Enhancing the Interpretation of Islamic Funerary Inscriptions in Museums: A Multi-Sensory Approach Using Holographic Storytelling and Sculpted Replicas

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Traditional museum displays often struggle to convey the historical and artistic significance of Islamic funerary inscriptions, whose interpretation depends heavily on textual analysis. This study examines the effectiveness of holographic storytelling and sculpted replicas as interpretive tools to enhance visitor engagement and understanding. Conducted at the Shaikh Abdullah Al-Salem Cultural Center (Kuwait), the experiment combined a holographic narrator providing historical context with hands-on interaction with sculpted replicas of inscriptions, enabling both visual and tactile forms of engagement. The results show that multisensory interpretation significantly improves visitor involvement and learning outcomes. Participants exhibited longer dwell times, more active participation in discussions, and stronger recall of historical information. Survey responses indicate that over 90% of participants found the holographic storyteller engaging and effective, while observational analysis confirmed that tactile interaction with the replicas encouraged deeper exploration of the inscriptions. Interviews further highlighted the influence of cultural familiarity, noting that the choice of a well-known artistic figure as the narrator strengthened visitors' emotional connection. These findings contribute to ongoing discussions about interactive interpretation in museums, underscoring the value of integrating digital and physical storytelling methods. The study demonstrates the potential of holography and tactile engagement to make text-based artifacts more accessible and immersive. Future research should investigate long-term knowledge retention and explore adaptive digital storytelling strategies to enhance visitor experiences across diverse museum contexts.

Keywords:
Holography, Islamic Heritage, Multisensory Interpretation, Tangible Interaction, Narrative Design, Digital Museology

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1. INTRODUCTION

Islamic art museums play a crucial role in preserving, displaying, and interpreting the cultural and artistic legacy of the Islamic world. These institutions house collections that encompass calligraphy, ceramics, textiles, architectural fragments, and metalwork, each reflecting distinctive regional and historical variations (Bloom & Blair, 2019). However, one of the key challenges these museums face is enhancing visitor engagement and comprehension, particularly when presenting objects that require historical, linguistic, or religious contextualization. Traditional display methods, including glass cases with textual descriptions, often fail to capture the depth and significance of artifacts, leaving visitors with a passive viewing experience (Falk & Dierking, 2016). In response, museums are increasingly exploring digital technologies such as augmented reality (AR), virtual reality (VR), and holography to create immersive, interactive experiences that bridge the gap between the past and the present (Carrozzino & Bergamasco, 2010). Among these technologies, holograms offer a particularly compelling medium for interpreting museum collections, as they can simulate three-dimensional forms, animate historical narratives, and integrate seamlessly into exhibition spaces (Kenderdine, 2016).

This study investigates the role of hologram technology in enhancing visitor engagement and interpretation of Islamic art collections, focusing on its potential for creating interactive and immersive experiences in museum settings. Specifically, the research explores the integration of holographic storytelling in presenting Islamic funerary inscriptions, a category of material culture that offers insights into social status, religious beliefs, calligraphic styles, and artistic traditions across different periods and geographies (Gonnella, 2022). The study also considers the impact of physical replicas alongside holographic displays, a combination that aims to provide visitors with a tangible, multi-sensory experience, thereby merging traditional and digital interpretative strategies (Claisse, 2016). Through a structured experimental approach, the research evaluates the effectiveness of holographic interpretation in conveying historical information, fostering engagement, and enhancing aesthetic appreciation within Islamic art museum settings. The original funerary inscriptions analyzed in this study are part of the collection of the Islamic Antiquities Museum of Kuwait, while the holographic and sculpted replica exhibit was implemented at the Shaikh Abdullah Al-Salem Cultural Center (Kuwait). By reproducing and contextualizing these dispersed inscriptions, the exhibition reunites artifacts originating from different historical and geographical settings, creating a holistic interpretative experience for visitors.

1.1 Research Questions and Objectives

Despite their historical and artistic richness, Islamic funerary inscriptions are often overlooked by museum visitors due to their textual nature and limited contextualization. To address this gap, this study investigates the following research question (RQ):

RQ: *How can hologram technology enhance visitor engagement and understanding of historical artifacts, particularly Islamic funerary inscriptions, in museum settings?*

To address this inquiry, the study aims to:

- Investigate how holograms contribute to the interpretation of Islamic art collections by making historical content more immersive, accessible, and engaging.
- Assess the impact of holographic displays on visitor learning and interaction, comparing them with traditional static presentations.
- Investigate how the combination of holograms and physical replicas can create a more engaging and comprehensive museum experience.
- Explore the curatorial and communicative potential of holograms in Islamic art museums, assessing their effectiveness in storytelling and visitor engagement.

This research aligns with broader discussions on digital heritage interpretation, particularly within the context of Islamic art museums, where technological integration remains relatively underexplored (Nofal et al., 2018a). The findings are expected to contribute to museum curation strategies by offering insights into how digital and physical interpretative methods can be combined to enhance visitor experience.

1.2 Methodology and Expected Impact

This study employs a multi-method research approach that includes a literature review, case study analysis, experimental implementation, and visitor feedback evaluation. The literature review examines existing applications of digital technologies in museum environments, with a particular focus on holographic storytelling and its role in cultural heritage interpretation (Sylaiou et al., 2010). A comparative case study of global museum practices that have successfully implemented holographic displays and physical replicas provides a contextual foundation for the study.

The experimental component involves designing and testing a holographic interpretation model within an Islamic art museum setting. The selected case study centers on Islamic funerary inscriptions from various historical and geographic contexts, presented through a holographic storyteller who narrates their artistic and cultural significance. These holographic displays are complemented by physical replicas of the inscriptions, allowing visitors to engage with the artifacts through both visual and tactile interaction. This combination is designed to test whether multi-sensory engagement enhances visitor learning, interest, and emotional connection with the displayed artifacts (Roussou & Katifori, 2018).

To evaluate the effectiveness of this approach, the study collects quantitative and qualitative data through visitor surveys, direct observation, and structured interviews. The survey instrument includes Likert-scale questions measuring visitor engagement, comprehension, and overall experience, while observational analysis records behavioral patterns such as dwell time and interaction levels within the exhibition space. Additionally, semi-structured interviews capture visitor perceptions of the holographic storyteller and the tactile experience provided by the physical replicas (Bitgood, 2013). The results are analyzed to determine whether holographic and physical interpretation methods collectively improve visitor experience when compared to conventional display strategies.

This research contributes to museum studies, digital heritage, and exhibition design by offering a practical framework for integrating holographic storytelling and physical replicas into museum

environments. By exploring how multi-sensory interpretation enhances visitor engagement and comprehension, the study provides valuable insights into the role of holography as an interpretative tool, particularly in Islamic art museums, where textual and symbolic content is central to artifact appreciation.

In an era where museums must adapt to evolving visitor expectations and technological advancements, holographic interpretation offers a compelling strategy for bridging historical content with contemporary engagement techniques. Beyond demonstrating the feasibility of integrating holography into Islamic art exhibitions, this study highlights the potential of multi-sensory curation strategies, combining visual, auditory, and tactile experiences to foster deeper visitor interaction. The findings contribute to the ongoing digital transformation of museum experiences, reinforcing the need for balanced approaches that integrate traditional curatorial methods with emerging technologies. The study also recognizes the sensitive nature of funerary artifacts in Islamic contexts and aims to present the content respectfully, avoiding any distortion of religious or cultural meaning.

2. THEORETICAL AND EMPIRICAL FOUNDATIONS

2.1 Digital Technologies in Museum Interpretation

The role of museums has evolved significantly from static repositories of artifacts to dynamic cultural institutions that emphasize visitor engagement, education, and interaction (Falk & Dierking, 2016). In response to changing audience expectations, museums worldwide are increasingly adopting digital technologies such as augmented reality (AR), virtual reality (VR), mixed reality (MR), and holography to enhance visitor experiences and create immersive storytelling environments (Sylaiou et al., 2010; Nofal et al., 2018b). Digital tools are particularly valuable in the interpretation of historical artifacts that require contextualization, allowing for interactive, multi-sensory, and personalized learning experiences (Kenderdine, 2016).

Recent studies have also explored the combination of physical replicas and digital storytelling in enhancing museum engagement (Nofal et al., 2023), as well as the role of projection mapping and multisensory installations in communicating heritage transformations (Nofal et al., 2018b). These studies lay the foundation for exploring holography within Islamic art contexts.

Holography, in particular, has gained attention for its ability to generate three-dimensional, life-like projections, allowing visitors to interact with historical narratives in ways that were previously unattainable (Nofal et al., 2018a). Museums are no longer restricted to traditional didactic methods but can employ holographic storytelling to bring historical figures, artifacts, and cultural narratives to life (Carrozzino & Bergamasco, 2010; Reffat and Nofal, 2013). By bridging physical and digital interpretation (Nofal et al., 2017), holographic displays increase visitor immersion while preserving the authenticity of museum collections (Bitgood, 2013).

Recent scholarship has explored the convergence of extended reality (XR) and mixed reality (MR) in cultural heritage interpretation, emphasizing embodied and emotional engagement through multi-sensory storytelling (Ciolfi & Bannon, 2007; Petrelli et al., 2013; Damala et al., 2008; Roussou & Katifori, 2018). These studies underline that visitor experience is shaped not only by visual immersion but also

by cognitive and affective dimensions, a perspective aligned with embodied cognition theories (Damasio, 1994; Antinucci, 2003; Ledoux, 1996). Furthermore, recent works highlight methods for evaluating digital interpretation through both quantitative and qualitative analysis (Malik et al., 2023), reinforcing the need for multi-modal data collection and triangulation when assessing visitor engagement and learning outcomes.

2.2 Hologram Technology in Museums: Current Applications

Several museums worldwide have experimented with holography as a means of enhancing the interpretation and accessibility of their collections. For example, the Imperial War Museum (UK) introduced holographic projections of historical figures to narrate wartime experiences, offering a more personal and emotionally engaging visitor experience (Roussou & Katifori, 2018). Similarly, the Musée du Louvre (France) has explored holographic reconstructions of ancient artifacts, allowing visitors to visualize lost or fragmented objects in their original form (Gonnella, 2022).

One of the most pioneering applications of holography in heritage interpretation was introduced at The Holocaust Museum in Los Angeles, where holographic survivors recount their experiences in real-time interactive sessions. Visitors can ask questions, and the system, powered by artificial intelligence (AI), retrieves appropriate pre-recorded responses (Claisse 2016). This model demonstrates the power of holography in fostering engagement, empathy, and historical understanding, a principle that can be extended to Islamic art museums to offer deeper insights into historical artifacts and inscriptions.

In the context of Islamic heritage, holography has been used in limited but notable applications. The Sharjah Museum of Islamic Civilization (UAE) has integrated digital projections to illustrate the architectural evolution of mosques over time. Additionally, Saudi Arabia's Ithra Museum has experimented with holographic storytelling to narrate episodes from Islamic history, although these applications remain relatively underdeveloped when compared to Western institutions (Nofal et al., 2018a).

Despite these advancements, few studies have systematically examined the role of holography in the interpretation of Islamic art collections, particularly in relation to epigraphic artifacts such as funerary inscriptions. This study addresses this gap by investigating how holograms, combined with physical replicas, can enhance engagement, contextual understanding, and sensory interaction with Islamic artifacts.

2.3 The Role of Funerary Inscriptions in Islamic Art Museums

Islamic funerary inscriptions hold significant historical, religious, and artistic value, serving as crucial records of calligraphic traditions, social hierarchies, and theological expressions (Bloom & Blair, 2019). These inscriptions, often engraved in marble, limestone, or ceramics, provide insights into the lives, professions, and spiritual beliefs of past societies (Gonnella, 2022). However, their interpretation in museum settings is often limited by language barriers, textual complexity, and the absence of interactive explanatory tools.

The challenge of presenting Islamic funerary inscriptions in a compelling and engaging manner stems from their inherently textual nature. Visitors who lack proficiency in Arabic script or historical context may struggle to appreciate the aesthetic and symbolic depth of these artifacts (Falk & Dierking, 2016). Conventional interpretation methods (such as wall-mounted translations, audio guides, or guided tours) are often ineffective in capturing the visual and emotional impact of these inscriptions (Bitgood, 2013). Holographic storytelling, however, presents a transformative solution, allowing curators to animate historical figures or narrators who can contextualize these inscriptions interactively.

2.4 Multi-Sensory Museum Experiences: Integrating Holograms with Physical Replicas

Recent museum studies emphasize the importance of multi-sensory engagement, highlighting how visitors learn more effectively when they can see, hear, and touch artifacts simultaneously (Roussou & Katifori, 2018). Research on tangible heritage interpretation suggests that combining digital and physical elements enhances visitor recall, emotional connection, and knowledge retention (Claisse 2016).

For example, the British Museum has introduced 3D-printed replicas of ancient sculptures, allowing visitors to physically explore artifacts that are otherwise too fragile for direct handling. Similarly, the Louvre Abu Dhabi has combined physical replicas with digital overlays, enabling visitors to see the original and restored versions of artifacts side by side (Nofal et al., 2018a). These examples illustrate how the integration of physical replicas with digital interpretation tools creates a more comprehensive and immersive museum experience.

In this study, physical replicas of Islamic funerary inscriptions complement holographic storytelling, allowing visitors to engage with the artifacts in both visual and tactile ways. By touching replicas while listening to holographic narrations, visitors experience a more holistic and meaningful interaction, reinforcing the educational and emotional impact of the exhibition. This approach aligns with current best practices in digital heritage interpretation, which advocate for interactive and participatory visitor engagement strategies (Sylaiou et al., 2010).

2.5 Contribution to the Field of Museum Studies and Digital Heritage

This study builds on previous research in museum curation, digital heritage, and interactive learning, contributing to ongoing discussions on how technology can transform visitor experiences in Islamic art museums. While previous studies have explored holography in western museum contexts, this research extends the conversation to Islamic heritage interpretation, a relatively underexplored domain (Gonnella, 2022).

By integrating holographic storytelling and physical replicas, this study provides new insights into digital-physical hybrid approaches for artifact interpretation. Its findings have implications for museum professionals, digital heritage researchers, and exhibition designers, offering practical recommendations for the adoption of holography in Islamic art museums. The study's experimental results will contribute to the broader discourse on immersive learning environments, demonstrating

how digital tools can enhance visitor engagement, accessibility, and cultural appreciation in museum settings.

3. CONTEXT AND SELECTED ARTIFACTS

3.1 Introduction to Islamic Funerary Inscriptions

Islamic funerary inscriptions serve as both artistic and historical records, reflecting the religious, social, and calligraphic traditions of different periods and regions. These inscriptions, often engraved on stone, marble, or ceramics, contain Qur'anic verses, prayers, names, and details of the deceased, sometimes accompanied by decorative motifs and poetic texts (Gonnella, 2022). They also showcase the evolution of Arabic calligraphy, with styles such as Kufic, Thuluth, Naskh, and Nastaliq developing over time (Bloom & Blair, 2019).

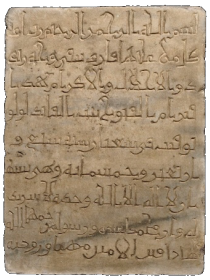
Despite their significance, funerary inscriptions can be challenging for contemporary museum visitors to interpret, as they rely heavily on script-based content. This study explores how holographic storytelling and 3D-printed replicas can enhance visitor engagement and accessibility by offering a more interactive, multi-sensory experience.

3.2 Selected Funerary Inscriptions for the Study

To ensure a diverse representation of Islamic funerary epigraphy, five inscriptions were selected based on their historical, artistic, and interpretative significance. These inscriptions originate from Egypt, Afghanistan, and India, spanning different time periods, calligraphic styles, and thematic expressions. The selection process aimed to cover a broad chronological range (11th–17th centuries) and represent different script styles (Kufic, Thuluth, and Naskh), regional influences, and epigraphic traditions. Some inscriptions feature purely religious texts, while others include poetic elegies or social titles, reflecting both the spiritual and socio-political aspects of Islamic funerary culture.

By integrating holographic storytelling and 3D-printed replicas, this study enhances visitor interaction with these inscriptions, bridging historical content with modern digital interpretation techniques. The holographic narrator animates the texts, explaining their meanings, artistic characteristics, and historical contexts, while physical replicas allow visitors to engage with the tactile qualities of the inscriptions. Table 1 presents the five funerary inscriptions selected for the study, highlighting their origin, period, material, calligraphic style, and key features.

Table 1. Overview of Selected Islamic Funerary Inscriptions for Holographic Interpretation

Artifact Code	Characteristics	Key Features & Significance	Image
LNS 4 S	• Origin: Egypt • Period: 11th century CE • Material: Marble • Calligraphic Style: Kufic (Simple Kufic Script)	A rectangular tombstone belonging to Umm al-Futuh bint al-Qa'id Lulu. The inscription starts with Bismillah (In the name of God) and includes two Qur'anic verses (Surah Al-Rahman: 26-27), emphasizing the inevitability of death. The date of death and Shahada (Islamic declaration of faith) are also included. The holographic narrator explains the symbolic use of Qur'anic verses in Islamic funerary epigraphy.	
LNS 77 S	• Origin: Egypt • Period: 12th century CE • Material: Limestone • Calligraphic Style: Kufic (Simple Kufic Script)	A cylindrical gravestone for Yusuf Al-Hajj, a merchant, featuring an incomplete inscription due to missing upper parts. It begins with Bismillah, followed by the Qur'anic verse, "Every soul shall taste death". The inscription includes the deceased's profession (merchant) and a prayer for mercy. The hologram explores the role of titles in Islamic funerary inscriptions and their reflection of social hierarchy.	
LNS 54 S	• Origin: Egypt • Period: 13th century CE • Material: Sandstone • Calligraphic Style: Thuluth (Decorative Calligraphy)	A highly ornamental tombstone featuring two mihrab-shaped frames with Ayat Al-Kursi (The Throne Verse, Surah Al-Baqarah 2:255) inscribed between them. The Thuluth script is characterized by its dynamic movement and elongated letterforms. The holographic storyteller demonstrates how Thuluth inscriptions were carved and their significance in religious and funerary contexts.	
LNS 28 S	• Origin: Afghanistan • Period: 14th century CE • Material: Stone • Calligraphic Style: Thuluth (Large & Decorative)	A tomb enclosure for Sheikh Abu Al-Fadl Muhammad Al-Tusi, consisting of four vertical panels, with the upper section forming a stepped, saddle-like shape. The large-scale Thuluth script makes the inscription highly visible from a distance. The hologram highlights the use of Thuluth in religious monuments and its role in commemorating prominent figures.	
LNS 314 S	• Origin: India • Period: 16th century CE • Material: Marble • Calligraphic Style: Naskh (Mixed with Kufic & Nastaliq)	The tombstone of Imam Sa'd Mas'ud bin Sadr Al-Amir Jalal Al-Din features a mihrab-shaped niche with a decorative mashrabiya-like pattern. The Shahada (Islamic declaration of faith) is inscribed in Kufic, while a poetic elegy is written in Naskh. The holographic storytelling animates the inscription's poetic meaning and visualizes how such tombstones reflected the deceased's social and religious status.	

4. METHODOLOGY

This study employs an experimental case study approach to examine the effectiveness of holographic storytelling and sculpted replicas in enhancing visitor engagement and comprehension in Islamic art museums. The research assesses how digital and physical elements contribute to the interpretation of Islamic funerary inscriptions, integrating experimental implementation, visitor evaluation, and both qualitative and quantitative data analysis to measure the impact of multi-sensory engagement on learning experiences.

4.1 Experimental Design and Implementation

The original inscriptions used in this experiment are part of the collection of the Islamic Antiquities Museum of Kuwait, known for its rich repository of Islamic calligraphy and funerary art. The experiment was conducted at the Shaikh Abdullah Al-Salem Cultural Center (Kuwait), where holographic storytelling and sculpted replicas were integrated into the exhibition space. The selected Islamic funerary inscriptions represented a diverse range of historical contexts, calligraphic styles, and cultural influences, ensuring that the study explored various interpretative approaches. Visitors engaged with the inscriptions through a three-phase interactive experience:

Viewing the inscriptions in their original form, displayed in the museum.

Interacting with sculpted replicas, allowing tactile exploration of textures, calligraphy, and relief details.

Listening to a holographic narrator, providing historical context, artistic interpretation, and cultural insights.

This setup allowed for a comparative analysis of visitor responses to traditional static displays versus multi-sensory digital and physical experiences, examining how holography and sculpted replicas enhance knowledge retention, engagement, and appreciation. The narration was delivered exclusively in Arabic, reflecting the linguistic and cultural background of all participants involved in the study.

4.2 Development of the Holographic Storyteller and Sculpted Replicas

4.2.1 Holographic Storyteller Design

The narrator was displayed using a holographic fan (i.e., a spinning LED display device that creates a 3D visual illusion by rapidly projecting light patterns in mid-air). This technique, often referred to as a 3D LED hologram, allowed for a visually striking presence of the narrator figure within the museum setting. The display was pre-programmed and non-interactive, ensuring consistency across all visitor sessions. The development process involved:

- *Script Development:* A carefully structured narrative was created to ensure historical accuracy while adopting an engaging, accessible storytelling approach to enhance visitor interest.

- *Character Design:* The holographic figure was based on a historical scholar dressed in period-appropriate attire, as shown in Figure 1 (a). This design choice aimed to enhance authenticity and relatability.
- *Voice and Animation:* The narration was recorded by a professional voice-over artist, with synchronized animated facial expressions and gestures to create a natural and engaging delivery.
- *Projection Setup:* The holographic narrator was displayed using a 3D LED holographic fan, a device that spins LED strips at high speed to create the illusion of a floating, three-dimensional figure. While visually engaging, the display was non-interactive and pre-programmed to deliver the interpretive narration consistently for all visitors.

This approach allowed visitors to experience a personalized, immersive interpretation of the funerary inscriptions, making historical content more accessible, engaging, and memorable.

4.2.2 Sculpted Replicas of Funerary Inscriptions

To complement the holographic experience, high-fidelity sculpted replicas of the inscriptions were created, providing visitors with a tactile, hands-on engagement opportunity. Unlike 3D printing, these replicas were manually sculpted to replicate the inscriptions' relief details, textures, and calligraphic intricacies. The production process involved:

- *Manual Carving and Molding:* Skilled artisans replicated the engraved inscriptions, ensuring high accuracy in letterforms, depth, and relief features.
- *Material Selection:* The replicas were crafted using materials resembling the original stone and marble inscriptions, chosen for their ability to mimic texture, weight, and aesthetic qualities.
- *Surface Finishing:* The final replicas underwent detailed surface treatment, including hand-painting and aging techniques, to ensure historical authenticity, as in Figure 1 (b).

(a) (b) (c) (d)

Figure 1: Holographic Storyteller and Sculpted Replicas; (a) holographic narrator during the design phase; and (b) samples of sculpted replicas replicating original inscriptions.

By integrating both digital (holography) and physical (sculpted replicas) interpretative tools, visitors could visually, aurally, and tactilely engage with the funerary inscriptions, creating a deeper and more meaningful museum experience (Nofal et al., 2023).

4.3 Visitor Evaluation and Data Collection

To assess the impact of holographic storytelling and 3D replicas, data was collected using a combination of observations, visitor surveys, and interviews. This approach allowed for a comprehensive evaluation of visitor engagement, learning outcomes, and interaction behaviors.

4.3.1 Observational Study

An observational study was conducted to examine how visitors interacted with the hologram and 3D replicas (Figure 2). Observations focused on:

- Dwell time (how long visitors spent engaging with each element).
- Behavioral indicators of engagement, such as facial expressions, gestures, and whether visitors discussed the artifacts with others
- Patterns of interaction, such as repeated engagement with the hologram or closer examination of the 3D-printed replicas

This non-intrusive method provided insights into visitor behaviors without disrupting their experience (Bitgood, 2013).

Figure 2. Part of the experiment shows the holographic narrator with the background along with the sculpted replicas of funerary inscriptions.

4.3.2 Survey Questionnaire

A structured visitor survey was designed to evaluate:

- Pre-existing knowledge of Islamic funerary inscriptions.
- Perceived effectiveness of holographic storytelling.
- Comparison between traditional static displays and interactive digital-physical methods.
- Overall visitor satisfaction with the exhibition experience.

The survey used a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), allowing for quantitative analysis of visitor perceptions (Cohen et al., 2018).

4.3.3 Semi-Structured Interviews

Ten semi-structured interviews were conducted in person at the museum immediately after the exhibition visit. Each interview lasted approximately 10-15 minutes and was recorded with participants' verbal consent. Interview topics included:

- The effectiveness of the holographic storyteller in conveying historical narratives.
- The impact of combining digital and physical interpretation methods.
- Suggestions for improving interactive museum experiences.

The interviews were transcribed and thematically analyzed by two independent coders to identify recurring themes. Inter-coder reliability was confirmed through consensus discussion, ensuring the consistency of the qualitative interpretation (Creswell & Poth, 2018).

The research protocol followed institutional ethical standards of the University of Sharjah and the host museum. Participants provided informed consent, were briefed on data use, and could withdraw at any time. No personal identifiers were collected.

Participant categories were defined as follows: employees (museum or cultural-sector staff), students (university attendees), homemakers (non-employed participants managing households), and residents/citizens (based on nationality status). These categories were non-exclusive but used to capture diverse visitor demographics transparently.

4.3.4 Data Analysis

The collected data was analyzed using a mixed-methods approach, combining quantitative statistical analysis and qualitative coding:

- Survey responses were analyzed using descriptive statistics, calculating mean scores, standard deviations, and frequency distributions to assess visitor perceptions (Cohen et al., 2018).
- Observational data was categorized based on engagement indicators, including dwell time, facial expressions, and verbal interactions (Bitgood, 2013).

- Interview transcripts were analyzed using thematic coding by two independent reviewers, identifying recurring themes such as perceived authenticity, engagement levels, and learning effectiveness.

By integrating quantitative and qualitative insights, this analysis provided a holistic understanding of how holographic storytelling and 3D replicas influenced visitor engagement and learning.

5. RESULTS

This section presents the results of the study, analyzing visitor engagement, perception, and learning outcomes following the integration of holographic storytelling and sculpted replicas in the interpretation of Islamic funerary inscriptions. The findings are derived from three key sources:

- Observational analysis, assessing visitor interaction and behavior
- Survey results, quantifying satisfaction, and engagement levels.
- Interview feedback, providing qualitative insights into visitor experiences.

5.1 Observational Findings: Visitor Engagement and Interaction

Observational analysis captured visitor reactions and engagement behaviors during the experiment. The recorded footage revealed that visitors exhibited strong engagement with both the holographic storyteller and sculpted replicas, demonstrating different levels of interaction.

Many visitors appeared fully immersed in the holographic narration, displaying focused attention and emotional reactions such as smiles, nods, and even expressions of amazement (Figure 3). Some visitors were particularly impressed by the realism of the hologram, expressing fascination at how the voice matched the digital character's appearance and movements. This sense of realism encouraged repeated viewings, with some visitors watching the presentation multiple times, which is an indication of sustained interest. Another notable observation was the way visitors actively engaged with the sculpted replicas. After listening to the holographic narrator, several participants approached the replicas and attempted to read the inscriptions, tracing the engraved calligraphy with their fingers. This suggests that the combination of visual and tactile experiences encouraged deeper exploration.

Social engagement was another key pattern. Groups of visitors discussed the inscriptions, posed questions to one another, and took notes, showing that the multi-sensory experience fostered curiosity and discussion. In addition, some visitors photographed or recorded the holographic storyteller, indicating a desire to capture and share the experience. These observations suggest that multi-sensory engagement significantly enhances visitor interaction and curiosity, particularly by bridging textual content with visual and tactile experiences.

Figure 3. Visitor engagement reflects interaction and immersion in the holographic storytelling experience.

5.2 Participant Demographics and Questionnaire Results

A total of 43 visitors participated in the post-exhibit questionnaire, representing diverse demographic backgrounds. The participants included both citizens and residents, with a mix of employees, students, and homemakers. Most participants were working professionals (81.4%), followed by university students and homemakers, as shown in Figure 4.a. The survey also included a diverse mix of nationalities (Figure 4.b).

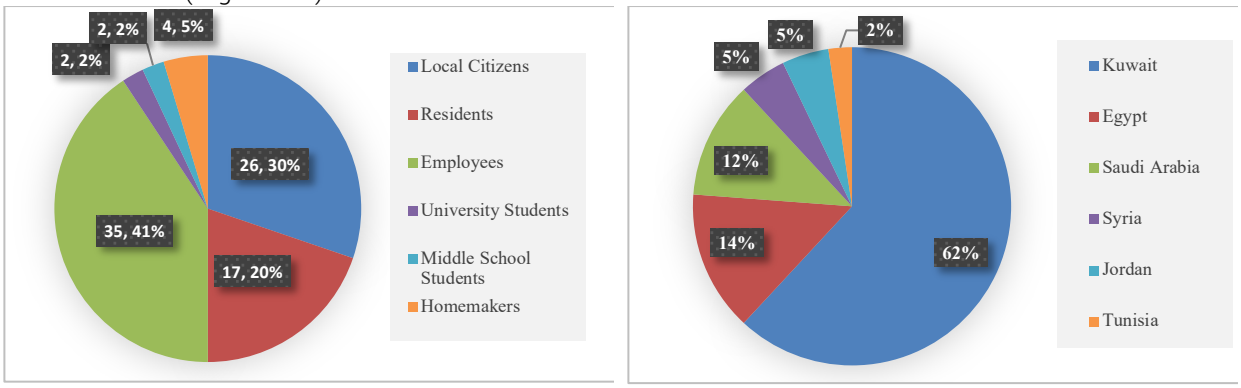


Figure 4. Participants demographic: (a) demographic breakdown of participants, and (b) nationalities of participants.

After participating in the exhibit, visitors were asked to evaluate their experience using a Likert scale questionnaire (1 = strongly disagree, 5 = strongly agree). The results are summarized in Table 2 and Figure 5. The highest-rated aspect was satisfaction with the holographic storyteller (4.91), followed by the acceptance of using a well-known figure (4.84). The lowest score (2.12) indicated limited prior knowledge of Islamic funerary inscriptions, demonstrating the exhibit's educational value.

Table 2. Visitor Satisfaction and Learning Outcomes (n = 43)

Survey Question	Mean Score	% Agreement (4 & 5 responses)	Satisfaction Level
Prior knowledge of Islamic civilizations before the exhibit.	3.00	48.9%	Moderate
Prior knowledge of Islamic funerary inscriptions.	2.12	16.3%	Low
The exhibit was clear and easy to understand.	4.33	86.0%	Very High
The exhibit was enjoyable.	4.35	83.7%	Very High
The exhibit was easy to follow.	4.51	93.1%	Very High
The exhibit exceeded expectations.	4.00	65.1%	High
The hologram added value to the museum environment.	4.67	93.1%	Very High
Acceptance of using a well-known artistic figure as the storyteller.	4.84	98.1%	Very High
Satisfaction with the holographic storyteller.	4.91	99.1%	Very High
The exhibit introduced new information.	4.56	91.0%	Very High
Overall satisfaction with the exhibit.	4.53	92.0%	Very High

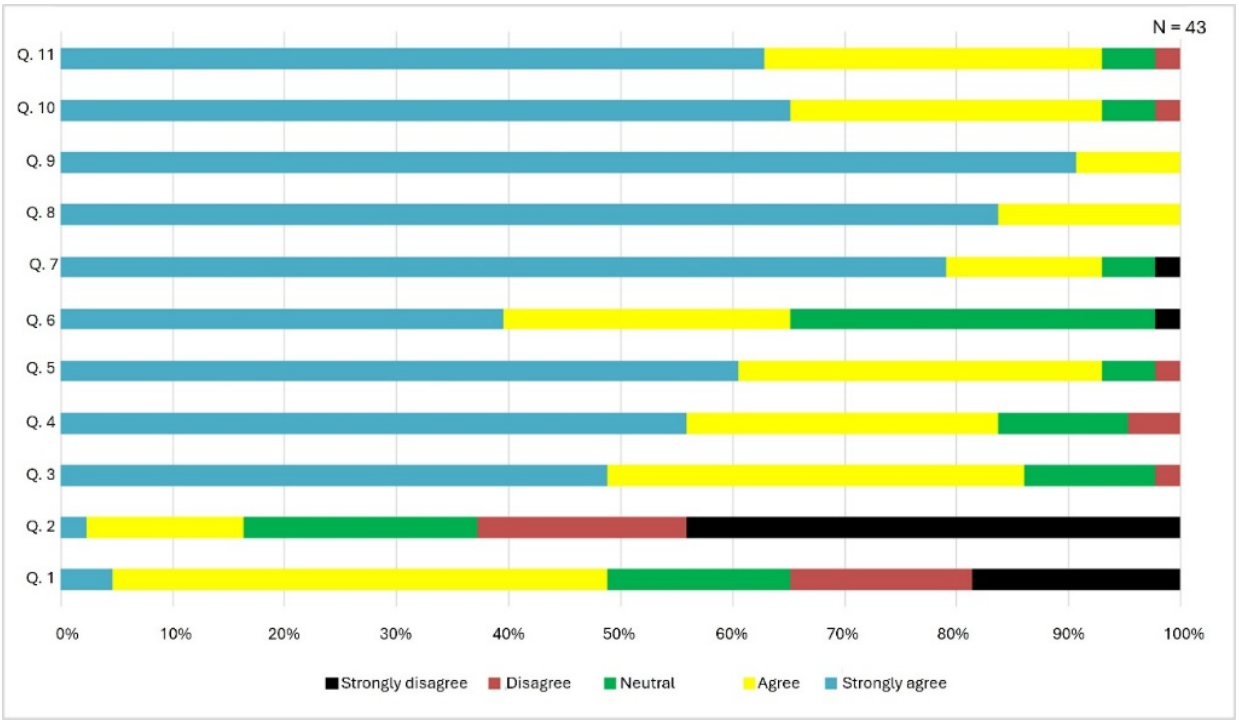


Figure 5. Analysis of the questionnaire results (n=43).

5.3 Qualitative Insights from Visitor Interviews

To gain deeper insights, semi-structured interviews were conducted with a subset of participants. The findings were categorized into key themes:

5.3.1 Learning and New Knowledge Gained

Many visitors were surprised by the artistic diversity of Islamic funerary inscriptions, noting that they had previously assumed tombstones were purely functional rather than historical artifacts. One of the participants stated: *"I never realized that inscriptions varied so much across regions—this exhibit made me appreciate the artistry behind them"*. Several participants mentioned that they had not known inscriptions included poetry and historical references. Another visitor remarked: *"I thought tombstones only included names and dates, but I learned that they also reflect cultural values and social status"*.

5.3.2 Impact of the Holographic Storyteller

Most visitors praised the engaging nature of the hologram, highlighting how storytelling made the information easier to understand and more memorable. One participant said: *"The hologram made me feel like I was learning from a real person, not just reading from a label"*. Some visitors expressed amazement at the realism of the digital character, noting how it felt like an actual museum guide was speaking to them.

5.3.3 Future Use of Holography in Museums

Most interviewees supported expanding holographic storytelling to other exhibits, emphasizing its ability to bring historical narratives to life. One visitor suggested: *"It would be great to have holograms for other artifacts, especially those that are incomplete or missing parts"*.

6. DISCUSSION

This section discusses the key findings of the study, interpreting the results in relation to existing literature and their implications for museum exhibition design and visitor engagement. The discussion is structured into several themes that emerged from the findings.

6.1 Multi-Sensory Engagement Enhances Learning and Retention

The study demonstrates that multi-sensory engagement significantly enhances visitor learning and knowledge retention in museum settings. Visitors who interacted with both the holographic storyteller and sculpted replicas exhibited higher engagement levels, as evidenced by extended dwell time and active participation in discussions. Survey responses confirmed this trend, with 91% of participants indicating that they learned something new from the exhibit. These findings align with Falk and Dierking's (2016) contextual model of learning, which emphasizes the role of sensory interaction in deepening museum experiences. Prior research also suggests that tangible interactions reinforce cognitive engagement, particularly in exhibits that rely on historical artifacts and textual interpretation (Sylaiou et al., 2010). These findings also resonate with research in cognitive and

emotional neuroscience, which highlights that sensory stimulation and emotional arousal jointly enhance learning and memory (Damasio, 1994; Ledoux, 1996). In this sense, holographic storytelling and tactile interaction activate both cognitive and affective pathways, making the museum experience not only intellectually stimulating but also emotionally memorable. Such embodied engagement reflects what Antinucci (2003) describes as the "technological body," where technology extends human perception and facilitates experiential understanding.

Given that prior knowledge of Islamic funerary inscriptions was low among participants (mean score: 2.12), the study suggests that traditional static displays may not be sufficient for transmitting complex historical and artistic information to general audiences. Future museum exhibits could benefit from greater integration of multi-sensory elements, particularly for text-heavy artifacts that require deeper contextualization.

6.2 Holographic Storytelling Improves Visitor Engagement and Emotional Connection

The study provides strong evidence that holographic storytelling significantly enhances visitor engagement and emotional connection to historical content. Survey results showed that 99% of participants were satisfied with the holographic narrator, while 83.7% fully accepted the use of a well-known artistic figure as the storyteller. Observational data further supported these findings, as visitors repeatedly viewed the holographic presentation, took notes, and discussed the content with peers. This aligns with Carrozzino and Bergamasco's (2010) findings, which highlight the effectiveness of immersive digital storytelling in fostering historical empathy. Roussou and Katifori (2018) also emphasize that interactive virtual narrators personalize visitor experiences, making historical events and figures feel more relatable and engaging.

Beyond engagement metrics, visitors' emotional resonance with the holographic narrator reinforces the link between emotion and comprehension in museum learning. As Damasio (1994) and Ledoux (1996) argue, emotions play a central role in shaping reasoning and recall; this was evident in the way participants described the hologram as a "real person" guiding them through the exhibit. Such responses confirm that affective connection can serve as a gateway to deeper cultural understanding.

While holography has proven to be a valuable tool for interpretation, one consideration is the balance between digital enhancement and historical authenticity. Some visitors suggested that combining holography with traditional museum guides could offer a hybrid approach, where human-led discussions complement digital storytelling. Future research could explore how holography affects long-term knowledge retention compared to traditional docent-led tours.

6.3 Bridging the Gap Between Static Epigraphy and Visitor Comprehension

Islamic funerary inscriptions often contain complex textual content that requires translation and historical explanation, making them less accessible to general audiences. Prior to the exhibit, 44.2% of visitors had little to no knowledge of Islamic funerary inscriptions, reinforcing the need for interpretative tools that make epigraphy more engaging and comprehensible. This study demonstrates that bridging textual content with interactive elements enhances visitor

understanding, as many participants attempted to read inscriptions after hearing the holographic narration. The concept of interactive epigraphy has been explored in previous studies, such as Nofal et al. (2018a), which found that augmented reality overlays help contextualize Arabic inscriptions for non-expert audiences.

However, a remaining challenge is ensuring accuracy and depth in digital interpretations. While the holographic narrator successfully explained inscription details, some visitors suggested that offering a choice between summarized and in-depth explanations could improve accessibility for different audience types. Museums implementing digital epigraphy solutions should consider adaptive storytelling techniques to cater to both casual visitors and specialists.

Finally, the study also touches upon the challenge of interpreting funerary artifacts, which inherently engage with themes of death and remembrance. By adopting a respectful narrative tone and focusing on the cultural and artistic dimensions of these inscriptions, the holographic storyteller enabled visitors to approach such "difficult heritage" with empathy rather than discomfort. This demonstrates how technology can serve as a sensitive mediator for complex or sacred heritage topics, maintaining authenticity while fostering understanding.

6.4 The Role of Cultural Familiarity in Visitor Reception of Digital Storytelling

One of the unique aspects of this study was the use of a well-known artistic figure as the holographic narrator, which received overwhelmingly positive feedback (98.1% acceptance rate). Many visitors expressed that the familiarity of the voice and character made the historical content more engaging, suggesting that cultural recognition plays a role in digital interpretation success. Previous research in museum engagement and media psychology suggests that familiarity with a narrator or presenter increases audience trust and attention retention (Bitgood, 2013). This is particularly relevant in heritage storytelling, where viewers may feel more connected to a familiar voice or figure explaining historical content.

However, a key consideration is the potential limitation of using region-specific figures for diverse museum audiences. While the choice of narrator was effective for this particular visitor demographic, broader museum contexts may require a balance between cultural familiarity and universal accessibility. Future research could explore whether customized digital narrators tailored to different visitor profiles enhance engagement further.

6.5 Implications for Future Museum Exhibit Design

The findings of this study contribute to ongoing discussions on the role of digital technology in museum interpretation, reinforcing the need for interactive, multi-sensory, and personalized approaches. This aligns with emerging trends in digital heritage, where museums worldwide are experimenting with VR, AR, and artificial intelligence-driven storytelling (Kenderdine, 2016).

Key takeaways for future museum design include:

- *Integrating digital and physical interpretation:* The combination of holography and sculpted replicas proved effective in bridging historical content with visitor engagement.

- *Offering adaptive storytelling options:* Museums could experiment with layered digital interpretations, allowing visitors to choose different levels of depth in explanations.
- *Enhancing accessibility through interactive epigraphy:* For text-heavy artifacts, overlay technologies such as AR or projection mapping could provide contextual translations and reconstructions.

By applying these insights, museums can develop more immersive and inclusive exhibits, ensuring that historical narratives remain engaging and accessible to diverse audiences.

7. CONCLUSION

This study explored the effectiveness of holographic storytelling and sculpted replicas in enhancing visitor engagement and comprehension of Islamic funerary inscriptions in museum settings. The findings demonstrate that multi-sensory interpretation significantly improves learning outcomes, with visitors displaying higher engagement levels, increased dwell time, and greater recall of historical content.

The results confirm that holography personalizes museum storytelling, making historical narratives more accessible and immersive, while tactile interaction with replicas reinforces learning through physical engagement. Additionally, the study highlights the importance of bridging text-based artifacts with interactive elements, ensuring that complex inscriptions become more comprehensible and engaging for diverse audiences.

From a broader perspective, these insights contribute to ongoing discussions on digital heritage and interactive museum design, supporting the integration of technology-driven interpretation methods in future exhibits. Museums can benefit from combining digital and physical storytelling approaches, offering adaptive, engaging, and accessible learning experiences. The study also demonstrates how holographic storytelling, when ethically and culturally contextualized, can contribute to the responsible interpretation of sensitive heritage themes such as funerary artifacts.

Future research could further explore long-term knowledge retention, the effectiveness of holography in different cultural contexts, and the potential of adaptive digital storytelling tailored to individual visitor preferences. By leveraging interactive technologies thoughtfully, museums can continue to evolve as dynamic, educational, and visitor-centered spaces.

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