

Gamified Interaction Empowering Exhibition XR: A Review of Practical Cases and Research into Integration Pathways Gamified Interaction Enhances Exhibition XR: A Review of Practical Cases and Research on Integration Pathways

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Abstract. At present, XR technology is driving a transformation in exhibitions. This shift is moving beyond ‘static displays’. It is moving toward ‘immersive experiences’. However, the industry widely faces some challenges. The interactive features often lack variety. User engagement remains insufficient. The efficiency of cultural information dissemination can be improved. User retention rates also need enhancement. Exploring the value of integrating gamified interactions has now become essential. This approach is key to breaking through the current bottleneck. This paper focuses on the need to upgrade XR experiences in exhibitions. It examines this need within the context of digital media technology. This article systematically reviews typical XR applications from the exhibition and gaming fields. It integrates theories of virtual interaction design. The paper then provides an in-depth discussion on how gamified interactive elements can enhance the exhibition experience. Research indicates that current XR exhibitions have limitations. These exhibitions are primarily focused on viewing. Their interactive elements are often weak. Exhibitions can adopt gamified design methods. These methods include mission systems, operational feedback, and branching narratives. Such approaches significantly boost user engagement. This paper integrates practical cases like ‘The Vanishing Pharaoh’ and ‘Floating Dunhuang’. It also draws on game design principles from titles such as ‘Half-Life: Alyx’ and ‘Beat Saber’. Based on this, the study constructs a fusion framework of ‘Technical Adaptation, Content Anchoring, and Layered Design’. This framework offers theoretical guidance for gamified innovation in the XR exhibition field. It also provides a practical path for implementation.

Keywords: Gamified interaction; Exhibition XR; Virtual interaction design; Practical cases; Convergence pathways.

1. Introduction

Digital media technology is developing quickly. It is fundamentally changing the ways that culture is communicated. Traditional exhibitions depend on static displays and one-way messaging. They can no longer satisfy modern audience expectations. The public now wants immersive, interactive, and personalized experiences. This is especially true for cultural heritage. Therefore, libraries and museums are actively expanding their exhibition methods. However, most exhibitions still focus on directly displaying artifacts and documents. They lack in-depth visual interpretation and effective information delivery. A core industry challenge is breaking venues' physical and temporal limits. The goal is to bring static artifacts and abstract historical scenes to life. The emergence of XR technology provides a technical solution to this challenge. XR includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). These technologies create immersive spaces that blend the virtual and the real. They transform visitors from passive observers into active participants. This tremendous potential has been successfully demonstrated in exhibitions on themes like ancient Egyptian civilization, Dunhuang culture, and cave art. For instance, the Shanghai Library has a project called ‘Reading People, Reading City, Reading World’. This project uses head-mounted MR devices and a digital humanities knowledge base. It combines archival documents with virtual scenes. This blend

allows the audience to interact with history in a hands-on way. A French VR brand collaborated with Harvard University on the ‘Lost Pharaoh’ project. This project created a 1:1, high-precision digital reconstruction of the Giza Great Pyramid. It attracted a massive audience through its immersive experience [1, 2]. However, current XR exhibition practices remain at an elementary stage. They mainly focus on replicating virtual exhibits and adding basic informational labels. Their interactive design is also minimal. The interaction is often confined to simple gesture-based clicking and scene navigation. These designs lack a logical framework that can drive deeper audience engagement. This creates a problem with the user experience. After the initial visual impact wears off, users lack the motivation to continue exploring. As a result, the efficiency of cultural information delivery is low. Furthermore, user retention rates fall far below expectations.

In contrast, the gaming industry has developed over many decades. It has cultivated a mature and highly effective interactive design system. This system includes clearly defined mission systems. It also includes real-time feedback mechanisms. It features difficulty levels tailored to different audiences. Furthermore, narrative branches that create emotional resonance are part of it. These design principles accurately stimulate users' intrinsic motivation. This motivation drives exploration and encourages sustained participation. For example, *Half-Life: Alyx* uses puzzle mechanics. These mechanics combine item and environment interactions. The game advances the plot through this. Players naturally absorb story elements in an immersive experience. *Beat Saber* employs an ‘action-rhythm-feedback’ design. This design is highly integrated. It reduces the operational barrier. At the same time, it amplifies the fun of participation. This design philosophy focuses on ‘conveying content through gameplay.’ It aligns closely with the core mission of exhibition XR. This mission is ‘transmitting culture through experience.’ This alignment offers a reference path for overcoming the current interactive limitations in exhibition XR.

In the background, exploring the integration of gamified interaction and exhibition XR is highly valuable. This exploration holds both theoretical and practical significance. At the theoretical level, existing research often focuses on two areas separately. Some studies concentrate on the technological application of XR in exhibitions. Others discuss the design logic of gamified interaction. However, there is a lack of systematic investigation. This investigation should target their dimensions of integration and adaptive principles. This paper constructs a new integration framework. This framework centers on ‘technology adaptation, content anchoring, and layered design.’ Our work fills this research gap. Furthermore, it enriches the theoretical system for digital exhibitions and virtual interaction design. On the practical level, this research provides concrete design guidelines for exhibition planners. These guidelines help planners avoid a common pitfall: sacrificing cultural meaning for showing off. At the same time, planners can use gamification design to enhance the user experience. This approach helps users better understand and remember cultural content. The ultimate goal of this research is to enable users to learn through exploration and inherit culture through experience. This injects new momentum into the dynamic dissemination of digital cultural heritage. For the reasons above, this paper systematically reviews relevant application examples. These examples come from using XR technology in both exhibition and gaming scenarios. Furthermore, this paper incorporates virtual interaction design theory. It provides an in-depth analysis of how gamified interactive elements enhance the exhibition experience. Based on this analysis, the paper extracts actionable integration pathways. This work aims to provide a practical reference for the innovative development of XR technology in the exhibition field.

2. Theoretical Framework: Core Integration Dimensions of Exhibition XR and Game Interaction

2.1. Classification Basis for Interactive Elements

Wu Bin and others proposed a virtual exhibition guidance theory. We have integrated game design logic based on this. The core integration elements can be divided into three categories. The first category builds exploration logic through mission objectives and operational constraints. For example,

Jeffrey Shaw's work 'Fall Again, Better Fall' uses pressure-sensing pads to trigger interactions. This design transforms loose experiences into rule-following exploration. It creates an information-intensive participation model. The second category uses cultural themes as anchors. We deeply integrate interactive mechanisms with cultural meaning. This integration focuses on the historical context of exhibits. We can refer to the 'Republican Street Scene' scene restoration model at the Nanjing Museum. This model is shown in Figure 1. The third category of integration uses digital media empowerment technology. It relies on Unity3D real-time rendering and PBR material technology. This approach achieves 'seamless integration of virtual and real.' It significantly enhances the realism of operational feedback [3,4].



Figure 1. Scene from the 'Republican Era Street' at Nanjing Museum, sourced from the museum's official Weibo account.

2.2. Technical Adaptation Logic

We need to customize XR technology solutions for different exhibition scenarios. For example, VR technology excels at creating large-scale immersive exploration experiences. This is like the 1:1 replicated pyramid in 'The Lost Pharaoh.' In contrast, AR technology focuses on providing augmented reality overlays for interpreting physical objects. The AR artifact annotations used by the Palace Museum are a good example. At the same time, MR technology enables the dynamic fusion of physical space and virtual content. The 'Reading People, Reading City, Reading World' project at the Shanghai Library is one such case. It is worth noting the GamIN platform developed by Joao Vilar's team. This platform uses mixed reality technology to construct interactive narratives within spatial environments. The team places special emphasis on the supporting role of multimedia materials. They believe these materials can effectively enhance the interactive experience. Audio information is considered particularly important. This concept provides sophisticated design inspiration for MR applications in exhibitions. In MR exhibitions like 'Exploring the Mysteries of Yungang,' the exhibition synchronizes voice narration with visual effects. When the lighting patterns on the Buddha's hand gestures shift, the narration is triggered at the same time. This design allows visitors to absorb cultural information through interaction naturally [5].

3. Case Study: Practical Experience and Gamification Improvement Pathways

3.1. XR Exhibition Space Case Study

'The Lost Pharaoh' is an immersive VR exhibition. It was jointly developed by the French company Excurio and the Harvard University Giza Project team. The entire development process took three years. This exhibition is set inside the Great Pyramid of Giza in ancient Egypt. The production team created a digital reconstruction based on archaeological survey data. They recreated the pyramid's interior structure, the landscapes of the Nile River, and the pharaoh's funeral ceremonies at a 1:1 scale. Visitors experience this in a 580-square-meter free-roaming space. They wear VR headsets. Visitors

will follow a virtual guide named ‘Mona’ on a 45-minute fantastic journey. During this journey, visitors will overlook the entire panorama of the Giza Plateau. They will also climb to the top of the pyramid. Visitors will pass through corridors and witness the anointing ceremony. They can explore the Queen's tomb. Finally, visitors will board a boat to drift on the Nile River and witness the grand funeral procession of Pharaoh Khufu. The exhibition's highlight is its high level of interactivity. The virtual guide Mona drives the narrative through tasks. These tasks include ‘Flying Slab’ and ‘Tomb Chamber Puzzle.’ She guides visitors to explore in this way. For example, in the Tomb Chamber Puzzle segment, visitors must observe the murals' symbols. These symbols are important clues. Visitors must use these clues to unlock subsequent areas. This design fills the entire exploration process with a clear sense of purpose. The environmental feedback design is equally impressive. For example, the device produces a rumbling sound when a giant stone falls. Meanwhile, the statue of Goddess Bastet in the darkness changes its brightness. These designs strengthen the connection between "action and consequence." When visitors activate specific mechanisms or reach story nodes, they can tangibly feel the actual impact of their actions through this feedback. Henning Schlieve studied the gamified exhibitions at the British Museum. He proposed a critical view: "Gamification design in cultural heritage exhibitions must prioritize 'cultural interpretation'." This means the design needs to avoid disconnection between tasks and cultural meaning. Based on this perspective, the team behind ‘The Lost Pharaoh’ can draw from the environmental puzzle-solving logic of ‘The Legend of Zelda.’ They could introduce a ‘symbol deciphering side quest.’ In this quest, visitors must identify symbols on murals within virtual corridors. They would need to interpret the meaning of these symbols using the cultural context of ancient Egyptian hieroglyphs. Successfully deciphering them would allow visitors to unlock hidden narratives, such as the principles of the ancient Egyptian calendar. Figure 2 shows the comparison between the original and enhanced versions. The newly added game mechanics have significantly improved audience participation and immersion [6]. For example, when visitors discover a set of symbols representing the "Four Seasons" in the corridor, they can associate these symbols with the surrounding ‘Nile River Flooding’ scene model. After successfully making this connection, the system unlocks a voice narration. This narration details how the ancient Egyptians developed their calendar based on the annual flooding of the Nile. This design makes exploration more interesting and, more importantly, achieves a deep transfer of cultural knowledge.

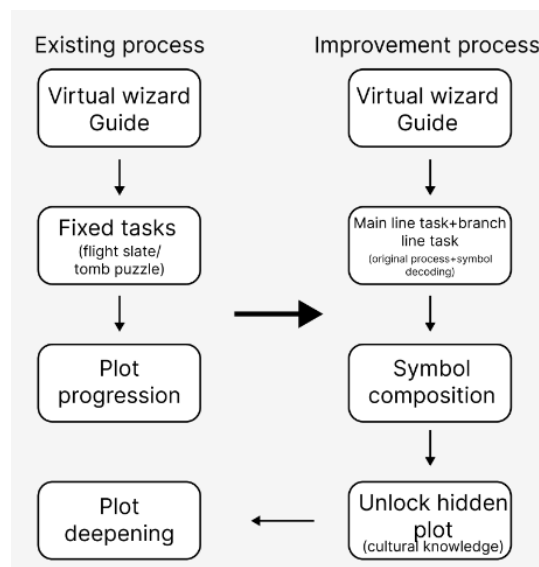


Figure 2. Comparison of Before and After Process Flowcharts.

The ‘Flowing Dunhuang’ exhibition achieves an extraordinary integration of culture and technology. It utilizes cutting-edge XR technology. The exhibition successfully breaks through time, space, and media limitations. It provides audiences with an immersive Dunhuang cultural experience. The current interactive design showcases several highlights. For instance, visitors can assume the role of the ‘Chosen One.’ They can interact with the virtual environment through hand gestures. Visitors can

illuminate the murals with a gentle wave of their hand. This action also triggers hidden storylines. It infuses the entire viewing journey with a sense of mystery and surprise. Furthermore, the exhibition includes an adventure quest to collect spirit stone fragments. This mission employs a tiered progression mechanism. Within the 720-degree panoramic space, the system guides visitors to gather these fragments. The ultimate goal is to complete the ritual of returning the Four Divine Beasts to their rightful places. This 'light gamification' exploration model allows visitors to experience the charm of Dunhuang culture through immersive interaction. Relevant case studies have confirmed the effectiveness of this approach. Scholars, including Lee, pointed out that integrating linear storytelling with user-driven interaction is crucial when using AR technology to build a narrative gamified museum guide system. He noted that this integration can significantly enhance the coherence of cultural narratives and audience engagement [7]. Building on this perspective, the 'Flowing Dunhuang' exhibition could introduce AR linear narrative branches to its existing gesture interaction system. For instance, when visitors use AR devices to scan specific murals such as the Flying Apsaras, the system would trigger a phased narrative called 'The Artist's Creative Process.' This narrative would progressively display the entire process, from sketching the initial outline and applying pigments to completing the mural. At each stage, visitors need to complete corresponding interactive tasks. For example, they use hand gestures to simulate mixing mineral pigments. After completing a task, the system unlocks a segment of the painter's audio diary. This design allows the audience to gain a deeper understanding of the creative process behind the Dunhuang murals through interaction. It also helps them better comprehend the cultural context. This approach can effectively address issues in the current exhibition. These issues include fragmented interactive experiences and a loosely connected narrative structure.

The "Exploring Yungang" digital light exhibition is a stunning fusion of Yungang culture and modern technology. This exhibition has attracted widespread attention since its opening. Its interactive features are awe-inspiring. The most distinctive element is the 3D light matrix decoding of Buddha hand gestures. Through the interactive technology of 3D light matrix and sensors, visitors can engage in an excellent dialogue with the wisdom symbols of Northern Wei Buddha hand gestures. When a visitor lightly touches the display screen, the Buddha's hand gesture suddenly radiates a brilliant light. It feels as if awakening a civilization code dormant for millennia. This immersive experience vividly conveys the mysterious heritage of the Yungang grottoes. The VR simulation of 'grotto excavation' is particularly impressive. It utilizes LBE large-space tracking technology and 4K ultra-high-definition imaging. This technology faithfully recreates the original appearance of Cave 20 from its early excavation period. Visitors wearing VR equipment can travel back 1,500 years in time. They can take on the role of craftspeople from the Northern Wei Dynasty. They can personally experience the entire process of excavating the grottoes. Relevant case studies have verified this design approach. The 'Exploring Yungang' exhibition draws on the research of Joao Vilar's team. Their work was published in the 'GamiN' journal, focusing on 'spatial-based interactive narrative design.' The exhibition used this theory to optimize its MR interaction logic. They set up multiple 'cultural anchor points' throughout the physical exhibition space. For example, replicas of Northern Wei carving tools are displayed. The system triggers corresponding virtual scenes when visitors use MR devices to scan these cultural anchor points. For example, visitors can see holographic images of artisans discussing excavation plans. At the same time, visitors need to complete interactive tasks. One example is the task to 'select appropriate carving tools based on rock texture.' After visitors complete these tasks, the system unlocks explanatory content about the evolution of grotto excavation techniques. This design allows MR technology to blend the virtual and real worlds effectively. It ultimately achieves deeper and more effective cultural transmission [5].

'The Lost Pharaoh,' 'Flowing Dunhuang: A Myriad Kingdom,' and the 'Exploring Yungang' digital light exhibition have distinct features. However, they share important commonalities in promoting the digital presentation of cultural heritage and enhancing audience engagement. All three utilize XR technology to create immersive experience spaces. This technology guides audiences to travel across time and space, allowing them to appreciate the charm of diverse cultures deeply. All three exhibitions

are committed to adopting diverse participation methods for interactive design. They successfully transform passive viewing into active exploration for the audience. This transformation effectively deepens visitors' understanding and appreciation of cultural heritage. Furthermore, all three projects place high importance on historical scene recreation. They utilize cutting-edge digital technologies to vividly present historical scenes like the Egyptian pyramids, Dunhuang Mogao Caves, and Yungang Grottoes before the audience's eyes. However, there are still notable differences among the three exhibitions. Regarding technical application, 'The Lost Pharaoh' primarily uses VR technology to create an immersive experience. It allows visitors to move freely within a 580-square-meter pyramid space. 'Flowing Dunhuang' employs the latest PICO 4 Ultra equipment to provide a 720-degree panoramic visual experience, immersing the audience in Dunhuang culture. 'Exploring Yungang' integrates digital light and shadow with large-scale VR technology to create a diverse visiting experience. In interactive design, 'The Lost Pharaoh' adopts a mission-driven narrative approach, such as the 'Flying Stone Slab' segment. 'Flowing Dunhuang' also utilizes PICO 4 Ultra equipment to achieve panoramic immersion, enabling visitors to experience Dunhuang culture deeply. 'Exploring Yungang,' meanwhile, combines digital light and shadow with large-scale VR technology to offer rich interactive experiences. The "Exploring Yungang" exhibition integrates digital light projection with large-scale VR technology. This integration provides visitors with a multi-dimensional immersive experience. In terms of interactive design, each exhibition has its distinct features. "The Lost Pharaoh" uses mission-driven narratives to guide exploration. Specific tasks include "Flying Stone Slab" and "Tomb Chamber Puzzle". "Flowing Dunhuang" emphasizes gesture interaction and collection tasks. Examples include activating murals with hand waves and gathering spirit stone fragments. "Exploring Yungang" offers unique interactive experiences. These include decoding Buddha hand gestures through three-dimensional light matrices and simulating cave excavation through VR. On the cultural level, each experience focuses on different heritages. "The Lost Pharaoh" centers on ancient Egyptian culture. "Flowing Dunhuang" presents Dunhuang art. "Exploring Yungang" showcases the Yungang Grottoes culture. They demonstrate the essence of cultural heritage from different regions and styles together. These exhibitions create distinctive cultural exploration journeys for visitors.

Exhibitions like 'The Lost Pharaoh,' 'Flowing Dunhuang: A Myriad of Forms,' and 'Exploring Yungang' all use XR technology to revolutionize the presentation of cultural heritage. These exhibitions successfully break through the constraints of time and space. They allow audiences to immerse themselves in the unique charm of cultural relics, free from geographical and historical limitations. For instance, visitors can travel inside an ancient Egyptian pyramid, walk alongside the murals of the Dunhuang Mogao Caves, or find themselves within the caves of the Yungang Grottoes. These immersive experiences significantly enhance audience engagement. They transform passive viewers into active explorers. The exhibitions also incorporate diverse interactive designs like task-driven activities, gesture controls, and simulation operations. These designs enable visitors to engage more deeply with the experience. This approach makes the visit more enjoyable and, more importantly, helps deepen the understanding and memory of cultural content. Through firsthand experience, abstract knowledge is transformed into vivid and concrete feelings.

However, such exhibitions also have certain shortcomings. On the technical level, some exhibitions suffer from interaction delays due to immature systems and insufficient tracking accuracy. For example, when visitors operate controllers, their movements may not synchronize instantly with the on-screen feedback. This can severely disrupt the sense of immersion. On the content level, some exhibitions face a disconnect between cultural themes and game mechanics. Specific interactive segments feel more like technology demonstrations rather than deep cultural explorations. For instance, some exhibitions incorporate simple mini-games that lack cultural relevance. They fail to integrate cultural elements into the gaming experience organically. Furthermore, user targeting lacks precision. The difficulty of interactions isn't differentiated across user groups. First-time technology users and experienced enthusiasts face the same level of complexity. As a result, some visitors find

the experience too lacking and a straightforward challenge. The high difficulty level deters others. Ultimately, these exhibitions fail to meet the needs of diverse users.

3.2. The Reference Value of XR Case Studies in Gaming Spaces

Both ‘Half-Life: Alyx’ and ‘Beat Saber’ provide valuable inspiration in game design. Their unique design approaches offer essential references for other creators. These successful experiences can be applied to exhibition design. This cross-disciplinary application can effectively enhance the visitor experience.

‘Half-Life: Alyx’ is a highly acclaimed VR work. It features an innovative core design. Players experience the game from a first-person perspective. They solve puzzles by combining various tools. Players also advance the plot through environmental interactions. For example, they must operate controllers to manipulate mechanical devices to open passages. This interactive approach deeply immerses players in the game world. It significantly enhances the sense of immersion and entertainment value. This design concept holds great potential in the field of historical exhibitions. For instance, we could develop a ‘cultural relic restoration toolkit system’. Visitors wearing VR headsets would be placed in a virtual restoration workshop. They can use virtual tools like magnifying glasses and brushes. Their task is to reassemble fragments of ancient murals. This design transforms visitors from passive viewers into active participants. It enables them to understand the restoration process better. It also helps them learn more about the relevant historical context.

The core design of ‘Beat Saber’ lies in the precise synchronization between musical rhythm and physical movement. Players need to swing controllers to the beat to slash approaching blocks. This design creates a rhythmic and immersive experience. The game also features a tiered difficulty system. This system accommodates users with different skill levels. It ensures both beginners and experienced players can enjoy the game. This design concept can be applied to intangible cultural heritage exhibitions. For example, a "traditional instrument interactive rhythm" segment could be created. Audiences can experience the unique charm of drumbeats and string sounds through cheerful rhythms. This allows them to appreciate the appeal of intangible cultural heritage. When visitors complete interactions, the system unlocks explanations about instrument crafting techniques. This helps deepen understanding of intangible cultural heritage. Researcher Zhang Xiaolin and colleagues studied this from a user experience perspective. They found that combining "instant feedback" with ‘graded difficulty’ in gamification design significantly improves continuous user engagement. It also enhances the retention rate of cultural memories [8]. This research conclusion provides theoretical support for transferring game design principles to exhibition settings. Whether it's the ‘artifact restoration tool system’ or ‘traditional instrument rhythm interaction,’ these experiences require real-time feedback. Feedback includes visual progress bars for restoration or auditory cues for rhythm hits. Meanwhile, task difficulty should adjust dynamically based on user proficiency. This ensures visitors at all skill levels have a positive experience. Ultimately, this approach deepens cultural memorization.

4. Analysis of Existing Issues and Requirements

4.1. Technical Bottlenecks

XR technology faces both equipment and technical limitations in exhibition applications. On the hardware level, XR headsets have weight and heat dissipation issues, which limit prolonged usage. Some equipment experiences interaction delays due to insufficient tracking accuracy [1]. Challenges also exist in technology integration. There is a lack of smooth switching between VR, AR and MR modes. For instance, the Shanghai Library MR project encountered delays during multi-user synchronous interactions. This situation damages user experience and hinders wider adoption of XR technology.

4.2. Content Design Deficiencies

Current exhibitions have noticeable shortcomings. On one hand, the cultural core and game mechanisms are disconnected. Many interactive elements become mere technical demonstrations. For example, some simple gesture-triggered animations lack cultural resonance [9]. On the other hand, user targeting remains unclear. Design teams fail to distinguish between ‘culture enthusiasts’ and ‘game players’. This results in interaction designs that may be too complex, such as intricate puzzles, or too simple, like requiring only a single click.

4.3. Core User Requirements

In XR technology applications, researchers point to an urgent need for lightweight equipment and extended battery life. On the content level, relevant studies show users expect personalized interactive experiences. These experiences should focus on niche cultural themes, such as local intangible cultural heritage. Furthermore, Li Zhouxun and his team discovered an essential phenomenon while studying metaverse exhibitions. Users need integrated ‘online virtual exploration and offline physical verification’ closed-loop experiences. This indicates that exhibition XR needs to integrate online and offline scenarios further. For example, visitors could exchange virtual cultural achievements unlocked online for guided tour services in physical exhibition halls. This approach can meet users' multi-scenario experience needs [10].

5. Game Mechanics Addressing Pain Points

5.1. Quest System

Exhibition designers can create various tasks, including main quests and side quests. These tasks guide visitors to deepen their understanding of the exhibition's cultural content by completing them. For example, ‘The Lost Pharaoh’ exhibition introduced a ‘symbol-deciphering side quest.’ This task design directs visitors through progressive exploration, helping them gain deeper insights into relevant cultural knowledge.

5.2. Feedback Mechanisms

Designers can draw inspiration from the instant feedback mechanisms in games. For example, providing sound prompts and visual effects for successful operations. This can be combined with layered interactive response designs. These methods effectively enhance visitors' sense of participation and achievement. The "Flowing Dunhuang" exhibition features a ‘Mural Restoration Rhythm Challenge’ segment. Through real-time progress feedback, this activity allows visitors to feel the value of their contributions tangibly.

5.3. Tiered Difficulty Levels

Interactive experiences use customized difficulty levels to meet the needs of different user groups. For cultural enthusiasts, designers can provide in-depth exploration tasks. For example, the ‘Exploring Yungang’ exhibition features an advanced task called ‘Tracing Stone Carving Techniques.’ This task requires visitors to analyze the differences in clothing fold carvings of the grotto statues. They also need to interpret the evolution of artistic styles within the historical context of the Northern Wei Dynasty. For the gamer demographic, designers can incorporate operationally challenging tasks. For instance, in the ‘Grotto Excavation’ experience, the system can increase the complexity of rock textures. Alternatively, it can set time-limited challenges that require ‘continuously and precisely carving designated areas.’ Researcher Zhang Xiaolin and colleagues highlighted a key finding in their study. They stated: ‘A difficulty tiering mechanism customized based on user capabilities can effectively reduce beginners' frustration while satisfying core users' exploration needs.’ This conclusion provides a theoretical basis for implementing tiered difficulty systems. It ensures that all user groups receive experiences suited to their skill levels during interactions [8].

5.4. Narrative Branching

Designing multiple narrative branches can enhance the richness of cultural content. This approach provides personalized experiences for visitors. The cultural content and storylines develop differently based on visitor choices and actions. For example, the 'Flowing Dunhuang' exhibition offers choices in its 'mural restoration' segment. If visitors choose 'restore Tang Dynasty style,' the system triggers a narrative about the Tang Dynasty Dunhuang artists' creative process. It also unlocks detailed explanations of Tang Dynasty pigment-making techniques. If visitors select 'restore Five Dynasties style,' they enter a storyline about cultural exchange during the Five Dynasties period. This branch demonstrates the historical background of cultural integration between China and foreign lands. Li Zhiqiang's team proposed an 'Augmented Reality Narrative Gamified Guide System.' It includes the design principle of 'user-choice-driven narrative branching.' This principle can further optimize the coherence of exhibition plot branches. The mechanism ensures each narrative branch remains closely anchored to specific dimensions of Dunhuang culture. It effectively prevents narrative elements from detaching from their cultural foundations [7].

6. Conclusion

This paper analyzes multiple cases in-depth and builds a systematic theoretical construction. It aims to establish a practical framework for gamification innovation in the XR exhibition field. The research shows that integrating gamified interactions into exhibition XR must strictly follow three core principles. These principles are technology adaptation, content anchoring, and layered design. At the technical level, designers should select appropriate technical solutions based on exhibition space characteristics. Large spaces are suitable for VR technology to achieve immersive experiences. Small spaces work well with AR technology to highlight augmented reality overlays and commentary functions. At the content level, interactive mechanisms must be closely anchored to cultural themes. Designers need to avoid disconnection between cultural context and gameplay. In the experience difficulty design, the needs of diverse user groups must be fully considered. This ensures all visitors can have a quality experience. Successful cases strongly validate this integration model. The Palace Museum's AR puzzle game increased artifact knowledge retention by 42%. 'The Lost Pharaoh' successfully attracted over 100,000 visitors through its mission-driven narrative.

Looking ahead, there are three development paths for gamified XR innovation in the exhibition field. On the technical level, R&D teams must prioritize developing lightweight XR equipment. They must also overcome several technical challenges. These technologies include synchronized multi-user interaction and low-latency rendering. Simultaneously, they must solve issues like device weight, thermal management, and tracking accuracy. Establishing a 'cultural element-game mechanism' mapping library in content innovation is crucial. We must transform 'Dunhuang mural storytelling' into 'branching narrative choices' gameplay. Or convert "grotto excavation techniques" into "operation simulation tasks." Such transformations can deepen cultural resonance. This approach can integrate Joao Vilar's design philosophy from the GamIN platform. This philosophy integrates cultural elements through spatial interaction. It ensures the mapping library aligns with actual exhibition needs. In ecosystem development, we need to build online-offline closed-loop experiences. For example, virtual achievements unlocked by visitors during exhibitions can sync to their mobile devices. This approach expands cultural dissemination scenarios. Li Zhouxun's team's metaverse exhibition research confirmed a critical finding. They verified that 'online-offline interaction can enhance user engagement.' This conclusion provides practical guidance for the solution. We could launch an 'online virtual artifact puzzle challenge.' Successful participants could receive exclusive cultural guide services in the physical exhibition hall.

The next step requires conducting empirical research. This should verify the impact of different interaction designs on cultural communication effects. Specifically, we must compare "task-driven" and "free-exploration" modes. Focus on examining differences in audience knowledge retention rates. Meanwhile, we can adopt methodologies from Henning Schliwa's British Museum case study.

Suggest introducing long-term tracking surveys by analyzing the sustained impact of gamified interactions on audience cultural heritage awareness. This will ultimately promote continuous optimization and development of gamification innovation in the exhibition XR field.

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