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ENHANCING CULTURAL HERITAGE LEARNING IN MUSEUMS THROUGH TANGIBLE INTERACTION: A STUDY OF PRIMARY SCHOOL STUDENTS AT MLEIHA ARCHAEOLOGY CENTRE

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ABSTRACT

Museums play a crucial role in preserving and communicating cultural heritage, particularly for young learners. This study examines how tangible interaction and multisensory engagement enhance primary school students' understanding of cultural heritage in museum settings, focusing on Mleiha Archaeology Centre in Sharjah. Using a mixed-methods approach, the research integrates questionnaires (200 students), interviews with museum educators, and observational analysis to assess how tangible interaction influences students' comprehension of cultural heritage and their engagement with museum exhibits. Findings reveal that students engage more deeply and retain information better when physically interacting with exhibits. The most effective learning experiences included touching replica artifacts, participating in excavation activities, and engaging with digital storytelling. Survey results showed a strong preference for interactive over static text-based displays, with tangible interaction rated as the most effective modality (Mean Score: 4.50/5). Museum professionals highlighted challenges related to artifact preservation, budget constraints, and balancing digital and physical engagement. The study recommends expanding hands-on learning opportunities, integrating multisensory approaches, and strengthening school-museum collaborations. Additionally, museums should adopt a hybrid approach that combines digital tools with physical interaction to optimize educational outcomes. This research contributes to museum education strategies, emphasizing the need for interactive, engaging, and inclusive exhibits to foster a deeper appreciation of cultural heritage. Future studies should explore the long-term impacts of tangible interaction and cross-cultural comparisons of interactive museum education.

KEYWORDS: Tangible Interaction, Multisensory Learning, Museum Education, Cultural Heritage, Primary School Students, Mleiha Archaeology Centre.

1. INTRODUCTION

Museums are essential institutions for the preservation and dissemination of cultural heritage, playing a crucial role in fostering cultural awareness and education. They offer dynamic environments that merge learning with engagement, where innovative display techniques enhance visitors' understanding and appreciation of historical and cultural narratives (Muntean et al., 2015). Over the years, museums have evolved from static exhibition spaces to interactive learning hubs, responding to the growing need for immersive and participatory educational experiences (Duranti et al., 2016).

Recent advancements in educational technologies have facilitated the integration of interactive techniques, such as virtual reality (VR), augmented reality (AR), digital storytelling, and hands-on activities, to engage diverse audiences (Nikolakopoulou et al., 2021; Boboc et al., 2022; Bachiller et al., 2023).

These methods are particularly effective for children, as they support active learning and multisensory engagement, improving both retention and comprehension of complex heritage concepts (Falcão & Price, 2010). Research suggests that museum-based learning is significantly enhanced when visitors can physically or virtually interact with exhibits, rather than passively observing them (Avram et al., 2019).

Given the increasing importance of interactive learning, this study investigates the role of tangible interaction in museums, focusing on its impact on primary school students' understanding of cultural heritage.

The research takes Mleiha Archaeology Centre in Sharjah as a case study, exploring how sensory engagement influences children's cognitive and emotional responses to heritage content. The study builds upon existing research that highlights the effectiveness of tangible interaction in making cultural heritage more accessible, particularly for younger audiences (Nofal et al., 2018). While several studies in the UAE have addressed museum education, few have empirically examined tangible interaction with primary school students. This study is among the first to provide evidence from the Gulf region, thereby filling a significant gap in regional museum learning literature.

1.1. Research Problem and Questions

Cultural institutions, including museums and heritage centres, have long been recognized as important educational resources. However, despite advancements in display technologies, many museums still rely on traditional, text-heavy approaches that may not be engaging for children (Chatzigrigoriou et al., 2021). Interactive techniques –especially those that involve physical interaction– are gaining recognition for their ability to enhance visitor engagement and promote deeper learning (Tan & Lim, 2017).

The challenge remains in assessing the extent to which these methods contribute to enhanced comprehension and long-term retention of cultural heritage knowledge among children. Understanding how different types of tangible interaction –such as hands-on replicas, interactive screens, and augmented reality affect children's engagement in museum environments is crucial for improving educational strategies in heritage institutions (Nikolakopoulou et al., 2021).

This study seeks to address the following key research question:

- How does tangible interaction influence primary school students' understanding of cultural heritage in museum environments?

Supporting sub-questions include:

- How does tangible interaction shape children's engagement and participation in museum activities?
- What types of interactive techniques are most effective in enhancing students' comprehension of cultural heritage?
- What lessons can be learned from the case of Mleiha Archaeology Centre to inform future museum practices?

1.2. Objectives and Significance of the Study

The primary objective of this study is to analyse the impact of tangible interaction on children's understanding of cultural heritage in museum environments. The research aims to evaluate the effectiveness of hands-on and sensory-based approaches in improving knowledge retention, engagement, and curiosity among primary school students.

Additionally, the study seeks to assess the current state of interactive learning experiences at Mleiha Archaeology Centre, identifying strengths and potential areas for improvement. By comparing findings with international museum practices, the study aspires to offer practical recommendations for enhancing visitor engagement in regional heritage institutions (Nofal et al., 2017).

The significance of this research lies in its contribution to museum education strategies, particularly in the context of the UAE, where cultural heritage plays a central role in national identity formation.

Findings from this study can support museum professionals, educators, and policymakers in developing more engaging, inclusive, and educational museum experiences for children (Avram et al., 2019).

By examining how interactive methods can enhance cultural appreciation among younger audiences, this research aims to bridge the gap between traditional heritage presentation techniques and modern interactive learning approaches, ensuring that museums remain vibrant educational spaces for future generations (Muntean et al., 2015).

2. TANGIBLE INTERACTION AND SENSORY ENGAGEMENT IN MUSEUM EXPERIENCES

Museums have long relied on visual and auditory-based approaches to convey cultural heritage, but recent advancements in technology and exhibition design have demonstrated the importance of multisensory engagement in enhancing visitor experiences (Duranti et al., 2016). Tangible interaction which allows visitors to physically engage with museum exhibits through touch, movement, and interactive elements– has gained increasing recognition as a powerful tool for improving cultural understanding, particularly among children (Nofal et al., 2020).

This section explores the role of tangible interaction in museum environments, highlighting its impact on visitor engagement, learning outcomes, and accessibility. It also examines the different types of sensory interactions commonly found in museums and how these elements contribute to immersive and inclusive museum experiences.

2.1. Multisensory Engagement in Museums: Enhancing Visitor Experience

Museums have traditionally relied on visual and textual representations to communicate cultural heritage, yet research increasingly highlights the significance of multisensory engagement in improving visitor experiences. Multisensory learning where visitors interact with exhibits through a combination of sight, sound, touch, smell, and even taste has been shown to enhance comprehension, engagement, and memory retention (Duranti et al., 2016).

This approach transforms museums from passive knowledge repositories into interactive educational spaces, making cultural heritage more accessible, immersive, and memorable (Avram et al., 2019; Boboc et al., 2022).

2.1.1. The Role of Multisensory Learning in Museums

Multisensory engagement in museum environments is based on embodied cognition theories, which suggest that learning is most effective when multiple senses work together to construct meaning (Falcão & Price, 2010).

Studies have found that combining visual, auditory, and tactile elements enhances concept retention and emotional connection to cultural artifacts (Nikolakopoulou et al., 2021). Multisensory engagement benefits diverse audiences, including children, elderly visitors, and individuals with disabilities, by providing alternative pathways to understanding cultural heritage. For example, the British Museum has incorporated tactile learning zones and audio guides tailored for visually impaired visitors, allowing them to experience artifacts through touch and detailed verbal descriptions (Chatzigrigoriou et al., 2021).

Multisensory museum experiences have been linked to higher emotional involvement and improved memory recall. Sensory stimuli, particularly tactile engagement and storytelling through sound and visuals, help visitors develop a stronger connection to the historical and cultural narratives presented in exhibitions (Muntean et al., 2015). When visitors can physically interact with exhibits whether by handling replicas or engaging in digital storytellingtheir ability to recall details and historical facts improves significantly (Nofal et al., 2018).

2.1.2. Sensory Modalities in Museum Engagement

Different sensory modalities contribute uniquely to museum learning experiences, each enhancing engagement and understanding in distinct ways, as illustrated in Table 1.

Research suggests that when multiple senses are engaged simultaneously, visitors retain more information and develop stronger personal connections to cultural heritage (Duranti et al., 2016).

Table 1: Sensory Modalities in Museum Engagement.

Sensory Modality	Description	Example in Museums
Sight (Visual Interaction)	The primary mode of learning in museums, encompassing paintings, artifacts, digital projections, and augmented reality.	The Museum of Islamic Art in Qatar uses projection mapping to reconstruct historical architecture in immersive visual experiences.
Hearing (Auditory Engagement)	Includes audio guides, oral histories, and soundscapes to create an immersive atmosphere and provide additional context.	The Louvre Museum offers an interactive audio tour that enhances visitor engagement through narrations and environmental sound design.
Touch (Tactile Interaction)	Hands-on experiences with replica artifacts, 3D models, and interactive screens, improving learning through physical engagement.	The Mleiha Archaeology Center allows visitors to handle replica tools and artifacts, making ancient history tangible.
Smell (Olfactory Stimulation)	Uses scents to evoke historical environments, cultural traditions, or archaeological contexts.	The Perfume Museum in France recreates historical fragrances, offering visitors a deeper sensory experience.
Taste (Gastronomic Experiences)	Provides historical or cultural immersion through food tastings and culinary experiences.	Spanish Gastronomic Museums offer tastings of traditional dishes to help visitors understand culinary heritage.

2.1.3. The Role of Multisensory Learning in Accessibility and Inclusion

Multisensory engagement is particularly valuable in making museums more inclusive, ensuring that visitors of all abilities can participate in heritage experiences. For instance: (a) Visually impaired visitors benefit from tactile models and detailed audio descriptions (Chatzigrigoriou et al., 2021). (b) Visitors with hearing impairments engage more effectively through visual storytelling, digital reconstructions, and text-based interactive displays (Tan & Lim, 2017). (c) Children and neurodiverse visitors find multisensory experiences more engaging, as they accommodate different learning styles (Muntean et al., 2015). Museums such as The Science Museum in London have introduced multisensory installations where visitors can touch, smell, and interact with historical reconstructions, improving engagement and accessibility for all audiences.

2.1.4. Challenges and Considerations in Implementing Multisensory Engagement

Despite its benefits, integrating multisensory engagement in museums presents several challenges, such as (a) Preservation Concerns: Some artifacts are too fragile to be handled, necessitating the use of replicas and digital alternatives (Nikolakopoulou et al., 2021). (b) Cost and Resource Limitations: Developing high-quality multisensory exhibits requires significant investment in technology, materials, and maintenance (Nofal et al., 2018). (c) Visitor Adaptation: Some visitors may be unfamiliar with interactive elements, requiring clear guidance on engagement methods (Avram et al., 2019).

To overcome these challenges, museums should adopt strategic approaches to multisensory learning, such as:

- Combining Physical and Digital Interaction – Using 3D-printed replicas, augmented reality, and projection mapping to provide interactive yet artifact-safe engagement (Tan & Lim, 2017).
- Developing Inclusive Sensory Displays – Implementing Braille panels, sensory-friendly exhibits, and multilingual audio guides to enhance accessibility (Chatzigrigoriou et al., 2021).
- Encouraging Interactivity in School Visits – Designing curriculum-aligned educational programs that incorporate hands-on and multisensory experiences, improving long-term knowledge retention (Muntean et al., 2015).

2.2. The Role of Tangible Interaction in Enhancing Museum Experiences

2.2.1. Enhancing Learning and Knowledge Retention

Tangible interaction has been widely studied for its ability to enhance learning by bridging the gap between passive observation and active participation (Avram et al., 2019). Studies have shown that multisensory engagement leads to improved information retention, as visitors are more likely to remember details from an experience that involved physical interaction and emotional engagement (Nikolakopoulou et al., 2021). Children, in particular, benefit from hands-on experiences that allow them to explore heritage artifacts through touch, movement,

and direct interaction (Falcão & Price, 2010). By engaging multiple senses simultaneously, museums can transform abstract historical narratives into tangible and relatable experiences, fostering curiosity and deeper understanding (Muntean et al., 2015).

2.2.2. Increasing Engagement and Participation

Museums that incorporate tangible interaction report higher visitor engagement and increased time spent at exhibits (Chatzigrigoriou et al., 2021). When visitors can touch, manipulate, or physically explore museum content, their level of curiosity and immersion increases, making them more likely to engage with educational material.

Interactive storytelling methods, such as projection mapping and augmented reality, further enhance engagement by blending physical and digital elements (Nofal et al., 2018). Museums like the British Museum and the Museum of Islamic Art in Qatar have successfully integrated these technologies to create interactive narratives that make cultural heritage more accessible and appealing to younger audiences (Tan & Lim, 2017).

2.2.3. Promoting Accessibility and Inclusion

Multisensory engagement is particularly valuable for making museums more inclusive. Traditional museum displays often rely heavily on text-based and visual content, which can be limiting for visitors with visual impairments, learning disabilities, or different cognitive abilities (Duranti et al., 2016). By incorporating tactile models, auditory storytelling, and olfactory cues, museums can cater to a wider range of learning styles and abilities (Avram et al., 2019). This approach aligns with the principles of universal design, ensuring that cultural heritage is accessible to all visitors, regardless of age or ability (Chatzigrigoriou et al., 2021). Tangible interaction and multisensory engagement have transformed museum learning, making cultural heritage more accessible, engaging, and memorable. Museums that adopt interactive storytelling, sensory immersion, and hands-on learning techniques not only enhance visitor experiences but also promote deeper understanding and cultural appreciation (Nofal et al., 2017). The following sections of this study will build upon these concepts, exploring the specific case of Mleiha Archaeology Centre and how its interactive features influence children's understanding of cultural heritage.

3. METHODOLOGY

This study employs a descriptive-analytical approach to examine the impact of tangible interaction on primary school students' understanding of cultural heritage in museum environments. The research focuses on Mleiha Archaeology Centre in Sharjah as a case study, using both quantitative and qualitative methods to assess the effectiveness of interactive learning techniques.

3.1. Mleiha Archaeology Centre: Context and Significance

Mleiha Archaeology Centre is one of the most significant heritage sites in the UAE, offering insights into the region's prehistoric and early Islamic past. Located 50 km east of Sharjah, the site has been recognized for its rich archaeological findings, including burials, artifacts, and inscriptions dating back more than 130,000 years (Overlaet, 2015). The centre was established as part of a broader initiative to preserve and interpret the cultural heritage of the region, transforming Mleiha into an interactive educational and tourism destination. The historical importance of Mleiha stems from its role as an ancient trade hub linking the Arabian Peninsula to neighbouring civilizations. Excavations have uncovered camel and horse burials, fortifications, and evidence of early settlements, demonstrating the area's continuous human occupation from the Palaeolithic to pre-Islamic periods (Jasim, 2006). The presence of South Arabian and Aramaic inscriptions further indicates its cultural and commercial connectivity with broader regional networks (Mouton, 1999).

(a) (b) (c)

Figure 1: Interpretation Displays at Mleiha Archaeology Centre. (a) Traditional Exhibits Featuring Explanatory Posters, (b) Interactive Hologram Touch Screen, and (c) Projection Mapping on Horse Sculpture.

3.2. Research Approach and Data Collection Methods

The study adopts a mixed-methods approach, combining

1. Questionnaire to measure students' engagement and comprehension.
2. Qualitative interviews with experts and educators to gain insights into interactive museum practices.
3. Observational studies to assess children's real-time interactions with tangible and digital exhibits.

This combination allows for a comprehensive evaluation of how tangible interaction, multisensory and hands-on learning experiences influence students' learning outcomes.

3.2.1. Questionnaire

A structured questionnaire was designed and distributed to assess students' engagement and comprehension following their visit to the Mleiha Archaeology Centre. The questionnaire consisted of two main parts

- Section 1 (Demographics): Collected basic information including gender, grade level, school type, and preferred language of learning.
- Section 2 (Perceptions of Interactive Learning): Comprised 14 items measured on a five-point Likert scale (ranging from 1 = Strongly Disagree to 5 = Strongly Agree). The items evaluated students' preferences for interactive learning methods, the effectiveness of different sensory modalities (visual, auditory, tactile), and their perceptions of how tangible interaction and multisensory engagement supported cultural heritage learning.

To ensure the reliability of the instrument, internal consistency was tested using Cronbach's alpha, which produced a coefficient of 0.82, indicating good reliability and scale consistency.

The questionnaire was administered to 200 primary school students (ages 7–12), and the sample was selected using a stratified sampling method. Stratification was based on gender, grade level, school type, and preferred language of learning. This approach ensured a balanced and representative distribution across key demographic variables, thereby improving the generalizability of the findings.

3.2.2. Interviews with Experts

Semi-structured interviews were conducted with (a) Museum educators and exhibition designers at Mleiha Archaeology Centre, and (b) School teachers who accompanied students on field trips. These interviews explored:

- The role of interactive techniques in fostering cultural heritage awareness.
- The challenges and best practices of implementing tangible interaction in museum environments.

The interviews were transcribed and thematically analysed, identifying recurring insights related to children's learning behaviours, challenges in exhibition design, and the effectiveness of sensory engagement.

3.2.3. Observational Analysis

To supplement survey and interview data, direct observations were conducted at the Mleiha Archaeology Centre. Researchers analysed students' interactions with

- Replica artifacts and hands-on displays.
- Augmented reality storytelling experiences.
- Interactive screens and sensory-based installations.

The observations helped identify patterns of engagement, learning behaviours, and preferred sensory modalities, which were categorized and analysed to detect behavioural trends in children's museum experiences.

3.3. Study Population and Sampling

The study targeted primary school students (ages 7–12) who participated in educational visits to Mleiha Archaeology Centre. The sample included:

- Students from both government and private schools in Sharjah, selected through stratified sampling to ensure diversity.
- Museum professionals and heritage educators, interviewed to provide expert perspectives on interactive museum experiences.

The study sample consisted of 200 students, who participated in the questionnaire survey, and a group of museum professionals and educators, who were interviewed to provide expert insights on interactive learning in museum environments. The stratified selection of students ensured a balanced representation of different educational backgrounds, enhancing the validity and applicability of the findings.

- To ensure research integrity and participant safety, the study adhered to ethical guidelines
- Informed consent was obtained from students' guardians and school representatives before participation.

- Confidentiality was maintained for all responses, ensuring anonymity in survey and interview results.
- Objectivity in data interpretation was ensured by cross-validating quantitative and qualitative findings.

4. RESULTS

This section presents the findings of the study, analysing how tangible interaction and multisensory engagement impact primary school students' understanding of cultural heritage at the Mleiha Archaeology Centre. The results are structured as follows

1. Questionnaire Analysis: Quantitative insights from student responses, including demographics, engagement levels, and learning preferences.
2. Interview Analysis: Qualitative insights from museum educators and heritage experts on interactive learning strategies.
3. Observational Findings: Analysis of student behaviour and engagement patterns during interactive activities at the museum.

4.1. Questionnaire Analysis: Student Engagement and Learning Preferences

A structured questionnaire was administered to 200 primary school students following their visit to the Mleiha Archaeology Centre. The survey focused on Demographic distribution of respondents, students' engagement levels with interactive learning, the role of sensory modalities in improving comprehension and retention, and the impact of school visits on students' understanding of cultural heritage.

4.1.1. Demographic Profile of Respondents

The study ensured a balanced representation of students based on age, gender, and school type, as summarized in Table 2. Findings indicate that 85.5% of students prefer Arabic in museum settings, highlighting the importance of using Arabic in educational materials and interactive content. The relatively even gender and school-type distribution ensures that findings are representative across different student demographics.

Table 2: Demographic Characteristics of Survey Respondents.

Category	Group	Frequency (n)	Percentage (%)
Gender	Male	94	47.0%
	Female	106	53.0%
Grade Level	Grades 1-4	118	59.0%
	Grades 5-7	82	41.0%
School Type	Government	104	52.0%
	Private	96	48.0%
Preferred Language	Arabic	171	85.5%
	English	29	14.5%

4.1.2. Student Perceptions of Interactive Museum Experiences

Survey results indicate that students strongly prefer interactive learning methods, particularly those incorporating modern technologies, tangible interaction, and sensory engagement. The detailed survey results are summarized in Table 3, presenting student perceptions on key aspects of interactive museum learning.

The survey results highlight that tangible interaction (touch) emerged as the most effective sensory engagement method, receiving the highest rating (M = 4.50). This finding underscores the crucial role of hands-on experiences in fostering deeper understanding and sustained engagement. Visual learning (M = 4.48) was also highly valued, reinforcing the importance of interactive screens and digital storytelling in presenting cultural heritage in accessible and appealing ways. Audio-based engagement (M = 4.41) contributed positively, though it was less influential compared to tactile and visual modalities, suggesting that sound is most effective when integrated with other sensory inputs. Students also emphasized the value of museum field trips (M = 4.47), which they associated with meaningful cultural heritage learning and stronger school–museum collaborations. Overall, the findings demonstrate that students perceive Mleiha Archaeology Centre as an engaging educational space, though some noted the need for further diversification of interactive exhibits (see Table III for

full results).

While the present study focused on descriptive statistical analysis, future research should employ inferential statistical methods (e.g., t-tests, ANOVA) to examine potential differences across gender, grade levels, or school types. Such analyses would provide deeper insights into how demographic variables influence students' engagement and learning outcomes.

Table 3: Student Perceptions of Interactive Learning in Museums.

Survey Statement	Finding Summary	Mean Score *(out of 5)*
Modern technologies enhance my engagement in museums.	The majority of students agree that interactive technologies such as screens and educational games increase their engagement.	4.39
Touch (tangible interaction) is an effective way to capture my attention.	Most students believe that touch-based experiences improve their engagement and learning.	4.43
Visual elements (e.g., digital displays, projections) enhance my understanding of museum content.	The highest-rated sensory modality; students find visual learning highly engaging.	4.48
Hearing (audio storytelling, sound effects) contributes to my engagement.	Audio elements are recognized as effective, though slightly less impactful than visual and tactile methods.	4.41
Tangible interaction is essential for enhancing children's engagement and understanding of cultural heritage.	Students overwhelmingly support hands-on learning as a crucial part of their museum experience.	4.50
Mleiha Archaeology Centre provides interactive technologies that attract visitors.	The majority of students view the centre as an interactive and engaging learning space.	4.36
Mleiha Archaeology Centre is an attractive interactive destination for visitors.	Findings confirm that students perceive the centre as a leading interactive museum experience.	4.39
The interactive technologies at Mleiha Archaeology Centre effectively communicate cultural heritage information.	Most students agree that interactive tools successfully deliver educational content.	4.33
There is a good variety of interactive technologies available at the centre.	Responses indicate a positive perception of exhibit diversity, but some students suggest further enhancements.	4.29
Visiting Mleiha Archaeology Centre helps me understand the region's cultural heritage.	A significant portion of students believe field trips enhance their historical knowledge.	4.47
I consider my visit to Mleiha an important experience for learning about cultural heritage.	Students strongly recognize the value of museum visits in reinforcing historical learning.	4.39
Interactive technologies help me remember the information presented.	Findings emphasize that technology-based engagement improves retention and recall.	4.33
The interactive activities at Mleiha are sufficient to engage students with heritage content.	Students view interactive elements as effective, reinforcing the role of hands-on learning in museums.	4.39
Interactive activities at Mleiha enhance student collaboration and discussions about heritage.	Many students believe that group activities foster collaboration and peer learning.	4.40

4.1.3. The Role of School Visits in Enhancing Cultural Understanding

The survey results confirm that museum field trips play a crucial role in reinforcing cultural heritage education, providing students with meaningful, hands-on learning experiences. More than half (52.5%) of students reported that their visit to Mleiha significantly enhanced their understanding of heritage, while an additional 43.5% acknowledged its positive impact, emphasizing the value of experiential learning beyond the classroom. Furthermore, 49% of students stated that group activities facilitated discussions about cultural heritage, highlighting the role of peer interaction in deepening engagement and knowledge retention. These findings underscore the importance of well-structured museum visits, where interactive activities are intentionally designed to foster collaboration, exploration, and critical thinking, ensuring that students actively engage with cultural

heritage rather than passively observing it.

4.2. Analysis of Expert Interviews

Semi-structured interviews were conducted with museum professionals and heritage educators to explore their perspectives on tangible interaction and sensory-based engagement.

4.2.1. Importance of Multisensory Learning in Museums

Experts unanimously agreed that multisensory engagement enhances knowledge retention and visitor satisfaction. One respondent emphasized "Children learn best when they can engage with exhibits through multiple senses—especially touch, vision, and sound. This interaction transforms passive observation into active learning". This perspective aligns with research indicating that multisensory learning fosters deeper cognitive connections (Hampp et al., 2025).

4.2.2. The Role of Touch in Enhancing Engagement

Experts agreed that tactile engagement fosters curiosity and emotional connection, particularly among young visitors. One interviewee explained "When students can physically interact with replicas of artifacts, they become more engaged and ask more questions, which enhances their learning experience". However, conservation concerns were raised regarding direct contact with original artifacts, suggesting that museums should rely on replicas and digital alternatives to balance education and preservation (Mayer, 2019).

4.3. Observational Analysis: Student Behaviour in Interactive Exhibits

Observational analysis at Mleiha Archaeology Centre revealed key engagement trends among students interacting with different exhibit types. Our observations indicated that students were most engaged with hands-on activities and augmented reality storytelling, as in Table 4.

Table 4: Student Engagement across Exhibit Types.

Exhibit Type	Engagement Level	Observational Notes
Hands-on artifact replicas	High	Encouraged curiosity and discussion.
Augmented reality storytelling	High	Sustained attention; students revisited content.
Traditional text-based exhibits	Low	Minimal engagement unless supplemented by teacher explanations.
Interactive excavation activities	High	Fostered collaborative learning and problem-solving.

5. DISCUSSION AND RECOMMENDATIONS

This section discusses the key findings from the study, comparing them with existing research on tangible interaction and multisensory learning in museums. It also presents recommendations for enhancing interactive learning experiences in cultural heritage institutions, particularly in the Mleiha Archaeology Centre and similar museums.

5.1. Discussion of Key Findings

The study revealed that tangible interaction significantly enhances primary school students' understanding of cultural heritage. This aligns with previous research emphasizing the importance of hands-on engagement in learning environments (Nofal et al., 2017; Avram et al., 2019). The key findings are discussed in relation to three major themes.

5.1.1. Tangible Interaction as a Key Learning Tool

Survey data indicated that students strongly preferred hands-on experiences, with a mean score of 4.50/5, confirming that tactile learning fosters higher engagement and information retention. Observational analysis further supported this, showing that students who interacted with replica artifacts and participated in excavation activities were more engaged than those who only viewed static displays. These findings align with studies by Falcão & Price (2010), which emphasize that interactive learning strengthens cognitive connections, allowing children to retain cultural knowledge more effectively.

5.1.2. Multisensory Engagement and Knowledge Retention

The results revealed that vision, touch, and hearing were the most impactful sensory modalities in facilitating student learning. Among these, augmented reality (AR) and interactive storytelling proved particularly effective in sustaining attention and enhancing understanding, supporting the findings of Nikolakopoulou et al. (2021) regarding the role of digital storytelling in heritage education. Our results are consistent with case studies in technological heritage museums where AR/VR enhanced didactical experiences and visitor satisfaction (Bachiller et al., 2023). While smell and taste were rated lower in effectiveness, previous research suggests that they hold significant potential in creating immersive historical experiences when properly implemented (Duranti et al., 2016).

An important cultural factor highlighted in the findings is the strong preference for Arabic (85.5%) as the language of engagement. This has direct implications for interaction design, as bilingual or multilingual displays may be necessary to ensure accessibility for diverse audiences, while prioritizing Arabic content strengthens cultural identity and inclusivity. The findings suggest that museums in the UAE and wider Arab region should consider language not only as a medium of communication but also as a cultural element that shapes visitors' connection with heritage narratives.

5.1.3. Challenges in Implementing Interactive Exhibits

Despite the benefits of interactive museum experiences, interviews with museum educators highlighted several challenges, including artifact preservation concerns, budget limitations, and the over-reliance on digital screens. These concerns align with the findings of Chatzigrigoriou et al. (2021), who argue that while technology enhances engagement, it must be carefully balanced with traditional tangible interaction to maintain authenticity.

Another limitation observed relates to the use of augmented reality (AR) and digital storytelling. While these tools sustained attention and enhanced engagement, some students displayed shorter attention spans when activities were highly screen-dependent, and educators reported challenges with technical maintenance and content updates. These findings indicate that although AR and digital media are powerful, they should complement rather than replace tangible experiences. A balanced "phygital" approach; integrating digital storytelling with hands-on interaction (Nofal et al, 2017), appears more sustainable for long-term learning outcomes.

Addressing these challenges requires strategic planning to integrate interactive learning methods without compromising artifact conservation or financial sustainability.

5.2. Recommendations for Enhancing Interactive Learning in Museums

Based on the study's findings, several strategies are recommended to improve tangible interaction and multisensory engagement in museum environments. These recommendations focus on expanding hands-on learning opportunities, integrating sensory experiences, balancing digital and physical interactions, strengthening school-museum collaborations, and addressing logistical challenges.

5.2.1. Expanding Hands-on and Multisensory Learning Opportunities

To enhance engagement, museums should increase the use of replica artifacts, allowing students to interact with cultural objects without risking damage to original artifacts. Establishing interactive excavation zones, where children can simulate archaeological discoveries, would further encourage experiential learning and teamwork. Additionally, "touch stations" featuring 3D-printed reproductions of delicate artifacts should be introduced, enabling students to explore historical objects safely (Avram et al., 2019).

Beyond tactile engagement, multisensory learning approaches should be expanded to deepen visitor interaction. Projection mapping and digital storytelling can enhance visual engagement, making historical content more immersive and dynamic (Tan & Lim, 2017). Sound-based interactions, such as narrated histories, environmental soundscapes, and interactive audio guides, can further enrich the storytelling experience. Museums should also consider introducing scent-based experiences, particularly in historical reconstructions of traditional markets or ancient environments, as research suggests that smell can evoke emotional and contextual connections to heritage (Duranti et al., 2016).

5.2.2. Balancing Digital and Physical Interaction

Given successful recent applications in varied museum settings (Boboc et al., 2022; Bachiller et al., 2023), we recommend integrating AR/VR with physical, hands-on exhibits for more holistic learning experiences. Digital tools should not replace physical interaction but should instead complement hands-on activities. A hybrid approach of Phygital (i.e., blending digital storytelling with tangible exhibits) ensures that visitors engage both physically and cognitively, improving retention and accessibility (Nofal et al., 2017). This approach fosters a balanced, immersive learning environment that maintains the authenticity of heritage experiences.

5.2.3. Strengthening School-Museum Collaboration

Stronger partnerships between schools and museums can further enrich student learning. Museums should develop curriculum-aligned educational programs, ensuring that school visits reinforce classroom learning objectives. Additionally, teacher training workshops can help educators integrate museum-based interactive learning into lesson plans, maximizing the benefits of field trips. Providing pre-visit digital learning

materials would also prepare students for their museum experience, enhancing engagement and comprehension during their visit.

5.2.4. Addressing Logistical and Preservation Challenges

One of the key concerns raised by museum professionals is artifact preservation when implementing hands-on exhibits. Museums should secure funding for replica-based exhibits, allowing students to engage with cultural objects without putting fragile artifacts at risk. Implementing rotational interactive displays would ensure that visitors can actively engage with exhibits without causing excessive wear and tear. Finally, public-private partnerships should be encouraged to finance innovative interactive exhibits, reducing financial burdens on museums while promoting technological advancements in heritage education.

By implementing these strategies, museums can create inclusive, engaging, and educational experiences that foster a deeper appreciation of cultural heritage while maintaining sustainability and conservation standards.

6. CONCLUSION

This study has highlighted the critical role of tangible interaction and multisensory engagement in enhancing cultural heritage learning for primary school students in museum environments. The findings from the Mleiha Archaeology Center case study confirm that interactive and hands-on experiences significantly improve student engagement, comprehension, and retention of historical knowledge.

The research demonstrates that children learn more effectively when they can physically engage with museum exhibits, whether through touching replica artifacts, participating in interactive excavation activities, or using augmented reality storytelling (Nofal et al, 2018). Surveys and observations confirmed that traditional static displays were less effective in capturing students' attention, reinforcing the importance of sensory-based learning strategies in museums. These findings align with existing literature, which emphasizes that multisensory experiences enhance cognitive and emotional connections to cultural heritage (Avram et al., 2019; Nofal et al., 2017).

Despite these benefits, the study also identified several challenges in implementing interactive learning techniques, including artifact preservation concerns, financial limitations, and the need to balance digital and physical engagement. To address these challenges, the study proposes practical recommendations, such as expanding the use of replica objects, integrating a mix of digital and tactile interaction, and strengthening partnerships between schools and museums to create structured, curriculum-aligned programs.

While this research provides valuable insights, further studies are needed to explore the long-term impact of tangible interaction on historical understanding, the potential of olfactory and taste-based experiences, and cross-cultural comparisons of interactive museum education strategies. These future directions will help refine best practices for implementing interactive and sensory-based exhibits, ensuring that museums continue to evolve as engaging and inclusive learning environments.

By implementing the strategies discussed in this study, museums can enhance their educational impact, increase accessibility, and foster a deeper appreciation of cultural heritage among future generations. As technology and exhibit design continue to advance, embracing interactive, tangible, and multisensory learning methods will be key to ensuring museums remain vibrant, engaging, and relevant educational spaces in the modern era.

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REFERENCES

Avram, G., Ciolfi, L., & Maye, L. (2019). Creating tangible interactions with cultural heritage: Lessons learned from a large-scale, long-term co-design project. *coDesign, 16*(3), 251–266. https://doi.org/10.1080/15710882.2019.1596288

Bachiller, C., Monzó, J. M., & Rey, B. (2023). Augmented and virtual reality to enhance the didactical experience of technological heritage museums. *Applied Sciences, 13*(6), 3539. https://doi.org/10.3390/app13063539

Boboc, R. G., Băutu, E., Gîrbacia, F., Popovici, N., & Popovici, D.-M. (2022). Augmented reality in cultural heritage: An overview of the last decade of applications. *Applied Sciences, 12*(19), 9859. https://doi.org/10.3390/app12199859

Chatzigrigoriou, P., Nikolakopoulou, V., Vakkas, T., Vosinakis, S., & Koutsabasis, P. (2021). Is architecture connected with intangible cultural heritage? Reflections from architectural digital documentation and interactive application design in three Aegean Islands. *Heritage, 4*(2), 949–973. https://doi.org/10.3390/heritage4020038

Duranti, D., Spallazzo, D., & Trocchianesi, R. (2016). Tangible interaction in museums and temporary exhibitions: Embedding and embodying the intangible values of cultural heritage. In *Systems & Design: Beyond Processes and Thinking* (pp. 160–171). https://doi.org/10.4995/ifdp.2016.3322

Falcão, T. P., & Price, S. (2010). Informing design for tangible interaction: A case for children with learning difficulties. In *Proceedings of the 9th International Conference on Interaction Design and Children* (pp. 190–193). https://doi.org/10.1145/1810543.1810568

Hampp, C., Novak, M., Lange, A., & Schwan, S. (2025). Please touch the hedgehog: Haptic exploration of mounted specimens increases inspection time and positive evaluation of an exhibit. *Science Education, 109*(6), 1701–1715. https://doi.org/10.1002/sce.21991

Jasim, S. A. (2006). Trade centres and commercial routes in the Arabian Gulf: Post-Hellenistic discoveries at Dibba, Sharjah, United Arab Emirates. *Arabian Archaeology and Epigraphy, 17*, 214–237.

Mayer, R. E. (2021). *The Cambridge handbook of multimedia learning* (3rd ed.). In L. Fiorella & S. Barbara (Eds.). Cambridge University Press. https://doi.org/10.1017/9781108894333

Mouton, M. (2009). The settlement patterns of north-eastern and south-eastern Arabia in late antiquity. *Arabian Archaeology and Epigraphy, 20*, 185–207. Wiley-Blackwell.

Muntean, R., Hennessy, K., Antle, A., et al. (2015). Belongings: Tangible interactions with intangible heritage. *CITAR Journal of Science and Technology of the Arts, 7*(2), 59–69. https://doi.org/10.7559/citarj.v7i2.159

Nikolakopoulou, V., Printezis, P., Maniatis, V., Kontizas, D., Vosinakis, S., Chatzigrigoriou, P., & Koutsabasis, P. (2021). Conveying intangible cultural heritage in museums with interactive storytelling and projection mapping: The case of the Mastic Villages. *Heritage, 5*(2), 1024–1049. https://doi.org/10.3390/heritage5020056

Nofal, E., Elhanafi, A., Hameeuw, H., & Vande Moere, A. (2018). Architectural contextualization of heritage museum artifacts using augmented reality. *Studies in Digital Heritage, 2*(1), 50–75. https://doi.org/10.14434/sdh.v2i1.24500

Nofal, E., Panagiotidou, G., Reffat, R. M., Hameeuw, H., Boschloos, V., & Vande Moere, A. (2020). Situated tangible gamification of heritage for supporting collaborative learning of young museum visitors. *Journal on Computing and Cultural Heritage (JOCCH), 13*(1), Article 3. https://doi.org/10.1145/3350427

Nofal, E., Reffat, R., Boschloos, V., Hameeuw, H., & Vande Moere, A. (2018). The role of tangible interaction to communicate tacit knowledge of built heritage. *Heritage, 1*(2), 414–436. https://doi.org/10.3390/heritage1020028

Nofal, E., Reffat, R. M., & Vande Moere, A. (2017). Phygital heritage: An approach for heritage communication. In *Proceedings of the 3rd Annual International Conference of the Immersive Learning Research Network (iLRN2017)* (pp. 220–229). https://doi.org/10.3217/978-3-85125-530-0-36

Overlaet, B., Macdonald, M., & Stein, P. (2016). An Aramaic-Hasaitic bilingual inscription from a monumental tomb at Mleiha, Sharjah, UAE. *Arabian Archaeology and Epigraphy, 27*, 127–142. https://doi.org/10.1111/aae.12072

Tan, K. L., & Lim, C. K. (2017). Digital heritage gamification: An augmented-virtual walkthrough to learn and explore tangible cultural heritage. *Journal of Telecommunication, Electronic, and Computer Engineering, 9*(2–12), 89–94.