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Research on the Impact of the Digital Environment in Museums on Visitor Cognitive Experience: A Case Study of Western Zhou Dynasty Bronzes[1]

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Abstract

Museums play a crucial educational role, yet traditional exhibition methods often fall short of fulfilling the audience's deep understanding of artifacts, especially for items like Western Zhou bronzes, which hold rich historical and cultural value. With the rapid advancement of digital technology, a fundamental transformation in museum exhibition methods is underway. Particularly in the display of cultural heritage, digital environments offer new possibilities for interaction, altering the ways audiences participate and perceive experiences. The presentation methods within digital displays are particularly pivotal. This study employs methods of literature review, field investigation, and interdisciplinary research to explore the construction of digital environments in museums, aiming to enhance the audience's cognitive experience of Western Zhou bronzes. It analyzes the historical value and symbolic meanings of these artifacts, the current application of digital environments in museums, and their impact on audience cognition. The results indicate that Western Zhou bronzes display their extensive history and rich cultural symbols, reflecting the political and religious structures of ancient society. Digital technology has become a crucial direction for advancing museum displays and educational innovation. It makes exhibitions more attractive and educational, significantly enhancing information transmission efficiency and audience learning motivation. Museum digital environments, through rich sensory experiences and audience-centered interactive designs, effectively enhance audience cognitive experiences, making complex historical content more accessible. Proper use of digital media technology can improve audience learning efficiency and deepen their understanding and appreciation of cultural heritage.

Keywords: Digital Environment / Museum Exhibition / Western Zhou Bronzes / Audience Cognitive Experience

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การศึกษาผลกระทบของสภาพแวดล้อมดิจิทัลในพิพิธภัณฑ์ต่อประสบการณ์การรับรู้ของผู้เยี่ยมชม: กรณีศึกษาของเครื่องสำริดสมัยราชวงศ์โจวตะวันตก[1]

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บทคัดย่อ

พิพิธภัณฑ์มีบทบาทสำคัญในการให้การศึกษา แต่ทว่าการจัดแสดงแบบดั้งเดิมมักไม่สามารถทำให้ผู้ชมเข้าใจวัตถุโบราณได้อย่างลึกซึ้ง โดยเฉพาะวัตถุที่มีคุณค่าทางประวัติศาสตร์และวัฒนธรรมสูง เช่น เครื่องสำริดสมัยราชวงศ์โจวตะวันตก สืบเนื่องจากการพัฒนาอย่างรวดเร็วของเทคโนโลยีดิจิทัล ส่งผลให้การจัดแสดงในพิพิธภัณฑ์เกิดความเปลี่ยนแปลงในระดับพื้นฐาน โดยเฉพาะการจัดแสดงมรดกทางวัฒนธรรม สภาพแวดล้อมดิจิทัลเสนอแนวทางใหม่ ๆ สำหรับการมีปฏิสัมพันธ์ เปลี่ยนแปลงวิธีที่ผู้ชมมีส่วนร่วมและสัมผัสประสบการณ์การรับรู้ วิธีการนำเสนอภายใต้สภาพแวดล้อมดิจิทัลจึงมีความสำคัญเป็นพิเศษ การศึกษานี้ใช้วิธีการทบทวนวรรณกรรม การเก็บข้อมูลภาคสนาม และการวิจัยสหวิทยาการเพื่อสำรวจการสร้างสภาพแวดล้อมดิจิทัลในพิพิธภัณฑ์ โดยมีเป้าหมายเพื่อเพิ่มพูนประสบการณ์การรับรู้ของผู้ชมเกี่ยวกับเครื่องสำริดสมัยราชวงศ์โจวตะวันตก การศึกษาวิเคราะห์คุณค่าทางประวัติศาสตร์และความหมายเชิงสัญลักษณ์ของวัตถุโบราณ การประยุกต์ใช้สภาพแวดล้อมดิจิทัลในพิพิธภัณฑ์ในปัจจุบัน และผลกระทบต่อการรับรู้ของผู้ชม ผลการศึกษาชี้ให้เห็นว่าเครื่องสำริดสมัยราชวงศ์โจวตะวันตกแสดงถึงประวัติศาสตร์อันยาวนานและสัญลักษณ์ทางวัฒนธรรมที่เข้มข้น สะท้อนโครงสร้างทางการเมืองและศาสนาของสังคมโบราณ เทคโนโลยีดิจิทัลได้กลายเป็นทิศทางที่สำคัญสำหรับการพัฒนาการจัดแสดงในพิพิธภัณฑ์และนวัตกรรมการศึกษา ทำให้การจัดแสดงน่าสนใจและเพิ่มพูนความรู้ในเชิงการศึกษา เพิ่มประสิทธิภาพการสื่อสารข้อมูลและแรงจูงใจในการเรียนรู้ของผู้ชมอย่างมาก ด้วยประสบการณ์ทางประสาทสัมผัสที่หลากหลายและการออกแบบที่เน้นการมีส่วนร่วมของผู้ชม สภาพแวดล้อมดิจิทัลในพิพิธภัณฑ์ส่งเสริมประสิทธิภาพในการเพิ่มพูนประสบการณ์การรับรู้ของผู้ชม ทำให้เนื้อหาทางประวัติศาสตร์ที่ซับซ้อนเข้าถึงได้สะดวกขึ้น การใช้เทคโนโลยีสื่อดิจิทัลอย่างเหมาะสมสามารถปรับปรุงประสิทธิภาพการเรียนรู้ของผู้ชมและเพิ่มพูนความเข้าใจ ตลอดจนความชื่นชมในมรดกทางวัฒนธรรม

คำสำคัญ: สภาพแวดล้อมดิจิทัล / การจัดแสดงในพิพิธภัณฑ์ / เครื่องสำริดสมัยราชวงศ์โจวตะวันตก / ประสบการณ์การรับรู้ของผู้ชม

วิธีอ้างอิง

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Introduction

Museums are vital venues for cultural engagement and act as records and symbols of regional and national civilizational development. Museum exhibitions often contain vast and complex historical information and cultural knowledge, serving an important educational function. However, traditional methods of artifact display in museums can struggle to facilitate a comprehensive understanding of their meanings and cultural significance. Additionally, rigid text and physical displays rarely engage visitors emotionally. In contemporary society, audience expectations for museum visits are becoming more diversified. With the rapid development of digital landscapes, traditional museum experiences are undergoing transformation, with new interactive methods and ways of interpreting artifacts gradually emerging. This study delves into the significant changes prompted by digital environments in museums, focusing on how these changes affect audience cognition and interaction.

Taking the museum exhibition of Western Zhou bronzes as an example, these artifacts are crucial for studying Chinese ritual culture and hold significant historical and exhibition value (Child-Johnson, 2020: 451-470). Traditionally, Western Zhou bronzes displayed directly in glass cases with accompanying explanatory plaques that offer detailed information (Figure 1). These conventional static displays and complex scholarly explanations often make the rich historical narratives and cultural connotations of these artifacts obscure and difficult to understand, thereby reducing audience engagement and comprehension. The rich cultural meanings embedded in the symbols are also not easily accessible. Therefore, there is a need to research and develop new methods to enhance the cognitive experience of visitors.

Figure 1

Traditional Museum Exhibition Space.

Nowadays, with the intervention of new media technology, museum exhibition methods have embraced new opportunities, creating rich digital visiting environments. Current trends in the development of museums worldwide indicate that digitization, integration, networking, and intelligentization are inevitable trends in the development of museums (Huang, 2008: 1). For instance, the use of augmented reality (AR), virtual reality (VR), and interactive exhibits can enrich exhibition content and enhance audience interaction and immersion. Thus, researchers believe that by creating interactive and immersive digital environments through digital technology, it may be possible to increase audience interest and desire to learn, thereby enhancing their cognitive experience.

In the context of the rapid development of digital media technology, museum digital environments provide unique display settings for artifacts. However, the different digital environments are suited to different types of artifacts displays. There is still a significant gap in understanding the specific impacts of these technologies on audience cognition and learning. If improperly used, technology can interfere with the cognitive process of visitors, degrade the visiting experience, and hinder the goals of cultural dissemination in museums. Therefore, in-depth analysis of the application of digital environments, consideration of how display methods affect audience cognition, and ensuring the effectiveness of technology applications to identify suitable technologies for artifacts are particularly important.

Research Objectives

1. To study the history, symbolic meanings, and value of Western Zhou bronzes.

2. To explore the significance and current application of digital environments in museums.

3. To investigate the impact of digital environments on audience cognition and discuss the feasibility of enhancing cognitive experiences through digital means.

Research Scope

The scope of this study primarily focuses on the following key areas:

1. Western Zhou Bronzes

Western Zhou bronzes refer to the bronzes from the Western Zhou period in China (1046-771 BC), which are crucial for studying Chinese ritual culture and hold significant historical and exhibition value (Childs-Johnson, 2020: 451-470). This research covers the historical origins, artistic characteristics, and functions and meanings in ancient society of these bronzes. Through detailed analysis of the design, inscriptions, and uses of the bronzes, the study aims to reveal their central role in Zhou dynasty culture and rituals.

2. Museum Digital Environments

Museum digital environments refer to the transformation of traditional museum spaces into new digital spaces through the intervention of digital technology. This involves the comprehensive application of software, hardware, and network technology with digital processing systems, aimed at creating interactive spaces that can effectively transmit information and provide specific experiences to users. The scope extends to how museums use digital technology to improve exhibition experiences and enhance audience understanding and cognition of artifacts like Western Zhou bronzes through digital means. The study includes examining the application of interactive exhibitions, virtual reality (VR), augmented reality (AR), and other digital tools in actual museum settings.

3. Audience Cognition

Audience cognition refers to the complex process through which audiences receive and process information, involving stages of perception, understanding, and thinking. This process is influenced by factors such as the psychological state, cultural background,

and emotional condition of the audience, as well as by the manner in which information is presented and environmental conditions (Carci et al., 2019). This research focuses on the cognitive processes of museum visitors, particularly how they interact with digital exhibit content and artifacts, and how they transform these interactions into personal knowledge and experience. This part aims to assess how digital environments affect the learning motivation, depth of perception, and breadth of cultural appreciation of audiences.

Research Methods

1. Literature Review

The literature review involves systematically collecting, analyzing, and interpreting published research and information to develop a comprehensive understanding of a particular field. In this study, both online and offline sources were consulted, including books and academic articles on Western Zhou bronzes, museum exhibitions, and digital environments in museums. This research involved analyzing and organizing these materials to provide a literature foundation, gathering information about the history and cultural value of Western Zhou bronzes, the application of digital media in museums, and the design of digital environments within museums.

2. Field Investigation

The field investigation entails collecting data through personal visits to specific locations, allowing researchers to directly observe the subjects and environments. In this research, field investigations were conducted at the Baoji Bronze Ware Museum in China and the Shaanxi History Museum to analyze how Western Zhou bronzes are exhibited within museum environments and gather related information. Additionally, the study involved inspecting existing traditional exhibition spaces, digital exhibition spaces, and digital environment spaces in museums to analyze their differences and advantages or disadvantages.

3. Interdisciplinary Research

The interdisciplinary research combines theories and methods from multiple disciplines to address complex research problems. This study utilized knowledge and methodologies from history, semiotics, digital art, and cultural space management to analyze the digital museum environments for Western Zhou bronzes. The aim was to obtain findings related

to the historical and cultural value of the Western Zhou bronzes, the digital environments in museums, and the impact of these environments on audience cognition.

The research process involved five main steps:

Reviewing literature related to Western Zhou bronzes, museum exhibition management, and museum digital environments, and analyzing and organizing the information obtained.

Conducting site visits to the Baoji Bronze Ware Museum and Shaanxi History Museum to gather museum data and exhibition information about Western Zhou bronzes.

Inspecting traditional and digital exhibition spaces in museums to identify their differences.

Analyzing the importance and current status of digital environments in museums based on literature results and site visit information.

Analyzing and organizing the research findings to discuss the impact of digital environments on audience cognition, the feasibility of enhancing cognitive experiences through digital environments, and making recommendations.

The comprehensive content outlined above is represented in the conceptual framework of the study, as shown in Figure 2.

Figure 2

Conceptual Framework.

Research Results

1. The History, Symbolic Meaning, and Cultural Value of Western Zhou Bronzes

1.1 Historical Background of Western Zhou Bronzes

Western Zhou bronzes were an integral part of early Zhou dynasty society, culture, and art. During the Western Zhou period, many bronzes were crafted specifically for ritual activities (Ni, 2011: 18). These artifacts are primarily excavated from Baoji City in Shaanxi Province and its surroundings, which is the birthplace of Western Zhou culture.

The site of Zhouyuan, located at the junction of Fufeng and Qishan in modern-day Baoji, Shaanxi, was once the capital in the early Western Zhou era (Figure 3). Baoji, as the cradle of Western Zhou, has yielded numerous bronzes, often discovered in hoards. Nearly seven such hoards have been identified in the area, each containing dozens or even hundreds of artifacts-a rare occurrence of such quantity and concentration of bronze artifacts being unearthed together (Yan, 1988: 92). This is a significant reason why researchers choose Baoji Museum as a key site for studying Western Zhou bronzes.

Figure 3

The Bronze Age Site of the Western Zhou Dynasty in Baoji Prefecture.

Note. From *Shaanxi released six important new archaeological discoveries, and the Baling site was selected,* by People's Daily Online-Shaanxi Channel, 2022 (http://sn.people.com.cn/BIG5/n2/2022/0124/c226647-35110445.html). Copyright by Shaanxi Provincial Bureau of Cultural Relics

The bronzes found in the Baoji area display high levels of craftsmanship and artistic value. Bronze art is generally considered a reflection of the ancient peoples' philosophical and religious thoughts. The motifs not only served practical functions but also carried symbolic meanings, representing the people's reverence for gods and ancestors, encapsulated with mystique and authority (Xu & Liu, 1985: 389). The inscriptions on these bronzes are crucial for studying ancient society, as they provide insights into family structures, clan relationships, and cultural customs. They are invaluable historical materials for understanding the social and cultural customs of the Western Zhou period (Peng, 2002: 421-436).

1.2 Symbolic Significance of Western Zhou Bronzes

The form, decoration, and inscriptions of Western Zhou bronzes are highly unique and symbolic. The most representative elements are the motifs and inscriptions, which reveal the ancient people's reverence for deities and supernatural powers as well as their understanding of the universe and nature.

Patterns are the most common decorative elements on Western Zhou Dynasty bronzes and symbolize the political and religious structure of Western Zhou society. Generally, the pattern types on Western Zhou bronzes can be summarized as follows:

Animal motifs: This is one of the most prominent categories in Western Zhou bronzes, including various animal images. The most important motif is the Taotie pattern (Figure 4). In addition to the visual descriptions of motifs, it is crucial to interpret patterns from their symbolic meanings. The Taotie pattern is usually symmetrical, characterized by an exaggerated and gigantic beast face. At that time, the Taotie was considered a mystical creature capable of warding off evil and disaster. Its image was used in ritual ceremonies to seek protection and blessings. Its strong visual impact and sense of mystery symbolize the power and authority of the ruling class, serving to consolidate and display their authority (Hong & Xuan, 2022).

Figure 4

Western Zhou Bronze Taotie patterns.

Note. From *Western Zhou Dynasty Bronze Album – Hezun,* by Chinese Painting and Calligraphy EXhibition, 2020 (http://tq.eocan.com/2020/03/21275.html). Copyright by Chinese Painting and Calligraphy EXhibition

Geometric motifs: These include simple repetitive shapes such as circles, squares, and spirals. Geometric patterns are often used as borders or fillers for blank spaces and can also be the main decorative elements on certain objects (Figure 5). The Western Zhou had a hierarchical system, which was political, meaning it was a state system. Geometric patterns involve the repetitive organization of a single element to form a continuous, repetitive band, creating a sense of order. This order has an indirect connection with the ritual governance required by the Western Zhou.

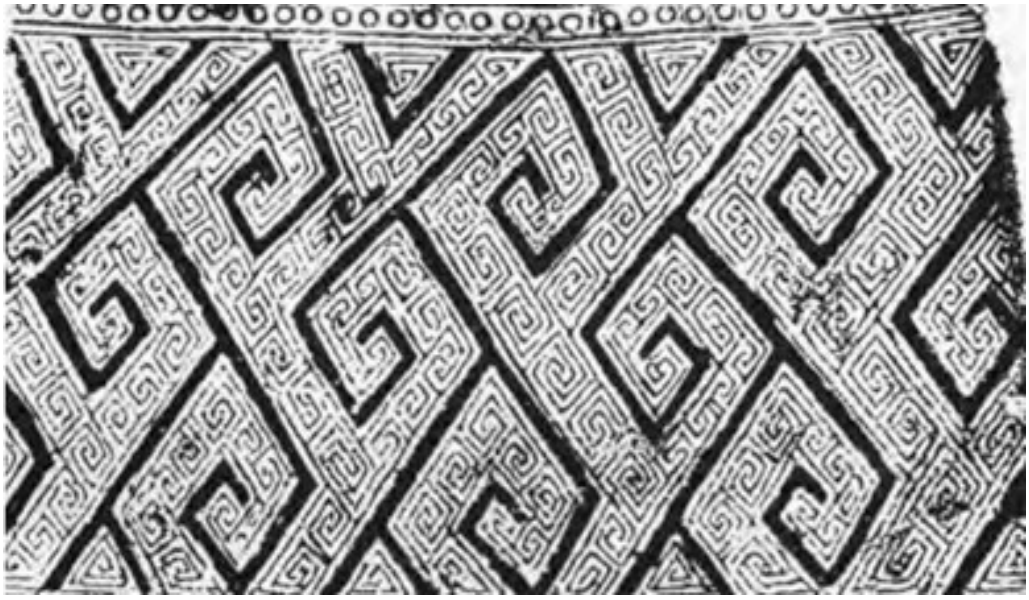

Figure 5

Western Zhou Bronze Geometric Patterns.

Note. From *Bronze Ornamentation,* by House of Document, n.d. (https://www.doczj.com/doc/212027030.html). Copyright by House of Document

Other motifs: Beyond common motifs, Western Zhou bronzes also employed floral and plant decorations to depict nature, including flowers, leaves, and vines, and sometimes even complete natural scenes. These decorations were made abstract or realistic, typically used to fill the space between other motifs or as standalone decorations. Additionally, human figures were also used, albeit less frequently, often depicting ritual or mythological scenes.

The decorations on Western Zhou bronzes exhibit diversity, with animal motifs not only representing a realistic portrayal of animals from nature but also more abstract creations, closely related to the spiritual and political trends of the time (Ni, 2011: 20). The Taotie pattern, in particular, dominated the decorative motifs on bronzes of this period.

Besides motifs, a distinctive feature of Western Zhou bronzes is the inscriptions cast into their bellies, bases, or lids (Figure 6). These inscriptions hold a very important place in historical research as they are key materials for understanding the society of the time (He, 2005: 12). The inscriptions cover a wide range of topics and contents, some of which record the family backgrounds of the object's owners, helping to understand the hierarchical

system and family structures of the Zhou Dynasty. Others reveal ancient ceremonial forms, and some inscriptions serve as personal biographies recording significant achievements and life events of individuals associated with the objects, reflecting the values and social customs of the era (Lao, 2007).

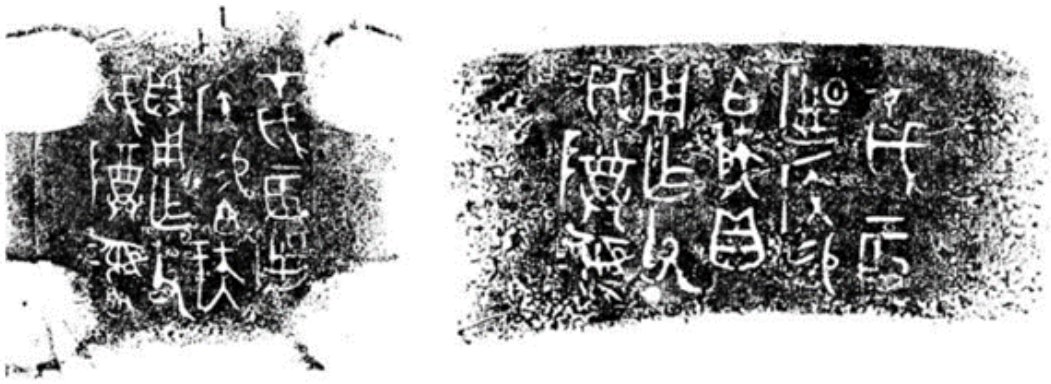

Figure 6

Western Zhou Bronze inscriptions.

Note. From *Boju Li of the Western Zhou Dynasty: Cultural relic characteristics,* by Sogou Encyclopedia, 2021 (https://baike.sogou.com/v68688555.htm). In the public domain

For example, the inscription on the Western Zhou bronze “Ying Yi” records the criminal code, specifying strict regulations for the administration of punishments in society, indicating that the legal system during the Western Zhou period was already highly developed. The “Ying Yi” inscription is the earliest and most complete judicial document discovered in China to date, clearly presenting the litigation procedures, legal system, and penal regulations of the time, and is hailed as China's “Bronze Code” (Lai, 1981).

1.3 Cultural Value of Western Zhou Bronzes

Bronze art is one of the key markers of human civilization, and the bronzes that have survived to this day hold immense historical, artistic, and scientific value. As central representations of Zhou dynasty culture, Western Zhou bronzes significantly reflect the societal, political, and ritual aspects of their time. Being used primarily for sacrificial and ceremonial activities within a feudal society, these bronzes carry deep symbolic meanings related to social class, power, religious beliefs, and secular rituals. Additionally, the symbols on these bronzes reflect the religious beliefs, political structure, and legal morals of the

time. Their decorations show ancient reverence for mystical powers and submission to the authority of rulers.

Furthermore, during the Western Zhou period, the forms of ancient Chinese literature began to take shape, rooted within the political and cultural context of the Zhou dynasty. The inscriptions on Western Zhou bronzes provide detailed accounts of political events, legal systems, and social orders of the time (Figure 7). With their rich content and mature stylistic forms, these inscriptions illustrate the early appearance of Chinese literature, shaping the aesthetic ideologies of the Chinese people and laying the foundation for the realism in Chinese literature.

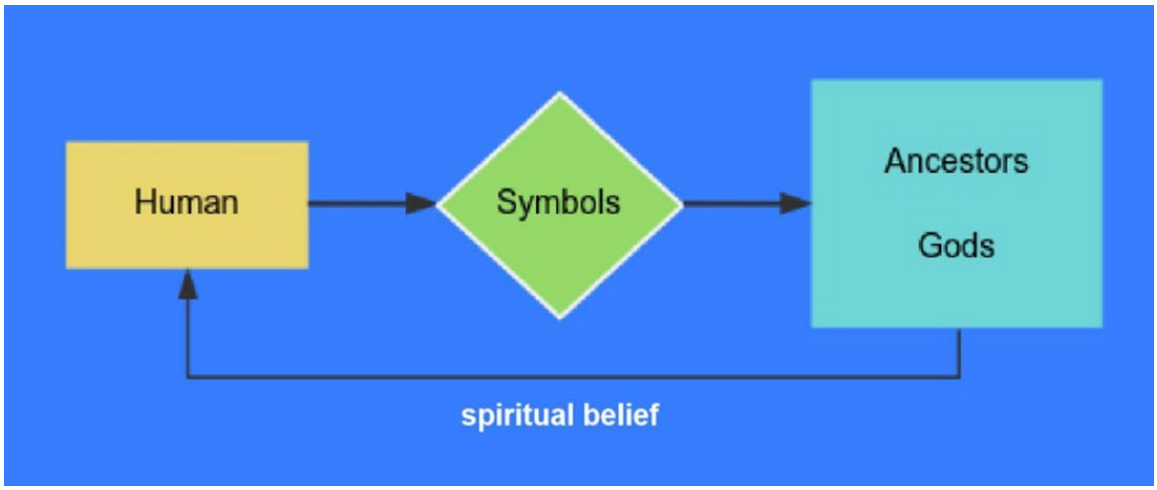

Figure 7

The Faith Structure in Western Zhou Dynasty Bronzes.

Therefore, researchers believe that Western Zhou bronzes possess significant cultural value and exhibit importance, necessitating broader and deeper public recognition and understanding.

2. Current State of Museum Digital Environments

Digital environments represent the application of digital media technology within exhibition spaces, creating new digital spaces through the integration of technology and environment. Museums are establishing interactive and immersive digital display areas that foster a closer connection between the environment and the visitors. Digital exhibitions narrate the stories behind artifacts, addressing the limitations of traditional exhibition

methods by effectively transmitting information and enriching the content available to visitors, thus deepening their engagement and learning within the exhibition space.

Today, the vast number of large-scale museums provides convenient access to cultural knowledge. As visitor demands become more diverse, museum designers realize that the attraction of physical exhibits is diminishing. The effective communication of information is crucial in exhibitions, making the integration of space display and digital media technology essential. This integration maximizes the role of digital media technology in museum spaces. The features of the technology facilitate the creation of immersive, interactive environments that significantly enhance the visitor's experiential feeling.

Digital environments cater to visitors' needs for exhibition information through multisensory experiences, offering new forms of digital environment communication that were not possible with traditional exhibitions. The introduction of technology has markedly transformed the way environments are displayed (Patel et al., 2005: 179-192).

2.1 Directions for Development of Museum Digital Environments

2.1.1 Spatial Dematerialization in Digital Environments

Traditionally, architectural spaces are thought to be enclosed by physical boundaries. With the advent of digital technology, a boundary-less virtual space has emerged, formed by digital information. This virtual space, crafted by digital media technology, consists of visual environments that are fundamentally virtual and surreal, offering audiences a new dimension of perception.

2.1.2 Interactivity in Digital Environments

Digital environments in museums facilitate interactivity, where digital media technology is used to create spaces that allow visitors to interact with exhibitions. Traditionally, visitors followed a predetermined path through exhibition spaces, which was a passive form of interaction. With advancing technology, visitors can now engage in activities within digital spaces that provoke changes in digital imagery, thereby enhancing their engagement with the digital exhibition space. For instance, in the Forest of Lights exhibition in Tokyo, visitors stand among colorful lights that change brightness and hue in response to visitor movement, enhancing engagement in the digital environment.

2.1.3 Multidimensionality in Digital Environments

According to Merleau-Ponty's phenomenology of perception, perception is the passive reception of external stimuli processed through active thought (Merleau-Ponty, 2010). Merleau-Ponty's phenomenology emphasizes the body as the primary medium of perceiving the world, asserting that subjective experience and bodily perception are central to constructing the perception of reality. VR and AR technologies, by creating immersive environments, not only expand the boundaries of perception but also allow users to deeply experience and interact in an embodied manner. These technologies simulate real-world interactions, enabling users to physically engage with virtual environments, thus deepening their perception and understanding of the virtual world. This process resonates with Merleau-Ponty's discourse on the central role of the body in perception formation.

In museum spaces, the integration of technology and art creates a media display format that enables a multidimensional understanding through the senses. Digital media diversify the digital environment, enriching exhibition formats with immersive experiences and interactive technologies that offer differentiated experiences to visitors, making museum exhibitions more engaging.

2.2 Applications of Museum Digital Environments

Digital environments not only define a technological innovation but also signify a fundamental shift in how museum spaces display and disseminate cultural heritage. Technologies such as augmented reality (AR), virtual reality (VR), and 3D scanning and printing not only improve visitor interaction and engagement but also play crucial roles in preserving fragile and precious artifacts. These technologies provide a richer and more diverse presentation of exhibits, making complex historical and cultural concepts more accessible and educational. The specific applications of museum digital environments include:

2.2.1 Virtual Reality Environments

Virtual Reality (VR) provides a sensory simulation experience, using posture tracking and 3D displays to immerse users in the experience. This technology is used across entertainment (especially video games), education (such as medical or military training), and business (virtual meetings). VR is now employed to reconstruct historical settings,

enhance on-site and off-site interpretation and experiences, increase visitor engagement, and create interactions within museum environments, offering immersive experiences to audiences.

For example, the VR experience project “National Treasure Mystery” located in the VR Digital Experience Hall on the first floor of the Hunan Provincial Museum (Figure 8) highly restores characters and scenes, and features full-body posture recognition and multidimensional sensory experiences, allowing visitors to realistically touch items within the scene.

Figure 8

Provincial Museum VR Walking Experience Project “National Treasure Mystery”

Note. From *OptiTrack, the virtual moving point, helps "Lost in the Treasure of the National Treasure" and opens up a new level of virtual reality,* by China's development and reform, 2020, Baidu (https://baijiahao.baidu.com/s?id=1673458075197214036&wfr=spider&for=pc). Copyright by China's development and reform

2.2.2 Digital Media Display Environments

Using screens, projections, and touch interfaces, these environments provide visitors with richer information. The integration of video, audio, graphics, and text in digital displays enhances the attractiveness and educational and entertainment value of exhibitions, making the communication of information more vivid and comprehensible (Lo Turco, & Calvano, 2019: 387).

The Irish Emigration Museum, heralded as the world's first fully digital museum, is located at the Custom House Quay in Dublin. Its exhibits are primarily presented through interactive media and immersive installations. The museum departs from traditional static displays and instead showcases its collections through interactive projections, flipbook installations, and touch-interactive screens (Figures 9). The use of diverse digital display methods enables visitors to grasp the history and culture of Irish emigration without the need to decipher obscure artifacts or textual descriptions, through a variety of fun and engaging experiences.

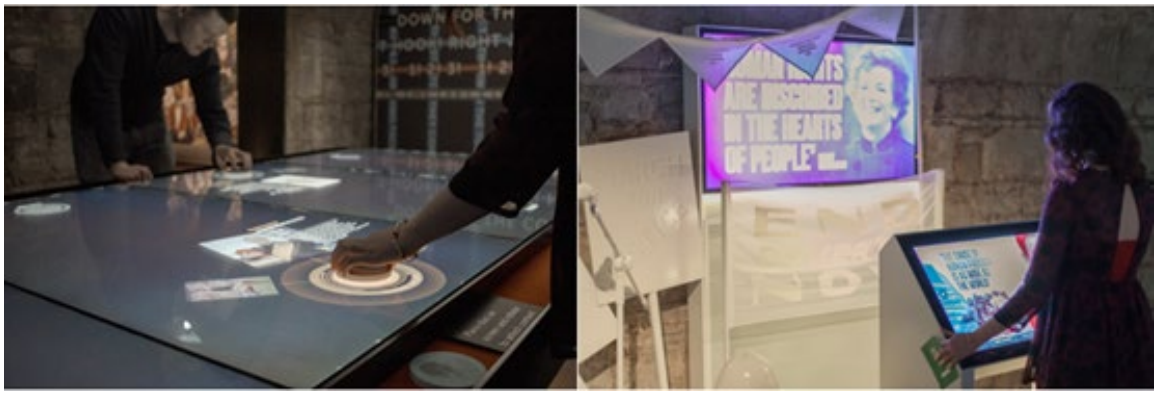

Figure 9

The interactive facilities at the Irish Emigration Museum

Note. From *EPIC Ireland – AV Installations & Interactives: EPIC The Irish Emigration Museum,* by ISO, n.d. (https://isodesign.co.uk/projects/epic-ireland-av-installations-interactives). Copyright by The ISO Organisation Limited

2.2.3 The role of 3D scanning and printing technology in replication, display, and preservation:

Cultural artifacts are precious historical treasures of a nation, holding significant importance for historical research and scientific guidance. However, as time passes, damage to artifacts is often inevitable, including both natural weathering of the artifacts themselves and accidental damage.

3D scanning and printing technology have played a positive role in the preservation and dissemination of cultural heritage, addressing the common desire of museum visitors for firsthand experiences and interaction. In 2015, Norwegian iron craftsman Nils Anderssen used 3D printing technology and ironworking skills to recreate a Migration Period sword for the National Museum of Art, Architecture and Design in Norway (Figure 10). Visitors to the museum can personally handle the replica sword instead of only viewing the original behind glass. Many visitors, seeking to enhance their experience and understanding, wish to directly touch the exhibits, but such actions can harm fragile or uniquely valuable items. 3D scanning and printing technology offer a solution to this problem by producing high-fidelity replicas that allow visitors to directly touch and explore the replicas without damaging the originals (Parry, 2013: 39).

Figure 10

Comparison of the actual Norwegian National Museum of Art's Migration Period sword (left) and its replica (right).

Note. (left) From *3D printing produces a perfect replica of a sixth-century sword; A damaged sixth-century sword in a museum in Norway has been perfectly reproduced as new through 3D printing, by M. Starr, 2015, CNET (https://www.cnet.com/culture/3d-printing-produces-a-perfect-replica-of-a-6th-century-sword/). Copyright by Nils Anderssen;* (right) From *Snartemo hilt both,* by E. I. Johnsen, 2022, Wikimedia Commons https://commons.wikimedia.org/wiki/File:Snartemo_hilt_both.jpg). Copyright by CC BY-SA 4.0

3. Impact of Digital Environments on Museum Visitor Cognition

3.1 Formation of Visitor Cognition and the Role of Digital Technology

Cognition in visitors is a synergistic product of individual, cultural, and environmental factors. It involves the process where visitors interpret their sensory experiences and transform these perceptions into personal knowledge. Visitors are not only experiencers of the museum's offerings but also providers of feedback. The evolution of digital technology has altered the traditional, austere atmosphere of museums and their singular approach to exhibitions, fostering a growing emphasis on the relationship between museums and their visitors (Huang & Ye, 2008: 74-75). Today, museums enrich their exhibitions with technology, transforming visitors from passive viewers to active information processors.

In China, museums primarily focus on the preservation of artifacts, presenting them with professional textual descriptions that often fail to convey their full meanings to visitors (Sun, 2021). Viewers may look at artifacts in glass cases and leave without understanding their significance, retaining little impression of the artifacts. The conventional mode of viewing reduces the interaction time between the visitor and the artifacts, hindering deep cognitive engagement. Therefore, to fulfill its educational role, a museum must facilitate high-quality interaction between visitors and artifacts within the limited time of a visit.

The creation of digital environments addresses this challenge effectively. Digital environments in museums, resulting from the fusion of technological development and the demand for cultural dissemination, have formed new spaces that enhance the connection between museums and visitors. Through interactive and immersive digital display spaces, museums can more effectively communicate information and encourage deeper visitor engagement and learning. This not only compensates for the deficiencies of traditional exhibition methods but also meets the visitors' desire for accessible information (Figure 11).

Figure 11

Museum digital environment applications.

However, it is important to note that the overuse of image synthesis and multimedia technologies in some museums, aimed solely at capturing visitor attention, may only provide a superficial engagement and fail to facilitate a deeper understanding of the artifacts. Museum environments should be designed with the visitor at the center, aiming to facilitate the absorption of knowledge in ways that enhance cognitive engagement during the visit.

3.2 Feasibility of Enhancing Visitor Cognitive Experience in Digital Environments

Jean Piaget's theory of constructivism suggests that cognition arises from the structuring of one's experiences (Carci et al., 2019). Piaget's theory of cognitive development highlights the importance of constructing knowledge through interaction and exploration of the environment. VR and AR technologies provide a dynamic platform full of interactions, allowing viewers to explore and understand the knowledge of exhibits in the virtual environment through manipulation, thereby promoting the formation and development of cognitive structures. These technologies support users in conducting experiments and solving problems in a controlled environment, adapting to the stages of cognitive development described by Piaget, such as the concrete operational stage and the formal operational stage, which are particularly important in educational applications.

Thus, visitor cognition is the outcome of interactions between individual and environmental factors. Visitors engage with and learn from their interactions in digital environments, converting received information into personal knowledge applicable to future learning contexts.

Museums craft digital environments through the integration of digital media technologies. Exhibitions have transitioned from traditional displays to interactive formats, where the immersive experience of digital environments can evoke visitors' emotions and enhance knowledge dissemination, thereby bolstering cognition. For instance, the "Immersive Performance at the Boccf" held at the Bank of Cyprus Cultural Foundation integrates new media technologies (Figure 12). Live music, augmented reality, and projection technologies combine with interactive installations to immerse visitors in a multisensory digital environment, deepening their understanding and cognition of the culture.

Figure 12

Posters for Immersive Performance at the Boccf.

Note. From *ReInHerit a Museum: Immersive Performance at the Boccf,* by Museum Lab, 2023 (https://museumlab.cyens.org.cy/project/reinherit-a-museum-immersive-performance-at-the-boccf/). Copyright by Bank of Cyprus Cultural Foundation

The fusion of digital media technologies and museums transforms the mode of exhibition presentation, diversifying exhibitions and enriching the visiting experience through narrative methods. Digital technologies can simplify complex exhibition content and present it in a visually intuitive manner, enhancing visitor comprehension. For example, in the Independence Hall of Korea, designers present history in an animated form, using VR and other digital media to simplify historical narratives, making it easier for visitors to understand. Ahdab Najib Hijazi's research on the effectiveness of digital technology in museums demonstrates significant impacts on visitor experiences, with artificial intelligence, wearable devices, and virtual tours enhancing the visiting experience (Hijazi & Baharin, 2022: 142-159).

Specifically, the spatial environment and the exhibits serve as the foundation for visitor learning. Visitors gauge their interest in the environment by perceiving the museum's layout, which in turn triggers their motivation to learn (Huang & Ye, 2008: 74-75). Research has found that professional interactive spatial arrangements keep visitors engaged for longer periods.

During field visits, researchers conducted random interviews with some visitors. After visiting, audiences were able to recall interactions with the exhibition, with feedback categorized into five aspects: (1) Fragments of exhibition content and related information. (2) Motivations for interacting with the exhibition. (3) Whether the exhibition is accessible. (4) Whether the exhibition is shareable. (5) Obstacles encountered during use.

Clearly, museums effectively utilize digital technology to provide sensory experiences through a digital environment, and through rich interactions, they can improve learning efficiency and enhance the cognitive experience of visitors. The relationship model can be illustrated as in the following figure (Figure 13).

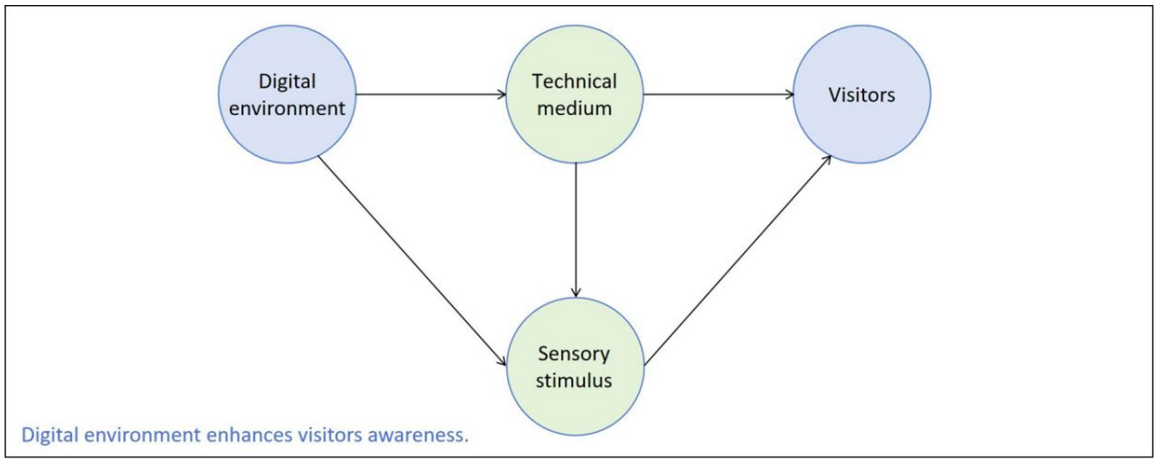

Figure 13

Modeling the relationship between museum digital environments and audience perceptions.

Conclusion

Based on the findings and discussions presented, the following conclusions are drawn:

1. The historical and cultural value of Western Zhou bronzes is vividly and deeply conveyed through modern digital display technologies. Using augmented reality (AR) and virtual reality (VR), audiences can explore the fine motifs and inscriptions of the bronzes from new perspectives and through interactive methods, thus gaining a better understanding of their historical background and cultural significance. This interactivity and immersion significantly enhance the learning motivation and information absorption efficiency of the audience.

2. The creation of a digital environment in museums is not just a technological innovation but also a significant shift in cultural education models. The digital environment makes the exhibition content more enriching and dynamic, allowing visitors to learn through multisensory experiences, which is crucial for enhancing their cognitive depth and breadth of cultural appreciation. Especially for younger audiences, this modern mode of presentation greatly increases the attractiveness of museums and helps to spark their interest in history and culture.

3. Although digital technology offers many conveniences, its application in museums should also be mindful of avoiding cognitive overload caused by excessive use of technology. Reasonable use of technology should ensure that visitors can fully understand and appreciate the artifacts themselves without being distracted by too many technological elements. Therefore, museums need to find a balance in the use of technology, ensuring both the advancement of technology and the educational and artistic integrity of the exhibitions.

Recommendations

1. Theoretical Recommendations

Deepening Interdisciplinary Research Methods: Enhance the complexity and adaptability of theoretical frameworks by integrating theories and methodologies from multiple disciplines such as sociology, psychology, information science, and art history, to more comprehensively understand the impact of museum digital environments on visitor cognition. For example, exploring the combination of visual arts and advanced technologies

(such as VR and AR) to effectively display the artistic features and symbolic meanings of exhibits. Such interdisciplinary approaches can provide theoretical support for designing more effective exhibition strategies.

Develop Digital Media Theories: As digital media technology offers new ways of interaction, theories related to its application should continually evolve and adapt. Research should focus on integrating these technologies into museum settings effectively, particularly how they transform the learning and experience processes of visitors.

2. Policy Recommendations

Establish Standards for Museum Digitization: Government bodies or relevant cultural heritage organizations should develop standards and guidelines for museum digitalization that ensure the effective application of technology while complying with cultural heritage conservation requirements. Standards should cover technology selection, content display, and user privacy protection, ensuring that the displayed content is not only technologically advanced but also historically accurate and educational, especially for items with profound cultural and historical value.

Increase Investment in Museum Digitization: Policy makers should increase financial support for museum digitalization projects, particularly those that use new technologies to enhance public education and participation. This includes investing in digital skills training for museum professionals and providing specific funding for developing and implementing VR and AR applications in exhibitions to enhance interactivity and educational impact.

3. Further Research Suggestions

Synchronous Research on Technological Advancements and Applications: Enhance high-quality interactions between visitors and exhibits in design to improve cognitive experiences. For instance, utilize digital media technology to provide more interactive and immersive exhibition experiences, or focus on the narrativity of exhibition content through the telling of historical or mythical stories to enrich visitor cognition. Periodically conduct field tests to evaluate the effects of different types of digital interface technologies, especially in terms of enhancing visitor cognition and learning motivation.

Evaluate the Experience of Different Audience Groups: Adopt an audience-centered design philosophy in museums, focusing on learning experiences in digital environments. Further research should focus on how different audience groups, varying by age, educational background, and technological proficiency, experience and interact in digitalized museum settings. Study the reactions and learning outcomes of different audience groups when exploring Western Zhou bronzes through augmented reality and virtual reality technologies to better understand and meet their needs.

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