

Digital Innovation in Museum Exhibitions: An Augmented Reality Framework for Dezhou City Museum

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Received Date: **10.11.2024**; Accepted Date: **07.04.2025**; Available Online: **10.04.2025**

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ABSTRACT

Continuity advancement of science and technology, coupled with a surge in cultural consciousness and improved cultural literacy. Recently increase year by year in the number of museums across China. Due with this national trend, Dezhou City in Shandong Province has also established its own museum, primarily dedicated to preserving and exhibiting the city's historical culture and significant artefacts. It serves as a place for local residents to visit, engage in educational and cultural dissemination, and provide valuable physical and documentary support for researchers studying relevant issues. However, as time progresses, traditional museum exhibitions have become inadequate in meeting the demands of modern visitors. The researcher has designed new exhibitions for the museum using AR (Augmented Reality) technology by taking Dezhou City as a case. This paper outlines the trend of exhibition design using AR technology and emphasises core issues including the accuracy and appropriacy of exhibits and whether the demands of visitors are well catered to. The researchers conducted field surveys and observations by qualitative research methods at the Dezhou Museum, for which the research findings were used to help devise an Augmented Reality (AR)-based exhibition framework. The aim is to investigate how the application of AR technology can help in the digital transformation of Dezhou's museum exhibitions and ultimately design an exhibition framework based on Augmented Reality (AR) technology for the Dezhou City Museum. Exploring the current situation through literature reviews, summarising the forms of AR technology applications, and analysing existing exhibitions and sections on a per-hall basis, the study intends to identify the weight and matching forms for the transformation of the first and the third exhibition halls. The conclusion outlines the design trends and paths for interactive exhibitions and potential research directions.

Keywords: *Interactive Exhibition, Augmented Reality, Museum Users, Museum Exhibition*

INTRODUCTION

The most intriguing feature of museums and museum exhibitions is their ability to provide visitors with novelty and engage their interest. When visitors feel there is much to explore and gain new insights and knowledge from their visits, the museum experience becomes more meaningful. Like in other countries, the number of museums in China is increasing yearly. Dezhou City in Shandong Province of China has also established its own museum, primarily showcasing the city's historical culture and artefacts, providing educational and cultural outreach to the surrounding communities, and offering valuable physical and documentary support to scholars researching relevant topics.

However, with the continuous advancement of science and technology and the increasing cultural awareness and consciousness, traditional museum exhibitions are no longer meeting the needs of modern visitors. Therefore, the researchers have designed a new type of exhibition for the Dezhou City Museum using Augmented Reality (AR) technology. According to statistics provided by the museum staff in Dezhou City (Zhang, 2023) in 2023, the number of visitors decreased by 27.2% compared to 2022, with similar decreases in previous years (23.4% in 2019, 22.1% in 2018, and 22.3% in 2017). Visitor satisfaction rate also declined, with a 25.3% decrease in 2023, along with comparable decreases in previous years (24.1% in 2019 and 22.3% in 2018). These data indicate a dwindling interest in the Dezhou City Museum among the local communities. As a regional museum and the hometown of the famous historical figure Dong Zhongshu, this declining trend has become a cause of concern. Meanwhile, the museum management has ascertained through visitor feedback (Zhang, 2023) that there is a significant interest in AR and VR technologies. It is believed that introducing these technologies may lead to an increase in both the number of visitors and their satisfaction levels. Therefore, the researchers sought to design an AR-based exhibition framework for the Dezhou City Museum. This initiative aims to explore the modalities of integrating Augmented Reality technology within the digitisation and transformation of the museum's exhibits and to enhance visitor numbers and satisfaction.

The fusion of Augmented Reality (AR) technology with exhibition design provides a unique framework for interactive exhibition designs to enhance visitors' curiosity (Han, Li, & Zhao, 2022). Cesário argue that user-driven innovation can attract visitors with modern and refreshing techniques (Cesário, & Matos, 2017). Additionally, due to the special nature and fragility of some cultural artefacts, museums often fail to exhibit them for extended periods, limiting visitors' interaction with them. This limitation results in a significant decrease in the number of artefacts available for observation, and repeated viewing of the same artefacts eventually leads to a further decline in the curiosity of regular visitors.

In summary, this study aims to investigate the application of AR technology in the digital transformation of Dezhou's museum exhibitions and ultimately design an exhibition framework based on Augmented Reality (AR) technology for the Dezhou City Museum. This research will yield insights into the weighting of exhibits' transformation and corresponding forms, elucidating the design trends and in-depth research pathways for interactive exhibitions.

LITERATURE REVIEW

The Necessity of Augmented Reality (AR) Utilisation

China is currently undergoing vigorous reform in museums and exhibitions to improve its market economy and enhance cultural diplomacy (Bollo & Zhang, 2017). One of the key pathways for this transformation involves accelerating technological advancements and increasing public interest in Chinese public museums and exhibitions. Augmented Reality (AR) technology serves as a platform for this transformation, with devices such as smartphones and tablets as the means of delivery. While exhibitions are traditionally held as physical, offline events, this does not diminish the significance of technological progress. The integration of AR technology with exhibition design provides a unique framework for creating interactive exhibitions aimed at enhancing visitors' curiosity (Han, Li, & Zhao,

2022). Cesário suggest that user-driven innovation can captivate visitors with modern and engaging exhibits (Cesário, & Matos, 2017). Moreover, some artefacts have specific characteristics and are fragile, preventing museums from long-term displaying. This limitation restricts visitor interactions with the artefacts, leading to a decline in the number of items they can appreciate and lowering their curiosity as they repeatedly view the same items. Additionally, for artefact researchers like archaeologists and historians, the inability to closely examine artefacts from various angles and study them in different contexts reduces work efficiency and increases professional burnout.

In the contemporary era, the appreciation of cultural heritage through mobile devices has become increasingly prevalent. As postulated by Han, the advent of augmented reality has ushered in an epoch wherein the digital life cycle is interlaced with the physical realm, consequently transforming global interpretive paradigms (Han et al., 2022). During this shift, we've noticed a drop in visitor interaction and an increase in technical issues. This indicates a pressing need to rethink China's established exhibition approaches. This study aims to fill these gaps. Nonetheless, there exists an inherent challenge in digitally encapsulating the essence of ancient cultural grandeur, exemplified by such evocative imageries as the celestial 'suspicion of the Milky Way cascading from the ninth heaven,' the imposing 'expanse of deserts marked by lone plumes of smoke against the backdrop of a setting sun,' or the serene 'play of autumnal waters reflecting a spirit in kinship with the boundless sky. Augmented reality technology can provide an immersive experience for these cultural elements, and it plays an essential role in instilling cultural confidence and fostering national pride among young people. Recent surveys in Europe indicate that approximately 45% of museums have started developing some form of 3D or virtual exhibitions to showcase their exhibits (Turner, J., 2024). Augmented reality technology poses social and real-world challenges, and these challenges, to varying degrees, have provided empirical observations for user-driven innovation, assessing the impact of augmented reality technology in exhibition settings.

In summary, the application of AR technology to museum exhibitions is a trend in the future development of museums. Simultaneously, it has the potential to significantly enhance the exhibition experience for visitors and may even increase their interest.

The Application of Augmented Reality (AR) in Museums

Augmented Reality (AR) aims to interactively showcase history and artistically replicate outdated exhibits (Marques & Costello, 2021). Extended reality provides a spatial environment for everyone visiting cultural heritage in exhibitions and museums. Extended reality fosters in-depth insights through visitor actions. AR professionals have created a user-experience environment to provide a deeper understanding of specific cultures and heritages (Noe, 2021). Xiao gathers relevant history from Chinese culture to offer enhanced digital media exhibitions (Xiao et al., 2022). It demonstrates diverse AR that overlays the physical world with digital space. According to Vistisen, a study was conducted on gamified digital installations in a Danish water park (Vistisen et al., 2019). Here, researchers introduce the dichotomy of experience and enlightenment. Experience sparks interest, while enlightenment educates through the exhibition (Vistisen et al., 2019). Issues related to the experience have been addressed through surveys and interviews. Insights from exhibition insiders have provided numerous solutions and remedies to address technical challenges associated with promoting cultural heritage through museums and exhibitions, making the application of AR technology in museum exhibitions feasible.

Enhancing the artistic quality is best achieved by introducing touch-based interactive technology for visitors. To bolster the functionality of cultural heritage, it must become more potent and enduring through research (Pierdicca et al., 2015). According to Skydsgaard, exhibitions and museums are artistic venues, where visitors explore not only for entertainment but also for cultural understanding (Skydsgaard et al., 2021). Their significance lies in transforming passive consumers of historical relics into active participants through typical media elements, including sound, imagery, and videos, to enrich the visitor experience. From an evaluative perspective, cultural resources are sustained by maintaining the excitement and engagement of interested users (Capuano et al., 2021). To distinguish children's learning experiences at a museum, the researchers conducted a case study at the Taipei Children's Art Museum (CAMT) involving parents and their young children. The most noteworthy and challenging aspect is

translating the concept of artefacts into interactive experiences. The study highlights the substantial development of museums in children's involvement and exhibit updates (Lee, 2020). Based on measuring the level of interaction, exhibit modules can be adapted to user needs, behaviours, and attributes (Rosales et al., 2021). Hence, by abstracting systems that involve users, environment, and exhibit interactions, user experiences and exhibit experiences merge into human-computer interactions.

Based on the research mentioned above, it is evident that the application of AR technology in museum exhibitions is not only feasible but also an essential path for the future development of museum exhibitions. However, the researcher needs to provide a concrete plan for integrating AR technology with the exhibitions at the Dezhou City Museum.

The current situation of the Dezhou City Museum

The Dezhou City Museum covers an area of 72 acres with a main building area of 21,000 square meters and an exhibition area of 7,785 square meters, as shown in Figure 1. The total investment is nearly 200 million RMB. The museum serves as a comprehensive institution combining cultural relic collection and exhibition, scientific research, and educational outreach. It is composed of an entrance hall, five basic exhibition halls, one temporary exhibition hall, one academic lecture hall, one 3D cinema, public resting areas, collection storage rooms, technical facilities, and office spaces, all of which collectively present a comprehensive overview of the historical development of Dezhou.

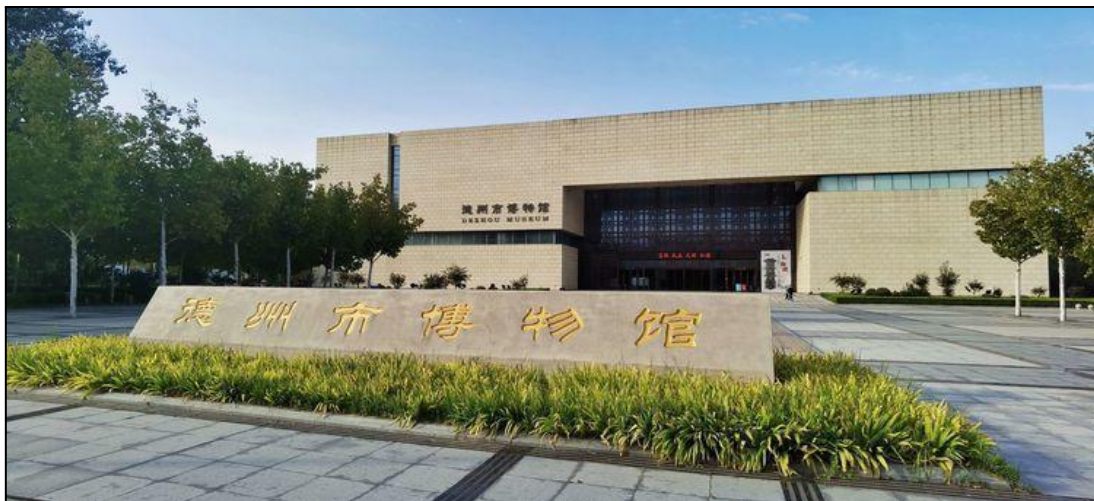


Figure 1. Dezhou City Museum
(Source: Author's personal collection, 2021)

Entrance Hall

The entrance hall, spanning 1,580 square meters, is in the public area at the museum's entrance, as shown in Figure 2. It serves as the foundational space for the museum's thematic concept and encompasses various public functions such as visitor orientation, crowd gathering, ticket inquiries, and leisure activities. A large relief wall in the entrance hall, themed "Jiuhetu" (Nine Rivers), features the essence of Dezhou's historical and cultural significance with motifs "Desu Anlan" (Peaceful De River) and "Jiudatianqu" (Nine Reaches to Heaven) based on the "Jiuhetu" painting.



Figure 2. Entrance Hall
(Source: Author's personal collection, 2021)

Temporary Exhibition Hall

The temporary exhibition hall, located on the western side of the first floor, spans an area of 1,160 square meters, as show as Figure 3. It is designed as a modern, open space equipped with contemporary exhibition methods, aiming to provide services for socially-oriented displays and exhibitions.



Figure 3. Temporary Exhibition Hall
(Source: Author's personal collection, 2021)

3D Cinema

The 3D cinema is located on the southern part of the eastern side of the first floor, covering an area of 268 square meters with a seating capacity of 86 people. It utilises computer-generated virtual reality technology to encapsulate the 5,000 years of Dezhou's cultural history. The high-quality 3D projections allow the audience to vividly and effectively appreciate Dezhou's historical heritage and natural beauty.

Lecture Hall

Situated at the rear of the first floor's eastern side, the lecture hall spans an area of 402 square meters. It is a high-standard, multipurpose lecture hall with the capacity to accommodate nearly 300 attendees for various academic conferences and exchanges.

Permanent Exhibition Halls

The First Exhibition Hall is shown as Figure 4. This exhibition hall, themed around the passage of time, presents the cultural aspects of Dezhou throughout different historical periods. It serves as the principal hall for Dezhou's historical and cultural heritage. The overall style of the hall is dignified and steady, seamlessly blending traditional exhibition methods with modern techniques. It expands the information of the exhibits, creates an immersive atmosphere for visitors, enhances artistic effects, and provides a visually impactful experience.



Figure 4. The First Exhibition Hall
(Source: Author's personal collection, 2021)

The Second Exhibition Hall is shown as Figure 5: This exhibition hall primarily focuses on the display of cultural relics, with special highlights being the reconstruction exhibits of the Song-Yuan porcelain kiln and Han Dynasty tombs. It showcases the brilliant aspects of Dezhou's cultural evolution. In this hall, there's an emphasis on creating a visitor-friendly environment that encourages exploration and curiosity. The design includes a series of interactive and immersive experiences, turning the visit into a process of expanding and applying knowledge.



Figure 5. The Second Exhibition Hall
(Source: Author's personal collection, 2021)

The Third Exhibition Hall is shown as Figure 6. City Memory encompasses a myriad of elements, it is not only the long-gone ancient courtyards and streets, not just the scenic landscapes preserved in texts and drawings, but it's also a collection of dialect proverbs, nursery rhymes, songs, customs, and traditions. In the third exhibition hall, historical Dezhou in its prime is predominantly showcased through simulated scenes, trying its best to help you shape a vivid urban impression of history.



Figure 6. The Third Exhibition Hall
(Source: Author's personal collection, 2021)



Figure 7. The Fourth Exhibition Hall
 (Source: Author's personal collection, 2021)

The Fourth Exhibition Hall as shown in Figure 7. This hall is divided into four units: "The Administrative Changes of Dezhou Since Liberation," "The Landscape of Dezhou During the Period of Socialist Revolution and Construction," "The Elegance of Dezhou as It Enters the Era of Reform and Opening-Up," and "Dezhou's Vision for the Future." The first three units mainly reflect the historical development and remarkable achievements in construction since the liberation of Dezhou in June 1946. The final unit provides a glimpse of Dezhou's future in the form of a special feature film.

Collection of Artefacts

The collection of the Dezhou City Museum is primarily sourced from civilian donations, acquisitions, items transferred by the Public Security Bureau, and rescue excavations. The categories of artefacts include ceramics, jade objects, bronzeware, iron items, calligraphy and painting, silk textiles, and various miscellaneous items, etc. As of the end of 2019, the Dezhou City Museum housed a total of 10,072 individual pieces or sets, including 177 items or sets of precious artefacts, Table 1 shows some of the more representative artifacts.

Table 1: Collection of Artefacts

Cultural Relic Name	Introduction	Picture
Jade Double Phoenix Relief Dagger	This jade ceremonial piece is 13.6 cm long, 3.8 cm wide, and 0.3 cm thick. It has symmetrical ridges, a double-edged blade, and intricate carvings of two standing phoenixes with distinctive features.	
Tri-Coloured Pottery Basin	Yellow-glazed pottery Ming ware, measuring 4.8 cm in height and 12.5 cm in diameter, features a colourful interior glaze and a delicately designed exterior with vibrant yellow cloud patterns and wavy edges. The piece showcases exquisite craftsmanship and an elegant form.	

Yellow-glazed bottle with dragon and phoenix motifs and lug handles	Ceramic container with a unique Persian-style design. It is characterised by a yellow glaze and features dragon and phoenix patterns on both sides, along with a symmetrical grapevine motif encircling the body.	
Tri-Coloured Pottery Stove	Ceramic censer with a diameter of 11.8 cm and a height of 12.6 cm. It features a unique shape with an outward-curved rim, rounded shoulders, and a bowl-shaped base. The exterior is adorned with a vibrant yellow and green glaze, giving it a beautiful colouration.	
Tri-Coloured Ceramic Plate	A glazed ceramic dish with a height of 3.5 cm and a diameter of 15.5 cm. It has a flat bottom, and a short footring, and features chrysanthemum patterns on the yellow interior. The outer bottom of the dish bears an inscription that reads "Yuan Zhen third year, Hu Jia Shuo."	

RESEARCH METHODOLOGY

The overall purpose of this study is to create an AR exhibition plan for the Dezhou City Museum and explore its application within the museum's exhibitions. This research was conducted using primary data collection methods, including interviews with 19 staff members from the Dezhou City Museum, including three museum directors, ten curators, and two museum volunteers. Additionally, preliminary research and literature review were conducted by examining articles, newspapers, announcements, and other relevant materials to support the study's objectives. The interviews aimed to gain an understanding of the current exhibition status at the Dezhou City Museum, the historical background of the artefacts, and the desired outcomes of AR exhibitions. This information was used to determine the specific technologies to be employed at the Dezhou City Museum and develop the exhibition framework, drawing from experiences and exploring design methodologies.

We engaged in brief interactions and random conversations with visitors and participants from various age groups and demographics to understand their perceptions of the benefits they can gain from visiting and participating in projects, as well as their levels of awareness regarding the experiences and new knowledge they can acquire. Observation, participation, and conversations with museum staff and visitors were also conducted near the museum's premises, and relevant photographs were taken. The collection of secondary data aimed to assist and complement the literature review in this study. Survey findings are based on a mix of primary and secondary data, with a particular focus on questions and concerns related to the relevance of AR technology at the Dezhou City Museum.

ANALYSIS

Through careful observations, random conversations with visitors, and discussions with museum staff,

both museum visitors and employees mentioned the difficulties associated with creating exhibition environments using AR technology, as well as the lack of relevant technical expertise. It is undeniable that there is currently a significant shortage of individuals who can simultaneously create AR scenes and engage in museum exhibition design. Consequently, the researcher has proposed some feasible solutions.

Using Computer Technology to Create Augmented Reality Exhibitions in Museums

Museums face two primary challenges when attempting to widely adopt augmented reality technology into their standard operating procedures: efficient creation of 3D models of artefacts and the establishment of virtual exhibitions based on these models. In recent years, 3D model scanners and 3D model printers have become more accessible and commercialised, allowing museums to have easy access to high-quality 3D scanners. The availability of 3D models is a prerequisite, but this is only the first step. To achieve widespread use of this technology, museums need efficient, cost-effective, and straightforward methods to create virtual reality and augmented reality exhibitions based on the 3D models they have collected. Setting up exhibitions is carried out by museum staff, who are not necessarily computer experts. Therefore, a system or approach accessible to the average person is required to support the construction of virtual exhibitions. Furthermore, the system must provide an intuitive human-computer interface for museum visitors. Users should be able to interact with virtual exhibits naturally and easily, much like they can interact with objects in the real world.

The design of interactive exhibitions in museums should be approached as a system design action with a user-centred and holistic perspective. The physical environment of the museum and the tangible products inside it represent the most direct points of contact for users to receive services and engage in exploration. In the early stages of setting up an interactive exhibition system in a museum, the primary questions are how and what to digitise. Converting physical objects from the real world into digital representations often requires a combination of technological methods and physical hardware support. This may involve creating, editing, utilisation, re-editing, and re-utilisation through computer-based 3D technology. Physical devices, such as scanners, capture equipment, lighting devices, and cameras, may assist in achieving this more efficiently and effectively.

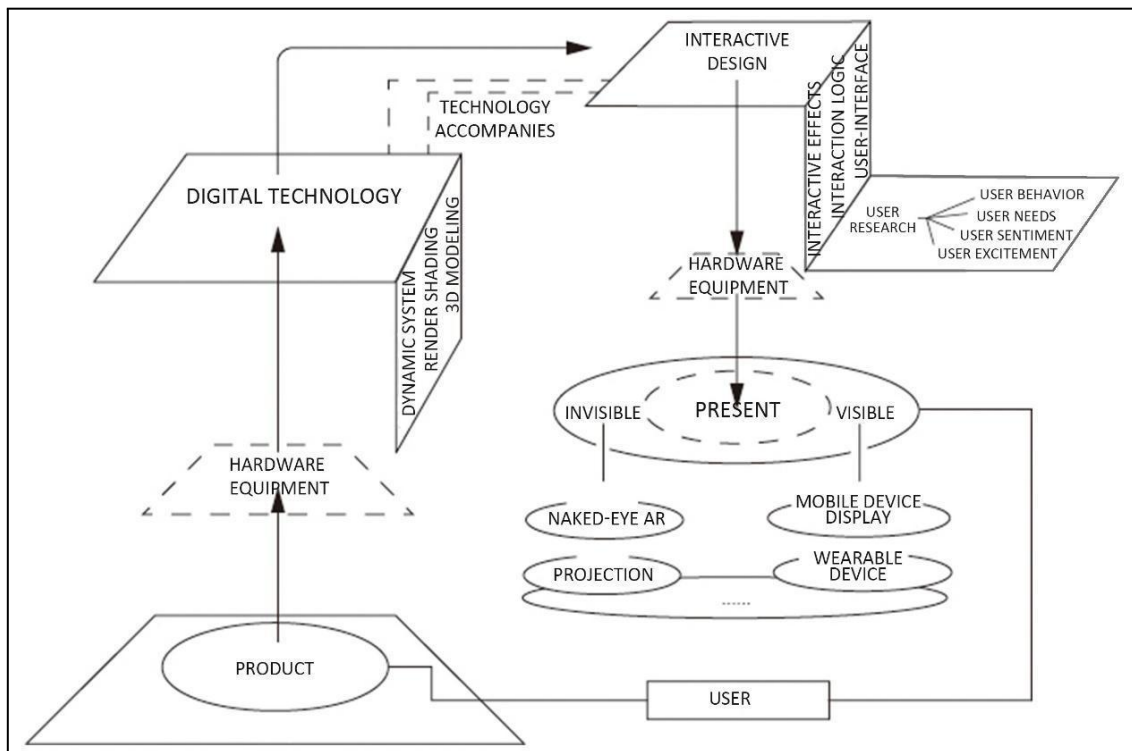


Figure 8: Interactive Exhibition Design System Framework Diagram
 (Source: Personally produced by the author, 2023)

In the mid-term phase, it is crucial to address issues related to the efficient use of digital assets and the enhancement of user experiences. Excellent interactive designs must align with user needs, which should be based on robust user research data. Furthermore, it should ensure that interactive behaviours are scientifically rigorous and that the interactive interfaces are aesthetically pleasing and straightforward. The preparatory and backstage work in the early and mid-term stages are tasks that users do not see but are critical to the success of the system. The last phase involves the visible aspects of interaction, where various presentation methods offer versatility in terms of visual effects. For instance, achieving good visual effects without the need for additional hardware display or touch devices is possible. This could include methods like scanning QR codes with a smartphone to view interactive effects, which is based on the product-technology-hardware device-effect chain. As shown in Figure 8, this could be summarised as a tangible augmented reality interaction method, whereas the product-technology-effect method could be summarised as an intangible augmented reality interaction method.

Interactive Exhibition Design Research at the Dezhou City Museum

The Dezhou City Museum has four permanent exhibition halls, which showcase the history, people, and objects related to Dezhou's development from ancient times to the present apart from offering insights into its prospects. The development of a city or region is influenced by multidimensional factors, and museums, as central institutions that elucidate this process, bear greater responsibilities and act as 'translators' throughout. Taking the first and third exhibition halls of the Dezhou Museum as examples, this study analyses how the exhibits and exhibition formats of these halls combined with augmented reality technology to enhance interactive experiences and ignite visitors' interest.

Table 2. The Analysis of The First and Third Exhibition Halls

	The First Exhibition Hall	The Third Exhibition Hall
Theme	History and Evolution	Scenario Recreation
The Number of Exhibition Hall Units	24	17
Static Exhibition Forms	Patterns Reliefs and Murals Historical Relic Tags Words Scenario Shows Exhibition Board Electronic Screen Video Model Projection	Patterns Reliefs and Murals Ancient Building Scenario Shows Scene Reconstruction Exhibition Board Video Model
Dynamic Exhibition Forms	Electronic Video Dynamic Projection	Electronic Video

The first exhibition hall primarily focuses on historical narratives, and therefore, there is a higher emphasis on informative and educational exhibits. In this hall, the predominant exhibition format is textual and image panels, which aligns with the historical and educational objectives. On the other hand, the second exhibition hall aims to create an immersive experience of old Dezhou, with a significant emphasis on immersive scene-based exhibitions. The chart shown in Table 2 illustrates the proportional distribution of exhibits in the first and third exhibition halls, based on the size and the level of visitor engagement with different areas. This can serve as a reference for how augmented reality technology can be integrated into various sections and interactive points. However, this chart could be further refined and validated by comprehensive user research. This could involve non-invasive observations, such as monitoring video recordings to analyse the real visitors' interaction patterns and reactions at different

contact points. It is recommended to use well-structured research methodologies, like the Analytic Hierarchy Process (AHP), to determine the most appropriate forms of AR integration, resource allocation, and other weight factors for a more precise exhibition enhancement strategy.

The primary objective of applying augmented reality (AR) technology in museum exhibitions is to enhance visitors' sensory experiences and provide immersion. The choice of appropriate AR forms should maximise the advantages of the technology to achieve a synergy effect. For instance, if visitors can use state-of-the-art wearable AR devices for their museum visit, they can perceive digital cultural assets vividly, with dazzling special effects. Complementing this with sound effects and tactile simulations can further enhance realism and create an outstanding experience. However, it's essential to note that the resources required to implement such a solution are substantial. When comparing the cost-effectiveness of creating rich, large-scale scenes versus basic informative labels, it's relatively more reasonable to allocate resources to the former.

Table 3. Three Types of Augmented Reality Technologies with Examples

CATEGORY	EXAMPLE
I Electronic Screen	Transparent Display Screen Giant Screen Surround Multimedia Interaction
II Projection	Holographic Projection Air Imaging Interactive Projection Digital Model
III Wearable Device	Touch Interaction Helmet-Mounted VR AR or VR Glasses Interactive Gloves

Therefore, when applying AR technology to the museum's exhibitions, it's important to determine the direction and form. Resource allocation should be based on the weight of the different components, focusing on the details. Augmented reality technology encompasses various forms. As show as Table 3, they can be broadly categorised into:

1. Dynamic effects displayed on electronic screens, including interactive functionalities, tend to be more feasible and cost-effective.
2. Projection technologies that introduce digital imagery into the real world, including holographic projection, volumetric displays, interactive projection screens, and more.
3. Wearable devices that enhance user sensory experiences, such as head-mounted AR devices, AR/VR glasses, and interactive gloves.

Table 4. Weight Levels and Matching Forms for the Renovation of the Exhibits in the First Exhibition Hall

EXHIBITION FORMAT	WEIGHT LEVEL	MATCH FORM
Patterns	High	I, III
Reliefs and Murals	Low	II
Historical Relic, Words, Projection	High	II, III
Tags	Middle	I
Scenario Shows	Middle	II
Exhibition Board	Low	I, II
Electronic Screen, Video	Low	I
Model	Low	II

Table 5. Weight Levels and Matching Forms for the Renovation of the Exhibits in the Third Exhibition Hall

EXHIBITION FORMAT	WEIGHT LEVEL	MATCH FORM
Patterns, Video	Middle	I

Reliefs and Murals	Low	II
Ancient Building, Scenario Shows	High	II, III
Scene Reconstruction	High	II, III
Exhibition Board	Low	I, II

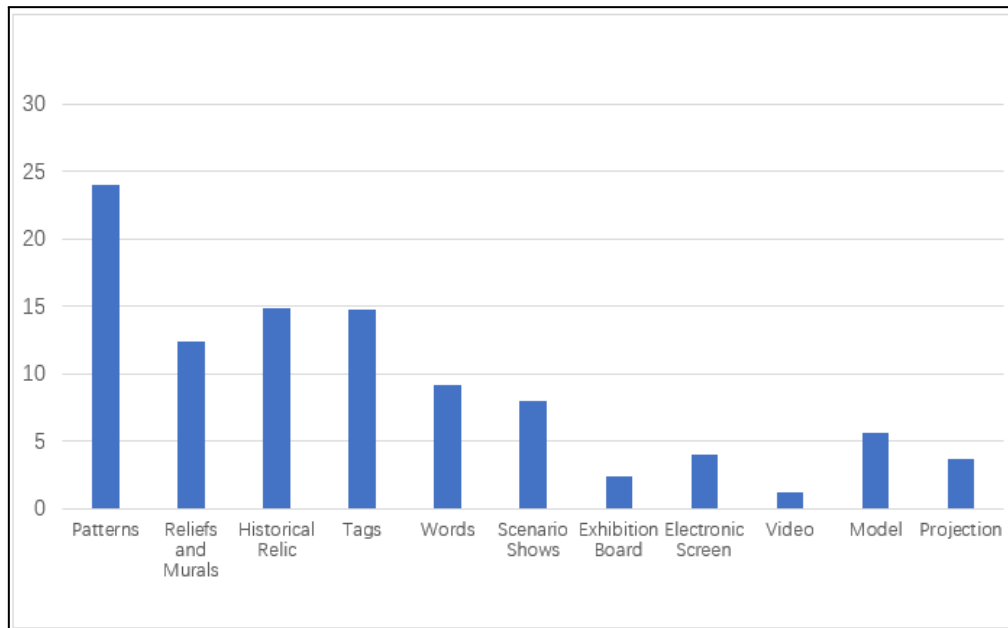


Figure 9. The Analysis of The First Exhibition Halls
 (Source: Personally produced by the author, 2023)

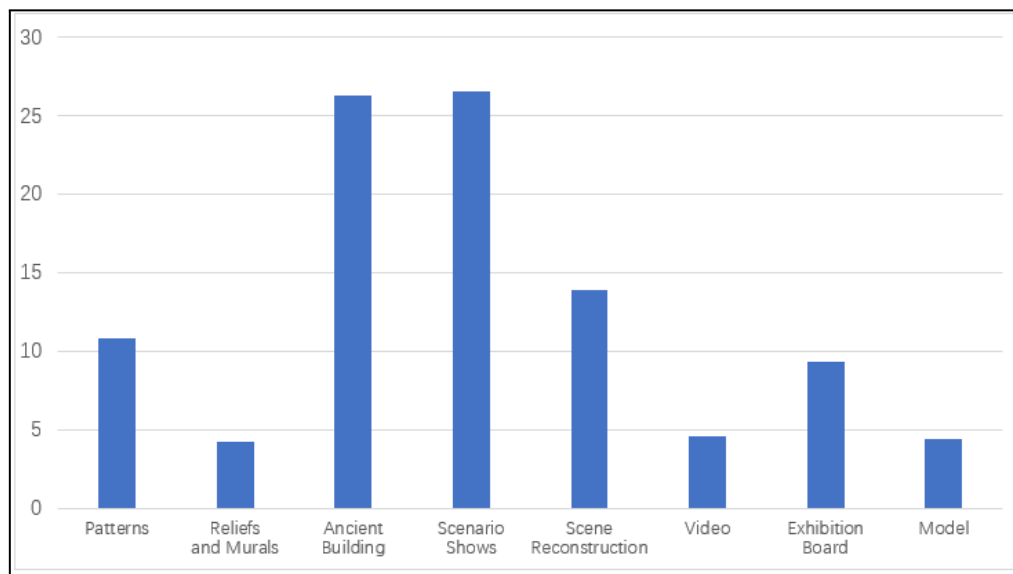


Figure 10. The Analysis of The Third Exhibition Halls
 (Source: Personally produced by the author, 2023)

Figure 9, Figure 10, Table 4 and Table 5 analyse the matching forms for the transformation of the museum's existing exhibits and their current weight levels. It's important to note that these weight levels are not fixed and should hinge on factors like technological advancements, changing user interests and emotions, budget considerations, and the cost of user education. In essence, they should undergo iterative changes as part of a gradual progression.

FINDINGS

This study, through on-site observations at museums in Dezhou and brief exchanges with museum staff, identified several prominent issues regarding exhibition formats and visitor interaction experiences. It further highlighted the potential value of Augmented Reality (AR) technology as an effective solution.

The research found that current exhibition practices at Dezhou museums predominantly rely on static displays, textual explanations, and traditional showcasing methods. These approaches provide limited interactive experiences and struggle to attract the attention of contemporary, particularly younger, audiences. Observations indicated low visitor engagement, brief stay durations, and reduced attention toward information conveyed solely through text and images. Conversations with museum staff further revealed shortcomings in exhibition content delivery and visitor interaction, resulting in declining visitor satisfaction and overall attendance.

However, museum staff exhibited an overall positive attitude towards the introduction of AR technology. They generally believed that AR could significantly enhance exhibition appeal, effectively stimulating visitor interest and participation in historical and cultural experiences. Particularly in Exhibition Hall One (Historical Evolution Theme) and Exhibition Hall Three (Scene Reproduction Theme), staff noted higher potential for AR application. Visitors in historical exhibitions preferred more vivid and intuitive ways to engage with historical content, while those in scene reproduction exhibitions expressed a strong desire for immersive experiences reflecting historical and cultural scenes of Dezhou.

Specifically, the research pointed out that Exhibition Hall One, as the main historical-cultural display area, failed to fully stimulate visitors' deeper exploration due to its static displays. AR technology, particularly via interactive electronic screens and wearable devices, could significantly enhance interactions between exhibits and visitors. For instance, by scanning QR codes next to exhibits, visitors could access intuitive historical contexts, craftsmanship details, or even virtual narrations by historical figures on their smart devices. This approach not only increases visitor engagement and interest but also deepens their understanding and retention of the historical-cultural significance of exhibits.

In Exhibition Hall Three, focused on urban memory through scene reproduction, visitors showed a pronounced interest in immersive experiences. Current static models and textual descriptions provided limited immersive sensations. The research suggested that AR methods, including holographic projection and immersive digital scene construction, could greatly enhance realism and interaction. For example, visitors could wear AR glasses to immerse themselves in historical street scenes and interact with virtual historical figures, thus gaining a more profound understanding of Dezhou's urban historical evolution.

The study further proposed a preliminary AR technology implementation framework for Dezhou museums, emphasizing the importance of balancing technological costs, visitor demands, and exhibit characteristics. For Exhibition Hall One, interactive electronic screens and selective use of wearable devices were recommended to enhance the intuitiveness and enjoyment of exhibit information. Conversely, Exhibition Hall Three was advised to prioritize holographic projection and immersive scene interactions, maximizing realism and visitor engagement.

Importantly, the observational and conversational outcomes also highlighted potential practical challenges for Dezhou museums in implementing AR technology, including a shortage of professional expertise, high technology costs, and difficulties in equipment maintenance and updating. These challenges necessitate not only clear technological implementation strategies but also partnerships with external entities such as universities and tech companies to develop professional technical teams gradually.

In conclusion, this study clearly demonstrates the significant value of AR technology in enhancing the interactivity of exhibitions and improving visitor cultural experiences and satisfaction at Dezhou museums. Future research could build on these findings by conducting more in-depth user experience studies and technological trials in specific exhibition scenarios, further refining the AR exhibition framework implementation.

CONCLUSION

Current development trends have transformed museums into multi-experience contexts, blending traditional cultural engagements—such as learning and educational activities—with emotional and unconventional experiences, including entertainment and social interaction. The integration of Augmented Reality (AR) technology into museum exhibitions offers distinct advantages, generating additional value, attracting visitors, and enhancing visitor curiosity and satisfaction. This study aims to investigate how AR technology facilitates the digital transformation of museum exhibitions in Texas. Consequently, it proposes an exhibition framework based on AR, aiming to reshape both exhibition and service models within museums. This implies a reconfiguration and innovation of museum exhibition content supported by immersive technologies, fostering technological and organizational synergy.

AR technology exhibits diverse and evolving application forms within museum exhibitions. The selection and creation of suitable AR interaction modalities require incorporating design thinking and systematic planning, taking into account user experiences, existing resources, and desired outcomes. Additionally, methodologies with a macro perspective need to be introduced for the weighted evaluation of interactive exhibit forms and resource allocation. This approach demands continuous observation and research to establish iterative design patterns.

The digitization of cultural assets represents a core challenge in applying AR technology. Valuable museum exhibits are often historical artifacts, whose digitization requires accurately capturing historical traces and external features. This process involves a dual technological integration of digital twins and digital reconstruction, aimed at producing richer interactive effects, thus stimulating visitors' interest in historical culture and enhancing the capability for cultural dissemination.

However, several limitations of this study must be acknowledged. First, the research primarily relies on observations and brief informal exchanges, lacking in-depth structured interviews or quantitative data support, potentially introducing subjectivity into the findings. Second, the proposed AR framework requires continuous validation and dynamic adjustments in alignment with actual museum environments and ongoing technological advancements.

Therefore, future research could expand sample sizes and conduct comprehensive structured interviews and quantitative surveys of visitor experiences to clarify the universality and adaptability of AR technology across different museum contexts. Moreover, addressing practical technological implementation issues within exhibition practices could involve prolonged observational and experimental research, facilitating iterative design and continuous optimization.

ACKNOWLEDGMENT

The author sincerely thanks the financial support from the Dezhou City Museum and the opportunity and enthusiasm provided by UiTM for conducting this research.

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