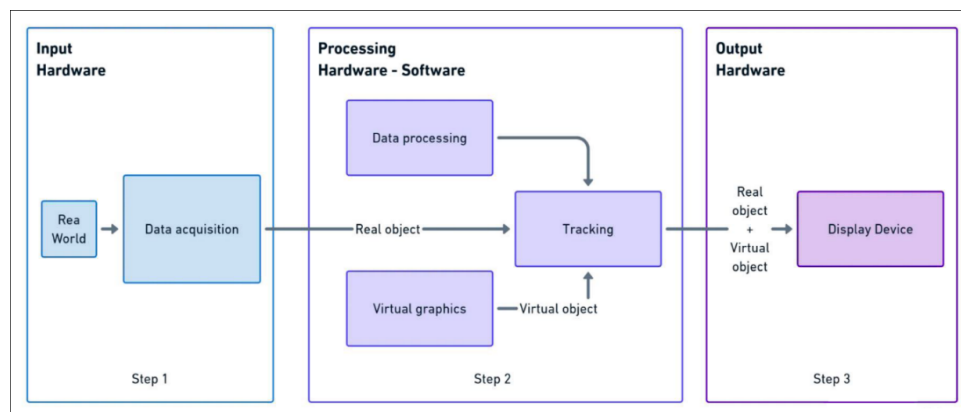

Fig 6: Components of an Augmented Reality System
After https://mafda.medium.com/ar-101-components-of-the-augmented-reality-system-part-3-878c71e68069 accessed on 29-9-2024

Fig 7: Augmented Reality at the National Museum of Natural History, Paris (REVIVE Project)
After https://www.mnhn.fr/en/experience/revivre-extinct-animals-in-augmented-reality accessed on 29-9-2024.

Fig 8: The use of (AR) technology at the Cleveland Museum of Art, Art Lens application
After https://mw2013.museumsandtheweb.com/paper/transforming-the-art-museum-experience-gallery-one-2/index.html accessed on 29-9-2024
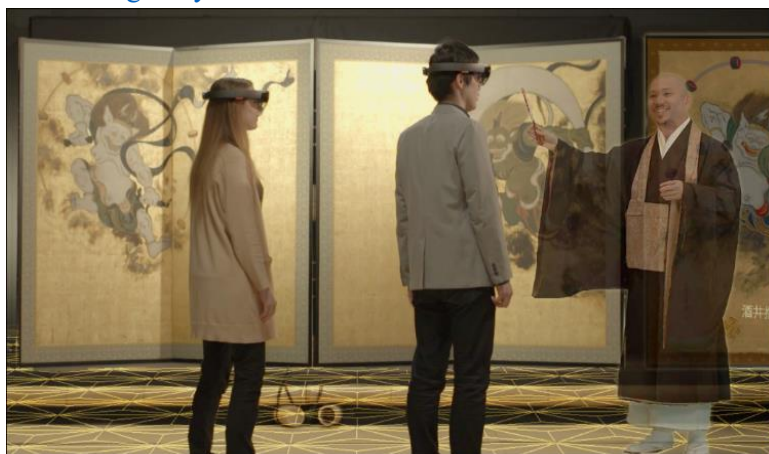

Fig 9: Mixed Reality Museum in Kyoto: A unique insight into centuries-old Japanese artwork
After https://news.microsoft.com/apac/features/mixed-reality-museum-kyoto-unique-insight-centuries-old-japanese-artwork/ accessed on 30-9-2024

Fig 10: Use of Mixed Reality Technology in the display of the treasures of Tutankhamun at the Egyptian Museum
After https://cairoscene.com/buzz/virtual-tutankhamun-is-giving-mixed-reality-tours-of-the-egyptian-museum-until-next-weekend accessed on 3-10-2024
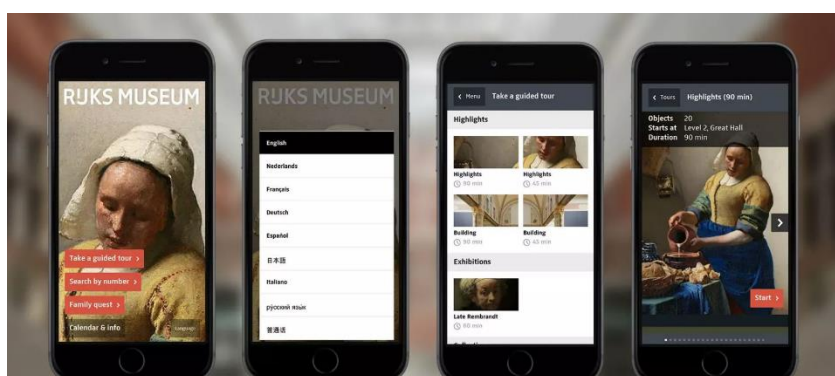

Fig 11: Using Digital Technologies at the Rijksmuseum
After https://northernlight.nl/project/rijksmuseum-app-2/ accessed on 29-6-2025

دور التقنيات الرقمية في تحسين التفاعل المتحفي وتجربة الزائر
(متحف رايكس بامستردام: دراسة حالة)

المستخلص

تسهم التقنيات الرقمية إسهامًا بالغًا في تعزيز تجربة الزوار في المتاحف وتوسيع نطاق الوصول إلى التراث الثقافي. تتضمن هذه التقنيات مجموعة من الأدوات والأنظمة التي تعزز فهم الزوار وتفاعلهم مع المعروضات مثل شاشات العرض التفاعلية. حيث تضيف هذه التقنية درجة عالية من الابتكار والتسلية بفضل تفاعل الزائر معها وقدرتها على جذب الانتباه بطريقة أكثر ذكاءً وإبداعاً من الطرق التقليدية وذلك عن طريق اللمس، أو التفاعل عن بعد. بالإضافة إلى تقنية الإسقاط المباشر التي تمثل تطورًا حديثًا في عرض المقتنيات، حيث تساهم في خلق تجارب بصرية فريدة وجذابة للزوار. تعتمد هذه التقنية على استخدام أجهزة العرض الضوئي لتحويل الأسطح المختلفة إلى شاشات عرض تفاعلية، مما يتيح تقديم محتوى مرئي متنوع يتفاعل مع البيئة المحيطة. تدمج تقنية الواقع المعزز المعلومات الرقمية مع البيئة المادية، وتيسر عرض معلومات إضافية عن المعروضات، مما يساعد الزوار في فهم السياق التاريخي والثقافي للمقتنيات المعروضة. تجمع تقنية الواقع المختلط بين العناصر الواقعية والافتراضية، مما يتيح للمستخدمين التفاعل معهما في بيئة واحدة في سياق المتاحف. يهدف البحث إلى تسليط الضوء على أهم مخرجات استخدام التقنيات الرقمية في المتاحف تحديداً زيادة عدد زوار المتحف. حيث وفقًا لتقرير المجلس الدولي للمتاحف (ICOM)في عام 2021، فإن تحسين تجربة الزوار وتحويل زيارة المتحف إلى تجربة تعليمية ممتعة وتفاعلية يعزز الفهم، ويزيد من الدافع للتعلم، ويجعل المتاحف منصات تعليمية حديثة تتماشى مع تطلعات الأجيال الجديدة. لذلك يعد دمج التكنولوجيا في متاحفنا المصرية وخاصة المتاحف الإقليمية مثل (كفر الشيخ والإسماعيلية) أولوية عاجلة لمواكبة العصر وتلبية مهمتها التعليمية والثقافية على نطاق أوسع.

الكلمات الدالة: شاشات العرض التفاعلية- الواقع الافتراضي- الواقع المعزز- الواقع المختلط ـ المساعد الشخصي الرقمي- متحف رايكس.