



THE UTILIZATION GUIDELINE OF DIGITAL MEDIA INTERVENTION
TECHNIQUES IN MUSEUM EXHIBITION DESIGN FOR MOTIVATING
VISITORS' INTEREST AND INTERACTION: A CASE STUDY OF SIX
SELECTED MUSEUMS IN CHINA



LU AI

**A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Doctor of Fine and Applied Arts Program Degree in Art and Design**

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Study of Six Museums in China"

by Lu Ai

has been approved by the Graduate School as partial fulfillment of the requirements
for the Doctor of Fine and Applied Arts Program Degree in Art and Design of
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Title	THE UTILIZATION GUIDELINE OF DIGITAL MEDIA INTERVENTION TECHNIQUES IN MUSEUM EXHIBITION DESIGN FOR MOTIVATING VISITORS' INTEREST AND INTERACTION: A CASE STUDY OF SIX SELECTED MUSEUMS IN CHINA
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ABSTRACT

Extensive research has emphasized that heritage digital interpretation and presentation technologies enhance visitor experiences and communication of heritage culture. The exhibition practice did not achieve the desired effect. And, few studies have explored how the attraction of digital interpretation is within one of its key scenarios: the museum exhibition environment. Therefore, the research question arises: Under the intervention of digital technology, what factors in the museum exhibition environment will affect the interest and interaction of visitors? How to propose a utilization guideline that can use digital technology to enhance the interest and engagement of different visitors?

The key points of this research include: first, to find out the factors that affect visitors' interest and interaction in museum exhibitions composed of digital technology by using the literature method and the analytic hierarchy process (AHP). The research shows that the top ten factors affecting visitors' interest and interaction are visual language style, the narrative type, color contrast, interactive form, and clear theme in design factors; digital exhibit location and layout in environmental factors; and cognitive characteristics, physical characteristics, number of museum-visiting per year of visitors, and identity characteristics in visitor factors. Secondly, through studying the physical environments of China's popular museums and evaluating their alignment with key factors, we conducted assessments using an exhibition walk-through, scenario

visits, and visitor interviews. Identified issues included: lack of specific tour information or improper placement of digital media in exhibition spaces; obstacles in main corridors; overcrowding that reduced visit efficiency; and poorly understandable exhibits coupled with subpar environmental ambiance, which further diminished the appeal of digital exhibits. The third part involves the study of museum visitors, which utilizes behavioral observation and visitor questionnaire surveys to further determine the behavioral preferences and needs of visitors, as well as their relationships with key factors. Research indicates that high-appeal digital exhibits and interactive displays share these key characteristics: environmental harmony, clear thematic focus, engaging presentation, innovative use of new media technologies, and the application of color visual language through 3D graphics to demonstrate internal structures or workflows. These exhibits are strategically positioned along main exhibition routes or within dedicated digital spaces. Fourth, the application guidelines were finally proposed through a summary and discussion. Through an image simulation questionnaire, it was proven that the design guidelines using the seven principles of universal design (7UD) could be used to improve visitors' interest and engagement.

This study is the first to disentangle the association between environmental conditions (design and environmental factors) of digital technology and attraction, and to determine whether visitor factors mediate this association. Based on factor analysis results, the research developed a post-occupancy evaluation (POE) framework integrating the stimulus-organism-response (S-O-R) model and attention value model. This framework not only covers design elements of digital interpretation and interaction as well as environmental dimensions, but also incorporates dimensions of attraction power (AP) and visitor experiential aspects. The findings confirm that this evaluation framework can be applied to assess the effectiveness of museum exhibitions. The results of the study reveal how the environmental characteristics in museum exhibitions affect the attractiveness of digital interpretation to different types of visitors, providing a utilization guideline and suggestions of digital media intervention techniques in museum exhibition design for motivating visitors' interest and interaction that focuses on the communication of cultural heritage.

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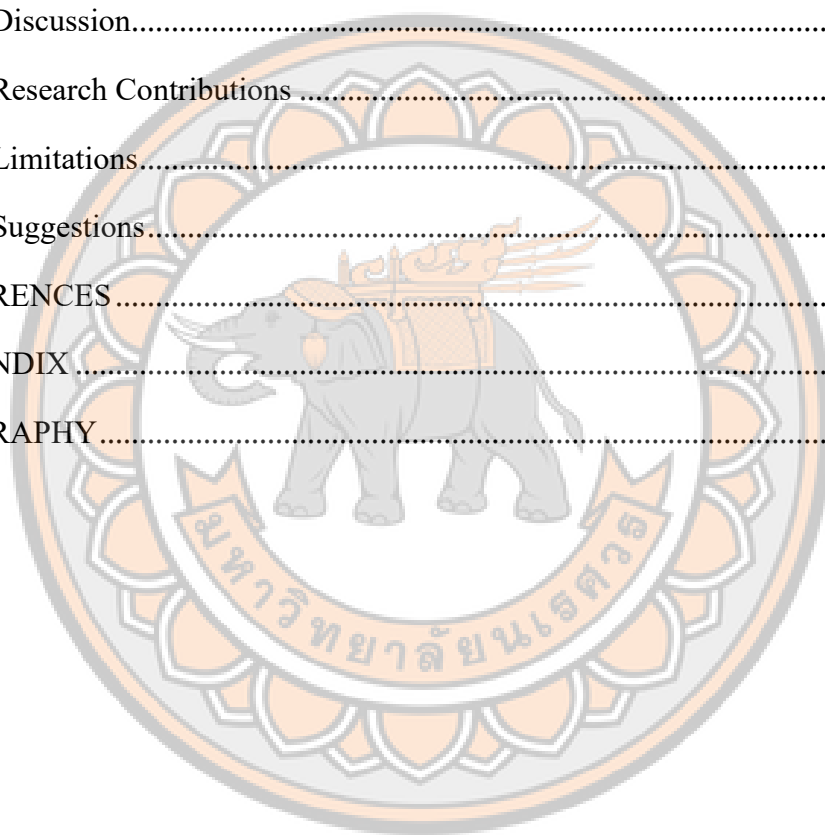
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CHAPTER I

INTRODUCTION

1.1 Overview

Chapter One provides a general overview of the study. To achieve this, Section 1.2 starts from the background of the article studies, explaining the current situation of museum exhibition design and exhibition digital media design under the background of cultural tourism integration, as well as the content related to digital media interactive technology and visitor experience. Section 1.3 provides a statement of the problem and research gap, including the origin of the Starting point of the research and the significance of the study. Section 1.4 research goal led to the research questions and resulted in the research objectives of Section 1.5. Section 1.6 provides the theoretical foundation for the study, which leads to the research framework. Section 1.7 provides the scope of the study, including the area scope for selecting cases, population, and sample. Section 1.8 describes the method for procedure investigation. Section 1.9 is for the expected benefits of research. Section 1.10 provides a list of definitions for the study.

1.2 Background

Museum Exhibition and Visitors under the Cultural Tourism: A new way of Communication with People-centered

Museums serve as social public cultural institutions with multiple attributes (Kasemsarn & Nickpour, 2023; Zhang & Luo, 2017). Meanwhile, cultural tourism is rapidly developing worldwide, and ‘museum + tourism’ has become the new trend in society (Gu, 2022; Li, 2022; Ren et al., 2020). The museum now serves not only the social-educational function of disseminating cultural knowledge but also the functions of urban tourism and regional cultural promotion (Teng, 2023). The museum provides a unique experience distinct from other leisure and tourism offerings, featuring cultural learning opportunities. (Zhang et al., 2018).

The characteristics of cultural tourism museums are personalized experiences and dissemination (Ren et al., 2020). Studies show that an increasing number of tourists are making museums in a region one of the destinations of their journey (Mo & Wen, 2022; Teng, 2023), and museum visitors are increasingly diversified (Kasemsarn & Nickpour, 2023; Li, 2021). Against this backdrop, the

concept of museum exhibitions is realizing a shift from ‘object-centered’ to ‘people-centered’ (Gu, 2022; Mason, 2020). Every individual in society, regardless of background or ability, has an equal right to enjoy the services provided by museums (Li, 2021; Lin, 2016). Museums should focus on increasing different groups of visitors to be more inclusive to support driving forces and remove barriers (Donglong et al., 2004; Filová et al., 2022; Kasemsarn & Nickpour, 2023).

Data indicates that since the launch of the “National Treasures” program (Chinese TV shows) in 2017, the number of searches for domestic tourism products related to “museums” has suddenly increased by 50%, and there are nearly a thousand domestic museum tourism routes available (Teng, 2023). Museum visitors are no longer a uniform and undifferentiated whole; the concept of a monolithic visitor is changing. Audience segmentation research has become one of the trends in the field of museum studies (Li, 2021; Shi, 2009). Since the inception of museum visitor research, grounded in the museum fatigue theory in 1916 (DeBacker, 2015), scholars from different fields are paying increasing attention to museum visitors and their visiting experiences.

Museums operate “for the benefit of the visitors” by attracting and satisfying them, meeting their specific needs across different groups, and providing diverse experiences (Eldamshiry & Khalil, 2018). Driven by cultural tourism, today’s museum visitors tend to expect more positive, interconnected, and participatory experiences in their engagement with museums (DeBacker, 2015). The visitors, filled with excitement and anticipation, stepped into the museum, eagerly looking forward to experiencing the personalized participation and exhibition viewing methods that transcend time and space, drawing inspiration, encountering surprises, and embracing challenges. (Knoespel, 2024). Thus, enhancing the attractiveness and inclusive of museum exhibitions, and increasing public engagement with tourism and diversity of visitors are the new requirements for museum managers and designers (Han, 2020; Kasemsarn et al., 2024).

Digital media interactive technology in museum exhibitions

The visitor-centered museum exhibition concept has led to increasing interest in User Experience (UX) (King et al., 2025) and visitor experience (VX) (Liu, 2020; Mason, 2017), as well as methods to enhance it across various research fields.(Black, 2012; Packer & Ballantyne, 2016; Phillips, 2011; Walzl, 2006). Yang (2023) pointed out that exhibition design has now been combined with other art movements, such as environmental art, performance art, etc. The form of museum exhibitions is transitioning from traditional information displays to creating immersive

experiences that integrate multiple disciplines (Li, 2022). Digital media, as a constantly evolving science and technology, meets such requirements and trends perfectly in the application of museum displays (Chen, 2022; Phillips, 2011; Wang, 2015).

However, as exhibition design theories continue to evolve, institutions and curators are pushing to utilize new technologies to provide novel experiences, and it is these technologies that offer possibilities for new forms of museum exhibitions (Phillips, 2011). Currently, in the field of museum exhibitions, widely applied digital media includes audio, video, touch screens, VR-Virtual Reality, MR-Mixed Reality, AR-Augmented Reality, projections, electronic sand tables, 3/4D dynamic cinemas, 3D printing, QR code navigation, etc (Kasemsarn et al., 2024; Ning et al., 2022; Wang, 2015; Yang, 2023). Especially, the newly built “New Museum” (Li, 2021) has become a popular tourist destination due to its emphasis on new media technology and immersive cultural tourism experiences (Chen, 2023; Li, 2022). At the same time, in the construction of museums, the bidding documents for various new museums have clearly stated the requirements for the construction of digital media, hoping to enhance the visitor experience and interaction.

The utilization of digital resources in cultural heritage exhibitions has proven advantageous, offering supplementary information in limited exhibition spaces more diversely (Ken, 2006; Lo et al., 2023; Phillips, 2011), while multisensory forms enhance the experience for all visitors (Dong, 2024; Freeman, 2016; Ning et al., 2022; Vaz, 2018). The widespread application of digital media meets the diverse needs of tourists (Kasemsarn et al., 2024). Studies have shown that exhibitions utilizing interactive digital media technologies offer more possibilities for experiences, making them more attractive and efficient in communication than traditional digital media technologies (Luo & Hu, 2020; Tong, 2020). They can also impact learning outcomes (Huang, 2014; Li, 2021; Lo et al., 2023; Phillips, 2011; Su, 2012; Tong, 2020).

With the digital context, museums are no longer confined to the limitations of physical space. Consequently, they can design museum experiences before, during, and after the visit, establish lasting relationships with their existing audience, reach out to new audience segments, and utilize various modalities to reshape the exploration of museum collections both offsite and onsite (Loboda, 2022, p. 32). Despite the opportunities that the use of digital media and interactive technologies brings to the development of Chinese museums, excessive technological integration and inappropriate use of interactive technologies not only fail to enhance

the exhibition effects of museums but also hurt the visitor experience (Ning et al., 2022). It must be clearly understood that if the use of digital resources neither effectively showcases content nor engages the audience, their utility will be significantly diminished, potentially rendering them unviable as interactive communication options for exhibitions, ultimately leading to resource wastage (Ken, 2003; Lo et al., 2023; Wang, 2015). In any case, how to utilize digital media to enhance visitor interest and interaction in museum exhibitions is an issue that exhibition designers and researchers must confront: improving visitor experience and the effective dissemination of exhibitions.

Exhibition environments and visitor behavior are affected by digital media interaction and interpretation

From the perspective of cultural tourism motivation, existing studies have shown that visitors' interests (e.g., motivations and perceptions) as well as the information and environment provided by museums (e.g., physical environment, collections, exhibitions, and activities) are key themes in determining whether the public decides to visit the museum (Li, 2021; Loboda, 2022; Kasemsarn et al., 2023; Zhang et al., 2018).

After the interaction of digital media interactive technology, the original exhibition environment has become more complex, forming a complex experiential space where physical space, informational space, and digital space are intertwined (Loboda 2022; Mason, 2020; Phillips, 2011; Tong, 2020). Research indicates that in digital media interactions, mere actions such as clicking or operating digital devices do not enhance visitor experiences. Instead, it is the environmental changes brought about by digital interactions that alter visitor perceptions and thereby improve their experience (Lu & Chen, 2018; Lo et al., 2023; Mason, 2020; Phillips, 2011; Shiang et al., 2015). Most visitors are not willing to participate in digital interaction during the visit (Ceccarelli et al., 2024; Liu & Chang, 2024). Meanwhile, some scholars in Taiwan have also pointed out that numerous issues exist in the practical application of digital media interactive interpretation technology, such as low utilization rates and high wear and tear, which stem from a lack of research on exhibition environment and visitor behavior (Ken, 2003; Lo et al., 2023).

From the perspective of environmental behavioral psychology, utilizing digital media interactive technology to elicit human responses in exhibition environments, thereby altering visitors' perceptions to create new visitor experiences (Phillips, 2011). This represents a new way that integrates the digital experience with the overall museum experience (Kelly & Lynda, 2016; Mason, 2017). Human behavior

is driven by motivation. Individuals with different traits enter environmental contexts carrying psychological states such as motives, expectations, and goals. Through perception and action, they selectively receive environmental information (Chiang, 2022; Ken, 2003). Visitors' visiting behavior reflects their perception of information in the museum environment, which is a behavioral response generated after cognitive and emotional processing. Therefore, the environmental factors affecting visitors' experiences include not only the physical environment (such as exhibit arrangement and exhibition techniques), but also their psychological environment (such as visiting motivation, expectations, and perceptions) (Lu & Chen, 2018; Wu, 2012).

The visitor attention-value model theory also confirms that whether visitors are attracted by exhibition items is jointly influenced by the characteristics of the exhibits, the exhibition environment, and the visitors themselves (Bitgood, 1992; Bitgood, 2013; Vázquez, 2016). Visitors, including older ones, are drawn to and retain information from museum exhibitions because of the quality of the exhibits (Wu, 2012) or their positioning within the layout, and also due to the structure of the remaining available space. The space has a significant impact on exploratory movement, visual engagement, and active interaction with exhibits (Wineman & Peponis, 2010). Moreover, this is closely related to the combination of social and behavioral factors that determine how tourists perceive and utilize these elements (Kokkranikal & Powell, 2014).

Visitors, as recipients and responders of museum information dissemination, are the ultimate service targets of museum exhibitions (Huang, 2016; Knez, 1970). The perception of environmental stimuli and exhibition information by visitors in the exhibition setting determines their willingness to engage in interaction (Bitgood, 2019; Chiang, 2022; Miao et al., 2024). Measuring the digital media interactions and interpretations within existing museum exhibitions against the broader exhibition context, while conducting visitor-centered evaluations, is both necessary and feasible. This study continues to engage in the discussion, exploring how the integration of various design elements supports the design of museum information spaces and how these factors influence visitors' behavior and experience.

1.3 Statement of Research Problem

1.3.1 Starting point of research

Through preliminary survey and articles study, an understanding was gained regarding the current application of digital technologies in newly built museums in China.

Based on policy interpretation, from an international perspective, digital technology is widely used in museum exhibitions to enhance visitor experience. Under the unique museum construction policy of China, diversified digital media applications have become a necessary condition (Ren, 2020). The overuse of digital media causes resource waste.

Based on cases study, a series of problems emerged in the actual operation. (1) Problems include equipment maintenance due to improper operation; (2) visiting obstacles caused by a lack of consideration for physical space in the initial design; (3) and ineffective interactions that focus too much on the entertainment aspect of interactivity, hindering the dissemination of information. This point is also confirmed in relevant literature. Museum exhibitions are becoming homogenized, tending towards entertainment (Li, 2020; Ning et al., 2022; Wang, 2015). (4) Although barrier-free design is considered necessary in museum environments, there is still a lack of facilities in actual exhibition sites to assist people with disabilities and those with physical impairments, such as wheelchair users and the blind.

Based on articles study: (1) Although studies suggest that digital technology can enhance the appeal of exhibitions and visitor interest, the communication impact and visitor experience have not met the anticipated communication effects of the exhibition design (Lo et al., 2023). (2) Phillips (2011) also stated that the application of existing digital media technologies has not promoted the development of exhibition theory. (3) However, in China's exhibition industry and academic research, scholars and designers focus on the improvement of technology and innovation in form. (4) The reason for problems of digital technology in museums is the lack of research on visitor behavior (Ken, 2003; Lo et al., 2023).

The application of digital media interactive technology has enriched the experiences and contributed to the development of inclusive museum design (Kasemsarn et al., 2023; Li et al., 2024; Loboda, 2022), but it still hasn't met the expectations of researchers and designers (Lo et al., 2023; Ning et al., 2022). Based on the internationalized development trend of cultural tourism, Chinese policy requirements, and visitor research, utilizing digital media interactive technology and increasing the attractiveness of different types of tourists is an indispensable theme in museum exhibition design. It is imperative to study digital technology in the

exhibition environment and to design the guide to attract the interest and interaction of different types of visitors according to the behavioral characteristics of visitors.

1.3.2 Research Gaps and Significance

Based on the results of the article study, which shows how the exhibition environment affects visitor behavior. There are two research gaps here: (1) which exhibition factors can influence visitors to engage with digital exhibits, including those with physical disabilities? And (2) how do visitors respond to these environmental stimuli?

Digital media interaction technology can enhance the appeal of exhibitions (Lo et al., 2023; Loboda, 2022), but it has been found that there is a lack of empirical studies demonstrating the effectiveness of digital media interaction technology in enhancing visitor interest and improving the experience of visiting behavior. How to measure the impact of visitor-centric museum digital media interactive technologies on the visitor experience remains a question. This study argues that the application effects of digital media interactive technologies need to be further advanced, requiring not only an evaluation of the relationship between visitor interest and engagement behaviors with digital interactive interpretation in exhibition environments, but also an assessment of the quality of visitor interactions and experiences during the visitation process. Therefore, this thesis emphasizes the need for a shared theoretical framework and evaluation system for visitor experience that scholars could follow and that would advance the research into this complex construct.

The study, based on the museum communication model, stimulus-organism-response model (S-O-R) (Li, 2021; Nian et al., 2025; Wu, 2014), visitor attention-value model (Bitgood, 2013), integrates digital media interaction technology into the broader field of environmental behavior studies. By evaluating the museum's digital media interaction technology from the perspective of visitor experience, it aims to address this knowledge gap to determine whether interaction with the digital media environment will have a positive impact on interactive behavior and experiences in physical museums. Furthermore, this paper responds to the broader research gap in conceptualizing and evaluating visitation interaction behaviors and experiences through empirical research across the entire standardized systematic process. This aims to advance research and design practices that enhance visitor interest and interaction through the use of digital media and interactive technologies under various visiting conditions.

1.4 Research Questions

The main question is: How can proposed strategies utilizing digital media technologies be effectively implemented in museum exhibition design to enhance visitor interest, engagement, and interaction, thereby contributing to the promotion of tourism in museums? And there are three sub-questions:

(1) What are the factors and principles for integrating digital media technologies into museum exhibition design to enhance visitor interest, engagement, and interaction, thus promoting museum tourism?

(2) Are the existing physical environments of popular museums in China compatible with key factors for effectively integrating digital media technologies to promote museum tourism? If so, how?

(3) How is it about museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital media technologies in exhibitions?

1.5 Research Objectives

(1) Objective 1: To analyze the factors and principles for integrating digital media technologies into museum exhibition design to enhance visitor interest, engagement, and interaction, thus promoting museum tourism.

(2) Objective 2: To examine the physical environments of popular museums in China and evaluate their alignment with key factors for effectively integrating digital media technologies to promote museum tourism.

(3) Objective 3: To investigate museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital media technologies in exhibitions.

(4) Objective 4: To propose strategies for effectively utilizing digital media technologies in museum exhibitions to enhance visitor engagement and promote museum tourism in China.

1.6 Literature Review and Conceptual Framework

This section summarizes the foundation of previous research, including six parts: museum exhibitions and museum visitors under the background of cultural tourism, digital media interaction in museum exhibitions, museum exhibition environment and visitor behavior, and evaluation, which constitute the basic theoretical foundation of this study. Theory and literature review issues topics are as follows:

(1) Museum exhibition design

This part interprets the trends and requirements of museum exhibition design in the contemporary era and defines the scope and concepts of the research. Includes:

Museums and museum exhibitions in the context of cultural tourism; The communication of museums; Museum exhibition design in the background of cultural tourism.

(2) Digital media interaction techniques in museum exhibitions

This part searches and summarizes literature from the perspectives of museum exhibition design and digital media interaction design, and seeking elements and relationships that can influence visitors' interests and interactions. The content includes: The application and development of digital media in museum exhibitions; Consistency between digital media application and exhibition design; and the impact of digital media technology on visitor interaction and interest.

(3) Exhibition environments and visitor behavior experience

This theoretical study provides a foundation for empirical research on environmental behavior and communication effectiveness, explaining factors that influence communication effectiveness in exhibition environments (both facilitators and barriers), and seeking factors and conceptual operational variables that can enhance visitor interest and interaction. The content includes Museum exhibition environment and museum visiting behavior; Museum exhibition environment and digital media interaction; Digital media technology, museum exhibition environment, and visitor experience. And this theoretical study focuses on the literature related to visitor behavior and experience in exhibition environments, with a particular emphasis on the personal environmental factors affecting visitor behavior and experience. It addresses the conceptualization and operational variables of the impact of exhibition environments on visitor behavior and experience under the interaction of digital media and interactive technology, resulting in a tested model. The content includes: Individual visitors' factors influencing interest; Perception and cognition; Visiting behavior and experience.

Conceptual Framework

Figure 1 illustrates the Conceptual framework of this research.

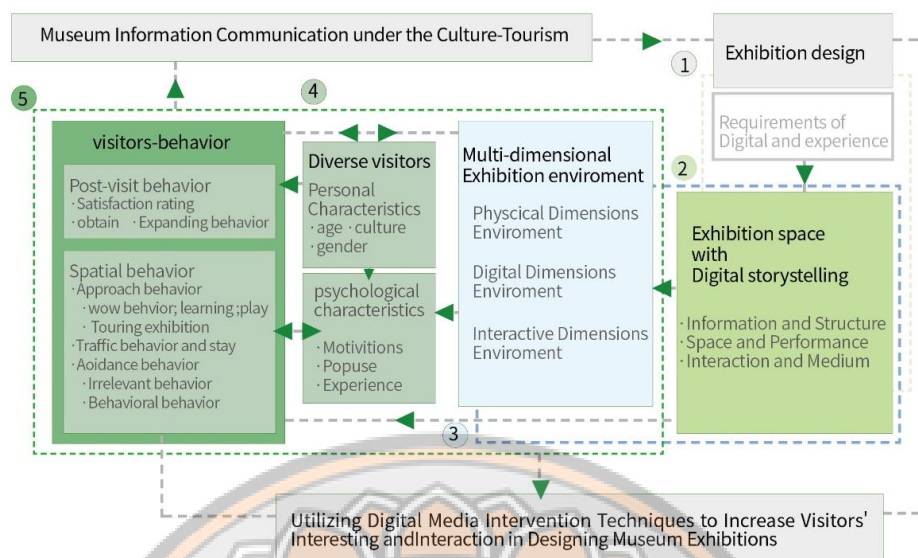


Figure 1 Research Conceptual Framework

1.7 Research Scope

This study consists of the Area scope, participants, population, and sample, as detailed below:

1.7.1 Scope of area

(1) Research geographical limits

The study area is limited to Chinese tourist cities (excluding Hong Kong, Macao, and Taiwan). The scope of the case study is limited to newly established museums in China that aim to promote cultural tourism development and publicize regional culture.

(2) Specific space of the case study

Cases are selected from newly built museums in mainland China's tourist cities, and field observations are conducted on museums built over the past decade. Ultimately, 5 museums are selected as the specific space for the main study. The data collection part of the study involves conducting case investigations at the Suzhou Museum West (SWM), Museum of Wu (WCM), Jiangnan Watery Region Culture Museum of China (WCM), and Wu-Yue Culture Museum (WYM). The China Grand Canal Museum (GCM) was selected as a comparative case study to verify the accuracy of the results.

The scope of this study is defined from the perspective of museum exhibition spaces, encompassing both the walkable and usable exhibition areas for visitors, as well as the participatory relationship between visitors and digital interaction exhibits.

1.7.2 Expert group

To enhance the reliability of this study, the heuristic evaluation method was adopted, inviting expert panels to conduct interviews and assessments at different research stages. The expert panel consisted of three experts in museums and museum exhibition design, including an associate professor in digital intelligent technology, a professor specializing in exhibition, and a senior researcher working for a national museum. The expert group was invited to participate in interviews, the Analytic Hierarchy Process (AHP), and expert evaluation to measure the elements and tools obtained at each stage.

1.7.3 Sample and Population

This sample was among the participants participating in the questionnaire, so the age range was determined as visitors over 7 years old. During the selection of study samples, visitors were not in the sample screening range for (i) Children without knowledge and culture, (ii) Visitors who are unaware of museums and museum digital media, and (iii) People who have no listening, speaking, reading, or writing skills.

This study is based on the concept of “museums designed for all,” aiming to enhance the museum visiting experience for different types and cultural backgrounds of visitors across various age groups through universal design principles. A comprehensive understanding of the diverse needs and satisfaction levels of all visitor types is crucial. Therefore, the population of this study is the all visitors to China’s cultural tourism museums (including both Chinese and foreign nationals), and grouped into categories based on classification criteria such as age, visitation characteristics, cultural background, and motivations (Kasemsarn et al, 2023; Li, 2021), with the target audience segmented as follows: (1). Parent-child families (FC); (2). Teenager student group (TS); (3). Alone visitors (A); (4). College Students (CS); (5). Companion visitors who visit with others; (6). The elderly (E); (7). Visitors with special needs (SP). Detailed classification criteria will be presented in Chapter 3.

During the data collection process, the researcher randomly selected different types of visitors on-site and explained the research objectives and details to them. Visitors who agree to participate should be chosen as research samples. According to the different stages of the research, the samples in this study are divided into the following five groups:

Group 1: Scenario access for UD evaluation group

A scenario access for UD evaluation in Phase 2 (Objective 2) investigated physical environment intervention by digital technology, as well as the physical barriers to users' spatial behavior and needs. In the six museums, a total of 162 groups of visitors from different age, characteristics, and behavioral preferences were invited. Sample participants were selected in the exhibition site, excluding those on tours, seeking directions, or exhibiting signs of fatigue. The number of participants in each category varied across museums, influenced by the daily visitor traffic of museums in different regions. Given that the location of interactive media exhibits directly influences their interaction behaviors, researchers did not intervene in the participants' process in any way for any purpose.

Group 2: Interview group

In the museum rest area, researchers randomly selected visitors of different ages, cultural backgrounds, and behavioral characteristics for semi-structured interviews in Phase 2 (Objective 2) to collect interview data from samples to further understand the constraints and obstacles visitors encounter during their visit. Participants who did not visit the target exhibition hall or had no impression of digital interpretation and interactive elements were excluded through pre-screening, resulting in 80 valid interview samples.

Group 3: On-site observation group

This group constitutes a participant sample engaged in non-contact direct observation. The purpose is to explore whether digital exhibits can attract the attention and interactive participation of different types of visitors in Phase 3 (Objective 3). Each device is limited to 15 minutes. The researcher of this study was responsible for observing and recording visitors who passed by each digital exhibit. Visitors who approach within a half-meter range will be considered valid samples. These visitors will be classified based on their appearance characteristics, posture, and movements, as well as their communication status. A total of 6,024 visitor entries were recorded across 9 exhibition halls in 5 museums. Since the same visitor may appear at different digital exhibits during various periods, the recorded number of entries does not represent the actual foot traffic of these museums.

The recorded content includes the duration of visitors' stay in front of digital interpretation exhibits, as well as their interactive behaviors with digital media and verbal communication records during that period. Because the research process will not interfere with the behavior of the visitors, it will not cause trouble or safety risks to

them. When visitors notice the researchers, an explanation will be provided. If the visitors do not agree to participate in the study, their behavioral characteristics and verbal communication will not be recorded.

Group 4: On-site Questionnaire Group

This group of samples participated in the post-visit questionnaire survey, with visitors who completed the museum tour being selected as participants. Researchers randomly selected volunteers according to the target demographic to collect sample data for Phase 3 (Objective 3) of the study to obtain visitors' attitudes and experiences regarding digital interpretation. More than 238 individuals across five museum sites participated in the survey, with an average questionnaire completion time of 8 minutes. All questionnaires were completed on-site by visitors immediately after they finished their tour.

Group 5: Questionnaire group

The sample group was 420 people (the goal is to receive more than 384 valid questionnaires), including visitors of different ages and genders, obtained by simple random sampling. Volunteers used an online questionnaire (closed) as a sampling unit for the study at the gorgeous district of Lao Men Dong in Nanjing, especially near the City Wall Museum. Collect questionnaire data for the research of Phase 4 (Objective 4) to evaluate whether the improved digital exhibition based on design guidelines is accepted and appreciated by visitors of different ages and cultural backgrounds.

1.8 Research Methods and Process

The study employed a mixed research approach, integrating qualitative and quantitative methods as its foundational methodology, with the research process divided into a theoretical research phase, generation phase, data collection phase, and data analysis and evaluation phase. To achieve the research objectives, this study employed a wide range of research methods for empirical research. These methods were used to analyze the relationship between the exhibition environment and digital media interaction and visitor behavior experiences, to extract relevant factors, and to obtain conceptualized operational variables. Including the documentation method (Li et al., 2021; Phillips, 2011), Analytic Hierarchy Process(AHP) (Nian et al., 2025; Russo et al., 2015), Heuristic evaluations by experts (Phaholthep et al., 2017), Post-occupancy evaluation (Martinez et al., 2018; Zeng et al., 2024), walkthrough the exhibition(Mason, 2020; Phillips, 2011; Li, 2022) behavioral observation(Li, 2024;

Lo et al., 2023; Shiang et al., 2015; Wang, & Chu, 2010) and questionnaire survey (King et al., 2025; Liu, 2020; Li & Ito, 2023).

1.8.1 Documentation method

Research and review the literature related to the investigation and presentation of factors, as well as the relevant theories and principles concerning how visitors influence interest, engagement, and interactive experiences. The initial literature review focused on four aspects: cultural tourism museums, the development of exhibition technologies (with an emphasis on digital media technologies), museum exhibition environments, and visitors, to determine how digital media inadvertently influences exhibition environments and visitor behavior. Relevant factors and indicators were identified and categorized for creating an evaluation system and developing research tools.

The documentation method includes a systematic literature review and an archival search, as follows:

(1) Systematic Literature Review (SLR)

Through the SLR and bibliometric analysis methods (Kasemsarn et al., 2023; Li et al., 2023), this study establishes a fundamental theoretical framework.

(2) Literature research

Based on SLR, further document searches were conducted for searching articles, book chapters, and policies using alternative search methods, focusing on digital media interaction, museum visitors, and evaluation.

1.8.2 Expert interviews and Analytic Hierarchy Process (AHP)

Conduct in-depth one-on-one interviews with three experts to evaluate the factors and indicators obtained in version 1.8.1 that influence visitors' interest and interaction- the first heuristic assessment. Revise and supplement the factors and indicators based on expert opinions. Then, using the evaluation form, invite the three experts to perform AHP to identify the factors of digital interpretation and environment that affect the behavior and experience of different types of visitors, allocating standard weights from a structured and objective perspective. Complete the preliminary construction of the evaluation system to be used as information for the research design.

1.8.3 POE- Physical environment measurement and assessment

Through a series of methods for case studies to examine the physical environments of popular museums in China and evaluate their alignment with key factors for effectively integrating digital media technologies to promote museum

tourism. A second heuristic evaluation was conducted during this process, and three experts evaluated the research tools. The research in this phase was conducted in five case study museums and one comparative case museum.

(1) Exhibition walk-through

Based on the results of section 1.8.2, design a Physical Environment and Design Features Recording Table. Through exhibition walk-through recordings, describe the basic characteristics, environmental features, and design features of digital interactive exhibits in the research cases, and analyze their appeal or visitation barriers for different types of visitors using the Environment Feature Assessment Checklist.

(2) Physical environment evaluation

Utilizing the seven principles of the Universal Design (7UD) to develop the 7UD Evaluation Checklist, three experts have used and evaluated the tool. Seven groups of visitors, each with unique physical and psychological characteristics, were invited to participate in a scenario-based accessibility evaluation (samples of Group 1 in section 1.7.3). The goal was to assess the physical environment and visitor experience of museum exhibitions in the context of digital intervention. The evaluation results uncovered existing accessibility issues within the current physical environment, digital media interaction, and exhibition information and content.

When participants entered the exhibition hall, the researchers began tracking observations, recording the participants' operations and interaction conditions with various digital media exhibits. During the non-contact natural observation, the researcher of this study compared and analyzed participants' primary behavioral manifestations, operational constraints, and experiential perceptions, and compared these to the 7UD evaluation checklist. This procedure aims to identify spatial layouts and digital interaction facilities that meet the needs of different types of visitors, while evaluating the effectiveness and shortcomings of these exhibition spaces and digital media designs.

(3) Semi-structured interviews with museum visitors

As part of the post-occupancy evaluation from the visitor's perspective, the focus of this study is to further explore the barriers and needs encountered by different types of visitors during their visits through interviews (samples of Group 2 in section 1.7.3). It emphasizes what is important to them in the exhibition environment and what positively or negatively influenced their experience during digital exhibitions. Based on an open interview outline, the Laddering Technique was

employed during the interview implementation process, and a series of “what” and “why” questions were posed to grasp the interviewees’ reasoning (King et al., 2025).

1.8.4 POE-Visitor behavior and Visiting Experience Survey

As part of the post-occupancy evaluation, this phase employed behavioral observation and post-visit questionnaire surveys to investigate museum visitors’ behaviors and needs regarding their engagement, interest, and interaction with digital media technologies in exhibitions. During this phase, the third heuristic evaluation was conducted, with three experts assessing the visitor experience survey questionnaire. The research in this phase was conducted in five case study museums. The specifics are as follows:

(1) Non-contact behavioral Observation Utilizing the IAE Scale

The purpose of the observation study is to investigate, from the observer’s perspective, whether and how different visitors engage with and interact with digital guide exhibits, thereby identifying their needs and preferences (samples of Group 3 in section 1.7.3). Special attention is paid to the visitors’ intentions and behaviors when they participate in digital exhibits. The visitors’ behaviors bio IAE (Ignore, Attend, and Engage) scale was employed during non-contact observation (Lo et al., 2023; Shiang et al., 2015). Through attraction power (AP) recording, the quantitative data on attraction scores can be utilized as an indicator of visitors’ engagement levels. And gain a deeper understanding of visitors’ behavioral characteristics by integrating verbal records with involvement level records (Lai & Qian, 2013; Wang, 2010; Yan, 2009).

(2) Post-Visit Questionnaire Based on Visitor Experience

The purpose of the post-visit questionnaire is to investigate visitor characteristics and their evaluations and experiential gains regarding the digital interactive and interpretive exhibits. A three-part structured questionnaire was employed as the research tool, encompassing demographics, visitation experience, and satisfaction survey. As the main part of the questionnaire, the visitation experience survey section included visceral, behavioral, and reflective levels. These questions were designed based on a literature review and pretested with three experts and ten participants to ensure satisfactory content validity (Liu, 2020; Wu, 2014; Zhang, 2018). The questionnaire included a preliminary screening section to filter visitors who had experienced the digital interpretation and demonstration setups, thereby ensuring the validity of the collected data (Liu, 2020). All questionnaires were completed on-site by visitors immediately after their visit, the samples of Group 4 in section 1.7.3.

1.8.6 Generation of the Utilization Guidelines

The purpose of this phase of research is to propose strategies for effectively utilizing digital media technologies in museum exhibitions to enhance visitor engagement and promote museum tourism in China. The method and steps are as follows:

(1) Results summary and generation of multiple solutions

Summarize the results of steps 1-5 and conduct an analysis. The methods employed include descriptive statistical analysis, correlation analysis, and comparative analysis. Ultimately, identify the factors and characteristics that can enhance visitors' interest and interaction through digital interpretation and engagement. When designing museum exhibitions, it is essential to meet the needs of visitors of various types, including those of different ages, cultural backgrounds, and behavioral characteristics, without requiring separate designs and using computer graphic design software to create 3D images of the exhibition environment to illustrate design guidelines for further evaluation.

(2) Image stimulation questionnaire survey

To obtain the preference and acceptance levels of a broad range of museum visitors regarding the improvement proposals, an image-stimulus questionnaire based on the Likert scale was adopted at this stage. This is a closed questionnaire composed of images, with its structure derived from the elements and indicators in Phase 2 (Section 1.8.2). The images were created based on computer graphics following the design guidelines in this subsection. The questionnaire was administered to the samples of Group 5 in section 1.7.3, with the survey conducted at the gorgeous district of Lao Men Dong in Nanjing, especially near the City Wall Museum.

(3) Generation of the final Utilization Guidelines handbook

Based on the findings of Objective 1-3 and the survey results from the image simulation questionnaire, this study identifies the characteristics and elements of digital museum exhibits that effectively engage visitors of diverse backgrounds. It ultimately proposes the 'Utilization Guidelines for Digital Media Intervention Techniques in Museum Exhibition Design to Motivate Visitor Interest and Interaction'.

1.8.7 Discussion and conclusion

Analyze and discuss based on the results of 1.8.6. Determine the impact of digital intervention technology in exhibition environments, visitor engagement, interaction, and visitor experience, as well as the relationships between these factors. Propose design guidelines for using digital media interaction technology in museum exhibition design to enhance visitor interest and interaction.

1.9 Expected Benefits

(1) **Benefit 1:** This paper proposes conceptual factors and standardized post occupation evaluation (POE) evaluation system and methods for digitally constructed exhibition environments composition containing digital media interaction and visitor behavior and experiences through the systematic literature review (SLR) and the Analytic Hierarchy Process (AHP) which contributes to consolidating and systematizing approaches to museum attractiveness and visitor experience from an interdisciplinary perspective.

(2) **Benefit 2:** Based on theoretical research and preliminary case studies, introduces universal design (UD) and proposes the measurement and evaluation tools for museum exhibition environments, containing digital interpretation and interaction from the visitor's perspective. It assists researchers and designers in quantitatively assessing the accessibility of exhibition environments and digital interpretation under various conditions, identifying barriers encountered by different types of visitors. Additionally, it can be utilized to analyze the current state of visitor behavior experiences in newly established cultural and tourism museums.

(3) **Benefit 3:** A full-process Empirical research study-- this paper also demonstrates how to quantitatively measure the effects of visitors' interaction with the exhibition environment and post-visit experiences in museum settings, with a focus on the needs of different types of visitors. Ultimately, it explores the relationship between digital media interactions, interpretive exhibit elements, and visitor engagement, interest, and overall experience. Ultimately, the relationship between digital media interaction and interpretation was examined, and visitors' interests, interactions, and visiting experiences were obtained.

(4) **Benefit 4:** Get a guide to museum exhibition design that leverages digital media interactive technologies to enhance visitor interest and interaction. The complete design process of museum exhibition design using digital media technology to enhance interest and interaction.

The research data is collected from a wide range of cultural tourism museums and newly established museums. It can be analyzed and compared by other scholars, and it can also serve as an additional source of information and personalized museum design guides for exhibition designers. Furthermore, the test model and design guidelines of this study can be replicated in other new cultural tourism museum environments; It does not require the

collection of a large amount of user data to generate new models, which may apply to many cases of preliminary research for scheme design.

This knowledge is crucial for academic researchers, museum managers, and designers to understand digital media interactive technologies and to adopt technical solutions that are suitable for their use environment in museum exhibitions, as well as to anticipate potential difficulties in the implementation process of digital media interactive design. Therefore, the discussion in this paper will help scholars, museum managers, and museum exhibition designers reflect on the challenges involved in the development and maintenance of interactive digital media technologies within museum exhibitions.

1.10 Definition of Terms

Museum

Museums are non-profit permanent institutions that serve society and its development, open to the public. By acquiring, preserving, researching, disseminating, and exhibiting the tangible and intangible heritage of human beings and their environment, museums aim to achieve multiple objectives such as education, research, and appreciation (Desvallées & Mairesse, 2010). The functional space of traditional museums has gradually shifted from mere collection, exhibition, and research to a more comprehensive service emphasizing leisure, education, aesthetic experience, and entertainment in multiple dimensions (Wang, 2015; Zhang, 2018). Against the background of the concept of culture-tourism, Immersive experiences at museums have become a new highlight in the era of digital cultural tourism (Chen, 2022; Yang, 2023).

New museum

refers to cultural tourism museums built in recent years in China to spread regional culture. This type of museum is more focused on interpreting regional cultures than traditional museums, with less emphasis on ancient history and artifacts. Its most significant feature is the lack of exquisite artifact exhibitions; instead, there is more display of geographical, ecological, cultural, and folk culture. Therefore, the exhibitions emphasize immersive experiences and narrative interpretations (Li, 2021; Tong, 2023). From a construction standpoint, the application of digital media technology is an indispensable part of this type of museum.

Museum visitors

Museum visitors are simply people who visit museum exhibitions (Ken, 2003; Knoespel, 2024). Visitors to museum exhibitions were once understood as cultural relics lovers, collectors, and researchers. As the museum's exhibition

function expanded from the traditional educational display to the venue for leisure, entertainment, and learning (Zhang et al., 2018), the museum's audience expanded to include people from all whole society, presenting a variety of characteristics. Museum visitors can be divided into three types: potential audiences, actual audiences, and target audiences (Li, 2021; Mile, 1986). This study refers to actual visitors, i.e., visitors to the museum.

·Motivation

The motivation to visit a Museum is meant to “a behavior driven by goals and values, which may originate from biological foundations or complex interactions with external stimuli, thereby inspiring various individual activities to achieve specific objectives (Slater,2007; Zhang, 2018). Drawing from various perspectives within human psychology theory, two distinct types of motivations have been identified that determine an individual's cognitive and affective responses: intrinsic and extrinsic motivations (Ryan, 2000). Motivation clarifies the reasons why an individual decides to visit a museum or not.

· Visitor Experience (VX)

is an individual's direct or sustained subjective and personal response to activities, environments, or events outside of their usual context (Packer & Ballantyne, 2016) The so-called museum visiting experience begins from the moment a visitor decides to visit a museum, to the point of actually entering the museum and extends to the memories of the museum that remain days, weeks, or even years after the visit (Falk & Dierking, 2016; Kotler et al.,2008).

Museum exhibition design

refers to the process of extracting the thematic concept based on preliminary research on the museum and in-depth analysis of the exhibits. Within a certain space, using the exhibits as the foundation and in conjunction with appropriate supplementary exhibits and props, the content of the exhibition is interpreted and performed. The exhibits are organized according to certain principles and artistic forms to achieve the goals of visual education, cultural information dissemination, and aesthetic appreciation (Dernie, 2023; Huang, 2014; Miao,2024). The proportions, colors, materials, lighting, sound, and graphics involved in the display will all influence the way the exhibits communicate with the visitor. The content of museum exhibition design includes content design, form design, multimedia design, artistic scene design, and graphic system design(Bitgood,2019; Capece et al., 2024;

Ceccarelli et al., 2024; Chiang, 2022; Furferi, 2024; Gándara, 2016; Huang, 2014; Jiang & Lin, 2020; King et al., 2025; Lu & Chen, 2018; Wu, 2012; Li & Luo, 2024; Li, 2022; Liu, 2020; Lo et al., 2023; Ning et al., 2022; Norman, 1981; Tang & Jiang, 2022; Wang, 2015; Su 2019).

Digital Media Intervention Techniques

refers to the influence of digital technology contenting the museum exhibition environment and visitor behavior. It includes digital interpretation techniques, digital presentation technologies and digital interaction techniques, and other digital technologies that are used in current museum exhibitions. Current research indicates that with the intervention of digital media technologies, museum visitors gain immersive and personalized experiences distinct from traditional exhibitions. The incorporation of digital media technologies has facilitated the evolution of museum exhibition design while also presenting new opportunities for exhibition dissemination (Mason, 2020; Ning et al., 2022). However, in real-world exhibition settings, visitors exhibit reluctance to engage with digital interactive exhibits (Ceccarelli et al., 2024). This study will further explore the impact of digital technology integration on visitor behavior and experience.

· Digital Media exhibits design

refers to the application of digital media technologies in the exhibition displays of museums in China. Designers integrate the content of the display with the exhibition space, using digital media technologies to create digital media exhibits or installations and spaces that can effectively showcase the content of the exhibitions. The digital media design in museums is divided into two parts. The first part is the design of the digital media form and content by exhibition planners and designers, aiming to explain and present the exhibition content. The second part is the deepening phase, where multimedia designers conduct in-depth design on technology and equipment, software, and interfaces based on the exhibition design plan (Chen, 2023; Mason, 2020; Phillips, 2011; Tong, 2020).

· Digital media interaction

involves the use of computer-interactive integrated technology and digital communication network technology to process various forms of media such as text, graphics, images, video, and sound, enabling the establishment of logical connections among multiple types of information and integrating them into an interactive system. They enhance the technological feel and entertainment of museum

exhibitions, fully engaging the visitor's visual, auditory, tactile, and kinesthetic senses. These technologies enhance the interactive experience during visits, providing a different emotional experience, a vast capacity for information, high communication benefits, and the ability to transcend temporal and spatial boundaries (Cipparrone et al., 2025; Ken, 2006; Xi & Luo, 2023).



CHAPTER II

LITERATURE REVIEW

2.1 Overview

In order to further verify the feasibility of the study, obtain theoretical support, a literature review was conducted on three theories, including the theoretical basis of museum exhibition design, digital technology and application, and environmental behavior which is the focus of this research. The review covers the following issues, shown as **Figure 2**:

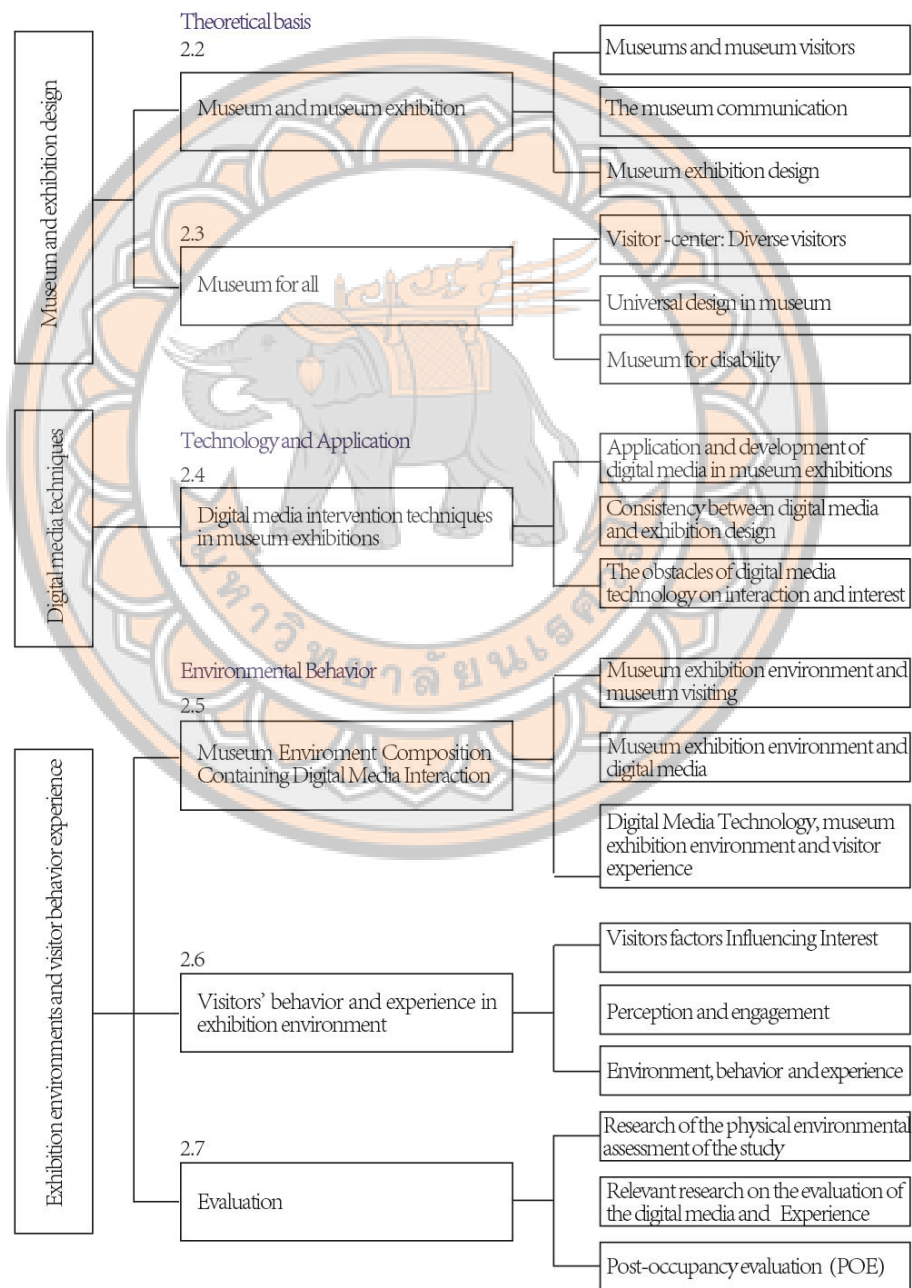


Figure 2 shows the content of the literature and the scope of related research

2.2 Museum and Museum exhibition

2.2.1 Museums and Museum visitors

Cultural tourism is rapidly developing worldwide, ushering in a new era of integration between culture and tourism. The integration of culture and tourism is the cross-border integration of cultural experience and tourism, which is a major opportunity and challenge faced by museums (Wang, 2024). Cultural tourism refers to “people movement by cultural motivation-driven, which encompasses study tours, artistic performances, cultural sightseeing, participation in festivals and various cultural activities, as well as visits to historical sites and monumental architecture” (Kasemsarn et al., 2023). There is something different from other tourism products offered by the museum through the unique cultural learning experiences and characteristics (King, 2023). However, compared to the significant attention that mass tourism garners, museum cultural tourism receives less attention. Currently, museum visitors are primarily learning-based tourists (Zhang et al., 2018). This, therefore, is an important issue faced by cultural tourism: the lack of visitor diversity (Kasemsarn et al., 2023).

The function of traditional museum spaces as exhibition venues has changed, shifting towards a composite function that includes tourism, art appreciation, historical tracing, scientific research, and educational implementation. They not only bear the social educational role of disseminating cultural knowledge but also the functions of urban tourism and regional cultural promotion (Teng, 2023), with museums becoming the preferred choice for people’s tourism (Wei, 2023). As stated by Zhang (2018):

“Museum visiting is a widely enjoyed activity within the tourism industry, particularly in cultural and educational tourism” (P1).

Museum exhibition under the Chinese policy

In China, museums are gradually becoming a must-visit spot for many tourists. In March 2018, the Ministry of Culture and Tourism of China was established, indicating that the integrated development of culture and tourism will be an inevitable trend in the development of tourism (Han, 2020; Li, 2022; Mo & Wen, 2023; Teng, 2023). In other words, museums become dual carriers for socio-cultural education and tourism development. Under the influence of this policy, Chinese museums are striving to enhance personalized experiences and tourism attractiveness through various display technologies and cross-media communication (Gu, 2022).

The Chinese government’s requirement for cultural tourism museums is “revitalization of cultural relics” (Gu, 2022). From related studies, the strategies proposed

for the “revitalization of cultural relics” in cultural tourism museums mainly focus on the new digital technologies, innovative forms, and enhancing the attractiveness of museums. This is consistent with the requirements for digital media construction and procurement proposed in the bidding documents for the construction of new museums in China. Ren et al. (2020) proposed the three aspects of museum activation in the context of the integration of culture and tourism to include: (i) digitizing cultural relics resources, (ii) creating more attractive museum exhibition environments through new technologies, and (iii) intelligent exhibitions. These are consistent with the viewpoint of the current study: using digital media applications to create better exhibition interpretations and more engaging exhibition environments, enhancing visitor interest.

Vaz & Veiga (2018) proposed that a visitor to a museum must be surrounded by unexpected and interactive experiences to capture their attention and take them, metaphorically, to these places, encouraging them to visit these places, using their collections to communicate and promote social education.” Shahab et al. (2023) empirically demonstrated that future research must determine causality between better user experiences and higher learning effectiveness. To attract cultural tourists, museums need to understand their motivations for traveling and meet the needs of highly motivated and partially motivated visitors from a cultural perspective (Cuccia & Cellini, 2009).

Summary: Requirements for digital media and visitor study

Cultural Tourism Museums tend to emphasize leisure, education, aesthetic experiences, and entertainment. The newly built museums in China are targeting cultural education and tourism promotion, using new technologies and strategies to create unique experiences to attract more visitors to the museums. Meanwhile, with the popularization of cultural tourism, the visitors entering museums are increasingly becoming more diverse, and the demand from the visitors shows a trend of diversification. The study of visitor segmentation is an inevitable part of museum exhibition research (Li, 2021). Wang (2024) identified in his research that ‘beautiful text, perfect stories, and pure spaces are what Chinese visitors like, congruent with their personality and characteristics, so that the visitor has memories. People’s interests are increasingly turning towards communication projects aimed at enhancing museum visits through mixed digital/physical experiences (Mason, 2020). As museums face the challenges brought by cultural tourism, exhibition design needs to develop efficient strategies to enhance exhibition effectiveness and the overall visitor experience, thereby standing out among numerous leisure activities.

2.2.2 The museum communication

Museum exhibition: new ways to communicate

In the context of cultural tourism, museums play various roles within the social structure. The essence of museum exhibitions is to utilize human responses within the environment to create new ways of disseminating and learning (Gu, 2022). According to (Lord & Maryland, 2001), contemporary exhibition experiences have become more interactive, emulating many science centers that have long attracted and stimulated visitors' interests in environmental matters (Ahmad et al., 2014). These centers understood how visitors' enthusiasm, awareness, and knowledge about different factors can be influenced and enhanced, an understanding that must be reflected in museum displays.

Whether it is a traditional museum or a cultural tourism museum, its essential requirement is the dissemination of information. The main body of information dissemination is people. This aligns with the audience research mentioned in the previous review. Therefore, during the theoretical construction phase, this study introduces museum communication theory.

Museum communication model

Museums are able to spread a kind of information reconstruction based on "museum objects"; this "information theory" has reached a preliminary consensus in the museum community (Zhou et al., 2023). Information dissemination, also known as information communication, refers to the process of transmitting information from the source across time and space to the information recipient using a certain carrier and through a specific information channel (Bao, 2012).

In 1968, Duncan Cameron published the article "Museums and Museum Education as a Communication System: Insights," which was one of the first studies to propose a model for museum communication. Cameron believed that in the museum's communication model, curators act as communicators, the visitors recipients, and physical objects as the medium, which is what differentiates museum communication from other mass media. Cameron suggested adding a feedback loop to the museum communication model, where information is fed back from the visit to the curators, aiding communicators in modifying their communication strategies (Huang, 2017). Knez & Wright (1970) raised doubts about Cameron and proposed the communication model shown in **Figure 3**. They argued that the primary function of museum communication is knowledge cognition, at least in the context of science museums.

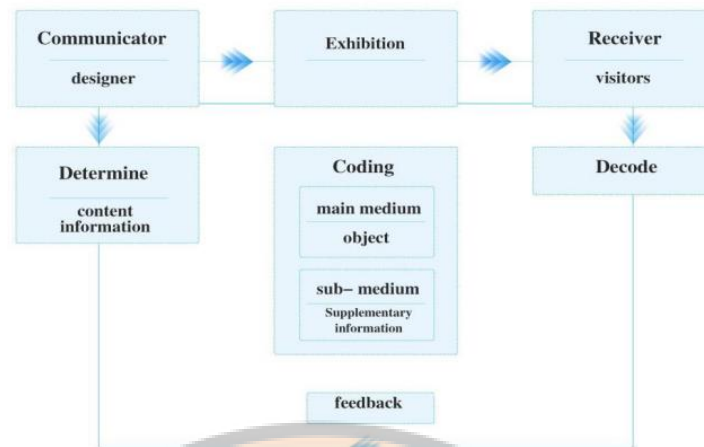


Figure 3 Information Communication Model of Museums

Source: Drawn by Lu Ai, based on the Knez & Wright (1970).

Greenhill (1991) constructed a new model for museum information dissemination, which led to a significant leap forward in the field of museum communication. In this communication model, the “communicator” is replaced by a team that encompasses planners, designers, custodians, and the interests of the visitor, who, as the ‘receiver’ of the information can be considered as an active creator of meaning and information based on their own experiences, and their prior knowledge, attitudes, understandings and values will contribute to understanding. The concept of ‘media’ is considered the middle ground between communicators and recipients, where a vast array of diverse and potentially conflicting meanings are continuously created and recreated. Starting from this communication model, museum communication has begun to fully recognize the subjective agency of the visitor (Greenhill, 1991; Huang, 2017).

As can be seen, cultural transmission is the core task of museums, which serve as the medium for cultural dissemination. The purpose of utilizing exhibitions of various types, functions, sizes, and interpretive methods in museum exhibition design is to achieve communication and interaction with the visitor (Wang, 2024). Space is the carrier of information dissemination, and it is also the place where the visitor obtains information and interacts with it. Designers need to change spatial elements such as form, structure, and color to create intuitive, visual, systematic, easy-to-understand, and lively spatial visual forms. They also need to present the information to be displayed in a planned, purposeful, and logical manner to the visitor, thus completing the communicator’s intention to convey (Sun, 2017). The visitors to the museum are much the same; they are far from being passive, mechanical, and easily manipulated as curators and museum staff

might imagine. Most visitors come to the museum actively and with their own opinions, having their own agendas (Greenhill, 1992). As a unique three-dimensional multi-sensory social medium, museums facilitate information dissemination throughout the entire process of transforming values into functions (Bao, 2012).

Factors affecting communication effectiveness

Eldamshiry and Khalil (2018) proposed that museum designers play a crucial role in bridging the gap between the information source, the curator, and the receiver, who are the visitors (p. 286). All concerns of communication are relevant to the information source, curator, and the receiver(visitor), or their power relationships. It often seems that exhibitions have no interpretation involving the translator of information. Visitors' interest, or their motivation, and the information provided by the museum, such as objects, events, and exhibits, are key topics in museum performance (Nowacki, 2005). At the same time, Eldamshiry & Khalil also believed that utilizing various digital media techniques can result in engaging outcomes that cater to the most generally preferred learning styles, intellectual capacities, and interest levels. This section will be elaborated in detail in Section 2.3 on museum visitors.

Summary

In museum exhibitions, the design of the information dissemination process that is multisensory, multi-experiential, multimodal, and multiform will become the new future of design development. According to the theme of the exhibition, the comprehensive use of narrative, experiential, and performative forms of information dissemination will be more conducive to the dissemination of exhibition information (Sun, 2017). Exhibitions will become more people-centered, emphasizing experience and information dissemination. A proportion of visitor research should be added as relevant research. Secondly, the factors that affect communication effectiveness include the communication source, the communication content, and the recipients. Therefore, research on visitors should consider relevant factors and conduct the research within the larger display design process.

2.2.3 Museum exhibition design

There is no debate regarding the exhibition's significance and role in the museum communication. The role of museums is outstanding and indispensable for preserving cultural and natural heritage. Additionally, communicating their related messages and information by providing different types of exhibitions. Displays of objects should encompass audio and visual image effects and interactive environments

(Jarrier,2012). Dawson (2006) highlighted the evolving trends in museum exhibitions, which serve as communication channels that enhance visitors' experiences through sophisticated, interactive, and contemplative exhibits, in addition to other methods of conveying museum topics (Eldamshiry & Khalil, 2018).

The Development of exhibition theory and technology

The museum exhibition development follows two stages: The first stage is the nascent phase of museum display: collection and exhibition, which reflects the evolution from collection and exhibition to aesthetic and educational functions. The earliest museum display prototypes can be traced back to the Roman Empire, which brought back thousands of artefacts and art from the Greek wars as trophies. These were transported back to Rome, where they were displayed in public places such as temples for the populace to view (Dernie, 2006).

In the second stage of museum exhibition development, the focus of the exhibition shifted from the subject to the service object, which was the establishment of displays, exhibitions, and other activities centered around “people”; that is, the visitor (Dernie, 2006; Wang, 2014). Towards the end of the 19th century and continuing into the 20th century, museums started to shift their focus from being “object-centered” institutions to “visitor-centered” public service organizations. This trend gradually became global until by the start of the 21st century, the visitor had become the center of the museum “experience”, the keyword of the era, and the core mission of museums to satisfy the visitor’s entertainment, educational, aesthetic, and escapism experience (Gofman et al., 2011; King, 2023).

Ken (2006) showed that museum displays had shifted from static exhibitions centered on “cultural relics” to participatory and interactive displays centered on “people”. Museum exhibitions have undergone several significant transformations during this period, and five stages of this transformation were defined:

- (i) Curio Cabinet;
- (ii) The concept of circulation;
- (iii) Categorized display;
- (iv) Interactive and participatory: The integration of digital media technology has greatly enhanced the possibilities for museum exhibitions and has brought museums closer to visitors.

- (v) Integrate the concept of humanized development: The exhibition should be people-oriented, focusing on the public and social issues, strengthening the exhibition function to meet diverse and varied demands, and striving for a diversified level of exhibitions.

The narrative design organizes information in a way that tells a story, guiding the visitor to continuously seek the next piece of information, making the entire viewing process lively and interesting. This design form not only meets the visitor's aesthetic needs but also satisfies their cognitive needs for information acquisition. With the continuous integration of digital media technology, the way design is expressed is also changing (Dernie, 2003). In narrative design, digital media technology is utilized by stretching or distorting "time", mapping the "past" and "future" onto the "present", weaving together a series of storylines. At the same time, by employing information and space, the visitor is guided, their imagination is stimulated, and thus effective communication of information is achieved (Phillips, 2011; Sun, 2017).

Performativity design has emerged with the development of people-centered museum exhibition design. Performativity expression is a method of exhibition design and an organizational model for information dissemination. Performativity is an organizational model for the dissemination of thematic information, and it is a perfect presentation based on visitor behavior patterns, cognitive needs, and communication thinking (Gu, 2022; Sun, 2017). The term performativity is used more frequently within the realm of philosophy, and the concept of performativity has become a new spatial organizational method in the construction field. It emphasizes the dialogue between space, people, and time (Dernie, 2003). When the scope of performative approaches extends beyond the display of symbolic design and promotes the concept of experience design, it becomes the most significant development in modern exhibition design.

Experiential body expression can be divided into scene construction, atmosphere creation, immersive experience, and other forms (Mason, 2020; Sun, 2017). Among these, immersive experience design is a form of design that emerged with the introduction of digital media interactive technology. Immersion refers to drawing visitors' attention and focus to the story or narrative created by the designer, involving them in the experience, separated from but adding to the visitor's real-world situation. It is a form of experience that, with the development of digital media technology, brings a

strong visual and auditory impact to the visitor, allowing them to enjoy a high-tech virtual experience as if they were there (Xi & Luo, 2023).

· *Experiential learning and Gamification design*

As public institutions increasingly seek to provide exceptional informal learning experiences, they have been working hard to communicate and encourage visitors to these spaces by adopting innovative technologies, thus meeting the visitors' desires (Shahab et al., 2023). In the current information age, museums and experts, scholars are all trying to better display items for the public to view, orienting the exhibitions, methods, and techniques to better guide the visitor's viewing and responses. Therefore, in order to provide better exhibitions to enhance the educational experience of the visitor, it is inevitable that museums must open up their exhibitions and displays and invite people to participate, create, and interact with each other. At this point, a new design thinking is introduced into museum exhibition design: gamification design.

Games can also be considered the most participatory form of activity (McClarty et al., 2012). American game designers and writers described the theories and empirical evidence related to such games in their 2012 research report. They claimed that using games in education can provide five advantages: principles of learning, encouraging participation in learning, more personalized learning opportunities, understanding modern learning skills, and providing authentic learning environments and relevant assessments. Studies have shown that gamification enhances the intrinsic motivation of the visitor for learning and fully utilizes the social educational functions of museums. In the literature review on museum exhibition design in China, it was found that gamification has gradually shown a positive social influence in museum exhibitions. Several museums in China have experimented with gamification in their exhibitions to create an immersive and engaging visitor experience, cultivating the interest of the visitor in the exhibitions and deepening their understanding of the cultural and historical significance of the exhibitions (Yang & Shen, 2022).

Gamification is the process of applying game or play concepts, mechanics, and elements to non-gaming contexts. Yang & Shen (2022) believe that the game's philosophy of "user experience-centric" aligns well with the museum's people-centered philosophy. However, some scholars have pointed out that interactive experience games in exhibitions can have different communication effects on people from different age groups. Therefore, it is suggested that appropriate interactive

software targeted at specific groups should be used as a means of communication for exhibitions, but this should only serve as an auxiliary to the display and not become the main axis of the exhibition (Huang, 2014). Moreover, the main form of exhibition should consider the needs of the target visitor for the theme.

The method and process of exhibition design

Museum exhibition design is a comprehensive design work that encompasses various aspects from spatial design to graphic design, from prop design to media design, and from copywriting to event planning. Through exhibition design, exhibits reinterpret and explain in a new environment (Sun, 2017). The traditional exhibition design process involves conducting preliminary research on the museum and in-depth analysis of the exhibits to refine the concept of the exhibition theme, arranging exhibits within a certain space based on them, complementing them with appropriate auxiliary exhibits and props, and combining them according to certain principles and artistic forms to achieve the goals of visual education, cultural information dissemination, and providing aesthetic appreciation. Eldamshiry & Khalil (2018) suggested that the traditional models of the museum exhibition development include the curator's assembly of the objects, text or and the various essential activities, such as writing the labels, captions, and textual descriptions of each exhibition, all of which contribute to establishing the overall conceptual framework.

However, Sun (2017) believes that as “viewing exhibitions” has shifted from “popular science education” to “a leisure activity in everyday life”, the design of the viewing process is no longer just about the design of spatial structures, spatial organization, spatial forms, and information layouts, but rather designs enabling the interaction of people, objects, and spaces. This viewpoint is consistent with Dernie (2006) and Mason (2020), whose opinion was that display design had become increasingly focused on explicitly drawing attention to the visitor, with the starting point being the relationship between the visitor and the brand/product/exhibit. This relationship would be based on the interactive nature of the exhibit or display, be it an automobile show or a museum collection display. The individual experience and how to integrate this element are what are considered important by the display designers.

• *Spatial narrative design*

The effect of the display depends first on how it is constructed: regardless of other qualities, a chaotic display would not enthrall, whereas a well-designed or well-constructed display would provide the visitor with a memorable experience. In exhibition

design, this background relationship is often referred to as a form of communication and storytelling, known in other theatrical activities. The method of categorizing exhibits based on their type and a strict chronological order has given way to a more flexible approach to constructing narrative backgrounds, according to the design of spatial storytelling (Dernie, 2006; Mason, 2020; Sun, 2017; Wu, 2012).

According to the spatial narrative design (Dernie, 2006), exhibition design is divided into three steps: First, consider and set a strategic storytelling plan at the beginning of the exhibition setup. Second, based on the thematic structure of the imagined narrative space, combine the exhibits and then arrange the space according to this structure. Third, design more details in each room. Effectively combining exhibits is like an orchestra playing together. This is consistent with the classification of museum exhibition design content in the exhibition design tutorial classified by Wu (2012) as creative design, spatial design, exhibit design, and artwork design. Notably, this classification includes digital media technology as a separate design element in the methodology.

The design of the museum's circulation path is the most important element in the overall exhibition design, and a reasonable circulation path design is directly related to the success or failure of the museum's display. The design of the immersive experience in museums, besides focusing on the safety, connectivity, and functionality of the visitor path, should also consider the fun and experiential quality of the path from the visitor's perspective, meeting their psychological needs (Li, 2021). At the same time, Mason (2020) considered narrative design as the foundation of the experience design process, and Mason introduced an "Experience Design Framework", defining it as the combination of three design element levels: the Experience Units, Experience Flowchart, and the Meta-narrative.

· *Experience design*

It is a design form that has gradually emerged with the integration of digital media technology. Digital media technology was initially introduced into museum exhibitions as educational equipment, but as exhibition theory and technology have developed, there has been an increasing emphasis on using digital technology to enhance cognitive experiences and complement physical displays. Simulated environments, reconstructed experiences, and virtual reality have taken up a larger component in contemporary exhibitions to update modes of communication (Dernie, 2006). Mason (2020) proposes a framework that starts from a more abstract level of experience design, progressively advances to interaction design and

information design, and ultimately refines to the specific details of interface design. The design model includes three levels of experience, structure, and surface.

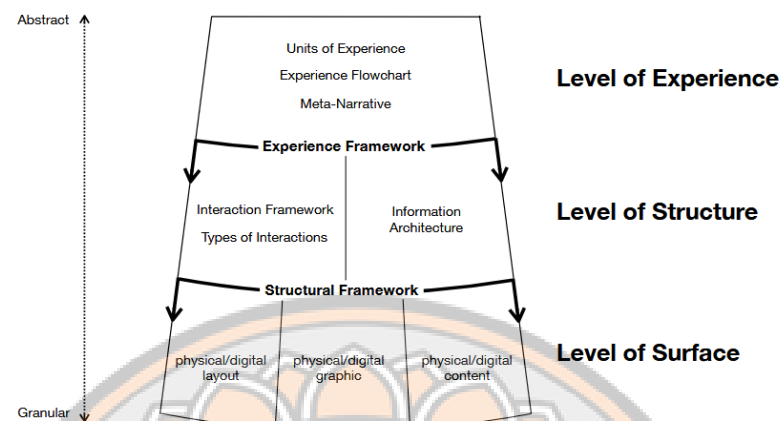


Figure 4 The Design framework with three levels

Source: Mason, 2020.

Sun (2017) also believes that “experiential expression refers to the cognitive process and reaction that occurs after obtaining information or a visual impression from the physical environment.” He categorizes experiential design into scene construction, atmosphere creation, and immersive experiences, among other forms. Immersive experience is a particularly prominent aspect in the design and related research of newly built museums in China today.

Immersive experience refers to engaging the visitor in a scenario created by the designer, causing them to forget the real-world context. It is a form of intense visual and auditory impact that has emerged with the development of digital technology, offering a high-tech virtual experience that makes the visitor feel as if they are truly there. Li (2021) points out that immersive experience design includes: visual communication design, multisensory immersive scene design, multi-scene environmental creation design, and human-computer interaction design. Immersive experiences in museum tourism mainly rely on exhibition content, using digital technologies such as somatosensory interaction and dynamic projection to create a gallery atmosphere and shape the exhibition scenes. Visitors engage in the viewing process through multiple sensory experiences, including visual, auditory, and tactile senses, with their bodies and minds participating, forming a natural interaction with the surrounding environment, and triggering emotional resonance (Li, 2022).

Whether in narrative exhibition design or in immersive exhibition design, with the continuous addition and update of digital media interactive technology, more gamification attempts have been brought to museum exhibitions. Interactive games and gamification thinking are one of the forms of the utilization of digital interactive technology in museum exhibitions can be found in section 2.3, Application of Digital Media Technology.

· ***Design factors affecting visitor experience***

Bitgood et al. (1992) proposed three influencing factors affecting audience visiting behavior, including design factors, environmental factors, and visitor factors. The “configuration” of exhibits and space, the “flow” of people and space, and the “shape” of space and space are indispensable elements in the planning and design of exhibitions. This section will summarize the design factors that affect the visitor experience.

Kaplan et al. (2021) argued that exhibition communication should not only serve an educational function, but also stimulate the audience's sensory experience and intellectual vitality. Good communication can effectively enhance the interaction between visitors and the exhibition. Exhibitions typically employ similar fundamental elements to display objects, narrate stories about the creations and uses of humans, or the natural world. They need text presented in the formats of wall panels and labels. Additionally, they incorporate other graphic elements, such as photographs, statistical charts, 3d drawings, or maps. Lighting and museum furniture, walls, cases, platforms, and other architectural elements can also be used to enhance viewing and enclose exhibition space. The color qualities and the textures attached to all those elements are also important (Eldamshiry& Khalil, 2018). Furthermore, Wu (2012) argued that for displays to effectively convey knowledge, they must utilize easily recognizable and interpretable visual elements such as forms, colors, and materials to shape and communicate different exhibition contents.

Designers create imagery by telling stories and engaging with the visitor through space. As the theme of the story changes, so does the psychology of the visitor, allowing them to fully experience the rich variations of the display form at different plot points. Designers guide the visitor to continuously explore the next piece of information through a storytelling approach, making the entire viewing process lively and interesting. This not only meets the visitor's aesthetic needs but also satisfies their cognitive needs for information acquisition (Sun,2017). Through interactive experience design, two-way communication should be formed between the

visitor and the exhibition space. Both parties should experience spiritual pleasure and a sense of participation during the communication process, and the space design should stimulate the visitor, causing an emotional resonance that leaves a unique place memory with them. Emotional experiences make the exhibition information more relatable to the visitor's hearts, easier to touch them, and therefore can be accepted more quickly by the visitor.

Summary

Under the stimulus of new museology and technological development, most countries have made even the most difficult and obscure scientific or archaeological museum exhibitions easy to understand and interesting. Museums connect the past, present, and future through objects, and as times change and museum objects diversify, the exhibition space has transformed from a place for the display of objects to a field that conveys high knowledge and human interaction (Ken, 2006). Research on exhibition design theory and methods, China's new museum construction shows a design trend that emphasizes experience and immersion. Whether it is narrative, experiential, or performative, all are based on space as a carrier, with the purpose of information dissemination, using multi-media as a means, and with the appeal to serve the visitors the goal of the information dissemination process design. However, whether such a design approach can truly enhance the interest and experience of the visitor and whether it truly promotes the dissemination of culture requires further empirical research.

2.2.4 Summary

The characteristics of cultural tourism museums are personalized experiences and dissemination (Ren et al., 2020). How can a museum understand the needs of its visitors and build a good mutual relationship with them? Museum exhibition design centered on human interaction emphasizes the interactivity between visitors and the exhibition environment. Narrative design, performative exhibition design, and experiential exhibition design have developed from this. Based on experiential design, immersive experience design, and gamified design have also emerged. The development of such theories and design methods is inseparable from the development and utilization of digital media technology. The expansion of time and space brought by digital interaction technology, the experience of multi-sensory, and the interactive ways of promoting learning experiences, have become important factors influencing the exhibition environment in museum communication, and are also factors that exhibition designers must study. In the construction of museums in China, there is a

presentation of design catering to the tourism needs of the visitor. However, little research has been found from literature analysis that focuses on the needs and characteristics of visitors from different age groups and cultural backgrounds. Many factors affect the visitor's interest and interactive behavior, which requires further research. Truly reflecting a “people-centered” design.

2.3 Museums for All

The importance of tourist studies has been widely mentioned in the previous review. This section will review and organize existing perspectives on museum visitor studies.

2.3.1 Visitor -Center and Diverse visitors

From 2020 to 2024, the focus of the research content gradually changed from cultural tourism development strategies to innovative development of museum tourism, with greater emphasis on museum visitor perception studies, as well as museum exhibition content and exhibition technology. This indicates that the design of contemporary museums in China that aligns with the cultural tourism development demand is an issue that designers and researchers must confront. From the articles' study, research on cultural tourism museums mainly focuses on four major aspects: tourists' perceptions and experiences, the design and development of cultural and creative products and souvenirs, the innovative development paths of museums, and the forms of museum exhibitions and technological innovations. It is evident that research on museum exhibitions and visitor experiences, in the context of cultural tourism and museum communication, emphasizing a “visitor-centered” approach, is still in its infancy.

Museums operate “for the benefit of the visitors” by attracting and satisfying them, meeting their specific needs across different groups, and providing diverse experiences (Eldamshiry & Khalil, 2018). Driven by cultural tourism, today's museum visitors tend to expect more positive, interconnected, and participatory experiences in their engagement with museums (DeBacker, 2015). Visitors stepped into the museum with anticipation and excitement, eager to experience the personalized participation formats and unique exhibition viewing methods that transcend time and space, drawing inspiration, embracing surprises, and welcoming challenges (Knoespel, 2024). The focus of museum exhibitions has shifted from objects to people. The investigation and research on audience composition, needs and expectations, how museums communicate with audiences, and how to define target audiences are all very popular research topics in the museum industry (Chen, 2005).

For museum managers and designers, how can to let the audience have a preliminary understanding before entering the museum? How to make every visitor to the museum gain something in a relaxed and enjoyable way? How to make the audience interact with the display in the process of visiting and leave a deep impression? And why do some museums attract more visitors? What kind of experience did visitors have after visiting the museum? What did the audience do in the museum? How to learn? And what have you learned? What do visitors expect from museums? Is the concept communicated to the audience? Does the museum have a clear understanding of the needs of its visitors? and whether the audience follows the designer's vision to visit the exhibition (Chen, 2005; Huang, 2014; Wang, 2010; Yan, 2009; Zeng et al., 2019). These are all problems that need to be solved through visitor research.

If the museum does not have specific survey data to obtain answers to relevant questions (Chin, 1998), it will only remain at the stage of “taking things for granted”, and all efforts will inevitably be wishful thinking if the audience is not analyzed in advance to understand the audience's perception of the museum. The visiting behavior in exhibitions represents the visitor's environment perception within the information, through the cognitive and emotional processing, resulting in responses (Chen, 2022; Ken, 2003). Therefore, the exhibition environment that influences visitor behavior and experience includes the physical environment, such as exhibition configurations and display technologies, as well as the visitors' psychological characteristics, such as motivations, expectations, and perceptions (Wu, 2012).

In research utilizing digital technologies to enhance museum user experiences, scholars focused on adult audiences (Eldamshiry & Khali, 2018), family audiences (Wang & Chu, 2010; Yan, 2019), and child audiences (Li et al., 2024; Li, 2022; Su, 2019), student audiences (Shaby et al., 2017). For instance, Shaby et al. (2017) employed the Visitor Engagement Framework model to examine the characteristics of adolescent students' engagement behaviors in science museums. Li et al. (2024)'s study investigated children's interaction with digital installations in science museums. However, the experience of elderly tourists during visits is seldom addressed. Most tourism institutions, including museums, frequently lack attention to the older visitor demographic, treating them no differently from other tourists (Kasemsarn et al., 2024). Against this research backdrop, studies on museum visitors' classification have been increasing annually.

Diverse visitors

In the increasingly prominent era of cultural tourism, an increasing number of tourists regard museums in a certain area as one of the destinations of their journeys (Mo & Wen, 2023). Museum exhibitions should focus on how to attract a diverse range of visitors (Shahab, 2023). Beliefs, values, and norms influence how people perceive and think about truth, and how they behave in words and deeds. Sensations arise because people decide what is happening, what is most important, what society expects of them, and what is considered socially demanding. Attitudes, on the other hand, are a mixture of perceptions and feelings that shape how people participate in social life. In summary, each person plays multiple roles in different physical and social environments, and these identities may affect the motivation of individuals to visit museums, and thus affect the visitors' visiting behavior and learning.

In the context of cultural tourism, for museum visitors, the main demand remains “learning”, that is, educational tourism (Zhang et al., 2018). However, Mo & Wen (2022) pointed out the opposite view in their research, which shows that more people visiting museums are tourists, while the proportion of residents is gradually decreasing. At the same time, residents live a relaxed and leisurely life, with the proportion of parent-child entertainment increasing, which has sparked a higher demand for leisure experiences, especially the desire to “check in” at various locations (Teng, 2023). This also illustrates from another perspective that visitors to cultural tourism museum exhibits have diverse characteristics: diversity in groups, diversity in objectives, and diversity in motivational needs (Kittichai et al., 2023).

Visitor classification

According to the Report on the Development of Museums in China (2019-2020), the total number of museum visitors in China reached 12. 2.7 billion person-times. In 2023, the museum ushered in a continuous wave of visits. However, this huge data does not have a “niche” model analysis (audience or consumer market segmentation), so what about it? There is a lack of scientific analysis and judgment (Fu, 2023; Li, 2021; Kasemsarn et al., 2023). Falk (1985) empirically analyzed the theoretical framework of “exhibition viewpoint”, “audience viewpoint”, and “environmental audience”, and concluded that the composition of museum visitors is diverse, but the behavior is quite predictable (Csikszentmihalyi & Hermanson, 1995). Only by mastering these predictable behaviors will it be easier for museum

management to provide services that satisfy visitors and their experience. This idea is still used today in research on museum visitors.

The development phenomenon in the field of foreign audience studies shows that museum visitor research has gradually become the core work of museum exhibitions, including the fact that more and more museums have begun to conduct audience research. In terms of audience characteristics, due to the increasing diversification of museum audiences, museums have begun to try to locate target audiences for targeted education in exhibition planning (Zhou, 2023). Yan et al. (2014) argue that the audience of museums is no longer a unified and undifferentiated whole.

The perception of the audience as monolithic is changing, and different characteristics and motivations of different groups of people are being treated differently. In the existing research on museum visitors, special museum visitor studies such as adult visitors (Eldamshiry & Khali, 2018) and family visitors (Fu, 2023; Wang & Chu, 2010; Yan, 2009), children (Li, 2022; Li, 2024; Su, 2014), students (Shaby, 2017), and elderly visitors (Kasemsarn et al., 2024; Smiraglia, 2016; Thomson et al., 2018), young visitors (Gofman et al., 2011; Zeng, 2019) are divided into special museum visitor studies.

In addition, among the relevant studies on the evaluation of exhibitions, there are also studies on the classification of visitor characteristics. Mo & Wen (2023) divide museum visitors into tourist and local audiences. Li (2021) classifies visitors according to their companion type when studying Chinese museum visitors. Yan (2019) classifies visitors according to their age, children (0-6 years old) and teenagers (7-17 years old), young people (18-35 years old), middle-aged (36-60 years old), and elderly (over 60 years old) in the study of museum exhibition environment and visitor behavior. Taiwan scholars Lu & Chen (2018) divided the audience type into parent-child audience and friend audience in the study. Chen (2005) conducted a study on the behavior of visitors in the Marine Biology Museum and divided the types of visitors into male and female pairs, family groups, student groups, and social groups according to the number of visitors and their peers.

In addition to cultural tourism, in studies related to museum exhibitions and learning outcomes, there is another classification of visitors' characteristics. Sellers (2001) identified several key characteristics of museum visitors, describing them as follows: they represent a diverse cultural group with nonspecialized knowledge, seeking to spend their leisure time. They are driven by curiosity and often have social agendas.

These visitors may come from intergenerational groups that enjoy engaging experiences, appreciate and require orientation, could be first-time museum-goers, have limited time, and have a strong inclination to learn. (Eldamshiry & Khalil, 2018). **Table 1** shows the classification of museum visitors in the literature review.

Table 1 Different museum tourist characteristics

Classification	Characteristics	Literature Review and Authors
Demographic Aspects	1.Age; 2. gender; 3. Ed; 4. Nation;	Chen, 2015; Li, 2021; Liu, 2020.
	5. Cultural Tours (more than four per year);	Kasemsarn et al., 2023;
	6. People uninterested in cultural tourism;	Kasemsarn & Nickpour, 2016.
	7. People with disabilities.	
Crowd Research	Teenager (15-24); Senility (Over 60);	Kasemsarn & Nickpour,
	3. Parent-child family;	2016; Li, 2021
	4. Number of visits: Single-person, multi-person, or team.	Yan, 2019
Purposive Aspects	1.Professionals/Hobbyists; 2. Learn-based, yet not an expert;	Kasemsarn, et al.;
	3. Focusing on things presented as commemorative;	Falk & Dierking, 2016;
	4. motivation of visiting heritage;	Eldamshiry & Khalil, 2018
	5. Collecting experiences;6. are social motivation.	
Motivational Aspects	1. Want to learn a specific region and culture;	Han,2013
	2. Pay attention to the content of the exhibition;	
	3. Educational values;	
	4. Community cultural values;	Stein et al.,2008
	5. Cultural identity values.	

Diverse purposes

Falk & Dierking (2016) noted that focusing solely on demographic characteristics cannot provide an in-depth understanding of key elements such as visitors' needs and expectations. The research focus should be on exploring why visitors visit museums, rather than merely on which types of visitors attend museums. Falk & Dierking (2013) categorized tourists into seven personas, as presented in 6 aspects (Kasemsarn et al., 2023):

- (i) Professionals/Hobbyists: feel a relationship between the exhibition and their profession/hobby;
- (ii) Explorers are curious to learn, but not experts ;

- (iii) Respectful pilgrims: focus on what is represented as a memorial;
- (iv) Affinity seekers are motivated by heritage;
- (v) Facilitators are socially motivated;
- (vi) Experience seekers: are collecting experiences through museums.

Diverse motivations

Zhang et al. (2018) investigated the motivations of the museum visitors; they found that “self-development”, “social communication”, and “informal education for family” are intrinsic, while “leisure and relaxation” and “attractiveness or interesting” are the five major motivations for educational tourism visitors. The research findings suggest that family education and self-development are the two most significant factors in improving visitor satisfaction through the physical environment.

Li (2021) believes that most museum visitors have expectations when viewing exhibitions, which stem from the spiritual needs of self-actualization and are important factors in guiding visitors' behaviors. At the same time, in the study titled “Museum Visitors' Behavior,” it is proposed that visiting motivation is a significant reason for the occurrence of visitors' viewing behaviors. The motivations of the visitor offer and their behaviors during the exhibition also vary. For example, in Li's (2021) observation case, the visitor whose main motivation is “leisure and entertainment” tends to exhibit behaviors such as “taking photos of exhibits” during their visit, while those motivated by “desire for knowledge” show behaviors like “spending a longer time in front of exhibits”. From the perspective of tourism experience, visitors' motivations and types are divided into four aspects: entertainment, education, escape, and aesthetics (Zou & Wu, 2003). Wei (2021) classified tourists into leisure experience motivation, self-experience motivation, cultural experience motivation, and emotional experience motivation based on their motivations when studying museum tourism through a literature review method. At the same time, Wei (2021) also found that museum visitors are showing a trend towards younger and more highly educated individuals.

Western scholars Stein, Garibay, and Wilson (2008) suggest that ethnic background, age, and social group are insufficient to understand motivations. Community's cultural values, Educational values, and Cultural identity values (Kasemsarn et al., 2023). This is consistent with Stein's research findings, emphasizing the social attributes of national communities and ethnic groups. And this shows a significant difference from related research in China, which focuses on the characteristics of individual visitors to cultural tourism museums. It is worth noting that there are documents both domestically

and internationally that have introduced tourist motivations into the study of museum visitors. Tourists' choice of destination is influenced by a range of factors, including the potential for learning, the diversity of facilities, the aesthetic experience, and the quality of the environment (Zhang et al., 2018).

However, from the results of the literature review, it appears that research on visitors in Chinese literature started relatively late (Li, 2021), focusing on visitor perception, visitor behavior research, the relationship between visiting experience, motivation, and behavior, especially, there is a lack of empirical studies on visitor characteristics and experiences.

2.3.2 Museum for disability

Cultural participation and inclusion of persons with disabilities has become an increasingly urgent topic and has been incorporated into legislation, as a result of the widespread socio-political and disability rights policies in recent years (Münch et al., 2022). Article 30, paragraph 1, of the Convention on the Rights of Persons with Disabilities on "participation in cultural life, recreation, leisure and sport" stipulates the right of persons with disabilities to participate in cultural life. It calls on States parties to "take all appropriate measures to ensure that persons with disabilities have access to cultural performances or services, such as theatres, museums, cinemas, libraries and tourism services, and, where possible, monuments and sites of national cultural importance (UN General Assembly, 2007). In other words, museums and their mediation content should ensure barrier-free access (Brinkmeyer, 2014). Barriers to museum entry may exist at spatial, sensory, or cognitive levels. Examples include uneven pathways, single-sensory mediation, and complex written texts.

Criteria for an inclusive museum for people with disabilities

Within the museum space, "accessibility" is fundamentally understood as the tension between keeping material culture safe and making it available to the public (Helen, 2013). Accessibility is interpreted as an effort to counter the systemic oppression that people with disabilities experience in their daily lives. Within this framework, accessibility advocates for a more comprehensive strategy for inclusion efforts. As a public space, museums should provide convenience and non-discrimination for individuals who consider themselves deaf, hearing impaired, visually impaired, blind, or wheelchair users. The core idea behind these initiatives is to provide facilities that make existing projects accessible (Starr, 2016).

The Americans with Disabilities Act (ADA)

Accessibility-targeted legislation is not new to the museum field. Several relevant “inclusion” laws target accessibility in public spaces, such as the Americans with Disabilities Act of 1990 (ADA). Although the statute does not explicitly use the terminology “accessibility” or “inclusion,” it articulates the need for public entities to provide “equal opportunity for participation” to individuals with disabilities. One further stipulation added to the ADA was the Criteria of Design. Museums and cultural institutions are required to provide standard accessibility facilities for specific groups (Starr, 2016).

At the ADA and accessibility practice, the following are the criteria and standards of museums for disabilities (Carmen, 2013; Filova et al., 2022; Münch et al., 2022; Starr, 2016): (1) Museums should provide visitors with three options: Braille, embossed text, or large font. The system should proactively identify each visitor's specific needs, rather than responding to complaints after they are filed. (2) Visitors can also access educational materials featuring 3D replicas of several museum exhibits. Audio guides and tactile guides are provided for blind visitors to enhance their interactive experience. (3) Accessibility facilities for visually impaired persons and visitors with impaired vision, such as the tactile paving, continue from the exterior through the interior and guide people to the exhibit and other service spaces. (4) Diverse ways to experience sensory action. (5) Barrier-free access from the museum entrance to the exhibition (6) Generous room design, the exhibit features a viewing area at the front for wheelchair users to navigate. (7) Counter/table/exhibit height is suitable for wheelchair users, but children and shorter people also benefit from this solution.

ADA and Universal Design (UD)

Following the adoption of the ADA, the concept of 'universal design' has been widely advocated and accepted as a crucial approach to enhance accessibility for visitors with diverse needs. Its core principle lies in ‘optimizing the design of spaces, elements, and systems to provide maximum convenience for the broadest possible population (Paul & Cynthia, 2005).’ In the museum sector, this design philosophy is also known as human-centered design. Universal design, rooted in the ADA, asserts that providing accessible design services to people with disabilities constitutes both a civil right and a human right, and this approach expands upon its provisions. Its core principle focuses on creating barrier-free environments and effective communication channels for individuals with disabilities from diverse backgrounds.

2.3.3 Exhibitions and Universal Design (UD)

The consistency of museum exhibitions and inclusive design

A literature review of museum exhibitions, digital media technologies, museum exhibition visitors, environmental behavior, and visitor experience identified a highly relevant topic: inclusive design. Museums in modern times have become cultural and educational institutions open to the whole society, regardless of age, culture, belief, race, and class. As long as there is personal freedom, you can become a museum visitor (Ji & Wang, 2024; Kasemsarn & Nickpour, 2016). Lin (2016) also believes that all kinds of people in society should be understood as museum visitors. The target group of museum exhibitions is not a fixed professional visitor, but rather all visitors of different ages and cultures, including children and teenagers, people with disabilities, and the elderly, designed for everyone (Li, 2021). There are some research has introduced the inclusive design into museum exhibitions to promote visiting museums as a cultural tourism activity, to better reflect the diversity of visitors, and to take action (Filová et al., 2022; Kasemsarn et al., 2023). Exhibition designs are no longer solely for individual users or a specific group (such as children or students).

Different target audiences (e.g., the elderly, the disabled, and the young) have different characteristics, behavioral preferences, and needs, which include barriers and motive power of cultural tourism participation (Mikus et al., 2020). In addition, inclusive design mentions that in order to encourage more non-cultural tourists, managers and designers should learn more about the lifestyles and motivations of groups that make up a smaller proportion of tourists (Mohd Isa et al., 2022). For instance, young Homo sapiens may lack enthusiasm for participating in cultural tourism due to an insufficient understanding of the intrinsic connection between urban history and culture. By conducting in-depth analysis of visitors' interests and behavioral patterns, museum exhibitions can be designed with more personalized display methods, thereby motivating them to visit, interact, and deeply appreciate the charm of museums (Tešin et al., 2020).

Universal Design (UD) principles

In today's technological context, museum exhibition design has become a new paradigm, emphasizing "people-centered" and "visitor experience center"; however, with the transformation of museum exhibition functions and social responsibilities, its exhibition design works are no longer just for a single user or a group of users (e.g., children, e.g., students). Rather, it is to actively meet the needs,

requirements, and interests of visitors of different ages and characteristics according to the diversity of potential visitors (Mason, 2023; Kasemsarn et al., 2023). This aligns with the universal design (UD) paradigm- a design concept which prioritizes social sustainability, believes differences in physical ability as a normal part of human life, and advocates for equal use to every function or service (Phaholthep et al., 2017). The universal design focuses on the availability of all different physical abilities so that everyone can access them, using the Universal Design Center to provide equal availability for most or all people.

Universal Design was first proposed by a United States architect, Ron Mays. Universal design emphasizes equal consideration for all users, fully recognizing that people possess varying levels of abilities and face different degrees of obstacles; human abilities are limited, and individuals possess varying capabilities across different environments. The UD paradigm was initially applied to physical products and environmental design, then gradually evolved and became widely used in digital media design, and includes seven design principles: Equitable Use, Flexibility in Use, Simple and Intuitive Use, Perceptible Information, Tolerance for Error, Low Physical Effort, and Appropriate Size and Space for Approach and Use (Filová et al., 2022; Phaholthep et al., 2016).

UD-1: Equitable Use for people with different abilities

Design should be equally usable by all. For example, different operating heights can be set in digital interactions to ensure that child users can also participate in the interaction.

UD-2: Flexibility in Use

The design needs to be able to respond to a variety of users and use environments, flexibly adapt to the visitor's visit rhythm and the interaction mode that different users like, and have a high degree of freedom in the choice of visitors.

UD-3: Simple and Intuitive

That is, ease of operation, as an exhibition designer, we should always try to eliminate unnecessary complexity when designing, keep the design as simple as possible based on meeting the expectations of visitors, and provide simple and easy-to-understand feedback during the visit, to ensure that visitors clearly know their current situation and what they want to do.

UD-4: Perceptible Information

Design can effectively convey the necessary information to users with varying sensory abilities by employing a range of expressions, including graphics and text.

UD-5: Tolerance for Error

Universal design needs to fully consider the accidents that may occur when users interact with digital media, and when users make mistakes, there should be warnings or other protective measures to ensure that users can undo the error or stop the error before it occurs.

UD-6: Low Physical Effort

The design meets users' needs for efficiency, comfort, and easy-to-use interaction to the greatest extent, and minimizes the manual labor required for visitors to interact. Reflecting this universal design principle in digital media design, it is necessary to ensure that the user is able to complete the task with minimal effort on the page, reduce repetitive actions, and make the user's interaction comfortable.

UD-7: Appropriate Size and Space for Approach and Use

When people use products, regardless of the user's body type, mobility capabilities, or posture, the product needs to be designed to provide the user with the size and space to move and interact comfortably and effectively. This Universal Design Principle. In digital product design, designers need to consider how design elements are presented on the screen, ensuring that the size and layout of interface elements can be touched, clicked, or manipulated. Universal design consists of three levels, namely the value level, the demand level, and the supply level. This is consistent with the focus of the museum's exhibition design on the psychological, experiential, and behavioral aspects of visitors (Filová et al., 2022).

The concepts of Universal Design were initially implemented in the field of museum architecture by Mace and his team in 1997 (Filová et al., 2022; Phaholthep et al., 2017; Story et al., 1998). The guidelines crafted by LMB and Berlin highlight the integration of Universal Design (UD) principles in the positioning, navigation, exhibits, content, and accessibility aspects of museums (Antona & Stephanidis, 2022; Landesverband & Senatskanzlei, 2011). **Table 2** and **Table 3** systematize the main criteria for evaluating both environments and exhibition content of the museum exhibition based on the 7 principles of UD (Antona & Stephanidis, 2022; Filová et al., 2022; Landesverband & Senatskanzlei, 2011; Phaholthep et al., 2016).

Table 2 The main implementation of 7 principles of UD in the museum environment

The UD Principle and Main Characteristics	Implementation in a Museum Exhibition
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Equitable Use—UD1 Designed to meet the needs of everyone. Designing for all in museum design aims to provide opportunities for cultural engagement for all visitors.	All visitors can enter the space/area equally. Accessible entry and routes (horizontal and vertical), rather than creating separate accessible solutions.
Flexibility in Use—UD2 Design can adapt to many choices, allowing visitors to choose from several route options, sequences, and spatial timings.	Use movable partitions to connect or divide media exhibition spaces. Different route choices and time schedules. Flexible routes also support the structure of the exhibition. Using elevators, ramps, stairs, escalators, and innovative vertical circulation methods. Enough channels allow for flexible entry and exit.
Simple and Intuitive Use—UD3 Self-explanatory solutions (regardless of the user's experience, knowledge, language, or current level of attention, the design can be easily understood on how to use it.) Means of helping in navigation are applied.	Intuitive moving and wayfinding are very important for every user. Open plan, orthogonal, circular route. Sign above the doorway to the room. The exhibition structure is clear, exhibits are easy to understand and learn, and the museum staff explains. Using contrast in colors or materials. Internal and external views. People from different cultural backgrounds can recognize language systems or visual information. Reduce the complexity of the physical environment. Consistency between content and form.
Perceptible Information—UD4 When different modes are combined, communication is effective. Provide information in a multi-sensory way; for example, exhibitions should be interactive, supporting hands-on activities and multi-sensory approaches.	Tactile models and relief maps, acoustic information, sign language, and tactile Latin and Braille—information that can be touched. 3D representation/layout of exhibition rooms in the entrance space Multilingual, easy to read, logos and pictograms. Indication of path location and space (informing the audience of their current location and the upcoming route to prevent getting lost). Compare the background behind the exhibits. Exhibits can be observed from various distances and angles with multiple visual perceptions.
Tolerance for Error—UD5 The environment is risk-free, with dangers and errors minimized. No sensory overload (intense light, reflections on smooth surfaces,	There are no prominent objects in the environment; the height of these objects should ensure that all visitors will not come into contact with them. Discourage unconscious action in tasks that require vigilance.

inappropriate contrast, colors, noise)	Spaces with lower ceilings, under stairs, or under beams are marked in various ways. A reasonable space ensures that visitors do not feel any danger or threat. Considering the small spatial scale, the safety hazards it brings when there are too many people. Diffuse effects and matte surfaces create an environment that is less visually fatiguing, and materials that absorb noise help to make spaces less busy and more tranquil.
Low Physical Effort—UD6 The design should minimize fatigue and repetitive movements. Layouts should not require unnecessary walking, which could lead to fatigue and discomfort. Comfortable exercise/Ergonomic solutions/Minimizes fatigue	Spaces with appropriate lighting, nonslip surfaces, and handrails can reduce physical exertion. Opportunity for rest. Easy to operate exhibits and forms. Seating: various seating options, providing suitable seating and space for people of all body types.
Size and Space for Approach and Use—UD7 Provides sufficient space for the use of assistive devices or personal assistance. Regardless of physical characteristics, such as body size or ability, appropriate size and space will be allocated for approach, contact, and operation.	The entrance and circulation areas allow free movement. The spatial solutions of the exhibition hall must accommodate a wide range of users. There is enough space between exhibits, such as between digital media and physical exhibits or explanatory information. The main information is located at the appropriate height.

Table 3 The main implementation in museum exhibition content based on 7UD

The UD Principles in exhibition content	Implementation in context
The content category is mainly about how to present text to the target audience to promote better understanding.	Well structured; Central questions for self-discovery Everyday relevance Easy-to-read information High-contrast layout Big font Text-to-speech system available Visualization with pictorial language Information material should be colorfully illustrated and offered as easy-to-read information

Although universal design was initially developed for physical products and environments, it has since been applied to digital products, emphasizing equal treatment for all users. In the sphere of digital media and technology, universal design has emerged as essential for fostering more inclusive digital interactions (Landesverband & Senatskanzlei, 2011). Examples encompass text-to-speech capabilities, alternative descriptions for images, and customizable user interfaces that can be tailored to users' specific requirements (Kasemsarn & Nickpour, 2016).

In the digital museum, digital interpretation and interactive exhibits aim to develop high-quality exhibition content, story, and narratives that are compatible across various platforms (Floch & Jiang, 2015). For all users, a straightforward and simple narrative structure is sufficient (Pujol et al., 2012; Wither et al., 2010). Digital exhibits and activities in museums require minimal effort so that children, the elderly, and people with disabilities can manipulate and interact with them (Kasemsarn et al., 2024). The concept of universal design can be reflected in the perceptibility of information. The design should effectively convey necessary information to users to meet the diverse perceptual needs of the audience (Zhang, 2024). **Table 4** shows the main criteria considered when evaluating museums' digital media devices based on the 7UD.

Table 4 The main implementation of the 7UD in museum digital media devices

The 7UD and main characteristics are implemented in the museum digital media interaction
UD1- Equitable Use All visitors can use, watch, and participate in media exhibits. Accessible operational forms (multi-form), such as not being a standalone solution (e.g., children's operation console); Videos with subtitles allow people to choose to listen to or read to understand the content.
UD2 -Flexibility in Use Videos with subtitles allow people to choose to listen to or read to understand the content. Allow others to understand the content while interacting with the operation. Provide adaptability to the user's pace; Arrange information by order of importance.
UD3 -Simple and Intuitive Use Operational instructions, visual emphasis, content highlighting, Visual Identifier Instructions; A well-organized, clearly explained display or instruction will facilitate users in obtaining information. Language conversion system; The control buttons on the device are clear and intuitive. Provide effective hints and feedback during and after the task completion.

UD4- Perceptible Information

Present basic information using different modes (visual, linguistic, tactile) to accommodate various users;

The media includes audio descriptions for visually impaired individuals; Content information suitable for all audiences to understand.

Text, graphics, colors, icons, and other elements guide different types of visitors;

Indicate that this is a media exhibit, where you can view/interact, etc. (call to action);

Indicate the operational method with clear positioning and expression.

UD5- Tolerance for Error

Interactive software programs provide guidance when users make inappropriate choices.

Provide indications for areas not suitable for viewing distance. ^[P]_[SEP] Indicate incorrect operational behaviors;

Reasonable viewing and interaction forms that do not cause danger or discomfort;

The audio, visual, and ambient lighting are suitable, not causing discomfort to the senses.

No noise, light, or shadow environment audio will interfere with the environment.

UD6 -Low Physical Effort

Display the appropriate scale of the screen, avoiding excessive focus. Reasonable operating force during interactive operation.

Avoid prolonged periods of watching or operating in the same position; Minimize repetitive operations.

UD7- Size and Space for Approach and Use

Provide a clear view of important elements for any users who are sitting or standing.

Adapt to changes in hand and handle size. Equipped with an adjustable console or a space for diversion.

Summary

Regarding the assessment of Universal Design principles, Filová et al. (2022) evaluated museum buildings in 2018, analyzing individual elements of the space from various angles instead of judging the whole structure according to the 7 principles of UD. This part of the literature review enhances the clarity of design elements and environmental factors that affect visiting behavior, facilitating further investigation and research. To ensure that all visitors to the museum have a positive experience and the information they need (Pujol et al., 2012).

2.4 Digital Media Intervention Techniques in Museum Exhibitions

Through a review of relevant literature on museums and museum exhibitions against the background of the integration of culture and tourism, it has been observed that museums are progressively adopting strategies aimed at enriching the museum

experience by integrating hybrid digital and physical information spaces (Mason, 2020). Museums are increasingly turning to practices aimed at enhancing museum visits through the integration of digital/physical information spaces. The digital techniques and resources in exhibitions of physical samples have been proven beneficial as they allow visitors to better understand the objects and ideas. As it offers supplementary details in a more captivating fashion, it avoids overwhelming the exhibition setting with an excessive amount of information (Freeman et al., 2016; Israel, 2011). However, are traditional exhibits (models, specimens, static displays, etc.) less appealing than the new experiences and stimulation provided by technological media (multimedia videos, surround sound effects, stage lighting, etc.)? Do traditional displays fail to meet the needs of visitors? Are exhibits that utilize special audio-visual techniques truly more captivating for modern visitors (Ken, 2006)?

Therefore, to study how digital media interaction technologies enhance visitor interest and interactive experiences, this study will review relevant research on museum exhibitions, museum exhibition environments, and design elements of digital media interaction technologies in this chapter, including attraction and obstruction, focusing on two key aspects related to digital media interaction: visitor engagement (facilitation and barriers) and visitor experience (Mason, 2020; Phillips, 2011; Su, 2019), aiming to enhance exhibition inclusivity (Kasemsarn et al., 2024). It aims to identify factors that influence visitor interest and interaction, providing a theoretical foundation for the research. More and more scholars are raising questions such as those.

2.4.1 Application and development of digital media in museum exhibitions

In the digital media era, interactive design in museums can be seen as the process of utilizing advanced digital interactive technologies to collect, record, process, and generate renewable digital forms of museum objects (including but not limited to specimens or cultural relics), exhibitions, or culture itself. It involves a perspective that combines technology and the humanities, redesigning and reinterpreting through effective design methods, and the outcomes are used for display, research, and public communication (Ning et al., 2022). With the development of new technologies in the 20th century, museum display modes have begun to become more diversified; many museums use technological media as a display strategy, engaging the visitor's five senses in participatory operations and interactive displays, transforming spectators into

active participants, and using the ‘learning by doing’ approach to deepen museum learning (Huang, 2014; Ken, 2006; Lo et al., 2023; Shiang et al., 2015).

As multimedia presentation methods continue to advance with technological development, they have become an important exhibition strategy for museums. However, if not used appropriately, they can easily become mere gadgets of temporary interest. Especially since the production and maintenance of multimedia technology, including hardware and software, are expensive. If they fail to attract visitors and serve educational purposes, it can lead to a waste of resources (Lo et al., 2023). Considering these facts, it’s not hard to understand why museums are more committed than ever to providing new interactive and engaging scenarios with their exhibitions. In certain contexts, technological solutions are considered key elements that drive narrative storytelling and the presentation of intangible processes, such as audio recordings, music, videos, and displays of other intangible heritage. In other cases, these technological means assist in expanding information about content that cannot be directly showcased, such as vanished artifacts and locations, thereby providing feasibility for reconstruction and digital replication (Chen, 2023).

Digital media techniques in museum exhibitions

In this part of the literature review, the induction will be carried out in chronological order, summarizing not only the categories of digital media interactive technologies in museum exhibitions but also allowing for a clear view of the development and preservation of these types. New technologies have provided new organizational forms and structures that are more diverse in presentation since the beginning of the new century. They also serve to update and strengthen old museum exhibitions, achieving the goal of offering visitors a more diverse and interactive choice, such as rapid access to information, stage-like audio-visual stimulation, exhibitions that balance depth and breadth, and the integration and consideration of both entertainment and educational aspects (Ken, 2006). The application of new technology has a significant impact on museum exhibitions. Starting from the 20th century, the early multimedia and theater, the mid-stage evolution of audiovisual technology, the late invention of computers, and the popularization of the internet, combined with the progress of materials science, have led to several types as follows:

(1) **Multimedia and Theater:** Multimedia encompasses the presentation of sound and images, utilizing new technologies to create a different experience and imaginative space. It is also a form of “virtual” expression, including slide shows,

three-dimensional theater, and space theater, among others. By employing multimedia and theatrical presentation methods, the visitor's senses are stimulated. Through interactive participation and presentation, the visitor gains different experiences with scientific phenomena, including IMAX theaters, optical, sound, and image displays, and a significant integration of computer graphics to provide real-time interaction for the visitor, or combining display documents with artifacts to guide the visitor's imagination from objects to the films.

(2) The evolution of audiovisual technology: From photographs, radios, televisions, and video recorders to the development of digital images, the cost has become increasingly lower, yet the potential has become greater. Through audiovisual presentations, many complex research findings and theories can be presented in an easy-to-understand manner, and the visitor no longer finds them difficult to comprehend. For example, by using headphones and infrared sensors, the visitor is provided with not only visual but also auditory sensory stimulation. Additionally, the use of multimedia, fluorescent lights, and synthesized sound effects constructs a futuristic exhibition space, allowing the visitor to experience a completely different alternative museum display.

(3) The invention of computers and the spread of the internet: From the end of the 20th century to the 21st century, computers have been widely used in various types of museums and are displayed in museums. And, the popularization of the internet has provided visitors with the possibility of accessing and using museum information, leading many museums to establish their websites and set up so-called "digital exhibitions", thus transcending geographical boundaries.

As the exhibition and educational functions of museums have undergone significant changes, they now convey exhibition information and provide a friendly viewing environment through exhibitions and educational activities. This allows visitors to learn through exploration, experience, and interactive participation, rather than passively receiving information. The diversity of perspectives has led to new theories and thinking in the related research of museum exhibition education. Museums attempt to apply technological techniques in exhibition narration and interaction, enhancing visitor experience and visitor research. Through the use of VR or AR, Beacons, 3D scanning, and other methods, they provide visitors with new experiences in museums and feedback technological applications in museum visitor research (Dong, 2024; Su, 2019).

The application of emerging technologies and techniques, combined with interactive installations that integrate sensory experiences with innovative technologies, offers visitors a deeper five-sense experience beyond the visual. However, early applications of interactive digital media technologies focused on enhancing the appeal of exhibitions. Due to the low quality of the exhibitions, the experience was not good, and evaluations from both the perspective of exhibition maintenance and the likelihood of visitors returning for repeat visits were unsatisfactory. Based on this, Ken (2006) raised the question of whether digital media technology could integrate with exhibition content to better achieve educational functions. Twenty years have passed, and literature reviews have provided a good answer to this question. Current experts and scholars not only focus on the forms of new digital media technologies but also on the interpretation of exhibition content.

The application of digital media interaction

With the innovation of technology, people are trying to interpret history in different ways, especially by combining digital technology to bring a better viewing experience to the visitor. The development of interactive exhibits originated from the Exploratorium in San Francisco, with subsequent developments at institutions such as the London Science Museum in the UK. In 1973, the Association of Science-Technology Centers established a clear definition for interactive exhibits, stating that they are designed to allow visitors to learn about science and technology through personal experience (Huang, 2014).

Interactive exhibits are subdivided into active, operational, and interactive. “Active” refers to exhibits that automatically activate or are triggered by visitors, with a pre-set dynamic process that is not affected by the visitors’ actions; “operational” emphasizes the visitor’s interaction with the exhibit, causing changes in the state of the exhibit due to operation, but there is no mutual feedback between the two; “interactive” refers to the mutual interaction between visitors and exhibits, with no preset program, and the exhibit responds differently to individual inputs from the operator, with mutual responses between the two. The above definition of interactive exhibits, although different researchers have varying opinions, emphasizes the importance of the visitor’s active participation. It involves engaging exhibits through various forms of participation, prompting different responses from the exhibits to enhance appeal and facilitate knowledge transfer. Therefore, multimedia interactive

installations have also become one of the commonly used display methods in today's museums (Lo et al., 2023).

The visitor's persistence towards interactive multimedia forms, from high to low, is in the following order: game-based, question-and-answer-based, reading-based, and image display-based. Content with high levels of fun and challenge, such as "game-based" content, is the visitor's favorite way of presentation; "3D animation" that can achieve virtual reality, and "videos" that present sequences of images are considered the most attractive multimedia elements by the visitor. Therefore, although multimedia presentations can help the elderly learn, the type of multimedia will also affect the absorption rate and learning effectiveness of the elderly (Huang, 2014).

Li (2021) categorizes digital media interactions into three types: manual experimental interactive projects, which involve setting up interactive exhibition areas in museums where visitors can engage in hands-on activities, reducing their sense of unfamiliarity with the exhibits and helping them better understand the history and traditional crafts, thereby stimulating their interest in learning; competitive interactive exhibition design, which typically involves the use of multimedia equipment and the construction of scene props to guide interactions between the visitor and the environmental props; and sensory experience interactive exhibition design, which enhances the interaction between the visitor and the exhibits by stimulating various senses such as hearing, smell, and sight, providing a better viewing experience.

• *Multi-touch screen*

The multi-touch screen was hailed by Alexander et al. (2013) as the "transparent lens of an artistic device." This equipment seamlessly integrates interactive experiences into the information space, establishing a close connection between digital content and exhibits to create a cohesive exhibition experience. The interface layout is meticulously designed, featuring question zones aimed at guiding visitors through exploration and surprise encounters, serving as entry points for interpretive experiences. It not only frames the physical artwork in front of the lens but also presents high-definition images of the artwork along with other media formats. (Mason, 2020).

• *Entity interaction*

Tangible interaction is the exchange of data between humans and digital information through interaction with the physical environment, a definition proposed by Hiroshi Ishii from the MIT Media Lab. A tangible user interface is an

interface through which users interact with digital information using physical objects and the physical environment (Luo et al., 2020). Compared to traditional interaction models, physical interaction allows for a more natural and intuitive way of engaging through the manipulation of physical objects. Physical interaction is more personalized, and when designing and creating the tangible elements, the form, size, and materials can be tailored to the content of the exhibit or designed to cater to the characteristics of visitors of different ages.

• *Interactive feedback*

Shedoff (1999) proposed the concept of “interactivity,” and he listed factors for measuring “interactivity,” one of which is called “feedback,” the most intuitive result of real-time interaction. Museums create learning environments that provide children with the ability to make choices, take the lead, and be autonomous. Through interactive display installations that engage all five senses, they guide the visitor to participate, replacing traditional static display exhibitions. Because personal involvement is more likely to leave a lasting impression and create a sense of closeness, the visitor gains knowledge in a “subtle and gradual” learning situation, effectively conveying knowledge and aligning with the current trend in museum education that emphasizes multiple intelligences (Lo et al., 2023). **Table 5** shows the relevant theories and characteristics of digital interactive technology.

Table 5 Theories and Features of Digital Media Interactive Technology Applications in Museums

Theories and Authors	Features
According to the division of numbers and spatial narration. (Tong, 2020; Mason, 2020)	Interactive narrative in 3D scenes Immersive narrative of historical culture Game-based learning narratives AI narrative simulating human thought The visual narrative of scientific research
According to the division by digital technology and type. (Ken, 2006; Wang, 2015)	Multimedia and Theater: Including IMAX theaters, optics, sound, and image displays, and a large integration of computer graphics, providing real-time interaction. The evolution of audiovisual technology: Multi-technology, multi-sensory constructs a futuristic exhibition space. Computers and the Internet: Information Retrieval and Consultation Dissemination

Theories and Authors	Features
According to the type of interactive experience. (Ning et al., 2022)	Sensory interaction Contextual Interaction Technology 3D imaging, 2D digital imaging, immersive dome Scene composition technology

Digital Storytelling and Narrative in Museums

Digital storytelling as a form of exhibition narrative for both online and on-site museums, for enhancing the visitors' interest. It's an important part of digital interaction. In the early days of digital media applications, the technique utilized involved showcasing live exhibitions to visitors via 360 or high-resolution images. 3D animations, graphics, and movies. This technique created authentic experiences by assembling collections to cultivate visitor experiences. This is consistent with what Ken (2006) presented in her research. As 3D technology developed, it has been used to provide interactive demonstrations that are more engaging than one-way communication. Studies have shown that 3D technology can increase visitors' interest and experience, and this technology has gradually been applied to create visitor experiences from live exhibitions (Kasemsarn et al., 2023); this can be understood as the precursor to digital storytelling in museum exhibitions.

Integrating virtual models with digital narratives enables visitors to interact with fragile cultural relics that cannot be touched in the real world or historical sites that are difficult to access (Kasemsarn et al., 2023). This digital technology, initially applied in online exhibitions, is currently being used in the design of interactive exhibition experiences (Tong, 2020). A theme summarized by Kasemsarn is "re-create no longer existing places," which aligns with what Chen (2023) described: Visitors can explore the original appearance of vanished sites and historical stories through digital technologies such as 3D virtual reality. Both studies unanimously agree on this viewpoint: museum exhibitions that rely solely on technology or novel technologies are far from sufficient; they must incorporate digital storytelling techniques to endow visitors with vitality and profound emotional experiences.

When utilizing digital storytelling and 3D scene restoration, it is possible to integrate the memory of the city, enhancing visitors' sense of place identity. This point is consistent with Kasemsarn et al. (2024)'s summary of creating a city's digital memories. By telling stories through digital means, technology is integrated with

content, and the works are presented through digital media, archives, personal narratives of the visitor, images, 3D models, news, books, articles, videos, games, and websites. These digital stories collectively represent the entire city as digital memories. Chen (2023) also points out that the significant difference between digital storytelling and traditional narrative techniques is the incorporation of game interactivity through digital technology during the storytelling process. Utilizing the interactive nature of digital storytelling stimulates the visitor to discover any mysteries related to the city's historical life while participating in the game. It is worth noting that this use of interactive digital storytelling, compared to traditional digital media games, places more emphasis on the interaction between the visitor and the information, rather than the interaction with the game device itself. Visitors generate new stories through interaction and play, triggering more contemporary imagination and experience.

Tong (2020) summarized five types of digital storytelling in her case study research on digital storytelling:

(1) Interactive narrative in 3D scenes: The narrative of 3D scenes utilizes VR, AR, and other 3D virtual technologies to break through spatial limitations and expand the physical space of museums, offering other possibilities such as attracting potential visitors through online digital content. This combination of virtual and real technology, when applied to exhibition spaces, allows virtual scenes to enter reality.

(2) Immersive narrative of historical culture: Narratives always involve the simultaneous transfer of both time and space dimensions, and the narrative of historical culture challenges the constraints of time (Tong, 2020). The addition of interactive media technology extends the time and space of the exhibition space, combining virtual or restored scenes, which can change the perception of visitors as if entering another historical time and space (Phillips, 2021). The innovative experiments of museums guide users to embark on a historical journey, understanding historical concepts in a "present" manner. With the support of digital technology, "the screen becomes dynamic, real-time, interactive... It exists in the real space we are in, as a window to another space (Chen, 2023).

(3) Game-based learning narratives: Game narratives are an informal educational approach to traditional educational models. Museums utilize a diverse array of gaming formats, such as simulation games, live-action games, and mobile games, to attract visitors and communicate effectively. These games provide interesting educational

tools for the visitor. The fun element is an important value of museum games, as well as diversity, richness, and even the uncertainty of museum games (Tong, 2020).

(4) The visual narrative of scientific research: Research is another important function of museums. Visualizing scientific research creates a context that facilitates communication among all parties: designers enhance the visitor's visual experience, allowing them to delve deeply into the cultural significance and historical connotations of the collections. Dong (2020) also suggests that exhibiting 3D models constructed with digital technology greatly extends and strives to restore the physical framework of the exhibition space, and by incorporating interactive technologies, such as multiple architectural structure diagrams linked to the same hotspot, viewers can complete viewing by sliding the interface. It should be noted that, freed from the temporal and spatial constraints of "here and now," the distance between the viewer and the exhibition tends to be infinitely close, and the viewing activity is flexible and independent.

As can be seen from the above review and analysis, at this "specific cultural moment" of rapid development of digital technology, the formation of digital culture, and the rise of museum digitization, digital media technology has brought new changes to the museum exhibition environment (Mason, 2020).

Summary

More and more new technologies are being used in museum exhibitions, and some design keywords have been generated, such as immersive and experiential design. Digital interactive technology is influencing visitor interest and experience across various aspects of exhibition design, including visual forms, interactive experiences, content interpretation, and more. Based on the design elements of museum exhibitions, including the configuration of digital media, interactive formats, explanatory formats, visual materials, and content frameworks, the intersection points of information space boundaries related to digital media are determined. These nodes, as concrete carriers of information, can effectively capture the audience's attention and stimulate their engagement in interaction. **Table 6** shows the current status and category of digital technology in museums.

Table 6 The current status and category of digital technology in museums

Category	Interactive format	Main media	Senses
Viewing	GAVE Cinema	Splicing screen +360 /720 panoramic	Auditory + Visual
	Audiovisual space	IMAX / optics /sound and image displays	Auditory + Visual

	Video	Display or projection	Auditory + Visual / Visual
	Art scene	Scenario model + projection	Visual
Trigger viewing	Object contact triggers playback	Intelligent Perception - Model + Sensing Module + Display/Projection	Tactile + Visual / Tactile + Visual + Auditory
	Screen click triggers playback	Single-point/multi-touch screen	Visual/Auditory + Visual
	Somatosensory-triggered playback	Intelligent Perception - Sensors (Mechanical Sensors, Acoustic Sensors, Electrical Control Switches, Induction Modules) + Display	Visual + somatosensory
	Linear click query	Single-touch screen	Visual + tactile
Interactive	Multi-point query	Multi-touch table/wall	Visual + Tactile
	Somatosensory interactive	Intelligent Perception - Laser Sensor + Projection Human/Body Recognition Sensor + Display	Visual + somatosensory
	Entity Interaction Query	Intelligent Perception - Model + Sensing Module + Display	Tactile + Visual
	Game interaction	Digital screen/touch screen/intelligent sensing/imaging system	Visual + Tactile
Sensory	VR/AR	VR/AR/MR device	Tactile + Visual
	Auditory perception	Scenario + sound-gathering hood/directional audio system	Auditory + Visual
	Sensory immersive	Integrated media	Olfactory + auditory + visual + somatosensory
	Immersive space	Projection \ splicing screen + dome	Auditory + Visual

However, professionals should recognize that technology should be employed as a means rather than regarded as an end in itself. Israel (2011) contended that ideally, the themes of museums should be seamlessly integrated with digital content to effectively convey the exhibition material while providing an incredible experience for visitors during their use: “Given the increasing importance of user experience, it is not enough to merely ensure that systems are usable” (O’Brien & Toms, 2008, p.939). Research also indicates that the enhancement of visitor experience through digital interaction stems from the changes digital interaction and interpretation bring to the exhibition environment, thereby affecting visitors’ perceptions and behaviors. The next subsection will continue exploring this topic.

2.4.2 Consistency between digital interaction and exhibition design

The intersections of boundaries of digital media interaction technology and museum exhibitions

Based on the previous literature review, museum exhibitions are crafted using visual materials and design approaches and techniques to create a specific space and environment for expressing and conveying information, thereby creating a favorable learning environment for visitors. How to evaluate the boundary intersections of digital spaces should be explicitly described. Ken (2006) proposed that technology media serve as a significant medium for exhibition and provide a possibility for in-depth explanation. For example, virtual exhibitions at science centers, virtual game exhibitions, or interactive devices for mechanics and optics, all utilize new technologies to allow the visitor to engage or interact more deeply, activating all five senses simultaneously, using the body to remember the essence of knowledge transmission in museums. According to Ciolfi (2015), integrating a more comprehensive and enriched perspective with practical considerations of the body and place is key to developing innovative technologies and interaction methods in the field of cultural heritage.

Huang (2014) cited several researchers' discussions, pointing out that interactive exhibits are more engaging than other types of exhibits and can enhance the learning effect of the visitor; multimedia elements such as sound, light, and video can also serve as media to trigger interaction, and appropriate applications can inspire learning and improve learning effectiveness. However, many scholars have pointed out that in the design and application of media, it is necessary to consider how to enable the visitor to participate effectively; otherwise, multimedia interactive devices will only become a passing fancy, losing their originally intended educational purpose.

Wang & Yu (2007) pointed out in their study that the type of exhibition is an inevitable factor affecting visitor participation, where interactive exhibitions can enhance visitor appeal and duration, but whether they can lead to meaningful learning remains to be discussed. The studies by Koran, Koran, and Longino (1986) and Kropf (1989) consistently affirm that visitors can gain profound museum experiences and leave clear impressions through the process of actual operation, simulation, and experience, thereby increasing the effectiveness of learning (Lo et al., 2023). Digital design is suitable for expressing intuitive experiences that are primarily driven by visual elements. It is common for museums to use digital narratives to simulate real-world conditions, presenting visual content in concrete

forms that depict “storytelling” image scenes. The examples of digital storytelling discussed in this article are mostly of this type (Tong, 2020).

Li (2021) found that interest in textual materials in acting is relatively low; however, exhibits that are visually appealing and large have a higher attraction. Traditional design methods centered on exhibits, where the form of the exhibits and the spatial planning are determined by the exhibits themselves. With technological advancements, an increasing number of new technological means are being applied in exhibition spaces. Therefore, interactive display design based on high-tech methods is conducive to attracting the visitor’s attention. The design elements of digital media interactive forms must fulfill the sensory requirements of the product, encompassing the shape factors of both physical and digital components, as well as the appearance and visual elements. Additionally, they should include various methods of content presentation (Mason, 2020). Digital design can also employ abstract and conceptual graphics, visualizing invisible data to create unique artistic effects (Tong, 2020).

The impact of digital interpretation and interaction on the museum exhibition environment

Existing research has extensively explored this interdisciplinary field through multiple exploratory studies, proposed the construction of digitally augmented space as a strategy for integrating digital content into physical environments (Petrelli et al., 2013) or viewing it from the perspective of embodied interaction-where visitor experiences are situated within dynamic physical settings (Hornecker & Nicol, 2012; Mason, 2020; Zancanaro, 2015). With the impact of digital technology, the exhibition environment has become more complex (Phillips, 2011; Mason, 2020), adding a digital space dimension to the original physical space dimensions, temporal dimensions, and content information dimensions. When conducting a case study on how media technology enhances visitors’ interest, Ken (2006) proposed several points on how digital media technology can improve visitors’ interest and experience, all of which are related to the changes from digital intervention in museum exhibitions.

(1) It prioritizes aesthetic and visual perspectives, such as the animal evolution exhibition in the large exhibition hall, which is designed with the image of Noah’s Ark. In addition to using the local dimming effects of fiber optic lighting and the stage effect of natural light, most of the exhibitions still maintain traditional display forms.

(2) Considering the interpretation of light and shadow in the presentation technique, the creative effect is very sufficient, and it also provides the visitor with a novel and special visiting experience.

(3) Design high-tech devices to create a strong atmosphere, combined with avant-garde art's fluorescent colors and multimedia image processing, further making this exhibition space present an intention to integrate technology.

According to Ken's (2006) research, creating an exhibition environment with a stronger sense of atmosphere through digital media technology relies on a profound interpretation of the exhibition content. If too much focus is placed on digital media technology while neglecting the content of the exhibition, and lacking a comprehensive research foundation, apart from having a dazzling exterior to attract the visitor's attention, the lack of exhibition content and insufficient research depth lead to the visitor being unable to achieve resonance and connect memories (Chen & Chang, 2009; Ken, 2011). From the perspective of physical space influence, apart from the impact on the atmosphere, spatial scale, light, and shadow, Digital media interactions can also impact the flow of museum visits and even cause obstructions. When Lo et al. (2023) conducted a measurement study on the layout and placement of exhibits, they found that many visitors were attracted to the exhibits and approached them. However, after approaching the exhibits, some visitors chose to leave because they were unable to operate the exhibits successfully in a short time. This part of the content involves the obstacles caused by digital media technology to exhibitions and museum visits and will therefore be analyzed in the next section.

When constructing an interactive ecosystem, museums should focus on optimizing the narrative space of exhibitions. By reasonably utilizing digital media, they can achieve a high degree of compatibility between content and technology. This enhances the rationality, systematic nature, and sustainability of museum interactive design, thereby creating an emotional network between exhibition content and visitors. This helps visitors experience a pleasant, immersive experience (Ning et al., 2022).

The impact of digital media interpretation and interaction on the information content environment

Through in-depth observation of professional projects and academic exploration, Norman (2004) discovered that museum information spaces are not merely simple superimpositions of physical components and digital elements, but are meticulously designed as a coherent and integrated experiential system. Mason

(2020) also pointed out that in this form of multi-dimensional interaction, the ability to integrate multiple types of multimedia enables visitors to engage through the fusion of diverse digital content. This not only includes curated multi-source materials such as interview texts, images, photographs, and videos, but also encompasses 3D renderings and animation effects for dynamically detailed exploration of exhibits. Mason (2017) emphasized the importance of the information architecture system when designing experiences using interactive digital media technologies. The information architecture plays an important role in “scaffolding” the structure and hierarchy of functions, which constitute the system as a whole. Without these structures, the whole design would be disjointed, a collection of not well-linked functionalities, information, and interpretation that visitors would struggle to use and make sense of. It can be said that information transmission and interpretation are the fundamental goals of the application of digital media interactive technology, but they also form the structural foundation that supports the digital experience.

However, during the literature review process, the phenomenon mentioned by Ken (2006) was discovered: Unfortunately, the lack of human and material resources in domestic museums has led most museums to compete for visitor numbers as a metric. This not only results in the content of exhibitions becoming superficial but also places the ecology of museum exhibitions in Taiwan in a fast-food culture dilemma. From another perspective, this illustrates the importance of content interpretation and information dissemination for the application of digital technology. In the same paper, Ken (2006) raised a question about digital technology: Will technology’s use in museum displays be abandoned due to overuse?

There are two key factors: one is whether the display method, due to being overly sensational, is incompatible with the content of the exhibition and cannot be integrated as one; the other is the issue of transferring and maintaining professional skills. Perhaps the current prosperity of digital media applications and theoretical research can already answer one of her. In terms of exhibition methods, although the interactive forms of current museum exhibitions may tend to be sensationalist, design concepts such as narrative exhibition design, performative exhibition design, and immersive experience exhibition design all demonstrate the integration of digital technology with the content of the exhibition. Especially for the “digital media storytelling” proposed for digital media technology.

The research on digital media interaction technology affecting visitor interest and interaction

For the public, museum exhibitions are no longer merely the display of static artifacts; they are the unique visiting experience that integrates multi-sensory stimulation (Ken, 2006; Wang, 2015). The uniqueness and innovation create a novel and lively exhibition, which has become the only way to attract visitors to museums. Whether it's a stage-like display effect or a market-style approach to gathering people, both are widely applied in museum exhibitions (Ken, 2006). Ken also proposed two ideas through case studies to enhance visitor interest and exhibition appeal using digital media.

- (1) The exhibition space is reorganized in a visually aesthetic way, and the focus and changes of the field of vision are enhanced through changes in lighting.
- (2) Special scenery is combined with sound and light effects.

When considering how to use digital media interactive technology to influence visitors' interests and interactions, it is necessary to consider the needs and behavioral characteristics of visitors from different age groups and cultural backgrounds (Kasemsarn et al., 2023; Ken, 2006). Mason (2020) proposed a framework for museum experience design based on digital media interactive technology. Experience units are designed within the exhibition where visitors can interact with them, such as interactive walls made up of digital interactions, large multi-touch walls, and mobile applications.

All these interactions and items are expressed through different "experience units" that are connected through the visitor experience "flow," expanding the visitor's understanding and curiosity about the museum's content in the immersive "stroll" of the first exhibition hall. The foundation of the experiential flow is that visitors can gain an understanding and prepare for visiting the main museum galleries through a series of different experiences. However, in the design process of Mason, there is no mention of testing for this type of experiential unit, nor of the evaluations of the experiences by different visitors. Many studies have attempted to identify the most effective methods for attracting visitors to museums and heritage sites, both on-site and online, without causing boredom. However, these findings can be applied in conjunction with digital storytelling to enhance visitor awareness of the context of a site or object and to motivate visitors to explore the site or object as an entertaining activity (Kasemsarn et al., 2023). Su (2019) proposed that, based on the behavior of the

target visitor and the characteristics of the space and display effectiveness, three ideas for digital media interactive design were put forward to meet the needs and behavioral characteristics of different visitors. These include using multimedia as a tool to guide children's learning for adults, satisfying the viewing needs of different visitor groups with interactive and diverse displays, and addressing the limitations of display space on the length of information.

(1) Exhibition design should possess qualities such as being fun, interactive, and providing a multisensory experience. It should guide the visitor in learning through diverse presentation techniques, helping child viewers to experience the exhibition and learn in an orderly manner.

(2) An exhibition aimed at parents, children, and school-age children often has adult visitors accompanying them. Supplementary reading materials can assist adults in taking on guiding and teaching roles, allowing parent-child visitors to explore and guide learning independently.

(3) Due to limited display space, the exhibition design can provide in-depth introductions for key exhibits, integrating the core concepts of the exhibition. It utilizes corner spaces to add extended reading and multimedia displays, balancing the proportion of display units and the completeness of display information. It also offers reference information for adult visitors to read and to guide child visitors, meeting the needs of different groups.

However, Lo et al. (2023) conducted a micro-field study based on Su (2019)'s research. They utilized non-participatory observation and semi-structured interviews to verify the attractiveness of the "Paleontology Exhibition" multimedia interactive installations to the visitor and their learning effectiveness, and found that the three considerations proposed by Su for utilizing multimedia interaction in this exploratory study did not yield significant results. The reasons for this phenomenon are twofold. First, Su's research lacks studies on the characteristics of environmental behavior. Second, although Su mentioned in the research that interactive exhibition design should consider family and child visitors, there is a lack of research on visitors' personal perceptions and behavioral characteristics. The fundamental reason is the lack of relevant empirical studies, which leads to a gap between design ideals and reality.

Summary

Relevant research on digital media includes technology research, application form research, a lack of research on application effects, and a lack of research on visitor

behavior and experience. Despite the fact that numerous studies have indicated that digital media interactive technology can enhance visitors' interest and experience at museums. Several studies have indicated that digital media interactive technology can enhance visitors' interest and experience at museums. Shahab et al. (2017) concluded through case studies that virtual reality technology in museum exhibitions can improve visitors' learning experience, but the relationships of impact still require further research, as well as the exhibition forms that attract visitors are not clear. However, Lo et al. (2023) have a counterargument, and their research conclusion is that digital media interactive technology has not achieved the desired results.

2.4.3 The obstacles of digital media technology on interaction and interest

Due to the interaction of digital media and interactive technology, museum exhibition formats are changing from traditional information displays to creating comprehensive experiences that integrate multiple disciplines (Li, 2022). The earliest introduction of digital technology was to compress exhibition space, expand content, and interpret knowledge (Phillips, 2011). However, with the development of technology and museum display theories and techniques, digital media technology has become a necessary means for exhibition experience design (Mason, 2020).

However, his research did not study the motivations and needs of visitors from different ages and cultures. We cannot know from the study whether valuable experiences can be created based on the design process he proposed. Interactive digital media technology enhances visitor interest and interaction in museum exhibitions and has the potential to improve VX, although this has not been confirmed by conclusive evidence (Ardissono et al., 2012; Kabassi et al., 2020).

During the initial case study phase of the research, researchers found that on social media websites, numerous voices expressed concerns, such as “form over content” and “museums becoming mere photo spots for influencers, failing to impart relevant knowledge” (Ning et al., 2023; Wang, 2015). However, in the literature search, no studies were found that investigated the negative impacts and experiential barriers caused by the application of digital media technology. Although various innovations and immersive experiences brought by digital media technologies are listed in the literature review, some studies have also mentioned the existence of problems and risks.

“The act of operating media devices cannot enhance the experience, but the expansion and change of time and space brought about by the media can enhance interest and interaction (Phillips,2011).”

Museums often utilize many technologies and interactive mechanical devices. Still, designers often overlook the psychological needs or habitual behaviors of users, resulting in many exhibition facilities being damaged or having their lifespan shortened in a very short time after opening due to improper use by the visitor (Ken, 2003). The root cause may be that designers neglected to understand the visitors' behavior habits before planning, leading to continuous maintenance and various inconveniences in use.

Taiwan scholar Huang (2014) also agreed with this perspective. Excessive interactive game operations can easily lead to the visitor's attention being focused on seeking visual and other sensory stimuli for entertainment; furthermore, the production costs of multimedia technology are high, and if the display and educational purposes cannot be achieved, it can easily lead to a waste of resources. On the path of exploring new models for museum development, many museums are being swept up by technology, blindly pursuing a sense of experience and entertainment. This alienation has led some scholars to worry that museums might turn into Disneyland, thereby degenerating into a cultural wilderness (Ning et al.,2022).

Wang (2015) pointed out that, in the post-Expo era, following the 2010 Shanghai World Expo, the “museum interaction design” model has been overutilized, leading to interaction design becoming disconnected from the exhibits' content. There is an overemphasis on technology over design, and often new technologies are used to compensate for old designs and a lack of creativity, leading to a uniform interactive experience across various museums. This wastes a significant amount of manpower and resources (Wang, 2015). Lo et al. (2023) also believe that multimedia interactive displays have developed rapidly with technological advancements, but their application in museums is clearly still in the exploratory phase. Multimedia interactive devices are attractive, but their effectiveness in information delivery and learning is less stable. Attractiveness does not correlate with learning outcomes; people's engagement with interactive devices mostly remains at the level of manual interaction, and few visitors reach the stage of knowledge transformation.

The use of digital technologies has brought new opportunities to the museums in China. However, some big museums offer a poor visitor experience, and medium and small museums do not pay enough attention to visitor experiences. The issues of forced technological implantation, homogenization, and superficiality are becoming increasingly prominent. The excessive implementation of technology and improper use of interactive technologies not only fail to enhance the display effects of museums but also negatively impact the visitor experience, leaving no lasting impression on the visitor (Hu & Song, 2017). Tong (2020) also points out that digital devices require dedicated maintenance personnel year-round. Compared to traditional video playback exhibition formats, interactive installations are prone to malfunction. Older visitors may give up further interaction due to their inability to operate new facilities such as VR, and so on.

The experience brought about by digital media interactive technology in the new museum exhibition is a composite experience based on the environment. However, there are very few studies that put digital media technology into the exhibition environment. At the same time, the application of digital technology did not lead to the development of display theory (Phillips, 2011). The research on the problems with the application of interactive media technologies seems not to have gone further.

Summary

The necessity of digital media technology design, however, is found from literature analysis that the introduction and development of digital media technology has not promoted the development of display design theory, and there is no empirical research on the currently applied technologies and types of exhibition items. Multimedia: The application of technology can promote visitor interest and cultural communication. There is a lack of research on digital media technologies in exhibition contexts.

2.5 Museum Environment Composition Containing Digital Media Interaction

The exhibition environment is crucial for museums, determining whether the exhibits can be effectively and artistically presented to the visitor. If the dissemination of information in a museum is compared to the propagation of sound in space, then the exhibition environment is like the medium of sound propagation: it determines the efficiency and speed of dissemination. A good exhibition environment must consider various aspects such as visual planning, spatial layout, flow of people, lighting, and color configuration, grasping the rhythm, feeling, and atmosphere of the exhibition space. It should not only meet the basic functions of display and education but also allow the

visitor to experience the art of the space and the fun of the information (Lo et al., 2023; Wu, 2012). This section will review and summarize this topic.

2.5.1 Museum exhibition environment and museum-visiting

The composition of the museum exhibition environment

The formation of a museum exhibition environment depends on several important factors, among which are those closely related to behavior or visitor experience, including: visitor flow, lighting, explanatory texts and content interpretation, interactive facilities, color, situational creation, and reflection of visitor needs. Explain each separately. Visitor Flow: In museum exhibitions, visitor flow refers to the path from the entrance to the exit of the exhibition. It can typically be divided into main flow, secondary flow, and point flow. A good exhibition flow must be unambiguous, not causing visitors to get lost or confused, and reducing the time and distance of the journey. Moreover, through the diverse design of the flow, sensory stimulation can be increased, making it less likely for visitors to experience “museum fatigue syndrome”. Visitor flows are divided into serial flow, parallel flow, and open flow (Wu, 2015).

· *Illumination*

Lighting is the key factor that gives vitality to the display objects; different lighting methods create different aspects of the display objects (Ken, 2003). In addition to clearly presenting objects, the angle of illumination can greatly alter their expression; even the lighting itself can become a method of guidance and spatial division. At the same time, it can enhance the performance effect of objects, increase multiple visual stimuli for the visitor, create scenarios, and strengthen the memory connection with the visitor. Properly combining special lighting and imagery can more effectively enhance the focus effect of the display, creating visual attraction.

· *Expository text and content explanation:*

Explanatory texts have long been used as interpretive tools for exhibitions. Traditional textual explanations mainly relied on wall panels and labels. More recently, exhibition content explanations have incorporated not just text but also a variety of images, audio guides, video screenings, and touch screens. The aim is to increase the liveliness of the exhibition and to provide the visitor with sustained attention to the cultural artifacts and in-depth information about the content. Inside the exhibition halls, display cases also make extensive use of video imagery, and sometimes models with text explanation, to provide in-depth information and to

strengthen the memory connections of the visitor's personal experiences (Ceccarelli et al, 2024; Li & Guo, 2024).

• ***Interactive design:***

Interactive facilities are designed to enhance visitor engagement by providing hands-on, touch-based, and experiential learning opportunities that create an atmosphere of “learning through play” and “learning by doing.” This allows the visitor to understand complex or obscure scientific principles and everyday knowledge through physical manipulation or direct experience. Interactive facilities are divided into physical interactions and digital media interactions. With the development of digital media technology, the interactions generated by digital media are further subdivided into various types (Wu, 2014). For more details, please refer to section 2.3, which reviews the types of digital media interactions.

In interactive facilities, there is a display method that utilizes games to satisfy children and parent-child visitors' understanding of the basic educational principles of science and physical phenomena. However, studies have shown that gamified interactive exhibits can not only meet the needs of children and parents but also enhance the interactive interest of adult visitors. However, an empirical study indicated that game interactive exhibits designed with children's needs in mind did not achieve the desired exhibition communication effects in practical application (Lo et al., 2023).

• ***Color***

Color and lighting have complementary functions in exhibitions. Color is the best tool for stimulating or creating emotions. Different colors can cause various psychological and emotional responses in visitors. Therefore, in exhibitions, color plans are often used to create a variety of different situations and tones, which is also a major aid in highlighting the exhibits. Inappropriately designed color schemes can often have the unintended effect of overshadowing the main attraction (Chiang, 2022; Tang & Jiang, 2022).

• ***Scene creation***

Contextual shaping and reconstruction of exhibits and their settings, including methods such as restoration, ecological landscaping, and period rooms, aim to create an immersive experience for the visitor upon entering the exhibition space, fostering a sense of resonance. For example, period rooms, reconstructed street scenes, and scale models, as well as virtual earthquake displays, are used to recreate the various lifestyles of the Edo period in Tokyo. This allows visitors to not only stimulate

their visual and auditory senses but also, through the reconstruction of the environment, feel as if they are traveling back in time on a time machine, experiencing an atmosphere of nostalgia that is different from the modern era. In the study of exhibition environments and visitor behavior, Yan (2008) has set up six testing dimensions for the exhibition space: layout and scale, materials and design, color and lighting, text and imagery, sound effects and performances, and display props.

The relationship between the exhibition environment and the visitor

Based on visitor behavior research, improving museum exhibition environments should be a priority over traditional thematic research-based exhibition planning. Future exhibition planning must incorporate visitor behavior research to thoroughly understand the various needs of the target visitor. This approach can eliminate unnecessary frustration among visitors, meet their physiological and psychological needs, and ensure that the interaction between the visitor and the exhibition is truly beneficial (Ken, 2003).

Most museums do not have so-called treasures that attract special attention. Therefore, they need to rely on or consider design to emphasize a more approachable and comfortable visiting experience, to win more favor from the visitor, and even become a place for socializing and leisure for the public (Ken, 2003). Hassenzahl (2011) notes how a post-materialistic orientation has led to an “Experience Economy” (Pine & Gilmore, 1999) and Experiential Marketing (Schmitt, 1999).

With the development trend of the new century museums, the needs and behaviors of visitors have been widely valued by the museum community, including not only the behavioral aspect but also the psychological aspect. This is reflected not only in museum exhibitions but also in various services and facilities of museums, to create a ‘suitable environment for visitors to go to, a comfortable environment, and a pleasant museum visiting experience (Ken, 2003). Digital media technology does have an impact on the exhibition environment, but there is insufficient research on whether these impacts have been used to enhance visitor interest and meet the physical and mental needs of the visitor.

2.5.2 Museum exhibition environment and digital media

Ning et al. (2022) found that “when digital media interactive design is well-matched with museum exhibition content, and the structure is clear, with appropriate new digital media technologies to assist, the interactive experience is better presented in the exhibition, enhancing the audience’s interest in visiting, which

is consistent with the original design intention and achieves the expected exhibition effectiveness. The results of audience interaction satisfaction provide necessary data support for case analysis, and also provide a useful direction for analyzing the interactive experience of the two museums (Ning et al., 2022, p. 4). It can be said that when the physical environment, information environment, and interactive environment in the exhibition environment are well-matched, they can enhance both the interest and satisfaction of visitors, as shown in **Figure 5**.

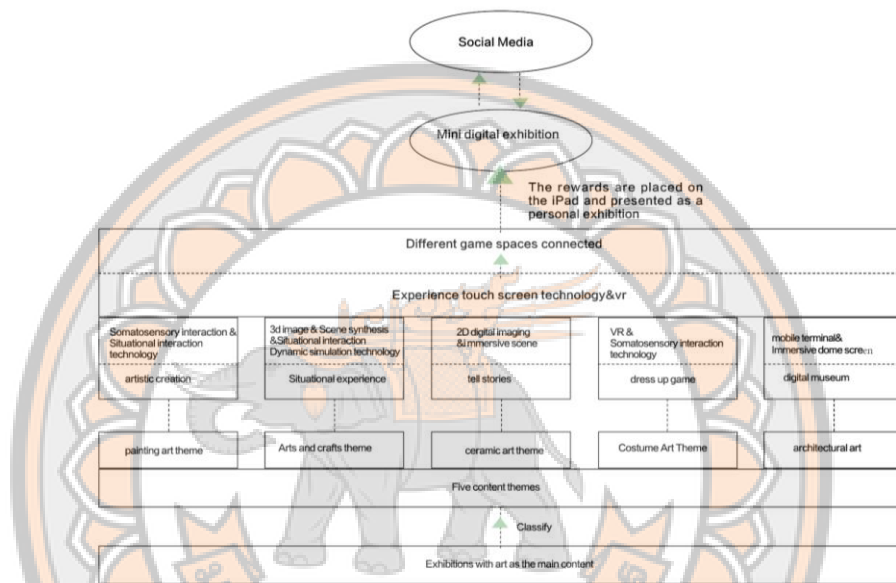


Figure 5 Interactive experience design

Source: Ning et al., 2022, p. 174.

Characteristics of exhibition environments that are affected by digital media interaction technologies are as follows:

(1) The exhibition area design is distinctive and immersive. The exhibition area integrates the corresponding exhibition theme, using this as the content of the levels, engaging in game interaction with the visitor, thereby reinforcing the thematic characteristics and enhancing the visitor's deep perception of the content. Integrating interactive design with spatial design, combined with the target visitor characteristics of the museum itself, forms the current game-style interactive experience exhibition area. Within this area, there are game interactions and artistic creations related to the exhibition content, as well as knowledge-based puzzle games.

(2) The exhibition content is highly matched with the space and interactive technology, including knowledge interpretation animations based on the visual aesthetics of the exhibition space, utilizing lighting and atmosphere to render

the exhibition environment, creating an immersive space that aligns with the exhibition content. Within the immersive space, there is a large number of interactive displays that are highly compatible with the environment and the content conveyed: interactive technology is based on the transmission of exhibition information, and the possibility of extending knowledge queries is set up. “Interactive films” present short films that decompose the digestive systems of different animals. Through touch, viewers can also watch close-up shots of topics they are interested in. Each exhibition area is closely centered around interactive content, paired with the most suitable technology, thus providing the visitor with a more intuitive and comfortable experience (Ning et al., 2022).

(3) The highly systematic nature of interaction design and the comfortable “game space”. Ning et al. (2023) summarized the characteristics of “comfort” to include independent gaming and interactive spaces, the choice between multiplayer or single-player game modes, clear guidance, a high level of consistency between game content and exhibition content, novel and interesting game forms such as AR, and a reward mechanism after gameplay. Additionally, the difficulty level and mechanics of the game align with the psychology of the gamers: it’s challenging, but achievable with effort.

(4) The complete interactive architecture and the sublimation experience of the “tail hall”. The post-exhibition visitor reward mechanism, the support for social media sharing, and other post-visit experience designs make the entire exhibition a complete experience. This is consistent with the visitor experience atmosphere proposed by Liu (2020), which includes pre-visit experience, process experience, and post-visit experience. It also corresponds to the stages of museum visitor behavior proposed by Li (2021): pre-visit behavior stage, visit behavior stage, and post-visit extension behavior stage.

(5) The ‘closed-loop’ visitor experience journey.

Begins with the purchase of tickets, at which point the visitor’s interactive experience journey commences. The ticket entry card distributed by staff serves as an important credential. Throughout the entire visit, the visitors were required to observe, experience, and use the instruments in the corresponding exhibition areas to stamp relevant microbial images on the ticket entry card, following the route for experiential exploration. This aligns with the experience design framework proposed by Mason (2020): experience design is not just about the experience on interactive exhibits, but the entire process, from the initial content structure, spatial layout, experience design, to the

final visual and formal presentation. It is not a linear relationship but an entire framework, where each part is fundamental to the structure.”

As Phillips (2011) suggests, the experience that interactive digital media technology brings to visitors should be a comprehensive experience that transcends time and space by altering the physical environment of exhibitions. As demonstrated by Mason’s experiential framework, the spatial experience brought about by interactive digital media in museums is an experience where the physical space and the digital information space are intertwined and integrated (Mason, 2017). The visitor experience brought by digital interactive technology has not been separated into something distinct from the overall museum experience, but is intertwined with the experience of the entire museum exhibition.

Unlike traditional museum exhibition designs that focus solely on the exhibits themselves while neglecting the interrelationships between objects and circumstances, objects and media, and context and cognition, museums in the digital era skillfully employ interactive design to deeply explore the value of collections. By leveraging diverse digital media technologies, they transform museums into multidimensional perceptual spaces based on contextual experiences. Digital media is suitable for storytelling that targets the “human multi-perception system,” as it maps information transmission to the visitor’s visual, auditory, tactile, and other sensory experiences, better endowing the visitor with a sense of reality (Tong, 2020).

“The interactive installation combines emerging technology with sensory experiences, aiming to provide not only visual experiences but also to deepen the visitor’s five senses through technology (Lo et al., 2023, p. 61).”

Digital media intervenes in exhibition environments at three levels, exploring how the integration of various elements supports the design of museum information spaces. In these spaces, the digital and physical dimensions are interwoven. Museums often utilize many technologies and interactive mechanical devices. Still, designers frequently overlook the psychological needs or habitual behaviors of users, resulting in many exhibits being damaged or having their lifespan shortened shortly after opening due to improper use by the visitor. The root cause may be that designers

neglected to understand the visitors' behavior habits before planning, leading to continuous maintenance and various inconveniences in use (Ken, 2003).

A limited number of studies have investigated tourists' perceptions of digital experiences. Kempia et al. (2017) included "interaction and digital media" as one of the evaluation dimensions in a study on tourist experiences. The research findings indicate that interactive digital media serves as "an important communication format for heritage, playing a crucial role in visitor experiences." Although some studies have explored tourists' digital experience heritage, most of these studies only appear as minor branches within the broader research on tourist heritage experiences, lacking in-depth and systematic discussion (Liu, 2020).

Factors and obstacles of digital media in the exhibition environment that affect the visitor's interest and experience

In the exhibition environment, there is another element that is very important but often overlooked, and that is the needs of the visitor (Zhang et al., 2018). Designers need to actually understand this, especially considering the needs of visitors at different levels, including children, families, adults, the disabled, and the elderly, each with different physiological or psychological needs. Therefore, it is essential to consider human factors, psychology, materials science, etc., to ensure that the visitor has a more comfortable and relaxed experience in the exhibition environment.

What needs to be pointed out here is that some exhibitions, due to poor quality control, often lead to disappointment among visitors after the visit, not only towards the exhibitions but also towards the museums themselves. Such exhibition methods mostly rely on the rarity of objects to attract non-regular museum visitors, but many of these exhibitions are launched without thorough planning or under conditions of poor visitor experience, resulting in the opposite effect and causing disappointment among those who come with high expectations. In terms of sustainability, it becomes even more difficult to create an incentive for visitors to return to the museum for another visit (Ken, 2003).

From the results of the literature review, the majority of studies assess the facilitators and barriers to the impact of digital media technology on visitors' interests and behaviors from three aspects: the content displayed (Lo et al., 2023), the form of interactive operations (Lu & Chen, 2018), and the location of the flow path (Wu, 2012). For instance, Lo et al. (2023) found in their research that multimedia interactive installations in the case studies were mostly concentrated in the same area--

central to the exhibition passage. This flow path setting easily leads to a large number of visitors gathering at the interactive installation area, causing some interactive installations to experience long queues, while ignoring the multimedia interactive installations that can be quickly passed through the passage. A crowded environment can easily cause visitors to lose interest in experiencing the installations and miss out on interactive experiences. This goes against the original intention of setting up digital media interactive experiences in museum exhibitions.

However, when the main route of the permanent exhibition is a single path, the secondary routes between different exhibition blocks are interconnected. Visitors can freely choose the order of their visit and are continuously attracted by the diverse sensory stimuli of the exhibits (theater, multimedia, scene restoration), which constantly drives the visitor's attention and satisfies their curiosity. In this way, it alleviates the physical fatigue caused by the visit. At the same time, it was discovered that most adult visitors would simply bypass the interactive installation area upon noticing that many children were queuing up; even if they were curious, they would only approach to take a quick look before leaving. Fewer adult visitors would queue up to wait. Among family visitors, adults generally only wait for the children to queue up or go directly to view the exhibits nearby. These factors are all due to the barriers that the introduction of digital media interactive technology has caused to the exhibition experience. The reason for this is that at the initial design stage, the exhibition designers did not conduct research on the characteristics and needs of the visitors, nor the characteristics of the interactive environment. That is, there was a lack of empirical research on environmental behavior.

2.6 Visitors' Behavior and Experience in the Exhibition Environment

Overview of environmental behavior

The visitors are the target of museum services, and museum staff need to better understand the needs of the visitors. Therefore, in terms of human living environments or the practicality of space, when planning museum architecture, space, and exhibitions, it is necessary to prioritize the study of "human behavior" as a key element (Ken, 2003). A better way to understand the visitor's needs is to focus on the visitor's behavior during the visit (Li, 2021). Researching the behavior of visitors in exhibition spaces relies on the discipline that studies the environment and behavior - environmental behavior science (Yan, 2018).

· *S-O-R*

In behavioral psychology, “behavior” can be explained as behavior, attitude, or behavioral patterns; John Broadus Watson (1878-1958) explained behavior and the environmental factors that cause behavior using the terms ‘stimulus’ and ‘response’, thus behaviorism has the intention to study human behavior and subsequently to predict and control it. The introduction of the “Environmental behaviorism” theory into the field of museum visitors is a research direction for the study of visitor behavior (Li, 2021). “Environmental behaviorism” focuses on the relationship and interaction between the environment and human behavior. The American psychologist J.B. Watson believed that the subject of psychology is not consciousness but behavior and proposed the basic formula of “S-R” (Stimulus-Response). American psychologist Watson believed that the subject of psychology is not consciousness but behavior and proposed the basic formula “S-R”. Edward Chace Tolman (1951) proposed the formula “S-O-R”, believing that human behavior is influenced by environmental and physiological factors.

Research in China started relatively late, and in the early 1980s, Chinese scholars introduced these theories into the study of museum visitors. Chinese researcher Chen (2018) takes the intermediary spaces of the West Bund Museum of the Shanghai Long Museum, the Shanghai Himalayas Cultural Center, the Zhejiang Art Museum, and the Suzhou Museum as case studies to introduce the behavioral manifestations and psychological characteristics of the visitor in these spaces. By using methods such as the Semantic Differential (SD) method and factor analysis, the study analyzes the visitors’ perception and evaluation of the exhibition architectural space, the elements, and dimensions that affect the architectural space, and ultimately derives design strategies for intermediary spaces. Taiwan researcher Yan (2018) conducted practical research on relevant venues and exhibition halls, utilizing literature research, interdisciplinary approaches, and questionnaire surveys, among other methods, to discuss the factors of exhibition design and visitor behavior analysis. The research also optimized the design for visitor learning behavior, communication behavior, interpersonal behavior, and consumption behavior. It explored patterns of visitor behavior characteristics in exhibition spaces and summarized exhibition design methods under visitor behavior patterns, providing insights for studying museum visitor behavior.

The main behaviors of the visitor are closely related to the S-O-R (Stimulus-Organism-Response) model. S-O-R, which stands for Stimulus-Organism-Response pattern, refers to the influence of environmental stimuli on individuals, which triggers internal emotional responses, thereby affecting human behavior. The behavioral tendencies of the visitor under environmental stimuli are divided into two types: approach and avoidance (Li, 2021). The environmental behavior in museum exhibitions is also influenced by individual, social, and environmental contexts. The individual context includes the visitor's perception of the museum's content and design, the visitor's motivation and interests, and the things they are concerned about; the social context refers to the visitor's companions in the museum, the knowledge level of the companions, and interactions with other people in the museum; the environmental context includes the architecture, the feeling the building gives, and the exhibits within the building (Ken, 2003).

The behavior exhibited by museum visitors is shaped by their emotional processing of environmental cues, which involves interpreting pertinent information about the museum setting. **Table 7** shows the three factors affecting visitor behavior proposed by Bitgood and others (Bitgood & Chen, 2012; Wu, 2012). The literature review on visitor behavior will be elaborated in Section 2.6.3 to further explore the factors influencing visitor behavior.

Table 7 Three factors influence audience visiting behavior

Factors	Details
Design factors	The display of exhibition content and quality, the lack of barriers to visiting, and the appeal of the exhibitions facilitate engagement in visiting behavior.
Visitors factors	Visitors use interest, motivation, knowledge, and past experiences as the basis for deciding whether to stay or leave.
Environmental factors	Consider the museum as a holistic environment where visitors receive stimuli from environmental messages, such as the scenarios, atmosphere, and the techniques and forms of the exhibits.

2.6.1 Visitor factors influencing interaction

Visitors to museums are no longer merely passively absorbing knowledge meticulously organized by the curatorial team; rather, it involves a comprehensive

experience that includes sensory, intellectual, aesthetic, and social aspects. Visitors may gain learning, questioning, contemplation, relaxation, and sensory pleasure, or they may experience new social relationships, lasting impressions, or profound reminiscences (King et al., 2025; Lin, 2016). These experiences are influenced by environmental behavior and personal context. Personal context includes the visitor's perception of the museum's content and design, the visitor's motivation and interests, as well as the things they are concerned about (Ken, 2003).

Pre-motivation and experience

Research shows that museum visiting behavior and subsequent cognition are affected by pre-existing motivations and experiences. Previous research has shown that the factors motivating people to visit museums encompass education, leisure activities, spending time with friends, work-related needs, the allure of physical amenities, and the quest for escapism. Among these, visitors aim to fulfill not a single goal but a range of leisure motivations (Brida et al., 2013; Falk, 2016). Additionally, earlier research indicates that personal satisfaction is shaped by an individual's motivations. Scholars have concentrated on either establishing the causal connection between service quality and customer satisfaction or validating the association between personal motivations and satisfaction. Little progress has been made in establishing a causal link between individual motivations, constraints, facility characteristics, and satisfaction within a museum setting. This study posits that motivations and constraints impact visitor satisfaction during their visit, as mediated by their physical environment perception of the museum (Zhang et al., 2018).

The traditional museum visiting experience is limited by the methods of display, often resulting in one-sided communication or message transmission, where the visitor can only receive the single message conveyed by the exhibition; modern museums, through diverse display techniques, stimulation of multiple senses, and two-way communication methods, allow the visitor to gain deeper memories and reflect their feelings, which serve as references for future improvements and revisions to the museum displays. Only by creating an interactive visiting experience can museums maintain the visitor's interest in the exhibits, even leading to word-of-mouth recommendations, which is the most effective and powerful marketing tool for driving visitor numbers, as revealed in various museum visitor studies in recent years (Ken, 2003).

• *Personal cognitive characteristics*

Children, teenagers, middle-aged, elderly, men, and women, visitors with diverse ages, cultural, and educational backgrounds possess distinct perceptions. Visitors of different ages and cultural backgrounds have different perceptions. The patterns of behavior in different cultures also vary greatly, such as the differences in the interpretation of colors, patterns (symbols, images), and positions among various ethnic groups. Therefore, as soon as one steps out of the cultural zone of their living environment memory, everything can be considered foreign to the individual; thus, looking back from the perspective of overseas visitors, apart from their language, there are also differences in memories of growth and cultural background; not to mention personal preferences, all of which are individual contextual factors that museums must consider and take into account. The so-called individual context refers to the direct influence of the visitor's past experiences, academic background, economic background, professional background, age, and gender on their expectations and patterns of behavior when visiting museums (Ken, 2003; Kasemsarn et al., 2023).

Before planning exhibitions, museum display personnel should have an in-depth understanding of or conduct an investigative analysis of the target visitor, and also consider other levels of visitor groups to set up relevant exhibitions, designing exhibition content to meet the needs of visitors at various levels (Ken, 2003). Since the last century, the museum world has been driven by the new museology, shifting its focus from “objects” to “people,” and striving to communicate with the visitor. Over the years, museums around the world have worked hard to develop exhibition methods that meet the needs and interests of the visitor, narrowing the gap between the visitor and the exhibition messages, in order to achieve the dual goals of exhibition and learning (Lo et al., 2023). Based on the fact that people's physical and psychological reactions are derived from the association of memories, which significantly affect the experience of visiting museums, we can understand that research and analysis of visitor behavior directly impact the success of exhibitions. Therefore, we will further explore the relevance of these factors below.

2.6.2 Perception and engagement

Exploring museums is a widely favored pastime in the realm of tourism, especially within the sectors of cultural and knowledge-driven travel (Zhang et al., 2018). When digital media interactive design is well-matched with museum exhibition content, and the structure is clear, with appropriate new digital media technologies to

assist, the interactive experience is better presented in the exhibition, enhancing the visitor's interest in visiting, which is consistent with the original design intention and achieves the expected exhibition effectiveness. The results of visitor interaction satisfaction provide necessary data support for case analysis, and also provide a useful direction for analyzing the interactive experience of the museums (DeLone, 1992; Yu & Lin, 2006). It can be said that when the physical environment, information environment, and interactive environment in the exhibition environment are well-matched, they can enhance both the interest and satisfaction of visitors.

Visitor attention

Attention spans are not solely psychological processes, including visual search and the extent of cognitive processing, but additionally measures or indicators of behaviors, such as moving toward exhibits, halting to observe exhibits, the length of observation, and perusing explanatory texts, which significantly influence various visiting behaviors. Visitors need to identify exhibits that seize their attention to derive any substantial experience (Bitgood, 2013; Vázquez, 2016). The attention processes of museum visitors during their visit are intricate and can be categorized into three distinct stages, aligned with the three principles of attention: the attention selection stage, the concentration stage, and the engagement stage. The attention selection stage involves visitors choosing exhibits that capture their interest. The concentration stage is governed by motivation, assessing whether an exhibit merits the investment of their energy (Ai & Phaholthep, 2025). The engagement phase is marked by restricted focus, where visitors prefer to investigate exhibits that entail minimal effort and are readily satisfying. Design components involve the elucidation of the theme and content, along with the appeal of the format (Bitgood, 2019). The behavioral traits of visitors function as an external gauge for evaluating the effectiveness of exhibitions, with particular indicators and details accessible for retrieval (Ai & Phaholthep, 2025).

Study

Kasemsarn et al. (2023) found that through a systematic literature review (SLR) on digital media technology, cultural tourism museums, and inclusive design, learning is an important dimension under the theme of Diversity in Museums, with the other three themes being Demographic aspects, Purposive aspects, and Motivational aspects. In the realm of learning, Levasseur and Veron (1998) identified four distinct categories of museum visitors, characterized by metaphors associated with animal movements. The emergent pattern is quite clear; nevertheless, certain studies have

indicated that this approach lacks sufficient detail, as the walking patterns are influenced by the museum's exhibition layout design. Some research indicates the importance of focusing on tourists' learning behaviors, demonstrating that tourists possess diverse learning styles: some favor jotting down notes, while others opt for reading diagrams, maps, or engaging with other visual or interactive media. This categorization is suitable and corresponds with the museum's objective as an educational space; however, it does not relate to tourists' identities (Kasemsarn et al., 2023).

However, in Liu's (2020) research, motivation and goals are identified as factors and dimensions that affect the interactive experience of multimedia interactive technology. Learning is a dimension of post-visit experience. Lo et al. (2023) proposed that the effectiveness of exhibition displays can be evaluated by investigating and analyzing visitors' learning outcomes after museum visits. Dawson (2006) has emphasized that the museum environment ought to address the requirements of learners and visitors, facilitating their active engagement rather than passive observation in the learning journey. Generally, learners form their comprehension and perception of the environment or the broader world by contemplating their interpretations and experiences of what they hear, see, and feel, thus grasping the significance embodied by the objects and messages presented in the exhibition displays.

Motivation is deemed a crucial element in the learning process (Hein, 2000). Public engagement and visitor satisfaction are significantly influenced by and interconnected with their learning experiences, discoveries, involvement, and motivation for learning behaviors within museums. This amplifies the museum's function in fostering and shaping a sustainable future, as well as reinforcing the role of museums as educational institutions. Understanding how visitors learn can aid in creating more effective tools and strategies for enhanced exhibition designs (Eldamshiry & Khalil, 2018, p. 283).

Learning within museum exhibitions can be divided into three primary categories. First, Formal Learning, akin to a traditional school setting, encompasses activities guided by staff and teachers, such as worksheets, passive engagement, and evaluations. Second, Self-Directed Learning is driven by the learner's interest in a specific issue, topic, or particular requirements, including vocational pursuits or academic assignments. Finally, Informal Learning usually involves spontaneous, casual interactions that result in novel thoughts, insights, and discussions (Eldamshiry & Khalil, 2018, p. 289). The learning behavior demonstrated within a museum context

is directly associated with the visitors' comprehension level and their capacity to manage their cognitive process:

- (i) Cognitive: gaining knowledge through tangible experiences and utilizing pre-existing knowledge through the processes of experimentation and problem resolution.
- (ii) Affective: increasing understanding of other viewpoints.
- (iii) Social: participating with visitors and increasing a sense of interaction with other viewpoints.
- (iv) Skills: enhancing abilities in collaboration and communication to aid others in their educational journey.
- (v) Personal: enhancing identity and self-assurance for deeper exploration via pleasant experiences.

A study on functional planning and visitor learning at earthquake museums indicates that the highest proportion of earthquake museum visitors' learning behaviors is participation or interaction with interactive facilities, followed by the perfunctory viewing type, and then the focused viewing type. This shows that interactive facilities at earthquake museums attract more attention, and museum visitors not only interact with objects; they also engage in discussions and conversations while statically viewing (Huang, 2014; Yen, 2014). Borun and Dritsas (1997) summarized seven design features that effectively convey learning objectives in a study on the effectiveness of multimedia interactive exhibits (Lo et al., 2023):

- (i) Spatial Multifacetedness: Family visitors can gather around the exhibit simultaneously;
- (ii) Multi-user: It can be operated by multiple people at the same time.
- (iii) Accessibility: Both adults and children can operate and use it;
- (iv) Multifaceted Outcomes: Through a combination of observation and interactive operation, it can promote discussion among members.
- (v) Diverse Modules: It presents a variety of learning forms and cognitive levels;
- (vi) Readability: The exhibit content is easy to read. (vii). Relevance: It provides cognitive connections with the visitor's prior knowledge and experiences.

In the research, Li (2021) categorized visitors' behaviors during their visits based on the s-o-r model, dividing the behavioral tendencies of the visitor under environmental stimuli into two types: approach and avoidance. In the museum environment, factors that measure approach or avoidance behaviors include: (i). the time spent in the museum; (ii). the curiosity and attention towards exhibits; (iii). the willingness to revisit, etc.

2.6.3 Exhibition environment, visitor behavior, and experience

Visitor behavior

A museum fundamentally constitutes an interactive realm encompassing individuals and artifacts. In the space of a museum exhibition, people are the visitors, and objects are the exhibits. To establish communication between the living and the inanimate, it is essential to first comprehend the characteristics of both. Through observing each other's actions or behaviors, one can guess the other's psychology and emotions nine times out of ten; there are many such examples, such as scratching one's head, fidgeting, looking around nervously, yawning repeatedly, or the relationships between people in the same space (Ken, 2003). All of these are various behavioral expressions of psychological emotions manifested through the body, and these behaviors contain hints or signs as vocabulary. In interpersonal communication behavior, if the receiver or observer fails to receive the messages presented by the other's body language, a red flag will be raised in communication or interaction. Therefore, memory can be said to be the best record of creating human special learning behaviors.

Li (2021) categorized museum visitor behavior into three aspects based on theoretical analysis and field investigation: basic visitor behavior, main visitor behavior, and extended visitor behavior. She obtained data and information on the basic information of museum visitors, reasons for visiting, duration of visits, routes taken during visits, specific behaviors, and attention performance. The results indicated that the duration of visits and information on visit routes vary due to individual differences; visitors are more attracted to famous exhibits, large in size, and aesthetically pleasing; the persistence index for calligraphy and painting exhibits is relatively high; and "museum fatigue" is likely to occur during the visitation process. She also proposed several suggestions:

- (i) Comprehensive planning of visitor routes;
- (ii) Increasing interactive display elements to enhance visitor attention and alleviate museum fatigue.

In the use of space, behaviors such as movement speed, the route of the visit, or distances are referred to as the environmental context. For example, being influenced by the arrangement of pathways, the relative distance between individuals, or walking on the right side, etc. Therefore, for the planning or design of walkways, exhibition spaces, the relative space reserved for exhibits, and public facilities, it is necessary to observe the behavior of the visitors to create a humanistic space that meets their needs (Ken, 2003). When designing museum exhibitions, it is common to use contextual cues to connect with the visitor's related memories and to allow them to interpret the exhibition through their contexts. But is the interpretation of the same exhibition the same for everyone? Or do different people have different interpretations, and how do these differences manifest? Under what circumstances can we predict or interpret these differences? For example, do visitors from different regions feel confused by the interpretation of the exhibition? The differences presented by museum exhibitions are already quite significant, not to mention when combined with lifestyle and ethnicity; the differences become even greater. In other words, different cultural backgrounds lead to different memory behaviors in people.

• *Approaching behavior*

Li (2021) divided the behavior of visitors into approach behavior and avoidance behavior according to the degree of investment. "Approach" indicates that the visitors' desire to stay "consciously" is dominant, and their acquisition of information is proactive; "Avoidance" suggests that the visitor has lost interest and wants to leave temporarily. Approaching behavior includes the act of taking photos, reading explanatory panels, and engaging in conversations. Visitors' conversational behavior during the exhibition can be considered as "in-depth exploration behavior," or it can also be seen as a form of "learning behavior". This is because when the exhibits resonate with the visitor's emotions or memories, it triggers conversations among the visitor (provided it does not disturb others). The mutual conversations among the visitors helped to deepen their understanding of the exhibits and their impression of the exhibition. Yan (2019) categorized museum visitor behavior into learning behavior, interpersonal behavior, and consumption behavior. According to Li's classification, these three types of behavior all belong to approach behavior.

• *Museum fatigue*

In 1916, Gilman coined a phrase in an article that has intrigued scholars for many years: "Museum fatigue." "Museum fatigue" refers to the

phenomenon of visitors gradually experiencing exhaustion and a lack of concentration, leading to a feeling of fatigue during the course of their visit. Some scholars believe that the phenomenon of “museum fatigue” is caused by two main factors: on the one hand, it is due to the physical fatigue from prolonged walking; on the other hand, it is due to the physiological and psychological boredom that results from the visitor’s prolonged intense concentration (Chiang, 2022; Miao et al., 2024;). Li (2021) believes that the causes of “museum fatigue” include:

(1) The museum display environment is a space in constant motion, where visitors stand for long periods and sometimes spend time pondering, which can lead to physical and mental exhaustion and a lack of concentration.

(2) There is limited space for visitors to sit and rest.

(3) There is a discrepancy between the knowledge system of the exhibits and the knowledge system that visitors already possess, which can easily lead to “museum fatigue” when visitors spend too much time at the exhibition. The alleviation of “museum fatigue” can improve visitor satisfaction with museums (Li, 2021). Research also suggests that the distribution of different types of interactive digital media exhibits can alleviate museum fatigue (Lo et al., 2023).

• *Game behavior*

Games are a very important method in interactive design and can also be considered the most participatory form of activity (McClarty & Frey, 2012). Interactive experience games in exhibitions can have different communication effects on people from different age groups; they can create interaction with participants in a very short time, bring good experiences, and immerse participants completely in the content and space (Ning et al., 2022). Game behaviors can be categorized into human-computer interaction and physical interaction based on the form of exhibits. They can also be classified by content into competitive, imitative, and other types.

• *Traffic behavior*

Yan (2018) proposed the concept of traffic behavior, refers to the movement of the visitor in the exhibition space, where they move from one location to another based on the purpose of their actions and the changing goals they seek, such as pausing briefly at the prologue section near the entrance of the exhibition hall before moving on to the first display case to stop and view. In the exhibition space, the flow of people can be classified based on their movement characteristics into: “Abortion with a strong purpose, people moving casually while accompanying other

purposes, abortion where the movement itself is the purpose, and people in a state of rest and pause.” The movement of people with a strong purpose, such as those heading to the rental counter for audio guide devices or to the restrooms, does not exhibit a state of viewing the exhibition.

Visitor experience

The key role of exhibits or digital exhibits is to enable museum visitors to interact with them: they view objects, read texts, watch videos, engage in digital interactions, and so on. Additionally, museums often solicit visitors’ opinions on exhibits and exhibitions, including what they have learned, their enjoyment, and whether there are aspects they would improve. These serve as indicators for evaluating exhibition effectiveness. All of these are within the scope of visitor experience research, making visitor experience studies an indispensable topic for museum visitor research.

The Museum exhibition visitor experience (King et al., 2023) was developed and adapted from product user experience (UX), which conceptualizes the interaction between users and products and serves as a theoretical framework for understanding users' perceptions of product features and quality. Given the numerous similarities between user interactions with products and visitor engagements with museum exhibits, this concept has been applied to museum studies and has gradually evolved into the study of the Museum Visitor Experience (VX) (King et al., 2023; Mason, 2020). The so-called museum visit experience begins the moment a visitor decides to visit a museum, continues through the actual entry into the museum, and extends to the memories left days, weeks, or even years after the visit (Falk& Dierking, 2001). These memories are typically influenced by personal, social, and environmental contexts (Ken, 2003). Visitor experience describes how the characteristics, qualities, and purposes of an exhibition come together, as well as how visitors perceive and interact with them.

Summary

Over the past century, the development of museum exhibitions has presented a diverse and rich array of appearances and has become the core function of museums. Entering the new century, the interactive relationship between “behavior” and exhibition has become one of the most important issues for museum exhibition planners. In addition to the impact of the exhibition environment on the visitor’s experience, the visitor’s own personal environment and knowledge interpretation environment will also affect the visitor’s interest in visiting, as shown in **Figure 6** However, according to the existing research data, there is a lack of comprehensive research.

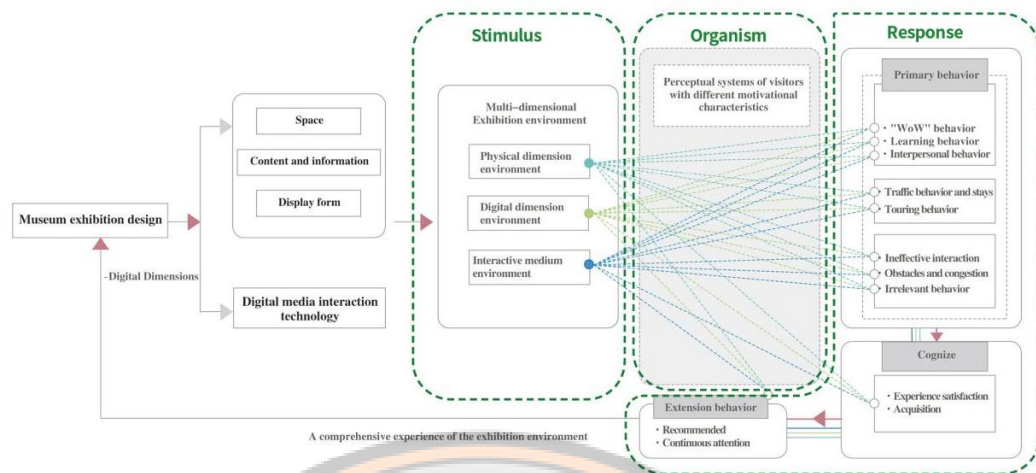


Figure 6 The theoretical basis based on the S-O-R model

Source: Ai (2025) redrawn based on Li (2021).

2.7 Evaluation

2.2-2.6 elucidates the role of museum digital media interactive technology in the context of tourism culture, and how digital media interactive technology affects the visitor experience within the museum exhibition environment. However, is there real-world evidence that suggests an improvement in the visitor experience when tourists interact with digital media interactive technology during their museum visits? Would such impacts enhance visitor interest and interaction?

Based on the literature review of the above questions. This chapter is organized into four themes for summary: Research on the physical environmental assessment of the study, Relevant research on the evaluation of the digital media, Research on visitor experience assessment, and Evaluation of the Communication Effectiveness of Museum Exhibitions. After the literature review, the assessment of the impact of digital media interactive technologies on visitor experience and interest in museum exhibition environments tends to use a range of methods focusing on the interaction between visitors and the environment:

- (i) Visitor behavior survey (Lu & Chen, 2018; Yan, 2009; Zeng et al., 2019);
- (ii) The visitor analysis and visitor studies (Eldamshiry & Khlood, 2018; King, 2025);
- (iii) Questionnaire including museum experience and learning behavior questionnaire (Liu, 2020; Li & Ito, 2023; Zhang et al., 2018);
- (iv) Observations (Chin, 1998; Lo et al., 2023; Li et al., 2024);

- (v) Interviews (Berkovich, 2003; Evans & Sterry, 1999; Grinter, 2002; Hatala & Luyten, 2006; Wakkary, 2005);
- (vi) Heuristic evaluations (Phaholthep et al., 2017);
- (vii) Attractiveness Survey (Chen, 2005; Lo et al., 2018).

From the standpoint of museums, the elements of an exhibition, such as content texts, visual materials, objects, accessibility, and digital interpretations, merge to create the envisioned display, which mirrors the museum's aspiration for how visitors will interpret it (Ceccarelli et al., 2024; King et al., 2025; Lu et al., 2018). Whether these design results align with the design objectives is assessed via exhibition evaluation, primarily involving visitor feedback. Comprehensive studies have been undertaken on the assessment of museum exhibitions and digital technologies. However, these widespread evaluation methods are not devoid of problems (King et al., 2025).

2.7.1 Research on the physical environmental assessment of the study

The physical environment can serve as both a limitation and an allure for visitors. Consequently, to more effectively anticipate visitors' choices regarding whether to visit a museum, the service quality of the museum in this study is assessed through visitors' evaluations and perceptions of the museum's environmental quality. To investigate the service aspects of a museum, the construct physical environment is defined in this context as the service functions integrated into the museum's facilities, covering both the internal and external environments, as well as information and exhibitions, which can be perceived and assessed by visitors (Zhang et al., 2018).

To further understand the behavioral characteristics of visitors in museum exhibition halls, in recent years, methods combining natural observation with video cameras and PDAs have been developed for visitor behavior research in the museum field (Henderson, 1997). The use of natural observation and video cameras in the evaluation of museum exhibitions has a history of over a decade, mainly focusing on observing the visitor paths, behaviors, and the time spent in front of each exhibit to identify the characteristics of the displays. For instance, in the Hall of Evolution at the Muséum National d'Histoire Naturelle in France, this method has been used for formative and summative evaluation work (Ken, 2003).

Scholars both domestically and internationally have conducted research and analysis on the effectiveness of interactive installations. Chen & Chang (2009) used questionnaires, observations, and interviews to explore the impact of exhibition atmosphere and the degree of interactivity of installations on students' learning. The

study found that the feeling of the exhibition atmosphere affects the visitor's willingness to operate the installations, and those with a higher degree of operation tend to retain deeper memories. This indicates that interactive installations should be studied within their environment, not just focusing on the exhibits themselves.

2.7.2 Relevant research on the evaluation of the digital media and Experience

Interactive technology, appeal, and learning effectiveness

Evaluating digital exhibits and user experiences in museums encompasses a range of assessment techniques, such as walkthroughs of the exhibition and behavioral observation, satisfaction surveys and questionnaires, visitor interviews, and other similar methods. These are commonly used techniques. In recent times, tools designed to assess the digital interpretation of the information space and the visitor experience have increasingly adopted Semantic Differential scales. Nevertheless, these scales depend on verbal evaluations, rendering their results vulnerable to the impact of respondents' educational levels and understanding capabilities, which can readily introduce biases (King et al., 2025).

Scholars studying environmental behavior frequently examine preferences and behaviors comprehensively (Brida et al., 2016). The behavioral traits of visitors in exhibition settings are deemed crucial indicators for assessing the efficacy of exhibitions, and behavioral observation is viewed as the predominant method for conducting museum audience research (Baharetha et al., 2025; Yan, 2009). Taiwanese researchers Shiang et al. (2015) merged conventional museum behavioral observation techniques with the IAE (Ignore, Attend, and Engage) Scale to quantitatively examine the correlation between visitors' behavioral preferences and exhibition settings. "Attraction power (AP)" and "Holding Power" are significant metrics utilized by museum scholars to study visitor behavior (Huang, 2014; Lo et al., 2023; Yan, 2009) applied exhibition appeal to assess various types of visitors' participation with digital technologies in natural history museums, and Li and Luo (2024) utilized "Average Holding Time" to assess children's engagement and interaction in science museums. Although current studies have pinpointed the influence of environmental factors on particular visitor behaviors, there still exists a deficiency in standardized methodologies to delve into the root causes of visitor actions, thereby neglecting the inclusive design of museums intended for everyone.

Lo et al. (2023) introduced their micro-study on the appeal of multimedia interactive devices to the visitor and their learning effectiveness. Through the

researcher's field operations and observations of the degree of attraction of different interactive devices to the visitor, combined with visitor interviews and literature references, this paper analyzes why users are interested or not interested in a certain interactive device, and whether they can absorb the messages that the interactive device intends to convey. It summarizes the factors that museums should consider when setting up multimedia interactive devices. The study adopted non-participatory observation and semi-structured interviews, referring to the IAE scale designed by Shiang et al. (2015) to measure the attractiveness of interactive multimedia devices, and combined with semi-structured brief interviews to understand the learning outcomes of the visitor after using interactive multimedia.

The IAE scale was adopted as the measurement standard for visitor behavior, with features including observation items such as stopping, viewing time, and the influence of human factors. The interaction of the display with the visitor is judged based on visitor behavior, with attention attraction levels rated as "participation," "approaching," and "ignoring," scored as 3, 2, and 1, respectively. A systematic approach is used to collect observations on the attractiveness of multimedia interactive installations to the visitor. Considering that the success of the operation of the installation can affect the effective engagement of the visitor, the definition of 3 points for "participation" is more stringent in this study. Only the successful operation of the display is counted as 3 points, while attempts without success are given 2 points, with researchers also noting explanations in the comment section. After collecting the scores, the study calculates the average, and an installation with an average score of 2 or above is defined as having attracted visitor attention, achieving the goal of this study to explore the attractiveness of multimedia interactive installations to the visitor.

To analyze the relationship between attractiveness and learning outcomes, Lo et al. (2023) took as the main interview subjects those who scored 3 points, indicating active and successful operation of interactive devices. Researchers summarized the learning objectives of each device based on the operation content and display information next to the devices, reached a consensus through multiple discussions and repeated operations, and then set interview questions according to each learning objective. The study conducted a result analysis from three aspects: exhibition content, interactive operations, and spatial movement. The research indicates that the attractiveness of multimedia interactive installations does not correlate positively with learning outcomes.

Interactive installations are often very attractive, but they seem insufficient in terms of message delivery and learning functions, with only a few participants achieving knowledge transformation. Respondents mostly focus their attention on the hands-on experience, failing to connect illustrations with text, which affects the absorption and transformation of knowledge. At the same time, when interactive exhibits lack content presentation, it also prevents respondents from clearly reflecting the learning benefits after using the device; in addition, when textual introductions are easily overlooked by users, even if the device successfully attracts a large number of participants, the design of the display content limits knowledge transfer and affects learning outcomes. Another significant outcome of this study is the observation of the actual operation of interactive devices. This is a richer aspect compared to other literature. Museums nowadays all use multimedia interactive devices for exhibitions; however, this study found that visitors still have difficulties in the actual operation of multimedia. users need clearer guidance, and the content design of multimedia devices lacks consideration for the operational aspect of museum visitors, resulting in a gap between operation and exhibition. For example, many visitors are attracted to the devices and approach them, but after approaching the devices, because they can't successfully operate the devices in a short time, they choose to leave. This is consistent with what Ken (2003) mentioned: due to the lack of research on visitor behavior, there are issues with the practical use of multimedia technology.

Research on the evaluation of the relationship between digital media and experience

To gauge visitors' anticipations, receptiveness, and encounters with digital interpretation and presentation technologies, Liu (2020) adopted a mixed method combining a questionnaire based on the Digital Experience Assessment Framework and semi-structured interviews and applied it to the typical heritage of digital display technology applications in Taiwan, Zuoying Old City. This evaluation framework provides a basis for further research on heritage visitors and is intended to refine digital interpretation and presentation design. The opening segment of the questionnaire (pre-visit) focused on respondents' familiarity with digital technologies and their existing knowledge of Zuoying Old City, and their motivations for and expectations of their visit. The second section (on-site visitation) of the questionnaire, which was the key part of this survey, was designed to measure the respondents' experience of digital interpretation and presentation technologies during their visit."

The questionnaire was structured into three sections: the initial section concentrated on the visceral aspect of the respondents' experience, capturing their preliminary reactions to the digital display system; the subsequent section explored the behavioral aspect of the respondents' experience during their visit, covering four pivotal areas (usability, information/knowledge, entertainment, and engagement) through items that combined the impact of both the digital product UX and the heritage visitor experience; the final section scrutinized the reflective aspect of the respondents' experience to acquire a more profound insight into the impact that the digital interpretation and presentation system exerts on visitors (Liu, 2020, p. 5).

A five-point Likert scale, spanning from 1 (strongly disagree) to 5 (strongly agree), was utilized for each question to assess the previously mentioned items. The concluding section, following the visit, sought to compile visitors' comprehensive evaluations and satisfaction levels regarding the digital interpretation and presentation system, their takeaways from the visit, and their suggestions for the design of digital displays at Zuoying Old City and other cultural heritage sites (Liu, 2020). To complement the data on visitors' attitudes and perceptions, follow-up interviews were conducted with participants willing to provide additional insights.

A questionnaire based on user satisfaction surveys is not the case in the survey of digital media experience. The "Questionnaire for User Interaction Satisfaction" (QUIS) can evaluate the effectiveness of interaction design. A short version of QUIS was adopted, including 27 evaluation items, across six major categories: (i) Overall Reaction, (ii) Screen, (iii) Terminology & System Information, (iv) Learning, (v) System Capability, and (vi) Usability & User Interface. To facilitate measurement and statistical analysis of visitor satisfaction, the study simplified the questionnaire's rating system to a 6-level scale, with the phrasing of the rating statements varying according to the different declarative stems. Among these, the first six items of the overall interaction reaction assessment do not have declarative stems, but only list contrasting indicative words, such as "very poor -very good", "difficult-easy", "frustrating - comfortable", etc. (Ning et al., 2022).

Research on visitors' experience assessment

Another theme identified from the literature review suggests that user experience (UX) is the most relevant topic in the domain of digital interaction within museums. Norman (1981) articulated the notion of UX perception in the domain of product design, categorizing user experience into three distinct tiers: the visceral level, the

behavioral level, and the reflective level. At the visceral tier, sensory inputs-such as visual, auditory, olfactory, gustatory, and tactile perceptions, generally instinctive- embody the user's automatic responses to external stimuli. The behavioral tier oversees the functional aspects of physical interactions, while the reflective tier is managed by the cognitive system, tasked with the interpretation and processing of information, including aspects of learning and memory (Norman, 1981). This concept, the UX, has been extensively utilized in the realm of design, covering areas such as museum exhibitions and digital media design. Mason (2020) leveraged this as the theoretical groundwork to introduce a methodology for museum experience design, while King et al. (2025) utilized UX theory as the cornerstone to formulate an evaluation approach for museum visitor experiences. UX integrates various evolving concepts, such as aesthetic and hedonic emotional factors, which emphasize the psychological aspects of visitors. This approach has been extensively applied in assessing museum visits. The pertinent research results further highlight the multifaceted nature of experiences within museum settings, including learning, enjoyment, satisfaction, a sense of value, and emotional responses (Ai & Phaholthep, 2025; De Backer et al., 2015; Li et al., 2024).

Zhang et al. (2018) investigated the relationship between motivation, a museum's physical environment, and satisfaction based on UX questionnaire surveys was used as the instrument of study to evaluate perception and experience in a museum context, done by synthesizing characteristics from previous studies and common planning features (e.g., the museum's reputation, open areas, environmental exhibits, events, and service amenities). Liu (2020) investigated visitors' experiences and attitudes towards digital heritage interpretation by employing a questionnaire-based user experience (UX) methodology. Despite this, there exists a notable gap in research concerning the dynamics between motivation, digitally interpreted environmental composition, and behavioral experience within the field of user experience research. Frequently, the influence of environmental factors and individual attributes-both physical and psychological, experiential outcomes is overlooked.

The study of visitor experience evaluation and the research on the relationship between the three have long been important means of museum exhibition evaluation in Western developed countries such as the United States and the United Kingdom. Taking the United States as an example, before the 1980s, museum research on visitors mainly focused on the number of visitors; in the late 1980s, museum educators began to attempt to draw on theories and methods from other disciplines, such as

psychology and pedagogy, to study the real needs of the visitor. In the 1990s, British researchers pointed out that visitor research is the basis for planning in all areas of museums, and if change is the direction of all efforts, they first need to provide a comprehensive and detailed description of the visitor and their behavioral characteristics. Since then, evaluation practices centered on visitor research have provided important reference points for museums in the evaluation of exhibitions and educational activities, as well as in macro planning and decision-making (Li, 2021; Shi, 2009). Nevertheless, the assessments derived from satisfaction surveys and visitor studies have amassed a substantial volume of data regarding the intricate identities of visitors. Yet, these assessments seldom delve into the particular methods through which these visitors engage with exhibits and exhibitions (Ardoin et al., 2016). Li et al. (2024) examined children's interactions with digital exhibits, focusing on the quality of their engagement with multimedia displays rather than the broader digital experience shaped by the exhibition setting. The likelihood of visitors being drawn to digital exhibits and choosing to interact is determined by both the overall exhibition environment and their attentional traits (Ai & Phaholthep, 2025; Bitgood, 2019; Tešin et al., 2010; Wineman & Peponis, 2010).

Lord et al. and Maryland contended that one purpose of museum exhibitions is to effectively transform interesting aspects of visitors, beyond their interests, values, or attitudes (Eldamshiry & Khalil, 2018). Huang (2014) employed questionnaire surveys, interviews, and observation methods to explore the relationship between visitors and visitor satisfaction and learning effectiveness with the multimedia interactive “Fortune Telling Game Machine” at the exhibition. Subsequently, the discussion revolved around how museums can evaluate and make decisions between the costs of multimedia interactive displays and learning benefits. Research questionnaire survey method, interview method, and non-participant observation method as research methods. Questionnaires and semi-structured interviews are used to uncover the reasons behind visitors’ unexpressed thoughts and behaviors, while participatory observation and recording are employed to obtain information that questionnaires cannot. The questionnaire mainly involves four research variables, which are: Exhibition planning and design, (2) learning benefits of exhibition design, (3) learning benefits of multimedia interaction, and (4) background variables. Statistical analysis is conducted using the SPSS 27.0.1 software package.

2.7.3 Post-occupancy evaluation (POE)

POE and the museum

POE, as an effective evaluation process and method, is widely applied to assess the post-occupancy usage effects of public cultural building spaces (Zeng, 2024). This customer-focused methodology constitutes an element of a novel democratic framework that encompasses autonomy, self-organization, ecological principles, sustainability, adaptability, and ongoing enhancement. The methodology ranges from qualitative self-reports of likes and dislikes to quantitative multivariate analysis, from verbal scales to observational techniques, and last but not least, expert judgment. This consumer-oriented approach is part of a new democratic paradigm that embodies autonomy, self-organization, ecology, sustainability, adaptation, and continuous improvement. The methodology spans various approaches, including qualitative self-reports of personal preferences, quantitative multivariate analyses, the application of verbal scales, the utilization of observational techniques, and, importantly, expert evaluations.

The primary social function of museums is to serve the public. To ensure the effective utilization of social resources, it is necessary to study the post-occupancy evaluation of their usage. Meanwhile, previous reviews have indicated that negative factors in the exhibition environment and services can lead to avoidance behaviors among visitors, affecting their willingness to participate (Zhang et al., 2018). Whether through visitor surveys or environmental satisfaction surveys, the goal is to assess visitors' experiences and evaluations of existing exhibitions, thereby understanding their needs and improving the exhibits (King et al., 2025). The core of this evaluation lies in the personalized experiences and gains of the museum's diverse visitors (Kasemsarn et al., 2023). Therefore, POE (Post-Occupancy Evaluation) serves as an effective method for assessing the quality of exhibition environments and identifying factors that influence visitor interest and interaction.

Development and Key Points in the Evaluation of POE

The first publication with POE as its title was an article written by Herb McLaughlin of KMD Architects in San Francisco in the January 1975 issue of the AIA Journal, which discussed POEs of hospitals in Utah and San Francisco (Daish, 1982; Preiser, 2008). In the 1980s, extensive POE activities were conducted in public engineering projects, government buildings, airports, and other areas in the UK,

Australia, the United States and Canada, leading to very large-scale and significant POE studies (Preiser, 2008).

Early POE was a process for assessing building performance after occupancy. It was based on the concept that understanding user needs through systematically evaluating human responses to buildings and other designed spaces constituted a legitimate goal of architectural research. As its application expanded to a broader range of building types, POE came to encompass any activities stemming from an interest in understanding how buildings perform after completion, including whether and to what extent they meet expectations, as well as how satisfied users are with the created environment (Preiser, 2008).

In the 1960s, Daniel (1960) pioneered a novel empirical framework for aesthetics, characterizing it as a positive reaction to stimuli. He formulated a motivational theory that connected preferences to curiosity and uncertainty, driven by collative factors such as complexity, novelty, and ambiguity. Simultaneously, the Kaplans, a team of researchers, embarked on the study of environmental preferences in 1972 (Preiser, 2008). From the empirical research perspective of designing, Oscar Newman (1972) regarded the environment and appearance as one of the parts of “Crime Prevention Through Environmental Design”, and a POE approach was taken to evaluate the public housing performance from the occupier’s perspective.

Nasar (1983) conducted a study aimed at assessing the perceived visual quality and fear of crime within actual communities. During the initial stage of the study, he pinpointed the prominent dimensions of perception related to 40 streets in Pittsburgh and then correlated these dimensions with individuals' assessments of crime preferences and fears. Consequently, the POE has gradually incorporated environmental aesthetics. visual quality. By the 21st century, the user-centered design concept replaced designer authority with egalitarian and bottom-up assessments (Preiser, 2008). Under such a concept, the design aims to attract a broader public to experience and perceive it. This aligns with the museum exhibition design philosophy within the cultural tourism context. Whether from a user-centered evaluation perspective or a multi-dimensional assessment of architectural performance, environmental aesthetics (visual quality), and environmental perception.

POE possesses the following characteristics and advantages relevant to the museum exhibition environment and performance evaluation:

- (i) By quantifying occupants' (visitors') perceptions and environmental (physical and psychological) factors, this study improves the measurement of building (exhibition space) performance and provides the architecture (museum) industry with information about buildings in use.
- (ii) The effectiveness of design (exhibition design) can be tested from the perspective of design factors, to formulate relevant guidelines and policies for designers or managers.
- (iii) Testing new concepts to determine their effects in environments where people (visitors) reside or visit (exhibition environment).
- (iv) Facilitate communication among designers, clients, managers, and end-users (visitors). By actively involving multiple stakeholders in the evaluation process, the attitudes and experiences of building occupants can be improved.
- (v) Information generated by POE can be used for decision-making during the pre-design phase of new projects.

Existing literature, whether international or Chinese, demonstrates relatively extensive application and practice of POE in cultural tourism and public spaces. For instance, Fan et al. (2022) conducted a POE and optimization study on the seating spaces in Fuzhou's Three Lanes and Seven Alleys historic district based on environmental behavior theory. Zhang et al. (2021) conducted research on the Sui-Tang Luoyang City National Heritage Park based on POE, while Wen et al. (2023) carried out a design study on intergenerational fitness facilities in urban parks based on POE and FAHP. Martine et al. (2018) assessed visitors' thermal comfort in historic museum buildings from a POE. Moreover, there are scholars and teams conducting POE evaluations on underground urban commercial complexes regarding architectural physical environments (Zeng et al., 2025), design elements (Zeng et al., 2024), and perceived environments (Wang, 2022).

However, existing literature lacks systematic POE studies on museums, as well as the application of POE for subjective perception evaluation across multiple museum exhibition cases. Therefore, this research adopts POE evaluation as the foundational framework for constructing the assessment system of this study.

Summary

Current methods and processes for evaluating museums and museum experiences are continuously innovating and developing, with a tendency toward interdisciplinary approaches and multi-method integration (Li & Luo, 2024). Although evaluation is widespread, it is often hindered by a lack of standardized methods, generalizable results, and quantitative approaches. King et al. (2025) proposed a systematic Museum Exhibition User Experience evaluation model, demonstrating the effectiveness and feasibility of standardized and quantitative assessment. Although the study emphasized this as a visitor-centered evaluation, the primary research methods employed in the process still relied on the creation and implementation by researchers, neglecting the diverse capabilities and needs of visitors with different types and cultural backgrounds. For special groups, such as young children and student teams, evaluation research also faces similar issues. Returning to the original starting point, museums should serve all members of society, regardless of one's abilities or age; everyone has the right to enjoy equal facilities and services in museums. It can be summarized as the methods currently used to study visitor interests, the content covered, and some of the summaries should be combined into a plan suitable for this research, which should be empirical, comprehensive, and a full-process study. This is also one of the issues that this research aims to address.

Research Conceptual Framework

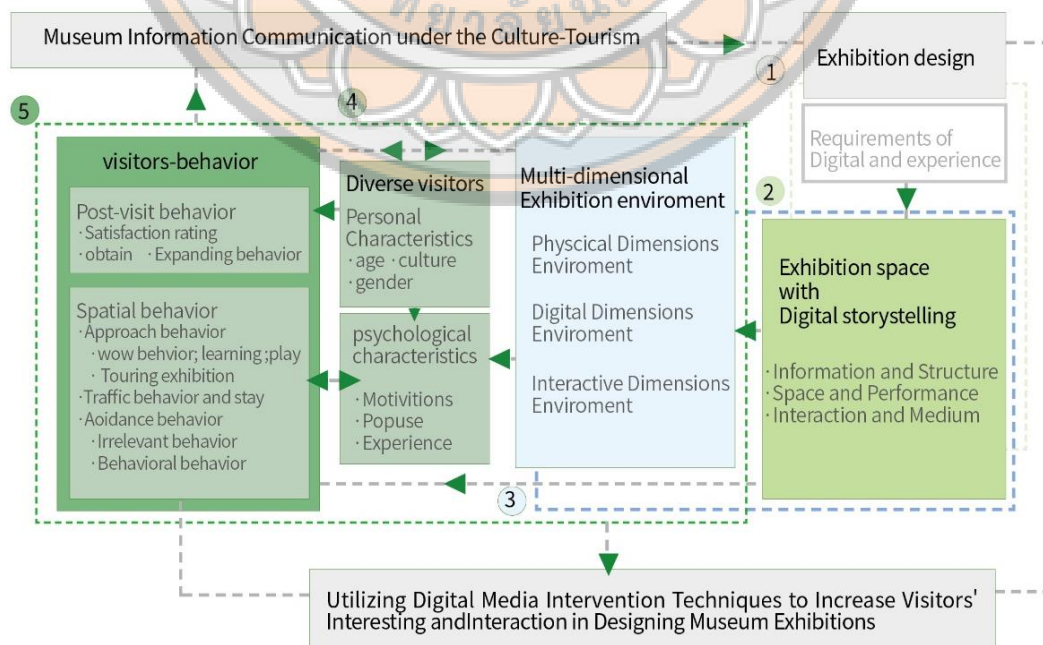


Figure 7 Research Conceptual Framework

CHAPTER III

RESEARCH METHODOLOGY

3.1 Overview

The purpose of Chapter 3 is to explore the methods, operating procedures, and tools used to achieve the four research objectives of this study. This chapter includes: describes the method regarding research procedure and methodology. Section 3.2 provides the research design and method. Section 3.3 provides the scope of the area and specific space of the case study, population, and sample groups in this study.

To achieve the four research objectives of this study, the research is divided into four major parts: Motivating Visitors' Interest and Interaction

(1) A conceptual framework and evaluation system for the factors of motivating visitors' Interest and Interaction through digital media technology;

(2) POE of assessing museum environment performance containing digital media interaction to examine the physical environments of popular museums in China and evaluate their alignment with key factors for effectively integrating digital media technologies to promote museum tourism.

(3) POE of visitors' perception and experience during museum visiting to investigate museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital media technologies in exhibitions.

(4) Generation and evaluation of the utilization guideline of digital media interaction techniques in museum exhibition design for motivating visitors' interest and interaction.

3.2 The Research Design

This study is a mixed-methods research. To obtain in-depth data and describe the situation, and to confirm the causes of the studied issues, in search of solutions for the relevant research objectives, this study employs a novel method that combines qualitative research with survey research as the foundational approach, shown in **Figure 8**. The research comprises a theoretical study and an empirical study, and is divided into three phases: the first phase is the theoretical study phase, including the Systematic literature review (SLR), Analytic Hierarchy Process (AHP). The second phase is the empirical research, which includes evaluating the physical environment, visitors, and visitor behavior study. The third phase is the Generative Research, Including Results analysis and image simulation questionnaire survey.

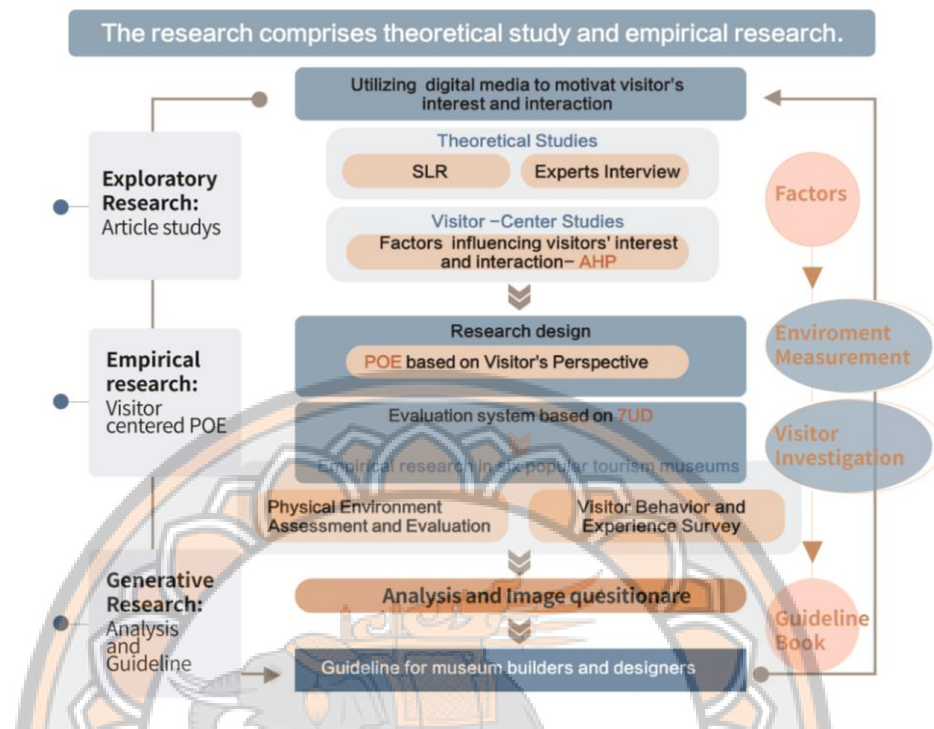


Figure 8 The research design of this study

The empirical Study of the second phase was conducted in the six museums. Based on the results of literature review and preliminary investigation, visitors with different identities and needs travel on different dates (Chin, 1998; Yan, 2009). For example, during weekdays from Monday to Friday, there are fewer student and family visitors, while elderly and professional visitors are relatively more frequent. On weekends (China's holidays), groups such as student groups, family visitors, and out-of-town tourists are more common. Therefore, to obtain as diverse a participant sample as possible, the survey was conducted every Wednesday and Saturday from February to March 2025 across six museums.

To ensure the reliability of the research process and its outcomes, this study employed heuristic evaluation methods, conducting a total of three expert evaluations during the research process.

3.3 Case Study and Sample Groups

This study consists of the area scope, participants, and sample, as detailed below:

3.3.1 Case study

Cases are selected from newly built museums in mainland China's tourist cities, and field observations are conducted on museums built over the past decade. Ultimately, 5 museums are selected as the specific space for the main study. The data

collection part of the study involves conducting case investigations at the Suzhou Museum West (SWM), Museum of Wu (WCM), Jiangnan Watery Region Culture Museum of China (WCM), Wu and Yue Culture Museum (WYM). The China Grand Canal Museum (GCM) was selected as a comparative case study to verify the accuracy of the results. **Table 8** presents the characteristics of six museums.

Table 8 The characteristics of the 6 case study museums

Name of the museum	Year & City	Museum features
Suzhou Museum West (SWM)	2021	• A museum collaborating with the British Museum for exhibition curation.
International Hall Historical Hall	Suzhou	Suzhou is a renowned tourist city, and the SWM is one of the few internationalized museums in China.
Museum of Wu (WCM)	2020	• Museum exhibitions focus on Parent-child family visitors
Basic Exhibition Hall 1 Basic Exhibition Hall 3	Suzhou	Interpretation and presentation of the history and heritage of Wu Zhong won the “Top Ten Display Exhibition Excellence Recommended Award” by Chinese museums in 2020.
Shanghai Museum East (SME)	2024	• The newly completed Shanghai Museum East Branch in Shanghai, China, is dedicated to displaying ancient Chinese art and cultural heritage.
Ancient Bronze Gallery Ancient Chinese Jade Gallery Chinese Numismatics Gallery Ancient Ceramics Gallery	Shanghai	• Its promotional focus is on creating a “visitor-friendly” and “digitally intelligent” museum. The Shanghai Museum East Branch has attracted large numbers of residents, as well as tourists and culture enthusiasts of all age groups.
Jiangnan Watery Region Culture Museum of China (WCM)	2022	• Telling cultural heritage stories with digital media, as recommended by professional designers.
Basic Exhibition Hall	Hangzhou	• For the unique culture and architectural heritage of the watery region of Chiangnan. “Top Ten Display Exhibition Excellence Recommended Award” by Chinese museums in 2022. The combination of media design has been well-received by the industry.
Wu -Yue Culture Museum (WYM)	2024	• A new museum that integrates cultural tourism, parent-child interaction, and valuable cultural relics.
Basic Exhibition Hall 1	Hangzhou	Part of the heritage park, it is famous for its exhibits and attracts many cultural tourists. At the same time, the exhibition utilizes a variety of digital media technologies to interpret history.
* China Grand Canal Museum (GCM)	2021	• Immersive media recommended by KOLs attracts tourists.
“Boats on the Canal” Exhibition Hall	Yangzhou	• Display canal cultural heritage. This is the hottest cultural tourism museum on Chinese social media, known for its immersive media experiences. It attracts a large number of young tourists. This is an excellent example of museums driving tourism.

*The GCM serves solely as a case study for the first-stage POE of the physical environment

The case was derived through the following steps:

Step 1: Select the newly built museums in the past five years through the list of the top 100 popular museums in the country from 2023 to 2020 released by the China Cultural Relics Exchange Center, Museum Headlines, and the State Administration of Cultural Heritage; publish the most influential tourism in China in 2022 through Sohu.com A list of the top 100 cities, looking for new museums in popular tourist cities in the past five years.

Step 2: Screen out the top ten museums with recommended indexes on social platforms and travel platforms.

Step 3: Through literature review and archive inquiry, obtain a list of cultural tourism museums in Chinese tourist cities to promote regional culture.

Step 4: Based on the “Table of Characteristics of Digital Media Technologies Being Used in Museum Exhibitions” obtained from the literature review and the museums visited in the case observation, select the usage of digital media in the cultural tourism integration museums of tourist cities newly built in the past five years. Museums that reach 50%. Standards refer to the digital media percentage standard in the design bidding documents

3.3.2 Expert Group

To enhance the reliability of this study, the heuristic evaluation method was adopted, inviting expert panels to conduct interviews and assessments at different research stages. Therefore, participants in this study, who were expert groups, were invited to participate in interviews and the Analytic Hierarchy Process (AHP) to measure the elements, models, and tools obtained at each stage.

Whether it is expert evaluation or AHP, both rely on obtaining results through expert interviews and questionnaire surveys. Most studies adopt small samples, depending on the knowledge and experience of experts, who make judgments, evaluations, and predictions on issues through investigation and research. The professional fields involved in the topic discussed in this paper include not only museum exhibition planning and design teams but also experts working in museums. Digital media interaction experts are also highly important. By having multiple experts and scholars from the museum and digital media interaction fields evaluate the importance of various factors and indicators, their expertise and experience in museums and design can not only objectively identify the factors influencing visitor interest and interaction and their significance, but also serve as more reliable reference

principles for future planners and designers. Therefore, the expert panel consisted of three experts, including a professor specializing in museum exhibition design research, an associate professor in digital media interaction and intelligent technology, and a senior research fellow at a museum. This study protects the personal thoughts of experts and scholars by presenting the results of each research phase with random codes from A to C, as shown in **Table 9**.

Table 9 The experts and scholars in the expert group in this study

No.	Professional field
A	A professor and Doctor specializing in museum exhibition design research, public space, and environmental design
B	An associate professor in digital media interaction and intelligent technology, museum lighting design
C	A senior researcher working at a national museum, Museology, curator

3.3.3 Sample and population

Population and target audience

This study is based on the concept of “museums designed for all,” aiming to enhance the museum visiting experience for different types and cultural backgrounds of visitors across various age groups through universal design principles. A comprehensive understanding of the diverse needs and satisfaction levels of all visitor types is crucial. Therefore, the target population of this study is visitors to China’s cultural tourism museums (including both Chinese and foreign nationals). The age range was defined as all types of visitors over the age of 7 years. When selecting research samples, visitors who did not meet the following criteria were excluded: (i) preschool children lacking knowledge and cultural awareness; (ii) visitors unfamiliar with museums and their digital media; (iii) individuals without listening, speaking, reading, or writing abilities. It is important to note that, during the selection of study samples for scenario access and behavioral observation research, visitors were not in the sample screening range for (i) Visitors who do not visit the museum exhibition hall (such as finding ways, looking for people, looking for specific information); (ii) Visitors participating in the official explanation activities of the museum; (iii) Visitors to the tour groups.

The target audience grouped into categories based on classification criteria such as age, visitation characteristics (number of people, behavioral traits), cultural background, and motivations and purposes (Kasemsarn et al, 2023), with the target audience segmented as follows: (1). Parent-child families (FC): Family

combinations consisting of children aged 7-12 accompanied by either father, mother, or both parents; (2). Teenage student group (TS): Defined as a middle school student organization consisting of 3 or more individuals aged 13-18. (3). Alone visitors (A): In this study, single visitors specifically refer to young and middle-aged individuals (19-59 years old) visiting alone. When participants are university students, they are first categorized as (4). College Students (CS); (5), Companion visitors who visit with others (CP): In this study, companion visitors refer to visiting groups such as couples, spouses, friends, etc.; (6). The elderly (E): This study defines visitors aged 60 and above as elderly visitors (China's retirement age); (7). Visitors with special needs (SP): Due to the limited number of both foreign and disabled visitors in this study, they were categorized collectively as visitors with special needs.

During the data collection process, the researcher randomly selected different types of visitors on-site and explained the research objectives and details to them. Visitors who agree to participate should be chosen as research samples. The samples in this study were divided into five groups, and the screening details for each group are elaborated as follows:

Group 1: Scenario access for UD evaluation group

A scenario access for UD evaluation in Phase 2 (Objective 2) to further investigate physical barriers that could affect the accessibility of exhibitions containing digital media, as well as the physical barriers to users' spatial behavior and needs. Sample participants were selected from the visitors on-site, characterized by their exhibition viewing behavior, excluding those on tours, looking for directions, or showing signs of fatigue. As the number of visitors in the museum will be affected by holidays and working days, it is impossible to estimate the specific number of samples that can be collected during the survey time. However, according to the relevant literature review and investigation, to ensure a sufficient number of samples, in this study, the number of tracked samples in each museum was determined as the minimum number of tracked samples in each exhibition hall of 5 (for individuals, such as 2 partners, 2 visitors, and so on). If the sample size of 5 people cannot be completed within the survey time, the researchers will continue to observe until the observation records of the 5 people are obtained. There are 5 museums and 7 exhibition halls, so the number of samples obtained is at least 35 people.

The researchers began at 9:00 AM on the survey day, randomly selecting eligible visitors in each target exhibition hall. They explained the purpose and methods of

the study, as well as the participants' rights. Visitors who agreed to participate were identified as research samples. Given that the placement of the media interaction exhibits impacts on their accessibility, the researcher exerted no influence over the participants' intent and method of visiting.

Influenced by the daily influx of visitors to museums, the number of participants in each category varies among different institutions. For the eleven exhibitions across six museums, a total of 162 groups comprising visitors from various age groups and cultural backgrounds were invited to take part in the survey. The quantity and type are shown in **Table 10**.

Table 10 The number of participants in the Scenario Access for the UD evaluation group

NO.	Museum	Visitor type							Total
		F-C	CP	A	CS	TS	E	SP	
1	SME	18	14	13	8	10	10	4	77
2	MCM	3	2	3	3	2	2	2	17
3	CWM	4	3	2	3	2	3	2	19
4	WYM	3	2	3	2	2	2	1	15
5	SWM	2	3	2	2	4	3	2	18
6	GCM	2	2	2	4	3	2	1	16
		32	26	25	22	23	22	12	162

Group 2: Interview group

In Phase 2 (Objective 2) of the research, the samples of this Interview group participated in a semi-structured interview after completing their museum visit. The purpose of collecting data from this interview group is to further understand the constraints and obstacles encountered by visitors during their visit, as well as their perspectives on interaction and interpretation with the museum environment and digital media.

On research days between 4 and 5 p.m. in the museum rest area, researchers randomly selected visitors of different ages, cultural backgrounds, and behavioral characteristics for semi-structured interviews. The researchers excluded respondents who had not visited the case study exhibition hall, had no impression of the exhibition content and form, and could not understand what digital media interaction was through 2-3 questions for pre-visit screenings. Taking the Shanghai

Museum East Branch as an example, the pre-visit questions included: Did you visit the Bronze Gallery? Do you still have an impression of this gallery? Did you notice the digital interactions in the exhibition? A total of 80 valid interview samples were obtained. The number and characteristics of participants are shown in **Table 11**.

Table 11 The number of participants for the interview group

NO.	Museum	Visitor type							Total
		F-C	CP	A	CS	TS	E	SP	
1.	SME	4	4	3	5	4	5	/	25
2.	WCM	1	2	1	/	/	2	2	8
3.	CWM	2	2	2	4	/	2	2	13
4.	WYM	2	3	2	2	/	2	/	11
5.	SWM	/	3	2	2	5	3	2	17
6.	GCM	2	4	3	4	4	2	/	19
		11	18	15	17	13	16	6	94

Group 3: behavior observation group

This group constitutes a participant sample engaged in non-contact direct observation. The purpose is to explore whether digital exhibits can attract the attention and interactive participation of different types of visitors in Phase 3 (Objective 3). Researchers observe and conduct surveys on visitors' behavior in exhibition environments from the perspective of a visitor, describing the impact of the exhibition environment's language on the behavior and experience of other visitors.

The sample size is the number of visitors recorded by the researchers for each digital media exhibition, recording the length of stay and the number of people staying during the full exhibition experience. Each device was limited to 15 minutes, with those approaching within half a meter of the exhibit considered valid samples. These visitors were categorized based on appearance, physique, and interaction status as distinguishing criteria for visitor types. Visitors exhibiting wayfinding behavior, fatigue, or other non-visiting activities were excluded from this phase of the study. If it is the same group of visitors who return during the visit, their attraction is still recorded only once, and the initial comprehensive calculation will continue to be performed. The research process does not interfere with visitor behavior, and it will not cause any inconvenience or safety risks during the visit. When visitors notice the researchers, an explanation will be provided. If visitors do

not agree to participate in the study, their behavioral characteristics and verbal communication will not be recorded.

The key point of non-contact direct observation is that the individuals being observed are unaware of the observation, and researchers refrain from interfering with visitors' behaviors for any reason (Li et al., 2022; Yan, 2009). During the data collection process, the investigator stood in concealed locations near the digital exhibits, responsible for observing and recording visitors passing by each digital exhibit. This study references the IAE scale proposed by Lo et al. (2023); the recorded content includes the duration of visitors' stay and their level of engagement in front of digital exhibits, as well as their interactive behaviors and verbal communication with digital media during their stay. Through observational records using scales, attraction scores for different types of visitors can be obtained as quantitative data for user participation.

Throughout the research process, behavioral data from 6,024 visitor instances were recorded, with specific numbers and groupings shown in **Table 12**. Since the same visitor might appear at different digital exhibits during different periods, the recorded visitor instances do not represent the museum's actual foot traffic.

Table 12 The number of participants for the On-site observation group

NO.	Museum	Visitor type							Total
		FC	CP	A	CS	TS	E	SP	
1	SME	443	266	345	127	123	141	73	1518
2	WCM	213	323	283	199	52	225	21	1316
3	CWM	296	271	133	155	0	109	19	983
4	WYM	372	249	268	125	35	139	0	1188
5	SWM	101	238	90	194	233	112	51	1019
		1425	1347	1119	800	443	726	164	6024

Group 4: On-site Questionnaire Group

This group of samples participated in the post-visit questionnaire survey, with visitors who completed the museum tour being selected as participants. Researchers randomly selected volunteers according to the target demographic to collect sample data for Phase 3 (Objective 3) of the study to obtain visitors' attitudes and experiences regarding digital interpretation. Since answering the questionnaire requires certain reading and comprehension abilities, the age range of participants in this group is between 18 and 60 years old. Visitors fill out a questionnaire at the end of their visit.

Questionnaires were used as research tools, with visitors completing the surveys at the end of their visits. The questions were designed based on a literature review and pretested with three experts and a group of 10 individuals to ensure satisfactory content validity. From February to March 2025, every Wednesday and Saturday from 2:00 to 4:00 p.m., researchers conducted questionnaire surveys and collected data in the lobby rest areas of five museums. Researchers randomly selected volunteers from the target population. Since some exhibition halls in various museums had limited digital media applications and thus fell outside the scope of this study, the questionnaire included a pre-survey section, **Table 13**, to screen visitors who had experienced digital interpretation and demonstration setups, ensuring the validity of the collected data.

On-site surveys were conducted at five museums with over 238 participants, averaging 5-10 minutes to complete the questionnaire. All questionnaires were filled out by visitors immediately after their visit. After excluding participants who were unaware of what digital media is or did not notice the digital media exhibits, 139 valid questionnaires remained.

Table 13 The sample of preliminary investigation questions.

Preliminary investigation of the question (the sample of the Shanghai Museum East)	
Q1	I visited the Bronze Gallery, Ceramic Gallery, Numismatics Gallery, and Jade Gallery of the museum.
Q2	I know what the digital media interpretation in the museum refers to.
Q3	I noticed the digital exhibit in the gallery. Such as projections, videos, or interactive games.

Group 5: Questionnaire group

This sample was among the participants participating in the questionnaire, so the age range was determined as adults between 18 and 60 years. Collect questionnaire data for the research of Phase 4 (Objective 4) to evaluate whether the improved digital exhibition based on design guidelines is accepted and appreciated by visitors of different ages and cultural backgrounds.

The population of this study was determined as the total number of visitors to the museum. According to the number of tourists received by national museums in 2023 released by the China Association of Museums, from 2019 to 2022, the number of tourists due to the impact of COVID-19, the total population sample is 66,000 tourists received by national (China) museums in 2023.

The sample size for the study is determined using the Krejcie and Morgan formula for calculating the sample size for a finite population. Where: n = sample size; N = population size; e = acceptable sampling error; x^2 = chi-square of degree of freedom 1 and confidence 95% = 3.841; p = proportion of population (if unknown, 0.5). The total population size(N) is 6600,000 visitors, a 95% confidence level, a margin of error of 5%, and a response distribution of 50%. The sample size is calculated as approximately 384 visitors.

$$n = \frac{X^2 * N * P * (1-P)}{(ME^2 * (N-1)) + (X^2 * P * (1-P))}$$

The samples are visitors who have visited the museum or are about to visit the museum in the cultural tourism scenic area (the gorgeous district of Lao Men Dong in Nanjing). Simple random sampling was used to select visitors to ask about their wishes. The Participants should cover visitors of different ages, genders, and types as much as possible. In order to ensure that the number of valid questionnaires is greater than or equal to 384, 60 people from each of the 7 groups of visitors (a total of 420 people) were sampled and invited to participate in the questionnaire survey.

3.4 Research Process, Method, and Tools

In this section, the research process and tools will be introduced according to the four research phases and research objectives. **Figure 9** shows the research process, method, tools, and main outcomes.

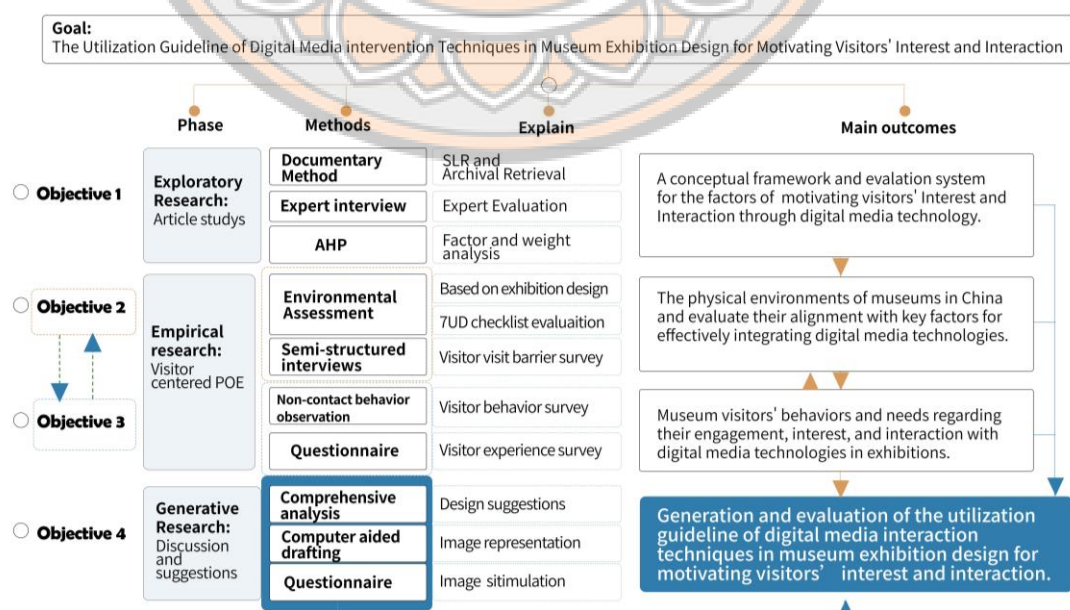


Figure 9 Research process, method, tools, and main outcomes

3.4.1 Phase 1 (Objective 1):

Establish the conceptual framework and evaluation system for the factors of motivating interest and Interaction through digital media technology

By systematically and deeply analyzing existing research literature on museum exhibitions, digital media interactive technologies, and visitor interests and interactions, we can gain a clearer and deeper understanding of the application of digital media interactive technologies in museum exhibitions under the current context of the integration of culture and tourism. Therefore, at this stage, the study adopted the systematic literature review (SLR), literature search in different databases, interviews, and AHP with an expert group to obtain relevant research and foundational frameworks, and create a systematic evaluation system on how to enhance visitor interest and engagement in museum exhibition design through the use of digital media technology.

(1) Documentation method and tools

(1.1) SLR

In the initial stage of this study, the literature method was used to conduct a comparative study of the current relevant literature on the development of museum exhibitions, facilitating the extraction of effective elements for subsequent case studies. However, discussions about museum exhibition experiences and their relation to museum digital media are complex and diverse, making it necessary to systematically organize the research findings.

This research employed a systematic literature review (SLR) and bibliometric analysis techniques to develop an extensive research framework. The literature review was executed in the main databases, Scopus and ScienceDirect, with Google Scholar serving as an auxiliary database when data were not found in Scopus or ScienceDirect. Four key terms, as delineated by prior researchers, have been systematically utilized throughout this examination of the issue: (i) Cultural Tourism Museum, (ii) Digital Media/ Interpretation/ Interaction/ Digital storytelling, (iii) Visitor Experience, and (iv) Universal Design. To improve the efficiency of the search process, the study adopted the Preferred Reporting Items for Meta-Analyses (PRISMA) framework (Li & Du, 2023). The implementation steps are as follows:

Step 1: A search integrating relevant keywords was executed in Scopus and ScienceDirect by employing Boolean operators to pinpoint articles featuring the designated key terms in the title, abstract, or keywords: (Cultural

Tourism * Museum) and (Universal Design) * (Digital Media * Experience). All articles that conformed to the Boolean search parameters were input into CADIMA to remove duplicates, resulting in 2,538 articles. Throughout the retrieval process, it was observed that several documents were related to universal design, museum design, and digital media interaction design. Therefore, a keyword search was conducted on Google Scholar using the combination of (Universal Design) and (Digital Media * Experience *museum). The keyword search produced 54 articles, which were chosen after a double examination of their titles and abstracts.

Step 2: The articles discovered in the three databases of CADIMA were subsequently refined to exclude 70 duplicate entries, 9 articles that did not include abstracts, and 18 articles written in languages other than English, culminating in a final count of 97 pertinent articles.

Step 3: There were of 2,213 pieces of literature were excluded through a thorough analysis of their titles and abstracts, confirming they were not closely related to physical museums and digital media design. Subsequently, 281 articles were deemed eligible.

(1.2) Literature search in different databases

Through a systematic literature review, it was found that there is limited research on storytelling in digital media, digital exhibition environments, and visitor digital experiences. Building on this, further document and archive searches were conducted. During this phase, researchers searched for studies in three main databases: CNKI (China National Knowledge Infrastructure), Scopus, and ScienceDirect, supplemented by secondary databases such as Google Scholar and Airiti Library. (When the information was not available in the core journals or doctoral dissertations on CNKI, Scopus, or ScienceDirect, Google Scholar and the Chinese Academic Library Database were used.).

The key research focuses on three aspects that affect visitors' interest and interactive experience: information sources, exhibition environment, and visitor behavior and attitudes. (i) The interpretation of exhibition content and information through digital (interpretation and interaction) technology; (ii) The consistency between the museum exhibition environment and digital media interactive technology; (iii) The interplay between the exhibition setting and visitor actions in the context of digital media technology's impact; (iv) Visitor interaction and experience evaluation. Through a systematic review of 181 articles and the collection of various researchers' academic

viewpoints (59 articles), a relatively clear conclusion has been reached regarding the issues explored, as detailed in **Table 14**. The elements that affect visitors' interest and interaction in museums and museum exhibition design have been identified.

Table 14 Results of research with keywords from three databases

Database	Search Terms (Titles, Abstracts, and Keywords)	Total (1 st Pass)	Total (2 nd Pass)	Total (3 rd Pass)	Total	Ref.
Scopus		2440	2409	222		83
ScienceDirect		98	41	16	281	8
Google Scholar	(museum*cultural-tourism) and	54	46	43		35
CNKI	(UD)*(digital media	/	/	/	/	
Airiti Library	interaction*visitor experience)	/	/	/	/	59

(2) Expert interviews

According to Jakob Nielsen (1993), Heuristic Evaluation is a method used during the observation of software interface design, which attempts to provide a perspective to discuss the strengths and weaknesses of this interface design. Its purpose is to identify design issues in the user interface, allowing us to notice problems and improve the design. Through literature review, it was found that heuristic evaluation is widely applied in the study of museum exhibitions and visitor experiences (Cinotti et al., 2004; Evans & Sterry, 1999; Hatala & Wakkary, 2005; Stock et al., 2007).

Therefore, this stage is the first assessment by experts: it is an evaluation of the factors that influence the enhancement of visitors' interest and interaction through the use of digital media technology. Based on the design factors that affect visitors' interest and interaction, as derived from the literature review, the interviews were conducted with three experts to identify the conclusions and to assess the feasibility and importance of these elements. The assessment elements are modified based on the results to serve as preliminary information collection and for the design of an on-site investigation.

This interview is based on a preliminary collated factor table, adopting an open-ended interview format to engage in dialogue with experts. During the process, researchers will explain the meaning of the factors to the experts and delve into their perspectives on these factors. Experts are requested to assist in the preliminary screening of factors by eliminating those with minimal relevance.

(3) Analytic Hierarchy Process (AHP) and materials

This segment will leverage the summarized indicators and factors affecting different visitors' engagement and interaction by using the Analytic Hierarchy Process (AHP) methodology for scoring (Chiang, 2022). The multilevel factors and indicators affecting visitors' engagement in digital interpretation are organized, arranged, and simplified for specific purposes. Upon assessments conducted by three specialists in museum and digital media fields, the factor weight analysis methodology, drawing on their professional knowledge and experience in museum and exhibitions digital interpretation design, not only objectively ascertains the relative significance of factors affecting visitors' engagement behaviors but also offers more dependable guiding principles for future planning and design (Chiang, 2022).

(3.1) Construction of AHP hierarchy

The AHP is a systematic decision-making method proposed by Professor Thomas L. Saaty (1971) of the University of Pittsburgh. For decision-makers, it helps simplify complex problems by gathering expert opinions and breaking down intricate evaluation issues into clear hierarchical structures of factors. These are then measured through rating scales to serve as reference information for decision-making (Chiang, 2022). The AHP consists of two parts in its application: one is the establishment of the hierarchy, and the other is hierarchical evaluation. The AHP method involves delegating complex problems to experts and scholars to assess the key elements, which are then represented in a simple hierarchical structure. Subsequently, pairwise comparisons of these elements are conducted using a scale evaluation to establish a matrix. The eigenvector is then calculated to determine the weights of various elements within the hierarchy. Finally, the consistency of the pairwise comparison matrix is examined to check for errors and determine its suitability as a reference (Huang, 2003). Using the AHP analysis method to establish a hierarchical relationship can effectively systematize the problem. As shown in **Figure 10**, the problem is divided into four levels: the goal of solving the problem, the objectives for achieving the goal, the indicators for measuring the objectives, and the considered alternatives. This study establishes the hierarchical framework for the AHP analysis method through literature review and expert interviews (Russo, 2015).

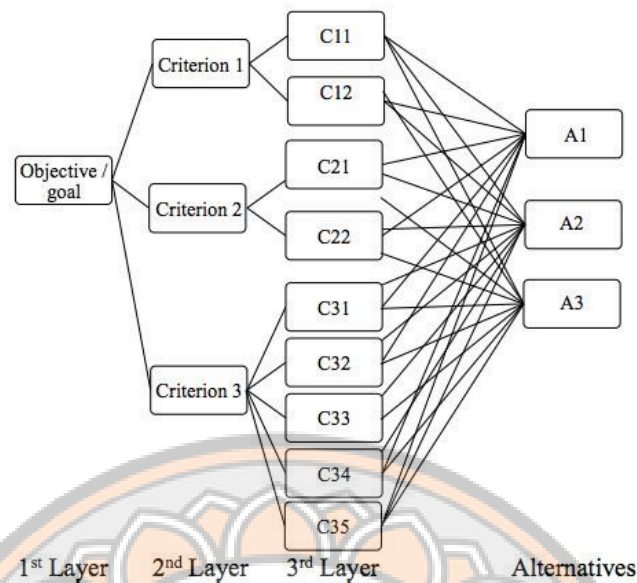


Figure 10 AHP Structural Diagram in this study

Source: Russo, 2015

(3.2) Evaluation of hierarchical factors

After establishing the hierarchical structure, the hierarchical factors can be evaluated by constructing a pairwise comparison matrix. The format shown in **Table 15** is used to facilitate pairwise comparisons of items within each level. Furthermore, respondents are requested to compare the importance levels of the two and provide ratings accordingly. Based on the scores assigned by each expert, a hierarchical matrix can be constructed in **Table 16**. The matrix data is then imported into EXCEL software, where the weight of each item is calculated using the square root method, along with the approximate values of the matrix eigenvectors. The consistency of the data is also examined (Huang, 2003; Wen, 2023). The steps are as follows:

Table 15 The sample of hierarchical factors evaluation format

	A		V		S		W		E		W		S		V		A	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Factor1																		Factor2
Factor1																		Factor3
Factor2																		Factor3

Evaluation scale description :

1-Equal Strong; 3-Weak Strong; 5-Strong; 7-Very Strong; 9-Absolution

Table 16 The sample of hierarchical matrix scores provided by expert A

Expert A			
	Factor1 Design Features	Factor2 Environment Features	Factor3 Visitor Features
Factor1 Design Features	1.00	9/3	9/7
Factor2 Environment Features	3/9	1.00	4/8
Factor3 Visitor Features	7/9	8/4	1.00

Step 1: Calculate the n th root of the product of elements in each row of judgment matrix A, with the formula as follows:

$$M_i = \sqrt[n]{\prod_{j=1}^n a_{ij}}$$

Step 2: Normalize M_i , the formula is as follows:

$$W_i = \frac{M_i}{\sum_{i=1}^n M_i}$$

Step 3: Calculate the maximum eigenvalue of the judgment matrix. The formula is as follows:

$$\lambda = \sum_{i=1}^n \frac{(Aw)_i}{nw_i}$$

Step 4: A Consistency test is conducted on the judgment matrix. CI is the consistency index that measures the deviation of the judgment matrix. $CI = (\lambda - n)/(n - 1)$. The larger the CI value, the worse the consistency of the judgment matrix. When CI is 0, the judgment matrix achieves complete consistency. CR stands for Consistency Ratio, calculated by the formula: $CR = CI/RI$, where RI represents the Random Consistency Index, shown in **Table 17**. When the CR value is less than 0.1, the consistency of the judgment matrix is deemed acceptable (Wen, 2023).

Table 17 The table of mean random consistency indicators RI

n	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41
n	9	10	11	12	13	14	15	
RI	1.46	1.49	1.52	1.54	1.56	1.58	1.59	

Source: Wen, 2023

3.4.2 Phase 2 (Objective 2):

Implement POE for assessing the museum environment performance, containing digital media interaction

In Phase 2, a series of case study methods were employed to examine the physical environments of popular museums in China and evaluate the alignment between these environments and the key factors for effectively integrating digital media technologies to enhance museum tourism. The research process consists of two steps. The first part involves preliminary investigations, where researchers document the design aspects of digital interactions incorporated in exhibition spaces and identify obstacles encountered by visitors in the exhibition environment through exhibition walkthrough and environmental measurements. The second part involves scenario-based access reviews utilizing the UD checklist, conducting a UD evaluation of the exhibition environment from the visitor's perspective to explore the relationships between environmental barriers, design factors, and UD. During this process, a second heuristic evaluation was conducted, with three experts assessing the research tools. The study at this stage was carried out in the five case museums (No.1- No.5) and one comparative case museum (No.6), shown in **Table 8**. Before the investigation study, the researcher submitted explanations and applications to the relevant management of the case museum. It will not affect any visiting activities of the visitors. The specific implementation process and research tools are as follows:

(1) Exhibition environment measurement based on design factors

Researchers conducted a museum exhibition walkthrough, observing exhibition visits and behaviors across 11 exhibition halls in six museums, while using an environmental feature assessment checklist to record exhibition environmental characteristics, analyzing and identifying general research questions. The records included several sections: design features of digital interactions and measurements, and evaluations of exhibition hall environments containing digital interactions. The aim was to investigate the current design status of digital interactive technologies in newly built museums prevalent in China, as well as the visiting obstacles and limitations caused by digital interactions for visitors.

(1.1) Design features of digital interaction

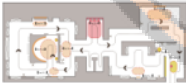
Based on the research outcomes from the first phase, the factors and indicators influencing visitor interest and interaction, as presented in Appendix A, **Table A1**, the research team designed a feature documentation form for digital

(1.2) The assessment of the museum exhibition environment containing digital media interaction based on design factors

In the previous stage (1.1), the current state of digital interaction design features was investigated and statistics. This stage involves measuring the exhibition environment based on design factors, conducting a critical examination of the exhibition space and environment to identify the issues faced by various types of users. The research tools include audit checklists and computer-aided drawings to map and review various digital interactive installations along with their respective circulation patterns and functional aspects, aiming to gather information on the difficulties and problems encountered by users and visitors.

Based on the results of Phase 1, the core design factors influencing visitor behavior and engagement in museum exhibitions have been identified. Based on **Table 19**, an accessibility environment evaluation checklist (approved by the expert panel) was developed to systematically document environmental characteristics and specific issue descriptions within exhibition spaces. It further explores existing problems and barriers in digital media interactive environments.

Table 19 The sample of the environment assessment checklist for accessibility

Exhibition environment assessment checklist for accessibility based on design factors			
Museum: Suzhou Museum West / International Hall		Date:	
·Exhibit: [Sw9-1]	Design features and elements, and Evaluation criteria	Level	
Cartoon video wall	*A. Interaction and physical environment, B. content	Good	Fair Poor
--Site of the exhibit	A1. The location of the digital device is clear and easy to access.	√	
	A2. There is plenty of space to interact and watch	√	
	A3. The movement of exhibition items is clear, and there is no obstruction to the tour route with the digital media devices		√
	A4. Flexible visiting routes and ignoring the time will not affect the exhibition structure through digital interaction.	√	
- On-site Photo:	A5. Interactive exhibit items can be identified and recognized		√
	A6. The exhibit is running normally and can be operated as expected.		√
	A7. The light and shadow from digital media are suitable and will not affect the surrounding exhibits.	√	
	A8. The exhibit is ergonomically designed, with appropriate viewing/operating space/Scale		√
	A9. The scale of interaction is reasonable, and there are no difficulties		√
--Description of the exhibits:	B1. Have clear operating instructions or an introduction	√	
	B2. An attractive title or image.		√
·This is an animated	B3. The content is clear and logically related to the exhibition content.	√	
projection wall located	B4. Content expansion. The information load will not be high or low.		√
on the left side of the	B5. Artistic expression, consistent with the exhibition content	√	
exhibition hall	B6. Clear information t conveyed, which will not confuse people.	√	
entrance.	B7. Interpretation of content and knowledge, Moderate difficulty		√

Source: Ai & Phaholthep, 2025

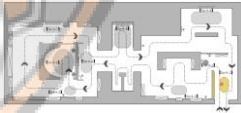
The investigator conducted gallery traversals and behavioral observations in six museums, measuring and recording exhibition environmental characteristics using an environmental feature assessment checklist. During the data analysis phase, the floor plans of the exhibition halls drawn in the previous step were utilized to analyze the constraints and obstacles encountered by visitors during their tours.

(2) Scenario access for 7UD checklist evaluation

This is a scenario access audit completed by observing and recording the experiences of different types of visitors by using the 7UD evaluation checklist.

Utilizing the criteria of 7UD and referencing the segment of the access audit checklist proposed by Filová et al. (2022), an evaluation checklist (Table 20) was developed to assess the physical environment and visitor experience in museum exhibitions influenced by combined digital media. This document highlights existing accessibility concerns pertaining to the physical setting, media engagement, and the content of exhibitions. Three specialists were enlisted to utilize and assess the tool. Following their feedback, the tool underwent revisions to ensure its readiness for deployment in the survey. The checklist includes a total of 31 details, which are fully presented in Appendix A, Table A2.

Table 20 Example of a segment of the 7UD checklist in the access audit

Environment Evaluation checklist of digital media design for all based on the seven principles of UD									
Museum: Suzhou Museum West Location: International Hall			Exhibit Number: [SW9-1]						
*Visitor types: FC - Family with children; S - Single middle-aged visitor; Ts - Group of four or more teenagers and students; E - Elderly audience; CP – With friends, partners, or family); SP - Audience with special needs; Cs - College students.									
*Y-meets the requirements; N-does not meet; F- partially meets the requirements; O- element does not exist									
UD1 Equitable Use			Target Visitor						
Evaluate criteria	Criteria details		Fc	S	Ts	E	Cp	Cs	D
UD1-1	☒ There are enough channels/entrances to enter.	☐ Y	√	√		√	√	√	√
Can all visitors watch/participate/enter this exhibition area or space?	☐ There are equivalent entrances with ramps.	☐ N	O	O	O	O	O	O	O
	☐ There are visual images and guidance suitable for visitors of all types.	☒ F	√						
	☒ The site of the exhibit will not be ignored due to the choice of route.	☐ O	√				√		
	UD1-2	☐ The exhibition form and style are suitable for all types of visitors, with no specific audience guidance.	☐ Y	√				√	
Can all visitors have an equal visiting experience?	☐ Accessible, adjustable operational forms to accommodate different types of visitors.	☒ F	√	√			√	√	
	☒ Multilingual or visual information caters to various types of visitors.	☐ O	√	√	√	√	√	√	√
	UD1-3	☒ Good content structure can be watched/understood without difficulty and does not require prior learning experience.	☒ Y	√	√	√	√	√	√
Are the operation and content of the exhibit suitable for all?	☒ The operation and understanding of the exhibit will not be affected by ignoring other exhibition contents.	☐ N							
	☐ Visitors can obtain knowledge based on their understanding.	☐ F	√	√	√	√	√	√	√
		☐ O		√					

Source: Ai & Phaholthep, 2025

Investigators invited a total of 162 diverse visitors from Group 1 to participate in a scenario assessment of UD evaluation in six museums. When participants entered the exhibition hall, the researchers began tracking and observing, recording the participants' operations and interaction conditions with various digital media exhibits. During natural observation, the participants' prevalent behaviors and operational limitations, coupled with their experiences, were subsequently evaluated against the 7UD checklist. This methodology was employed to pinpoint spaces and media interaction facilities that cater to the requirements of diverse visitor types, as well as to assess the effectiveness or shortcomings of these spaces and digital media devices.

The collected quantitative data, which included the 7UD evaluation scores for 125 digital interactive exhibits spread across 11 exhibition halls, were input into SPSS 27.0.1. All outcomes were documented, identified, analyzed, and then classified. Issues were assessed group-by-group and isolated based on frequency levels, culminating in a percentage-based system. The detailed instructions are as follows:

Import the initial UD evaluation data for each digital exhibit, obtained during the assessment phase, into SPSS 27.0.1 for recoding and analysis. Assign a value of 1 for compliance (Y) and 0 for non-compliance (N), thereby calculating the 7UD scoring rate percentage. This is accomplished using basic statistical formulas, resulting in a percentage system. (i). Conduct descriptive statistics and cross-variant analysis to ascertain the influence of various indicators on visitor behavior. Classify the outcomes into five levels according to the scoring rate: 0-20% = Failed, 20-40% = Poor, 40-60% = Fair, 60-80% = Good, 80-100% = Excellent. (ii). Conduct a bivariate analysis using SPSS 27.0.1 to examine the correlation between visitor attributes and UD.

(3) Semi-structured interviews with museum visitors

As part of the post-occupancy evaluation from the visitor's perspective, the focus of this study is to further explore the barriers and needs encountered by different types of visitors during their museum visits through interviews. Investigators randomly selected visitors at the museum exhibition site, regardless of whether they were satisfied or dissatisfied with the exhibition or whether they were willing to engage in digital interactions. After obtaining informed consent, interviews were conducted. Visitors who were wayfinding or not paying attention to any digital exhibit information were excluded. Among the visitors who participated in the interviews, six exhibited implicit resistance during the interviews. Although they understood the content of the study and the confidentiality agreement and agreed to be interviewed, their responses remained

superficial, such as “I think it’s good” or “I have no opinion, I’m just looking around,” leading them to withdraw from further interviews. Ultimately, 80 sets of valid interview samples were obtained. The number and characteristics of these participants are presented in Sample Group 2 (Interview Group).

The core of this research focuses on exploring, through in-depth peer-to-peer interviews, what aspects of the exhibition environment are important to visitors and what types of attractions and barriers different visitor groups encounter during their visits. Special attention is given to identifying the factors that influence their experience with digital exhibitions. In order to obtain more attitudes and perspectives, the interviews did not set specific questions but instead followed an outline, during which a series of “what” and “why” questions were raised to grasp the reasoning of the interviewees. This technique is referred to as the Laddering Technique, designed to systematically reveal reasoning across different levels of abstraction (Ai & Phaholthep, 2025; King et al., 2025). The interview outline was established based on three aspects, including inner-level feelings, operational experiences, and satisfaction with gains (Zhang et al., 2018; Liu, 2020). **Table 21** outlines the potential questions that could be posed during the interview process.

Table 21 Outline of semi-structured interview

Outline of semi-structured interview	
Questions that may be posed to interviewees during the interview	
1	Why did you come to the museum? Do you like museums?
2	Which digital exhibit attracted you? What was the reason it caught your attention?
3	What are your thoughts on the design of the digital exhibits? Did it meet your expectations?
4	Did you use the digital interactive device? How was your experience with the operation?
5	What issues have you encountered while engaging in digital interpretation and interactions?
6	What issues do you encounter during the process of acquiring knowledge or information?
7	How do you find the exhibition environment?
8	Do you have any other terrible experiences?
9	What suggestions do you have for the digital exhibits in this museum?

Source: Ai & Phaholthep, 2025

3.4.3 Phase 3 (Objective 3):

Implement POE for assessing visitor behavior and visiting experience with digital media interaction in the museum environment

In phase 3, a series of audience surveys was conducted to investigate museum visitors’ behaviors and needs regarding their engagement, interest, and

interaction with digital media technologies in exhibitions. The research process consists of two steps. The first part involves behavioral observation, where qualitative and quantitative data on the involvement levels of different types of visitors and the attractiveness of digital exhibits are obtained through the IAE scale. The second part entails an experience questionnaire survey to collect quantitative data on visitor characteristics and experiences, aiming to explore the relationships among digital interaction, exhibit attractiveness, and the exhibition environment. During this process, a third heuristic evaluation was conducted, with three experts assessing the research tools. The research at this phase was conducted in 10 exhibition halls across museums numbered No. 1 to No. 5, as shown in Table 8. Before the visitor investigation study, the researcher submitted explanations and applications to the relevant management of the case museum. It will not affect any visiting activities of the visitors. The specific implementation process and research tools are as follows:

(1) Non-contact behavioral Observation Utilizing the IAE Scale

The effectiveness of exhibition communication relies on the active participation of visitors, which plays a crucial and foundational role in exhibitions (Fu & Pan, 2023). Therefore, at this stage, behavioral observation methods are employed to comparatively analyze the attraction power (AP) of multimedia interpretation devices in the exhibition hall to audiences (Lo et al., 2023; Wang & Chu, 2010; Wu, 2012; Yan, 2009). This observational study aims to investigate, from a bystander's perspective, whether and how different types of visitors engage with and interact with digital exhibitions. Particular attention is given to the intentions and behaviors of various visitor types when participating in and interacting with digital exhibitions.

Investigators conducted behavioral observations in the target museum's exhibition halls every Wednesday and Saturday from 9:00 AM to 11:30 AM and 1:00 PM to 4:00 PM. Each exhibit is limited to 15 minutes, and visitors within half a meter of the exhibition object are considered valid samples. Visitors exhibiting wayfinding behavior, fatigue, or other non-visiting activities will be excluded from this research phase. If the same group of visitors returns during their visit, their attraction is recorded only once, and the initial comprehensive calculation will continue. The entire research process recorded the visiting behavior data of 6,024 visitor instances. The data and characteristics are presented in Group 3 (behavior observation group) of the sample.

Visitor observation has long been considered a reliable and effective method for analyzing user behavior in museum environments (Yalowitz & Bronnenkant,

2009). The key aspect of this observation is that the observed individuals remain unaware of being observed, and researchers do not interfere with visitors' behaviors for any reason (Li et al., 2024; Yan, 2009). During the data collection process, investigators stood in concealed locations near the digital exhibits, responsible for observing and recording visitors passing by each digital exhibit. The recorded content included the duration of visitors' stay in front of the digital interpretation exhibits and their level of engagement, as well as their interactive behaviors and verbal communication with the digital media during their stay. When visitors notice the researchers, the researchers will explain the uses and benefits of the study in detail. Explain the use of the observation records (Including written records, photos, and audio records, interview related to visiting the exhibition), and sign the informed consent form. If the observer does not agree to participate in the study, the researcher will delete the records immediately, and any information that can be used to identify the visitor will not appear in the study.

Since audiences exhibit various behaviors during the visiting process, it is necessary to establish measurement criteria for observation (Lo et al., 2023), as shown in Table 22. This study refers to the visitors' behaviors bio IAE (Ignore, Attend, and Engage) scale (Lo et al., 2023; Shiang, 2015), which features the inclusion of stopping, viewing time, and human factors influence in the observation items, and judges the attraction power and attention level of digital device to the visitors based on their behavior: "Successful Engage", "Engage", "Attend", and "Ignore", are rated in order with 3, 2, 1, and 0 points. It should be noted that only those who successfully engage with the digital interpretation will be awarded 3 points; failure to fully watch the interpretation, unsuccessful attempts to operate, or focusing on watching others operate will result in 2 points. Visitors who notice the digital interpretation but do not stop or enter within 1 meter of the device without acknowledging it, will be considered as having ignored it - 0 points. If it is the same group of visitors returning during the tour, their AP is still only recorded once.

The number of revisits, learning behaviors, communicating behavior, interaction or playing behaviors, and photo-taking behaviors, which can reflect visitors' level of involvement, can also be used in combination with AP as additional indicators to reflect the appeal of digital interpretation to visitors (Chin, 1998; Lai & Qian, 2013; Li et al., 2024).

Table 22 The sample of visitors' behaviors bio IAE scale

Digital media attractiveness record for different types of visitors												
Museum: WCM										Date: 25.01.25		
Location: Natural Heritage Gallery - "Wu Wind"										Page: 11-1		
*Visitor types: FC: Family-Child; A: Alone, middle-aged visitor; T-S: Group of four or more teenagers and students; E - Elderly visitors; Cs - College students. C-P - With others (friends, partners, family members); S-P- Visitors with special needs;								Digital Device Number and Location Map: 				
Item	W12-1							Record time				
NO.	Visitor Types							Time	Score Based	Add	Mark	
	FC	A	TS	E	CP	CS	SP					
E.g.												
1.												
2.												
3.												
4.												
5.												
Observation notes:												
*Scoring Criteria:												
[0] Ignore: The visitor is within 1 meter of the device but is not attracted.												
[1] Attend: The visitor looks at the exhibit for at least two seconds before departing after a brief interval.												
[2] Engage: The visitor stays and tries to operate/view the digital interpretation device, but fails.												
[3] Successful Engage: The visitor actively participates and successfully operates/views the exhibit, or parents are willing to guide children to understand the exhibition content and operate the device.												
[+1] Involvement: Number of return visits, learning behaviors, communication behaviors, etc.												

Through the systematic data collection using the IAE Scale, attraction power (AP) scores of different types of visitors can be obtained as quantitative data for visitor engagement. This study ultimately observed and recorded 140 digital interpretation devices and 6,024 visitors' IAE quantitative data. In SPSS 27.0.1, the raw data were used for further descriptive statistical analysis, resulting in (1) the mean IAE score of digital interpretation devices for each museum, (2) the score distribution and the proportion of the visitors, and (3) the mean IAE score of each type of digital interpretation device for various target audiences. In this phase, only digital devices with an average score of 2 or above are defined as having attracted visitors' attention, in achieving the desired effect of the digital interpretation device being attractive to the visitor, as per this research study.

(2) Post-visit questionnaire based on visitor experience

To further investigate the factors influencing visitors' interest and engagement, such as visitor characteristics and motivations, post-visit experience questionnaires were employed to survey different types of visitors regarding their attitudes and experiences toward digital interpretation. The sample group consists of various types of visitors to the case museum. Researchers randomly selected

volunteers based on the target demographic. The sample group for this phase of the study is detailed in Sample Group 4 (on-site questionnaire group) of the sample.

On every Wednesday and Saturday afternoon from 14:00 to 16:00, researchers collected data through questionnaires conducted in the lounge areas of five museum lobbies. Visitors filled out the questionnaires upon completing their visits. Since some exhibition halls in various museums featured minimal digital media applications and thus fell outside the scope of this study, the questionnaire included a pre-survey section, **Table 23**, to screen visitors who had experienced digital interpretation and demonstration setups, ensuring the validity of the collected data (Liu, 2020). All questionnaires were completed on-site by visitors after finishing their tours. Over 238 individuals participated in the survey across the five museums, with an average completion time of 8 minutes per questionnaire. After excluding participants who were unaware of digital media or had not noticed digital media exhibits, 139 valid questionnaires remained.

Table 23 The sample of preliminary investigation questions

Preliminary investigation of the question (the sample of the Shanghai Museum East)	
Q1	I visited the Bronze Gallery, Ceramic Gallery, Numismatics Gallery, and Jade Gallery of the museum.
Q2	I know what the digital media interpretation in the museum refers to.
Q3	I have noticed the digital media in the gallery. Such as projections, videos, or interactive games.

The questionnaire serves as a research instrument. The questions were crafted following a literature review and pre-tested to guarantee content validity (Liu, 2020; Wu, 2014; Zhang et al., 2018). The first part of the questionnaire covers the demographic variables of the respondents and their motivations and expectations for the visit. The second and third parts of the questionnaire constitute the main content of the questionnaire, as shown in **Table 24**. Each question is rated using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, some questions also include an option for reasons. The second part of the questionnaire gathered visitors' experiences at the visceral and behavioral levels with various digital interpretation technologies during their visit. By integrating the user experience of digital products with the impact of heritage tourist experiences, three key areas have been addressed: usability, information/knowledge, and entertainment (Liu, 2020). The third part examined the reflective level of visitors'

experiences to further understand the impact of digital interpretation and presentation on visitors. The whole questionnaire has been shown in Appendix A, Table A3.

Table 24 The sample of the main questionnaire

Level	Items (Partial excerpt)
Visceral	A1 I am willing to participate in digital interpretation and interaction.
	A2 I am satisfied with the experience of digital devices in the museum.
	-Choose the reasons for my satisfaction with the digital device *
	·There was a digital device that I was dissatisfied with, because *
behavior	-The digital devices are easy to approach and operate.
	B1
	Usability -I can obtain the information I want through digital interpretation
	-I can understand the different ways of interaction and participation with various digital devices in a short period.
	B2
	Content -Digital interpretation vividly recreates historical scenes and stories.
	-Digital interpretation technology allows me to better understand knowledge.
	-Through digital interpretation, the content has left a deeper impression on me.
	B3
	Entertain -The way cultural history is presented through a digital exhibit is interesting.
	ment -Digital interpretation provides me with an immersive experience.
	-The entertainment and games brought by digital interaction make me feel relaxed and leisurely.
Reflective	C1 ·The digital interpretation and interaction have met my expectations for the visit.
	C2 ·I am willing to recommend this museum to others, which is due to the digital experience.
	· I visited all the digital interpretations and presentations*.
	· Digital technology has interfered with my visiting experience*.
Note: The * symbol marks the reason option question.	

The data collected by the questionnaire were imported into SPSS2727.0.1 for re-encoding and analysis. The analysis of the questionnaire results is divided into three parts: Demographic and Motivation Analysis; Descriptive Analysis - exploring the needs and characteristics of different types of visitors, and Factor Analysis - the correlation between various variables.

3.4.4 Phase 4 (Objective 4):

Generation and evaluation of the utilization guideline of digital media interaction in museum exhibition design for motivating visitors' interest and engagement.

The objective of this phase of research is to propose strategies for effectively utilizing digital media technologies in museum exhibitions to enhance visitor engagement and promote museum tourism in China. The method and steps are as follows:

(1) Problem identification and generation of multiple solutions

Summarize the results of Objective 1-3, and conduct a comprehensive analysis. The methods employed include descriptive statistical analysis, correlation analysis, and comparative analysis. Ultimately, identify the factors and characteristics that can enhance visitors' interest and interaction through digital interpretation and engagement to propose design guidelines: When designing museum exhibitions, it is essential to meet the needs of various types of visitors, including those of different ages, cultural backgrounds, and behavioral characteristics, without requiring separate designs and using computer graphic design software to create 3D images of the exhibition environment to illustrate design guidelines for further evaluation.

(2) Image stimulation questionnaire survey

To obtain the preferences and acceptance levels of a wide range of museum visitors regarding the improvement proposals, a visitor questionnaire survey was conducted in the final stage of the study. The samples are visitors to the museum on-site. Simple random sampling was used to select visitors to ask about their wishes. The Participants should cover visitors of different ages, genders, and types as much as possible. A total of 384 visitors participated in the questionnaire. The questionnaire was administered as a simple random sample group; the details of sample screening are presented in Sample Group 5 (Questionnaire Group).

An image-stimulus questionnaire based on the Likert scale was adopted at this stage. This is a closed questionnaire composed of a demographics section and images, with its structure derived from the elements and indicators in Phase 2 (Section 3.2.2). The images were created based on computer graphics following the design guidelines in this subsection, all of which are measured on a Likert scale ranging from Not at all (=1) to Mostly (=5), shown in **Figure 12**. Descriptive statistical analysis of the questionnaire results will be performed through SPSS 27.0.1. Volunteers used an online questionnaire (closed) as a sampling unit for the study at the gorgeous district

of Lao Men Dong in Nanjing, especially near the City Wall Museum. To improve the quality of the questionnaire. Participants will be screened through two questions before the start of the questionnaire survey to decide whether participants need/to spend more time answering the main questionnaire.

Image 4

This is an interactive desktop in a museum.



The old design has without operation instructions [the picture above].

The picture below is the new design, where the designer has provided clear and accessible operation instructions, including an accessible color design. This is to ensure that visitors with any characteristics can easily access participation methods, and tactile models have been set up for those with visual impairments to usability for all with simple and intuitive use.

Question: Compared to the exhibit without operational instructions (the picture above), do you think the design with operational instructions (the picture below) is more likely to capture your attention and engagement? please make a truthful choice based on the newly designed image (the picture below):



Level of Perception	5	4	3	2	1	Level of Perception
Mostly satisfied	Mostly	Very	Moderate	Slightly	Not at all	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Accessible to diverse visitors	☐	☐	☐	☐	☐	Accessible to limited visitors
Clear communication, easy to see, and easy to understand	☐	☐	☐	☐	☐	Unclear communication, difficult to see and understand

Figure 12 Image simulation example

(3) Generation of the final Utilization Guidelines handbook

Based on the findings of Objective 1-3 and the survey results from the image simulation questionnaire, this study identifies the characteristics and elements of digital museum exhibits that effectively engage visitors of diverse backgrounds. It ultimately proposes the 'Utilization Guidelines for Digital Media Intervention Techniques in Museum Exhibition Design to Motivate Visitor Interest and Interaction'.

CHAPTER IV

RESULTS OF OBJECTIVE 1

4.1 Overview

Objective 1 aims to analyze the factors and principles for integrating digital media technologies into museum exhibition design to enhance visitor interest, engagement, and interaction, thus promoting museum tourism. Data analysis and results presentation are divided into two parts: the first part involves an analysis of factors influencing visitors with different interests, and the second part focuses on the establishment of an evaluation system. Presenting the results of data analysis, divided into 2 parts as follows:

4.2 Factors that Affect Visitors' Interest and Interaction

According to the museum communication model, environmental behavior theory (SOR model), visitor attention model (museum fatigue theory), visitor experience, and museum exhibition design principles, the factors influencing visitor behavior and exhibition effectiveness have been identified to include design factors, environmental factors, and visitor factors. Digital media interaction technology provides intense emotional impact (such as historical reenactment, sensory immersion), environmental transformation (such as creating spatial dimensions, lighting effects), and new information spaces (such as expanding information capacity, altering time and space).

The interactivity of digital media also influences the visiting process and may even create obstacles for visitors (Lo et al., 2023). Individuals with different characteristics enter an environment with motivations, expectations, goals, and other psychological states, and choose to receive environmental information through emotions and actions (Chiang, 2022). Visitors must seek exhibits that capture their attention to gain meaningful experiences (Bitgood, 2019). Therefore, it can be concluded that factors influencing visitors' interest and interaction include design factors (exhibit design, spatial environment design, content design), environment factors (physical environment, information perception, etc.), as well as visitor personal factors (motivations, behavioral characteristics, etc.). Under three factors, there are a total of 10 dimensions and 28 sub-dimensions. The factor results are summarized in **Table 25**.

Table 25 The factors influencing visitor behavior and exhibition effectiveness from the literature review

Primary Factor	Second Factor	Third Factor	Details
Design Factor	Device	Viewing	Theater
			Video multimedia
			Comprehensive scenarios
			New technology, Virtual Tour
		Interactive Display	Trigger viewing
			Touchscreen click to query
			Interactive screen interactive query
			Entity Interaction
		Interactive game	Clicker games
			Content interaction game
		Sensory immersion	Visual (PMT) + Auditory
			Multi-sensory experiences
	Space form	Spatial separation	Wall Partitioning
			Color / Light brightness partitioning
			Integrate with surrounding exhibits
		Spatial atmosphere	Lighting, projection, atmosphere
			Sound atmosphere
	Visit route	The form of the route	Integrate with the surrounding atmosphere
			Fixed route
			Flexible route
			Multi-corridor complex route
		Digital device node	The device is located on the main/secondary outlet.
			The device is located at the main nodes
	Display content	Theme and Content	Clear theme
			Similar themes
			Coherent and consistent content
			The device is within the main content framework.
		Narrative form	Archaeological Documentary Narrative
			Artistic Aesthetic Narrative
			Process/Deconstructing Narrative
			Reenactment Narrative of Historical Scene Restoration
Visual Communication		Instruction	Clear identification instructions
			Artistically instructions
		Color	Bright colors - dim
			Color uniformity
			Color has specific variations.
		Visual materials	Colorful and lively
			Abstract art
			Realistic or documentary style
			Cartoon animation/Cute/ Ancient Chinese

Visitor Factor	behavioral preference	Demographic characteristics	style
			three-dimensional imaging
			Age
		behavioral characteristics	Knowledge background
			Number of museum visits per year
			The motivation for the visit
	Space Behavioral Perception	Commitment level	The purpose of the visit.
			Characteristics of visitors
			Fatigue
		Process level	Degree of involvement
			Seeking-Engagement
			Visit barrier
		Gains level	Whether successful engagement
			Visceral level
			behavioral level
			Cognitive level
Environ mental Factor	Physical environment	Accessibility	Environmental accessibility
			Operational accessibility
			Content accessibility
		Convenience	Safety to visit and engage
			Convenience of pathfinding
			Ease of operation
		Comfortability	Comfort of the space
			Comfort level of the facilities
		Legibility	The pleasure during interactive
			Ease of identification of spatial location
	Ease of recognition of device functions		
	Information perception	Readability	Ease of recognition of display content
			The readability of the introduction
			The readability of the exhibition content
		Message framing	Information load (high-low)
			Difficulty level
			Information prompt
		Learnability	Can meet the learning needs of visitors
Flexible and vivid forms of education			
Spiritual perception	Aesthetic Programming	Distinct architectural and interior design style.	
		Decorative elements, including modeling and landscaping.	
	Cultural nature	Scene installation	
		Spatial contextualization	

4.3 Results of the expert interview

Based on the summary of results in Table 1, interviews were conducted with three experts from the expert panel. The experts provided two key points of information. First, the experts believe that visual materials-namely, the scale, color, and presentation effects-play a crucial role in attracting visitors' attention. This involves whether visitors will be drawn to the digital exhibits and whether they will effectively receive the exhibition's message (Capece, 2024). Visitors rely on visual materials to

understand exhibitions and make value judgments (Bitgood, 2013; Ceccarelli et al., 2024). This includes whether the interpretation of themes and content is clear and comprehensible, whether the presentation is engaging, and the use of color in the environment (Tang, 2022). Attention theory posits that visual search and the depth of cognitive processing are not merely psychological processes, but also encompass behavioral measurements or indicators. These include approaching exhibits, pausing to view exhibits, viewing duration, and reading explanatory texts—all of which serve as behavioral measures or performances that directly facilitate various visiting behaviors (Bitgood, 2013; Gándara, 2016; Li & Guo, 2024). Therefore, based on the literature review and expert consensus, it is concluded that visual materials such as color, display configuration, and content presentation influence visitors' interest and interactive behaviors. Secondly, experts suggest that since this research ultimately aims to propose design guidelines for museum exhibition planning, it is essential to define the intersections of information spaces and psychological environments, translating them into design language. For instance, the narrative type of content and the information load of the content framework can impact the legibility and readability of exhibitions (Bitgood, 2013; Chiang, 2022; Tong, 2020), while the design of labels or explanatory texts may influence the readability and recognizability of exhibitions (Li & Guo, 2024). The location and spatial arrangement of exhibition items affect the accessibility, convenience, and safety of the exhibition (Ceccarelli et al., 2024). The visual style or artistic creation of the exhibits influences the aesthetic appeal of the exhibition (Tang, 2022). Interactive design or gamification design impacts the entertainment value of the exhibition (Cipparrone et al., 2025; Su, 2019). The literature review aligns with expert opinions. Therefore, further screening, consolidation, and summarization were conducted on the factors in **Table 25**, transforming psychological environmental factors into design factors and physical environmental factors. The psychological environmental factors were then converted into observational indicators for evaluation.

Ultimately, the factors and indicators influencing visitor interest and interaction, as shown in **Figure 13**, and which also shows the evaluation system of this study based on the factors, were obtained. A total of 9 dimensions and 29 indicators were identified across design factors, environmental factors (physical), and visitor factors. Details of relevant factors and references are in Appendix A, **Table A1**.

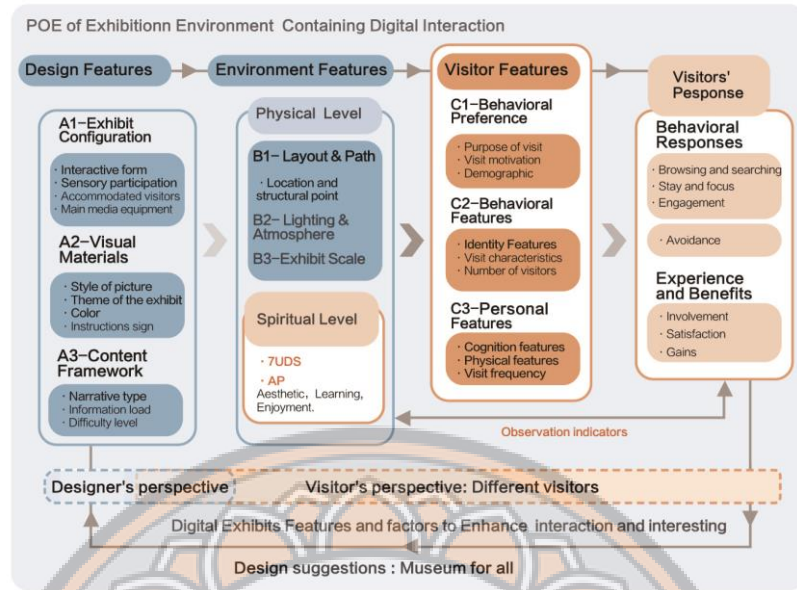


Figure 13 The evaluation system of this study

4.4 AHP and Factor Weight Analysis and Consistency Test

Based on the results of the literature review and expert interview, hierarchical relationships were established using the AHP analysis method, and the results are shown in Figure 14.

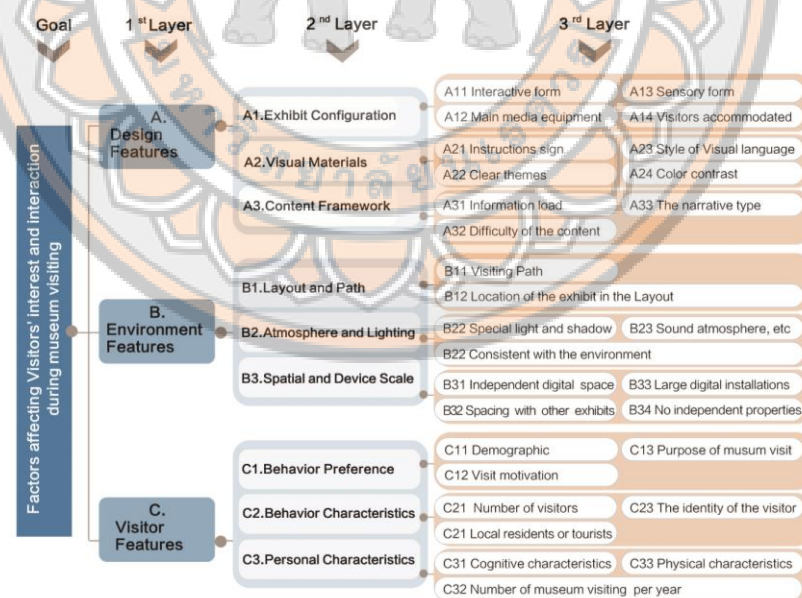


Figure 14 Hierarchical diagram of factors influencing visitor interest and interaction

Source: Ai & Phaholthep, 2025

Next, the pairwise comparison of elements was conducted, and a matrix was established based on the evaluation results from three experts, as shown in Table 26.

This section utilizes the Excel software tool to calculate and analyze the questionnaire content completed by three experts (using the square root method), obtaining eigenvectors to determine the weights of various elements in the hierarchy. A consistency test analysis was conducted for each questionnaire, with all three questionnaires being valid ($CR < 0.1$) and suitable for further analysis.

Table 26 The sample of hierarchical matrix based on the scores by three experts

	Factor A Design Features	Factor A Environment Features	Factor A Visitor Features
Factor A Design Features	1.00	1.74	1.30
Factor B Environment Features	0.58	1.00	0.84
Factor C Visitor Features	0.77	1.20	1.00
* Geometric mean of evaluation scores from three experts			

(1) First-Layer analysis

First, under the scoring goal of “Factors Affecting the Interests and Interactions of Different Types of Visitors,” the first-layer evaluation factors are “A-Design Features Factors,” “B-Environment Features,” and “C-Visitor Factors.” The analysis results indicate that the most important factor is “A-Design Features,” with an average weight of 0.428, followed by “C-Visitor Factors” with an average weight of 0.317, and lastly “B-Environment Features” with an average weight of 0.255. Additionally, $CR \leq 0.1$ meets the consistency requirement. The analysis data is shown in Table 27 below:

Table 27 Expert weights and consistency analysis of the First-Layer

Expert	A-Design Features	B- Environment Features	C-Visitor Features	CI	CR
A	0.479	0.168	0.354	0.001	0.002
B	0.343	0.229	0.428	0.002	0.004
C	0.426	0.386	0.188	0.007	0.015
AW	0.428	0.225	0.317	0.0005	0.001

(2) Second-Layer analysis

In the second-layer analysis, all three experts acknowledged the factors and indicators proposed in this study. Under the A-Design Features Factors, the order

of importance was A2-Visual Materials ($W=0.441$), A1--Exhibit Configuration ($W=0.301$), and A3-Content Framework ($W=0.288$). Expert C held a differing view, considering the order of importance to be A3-Content Framework($W=0.419$) > A2-Visual Materials ($W=0.353$) > A1-Exhibit Configuration ($W=0.336$). The analysis data is shown in **Table 28**:

Table 28 Expert weights analysis of the Second-Layer in “Design Features”

Expert	A1-Exhibit Configuration	A2-Visual Material	A3-Content Framework	CI	CR
A	0.359	0.430	0.210	0.012	0.024
B	0.294	0.449	0.257	0.001	0.002
C	0.242	0.338	0.419	0.003	0.005
AW	0.301	0.411	0.288	0.004	0.008

Under the “Environment Features” factors level, the order of importance is as follows: B3-Spatial Configuration and Exhibit Scale ($W=0.364$), B1- Layout and Visiting Path ($W=0.349$), B2- Lighting and Atmosphere ($W=0.288$). There are significant differences among the opinions of the three experts. Expert A considers that B3-Spatial Configuration and Exhibit Scale ($W=0.519$) > B1- Layout and Visiting Path ($W=0.304$) > B2- Lighting and Atmosphere ($W=0.177$), while Expert B believes B1-Layout and Visiting Path ($W=0.377$) > B3-Spatial Configuration and Exhibit Scale ($W=0.362$) > B2- Lighting and Atmosphere ($W=0.261$). However, Expert C provides a different perspective: B2-Lighting and Atmosphere ($W=0.451$) > B1-Layout and Visiting Path ($W=0.325$) > B3-Spatial Configuration and Exhibit Scale ($W=0.224$). The analysis data is shown in **Table 29** below:

Table 29 Expert weights and consistency analysis of the Second-Layer in “Environment Features”

Expert	B1- Layout and Visiting Path	B2- Lighting and Atmosphere	B3- Spatial Configuration and Exhibit Scale	CI	CR
A	0.304	0.177	0.519	0.123	0.236
B	0.377	0.261	0.362	0.0007	0.001
C	0.325	0.451	0.224	0.011	0.021
AW	0.349	0.288	0.364	0.007	0.126

Under the “Visitor Features” level, the importance levels of each factor indicator are as follows: C3-Personal Characteristics ($W=0.442$), C1-behavioral

Preferences ($W=0.287$), and C2-behavior Characteristics ($W=0.272$). The analysis data is shown in Table 30 below:

Table 30 Expert weights analysis of the Second-Layer in “Visitor Features”

Expert	C1-behavioral Preferences	C2-behavior Characteristics	C3-Personal Characteristics	CI	CR
A	0.258	0.301	0.441	0.012	0.024
B	0.298	0.280	0.422	0.007	0.014
C	0.302	0.236	0.462	0.036	0.068
AW	0.287	0.272	0.442	0.166	0.317

(3) Third-Layer analysis

The third level corresponds to the solution layer, with its factors serving as evaluation indicators and also as design strategies for subsequent improvements. In the consistency check, the CR of the geometric mean matrix for the 29 evaluation factors and indicators was >1 , indicating that the assessments of the three experts passed the consistency test and can thus be used as a basis for further analysis. The analysis data is shown in Table 31 below:

Table 31 Expert weights analysis of the Third-Layer in nine dimensions under three factors

Dimension	Indicator 1	Indicator 2	Indicator 3	Indicator 4	CI	CR
	A-1/2/3-1	A-1/2/3-2	A-1/2/3-3	A-1/2/3-4		
A-1	0.306	0.198	0.286	0.210	0.011	0.013
A-2	0.201	0.252	0.326	0.219	0.015	0.017
A-3	0.273	0.260	0.467	/	0.000	0.000
	B-1/2/3-1	B-1/2/3-2	B-1/2/3-3	B-1/2/3-4		
B-1	0.427	0.573	/	/	/	/
B-2	0.436	0.374	0.190	/	0.006	0.011
B-3	0.223	0.275	0.330	0.171	0.034	0.038
	C-1/2/3-1	C-1/2/3-2	C-1/2/3-3	C-1/2/3-4		
C-1	0.190	0.397	0.413	/	0.000	0.000
C-2	0.205	0.334	0.461	/	0.009	0.017
C-3	0.363	0.318	0.319	/	0.000	0.001

A1-Exhibit Configuration

Under the A-Design Features factor, the A1-Exhibit Configuration dimension includes four evaluation indicators: the A11 Digital interaction Form, the

A12 Main media equipment, the A13 Sensory participation forms of the digital exhibits, and the A14 Number of accommodated visitors (the maximum participant capacity of the exhibit). Among these, the average weight of 0.306 for the “A11 Digital interaction Form” is the highest, followed by the average weight of 0.286 for the “A13-Sensory participation formats”.

A2 -Visual materials

Under the A-Design Features Factors, the A2-Visual Materials dimension includes four evaluation indicators: A21-Instructions sign or system (clear and easy-to-understand), A22-Explicit theme of the exhibit, A23-Style of the exhibit’s visual language, and A24-Color contrast of the exhibit. Among these, the “A23-Style of the exhibit’s visual language” received the highest average weight ($W=0.326$), followed by “A22-Explicit theme of the exhibit” with an average weight of 0.252.

A3-Content Framework

Under the A-Design Features factor, within the A3-Content Framework dimension, there are three evaluation indicators: the A31-Information load degree, the A32-Difficulty level of exhibition content, and the A33-Narrative type of exhibition content. Among these, the average weight of the “A33- Narrative type” is the highest, at 0.467.

B1-Layout and Visiting Path

Under the B-Environmental Features factor, the B1-Layout and Visiting Path dimension includes the B11-Visiting Path (spatial layout and route type of digital exhibits), and B12-Location of the exhibit in the Layout, with weights of 0.427 and 0.573, respectively.

B2-Lighting and Atmosphere

Under the B-Environmental Features, the B2- Lighting and Atmosphere dimension includes three evaluation indicators: the B21-Special light and shadow (Dedicated lighting, projection, and other atmospheric elements), the B22-Consistent with the environment without distinction, and the B23-Sound atmosphere and other. Among these, the “B21-Special light and shadow” received the highest average weight of 0.436.

B3-Space configuration and scale

Under the B-Environmental Features factor, the B3-Spatial Configuration and Exhibit Scale dimension includes four evaluation indicators: B31-Independent digital interactive space, the B32-Have spacing with other exhibits (independent partitions/desks with spacing from other exhibits), the B33-Largedigital media installations/scenes, and the B34-Digital interactive exhibits lacking independent

attributes (are integrated with surrounding exhibits or objects). Among these, the “B33-Large digital media installations/scenes” received the highest average weight, 0.330, followed by the “B32-Have spacing with other exhibits”, 0.275.

C1-behavioral Preference

Under the C1-behavioral Preference dimension of the C-Visitor Features factor, there are three evaluation indicators: the C11-Demographic characteristics, the C12-Visit motivation, and the C13-Purpose of museum visiting. Among these, the “C13-Purpose of museum visiting” obtained the highest average weight of 0.413, followed by the “C12-Visit motivation” with a weight of 0.397.

C2-behavioral Characteristic

Under the C-Visitor Features factor, C2-behavioral Characteristic dimension, there are three evaluation indicators: the C21-The number and characteristics of accompanying visitors (alone or in a pair/group), the C22-Whether visitors are residents or tourists, and the C23-Visitor identity characteristics (such as parent-child families, students, couples, experts, etc). Among these, the average weight for the “C23-Visitor identity characteristics” is the highest at 0.461.

C3-Personal Characteristic

Under the C-Visitor Features factor, the C3-Personal Characteristic dimension includes three evaluation indicators: the C31-visitors’ cognitive characteristics, the C32-Number of museum-visiting/year (annual museum visitation frequency), and the C33-Visitor’s physical characteristics and restrictions. Among these, C31 visitor cognitive characteristics—comprising cultural background, educational level, professional background, and whether they are museum enthusiasts—received the highest average weight of 0.363.

(4) Overall weight analysis

After analyzing the weights of each level, further analysis was conducted on the overall influencing factors’ weights. The consolidated results of the average weights from the previous three sections are presented in **Table 32**. The impact of “A-Design Features” on visitor interest and interaction is the most important in the first layer of factors. The second layer ranks the weights as follows: “A2-Visual Materials,” “A1-Exhibit Configuration,” “C3-Personal Characteristics,” “A3-Content Framework,” “C1-behavior Preferences,” and “C2-behavior Characteristics”. The most important indicators in the third layer are “A23-Style of visual language” in the “A2-Visual Materials”. The second and third important factors are both “C31-Cognitive Characteristics” and “C33-

Physical Characteristics and restrictions” in “C3-Personal Characteristics.” The “B12-Location of the exhibit in the Layout” in “B1-Layout and Visiting Path” dimension is listed as the third most important influencing indicator. And “A22-Explicit and clear themes”, “C32-Number of museum-visiting per year”, “C23-The identity of the visitor”, “A11 Interactive form of the exhibit”, “A24 Color contrast” are the top ten influencing factors with higher weight in sequence.

Table 32 Overall weights analysis

1st Layer	W	2nd Layer	W	pW	R	3rd Layer	W	pW
A-Design Features	0.428	A1- Exhibit Configuration	0.301	0.129	2	A11 Interactive form of the exhibit	0.306	0.039
						A12 Main media equipment	0.198	0.026
						A13 Sensory participation forms	0.286	0.037
						A14 Number accommodated visitors	0.210	0.027
		A2-Visual Materials	0.411	0.176	1	A21 Instructions sign or system	0.201	0.035
						A22 A clear theme of the exhibit	0.252	0.044
						A23 Style of visual language	0.326	0.057
						A24 Color contrast	0.219	0.039
		A3-Content Framework	0.288	0.123	4	A31 Information load degree	0.273	0.034
						A32 The difficulty of the content	0.260	0.032
						A33 The narrative type of content	0.467	0.057
B-Environmental Features	0.225	B1-Layout /Path	0.349	0.079	8	B11 Visiting Path	0.427	0.034
						B12 Location and structural point	0.573	0.045
		B2-Lighting & Atmosphere	0.288	0.064	9	B21 Special light and shadow	0.436	0.027
						B22 Consistent with the environment	0.374	0.024
						B23 Sound atmosphere and other	0.190	0.012
		B3-Spatial Configuration/ Exhibit Scale	0.364	0.082	7	B31 Independent digital space	0.223	0.018
						B32 Have spacing with other exhibits	0.275	0.022
						B33 Large digital media installations	0.330	0.027
						B34 No independent properties	0.171	0.014

C- Visitor Features	0.3	17	C1-behaviorPreferences	0.287	0.091	5	C11Demographic characteristics	0.190	0.017
							C12 Visit motivation	0.397	0.036
							C13 Purpose of visit	0.413	0.038
	0.3	17	C2-behaviorCharacteristics	0.272	0.086	6	C21 Number of visitors	0.205	0.018
							C22 Local residents or tourists	0.334	0.029
							C23 The identity of the visitor	0.461	0.040
	0.3	17	C3-Personal Features	0.442	0.140	3	C31 Cognitive feature	0.363	0.051
							C32 Number of museum-visiting / year	0.318	0.044
							C33 Physical feature	0.319	0.045

4.4 Summary

Analyze the factors and principles for integrating digital technologies into museum exhibition design to enhance visitor interest, engagement, and interaction

Based on the results of the literature review, expert interviews, and AHP analysis, three major factors influencing visitor interest and interaction were identified: design characteristic factors, environmental characteristic elements, and visitor characteristic elements. These were measured, evaluated, and investigated across 9 dimensions and 29 indicators. **Figure 14** presents the 29 evaluation indicators. Based on this evaluation metric, an evaluation system of POE from the visitor's perspective was established to determine the mechanisms and relationships between factors influencing visitor interest and interaction and their behavioral experience. Based on the AHP research results, the influence of visitor factors on interest and interactive behaviors outweighs that of the physical environment. How to incorporate visitor behavior observation indicators into the evaluation of exhibition environments has become a key point in this assessment. To this end, the seven principles of Universal Design were introduced as one of the criteria for assessing environmental and design features. **Table A1 in Appendix A** presents the factors and evaluation indicators at various levels, along with the relevant technical methodologies.

CHAPTER V

RESULTS OF OBJECTIVE 2

5.1 Overview

Objective 2 aims to examine the physical environments of popular museums in China and evaluate their alignment with key factors for effectively integrating digital media technologies to promote museum tourism.

This empirical research on barriers and limitations in the museum exhibition physical environment containing digital techniques regarding the universal design among the six museums listed in **Table 8**. The data analysis and results presentation are divided into three parts: The first part is the measurement of the exhibition's physical environment based on design elements, focusing on the constraints and barriers in the physical environment under the intervention of digital technologies. The second part presents the evaluation results of the physical environment and visitors' visiting behavior using the 7UD (seven principles of Universal Design) evaluation checklist, emphasizing the relationship between visitor behavior and the environment, and exploring the potential of applying 7UD to address constraints and barriers. The third part covers the outcomes of on-site visitor interviews, with a focus on whether the design meets the behavioral characteristics and needs of diverse visitors, as well as identifying any existing constraints or barriers during the visit.

The results are analyzed as follows:

5.2 Result of Physical Environment Measurement Based on Design Factors:

(1) Statistical results and feature description of digital media exhibits

Using Table 18, the design and environmental features of the digital exhibit measurement record table, statistics were recorded for digital exhibits in six museums. The floor plan of the exhibition hall was drawn to mark the locations and characteristics of digital exhibits, and descriptive statistical analysis was conducted using SPSS 27.01.

As case studies of five museums (SEM, SWM, WCM, CWM, WYM), a total of 10 major exhibition halls were surveyed, including 9 permanent exhibition halls and 1 special exhibition hall. A total of 141 digital media devices were recorded. **Figure 15** illustrates the interactive forms and quantity distribution of digital exhibits across five museums. During data analysis, three damaged exhibits were excluded, leaving the

remaining exhibits divided into 135 groups: among these, 72 were viewing-type exhibits (with 2 damaged exhibits removed) and 49 were interactive installations (with 1 damaged exhibit removed), 6 interactive game exhibits, 5 trigger viewing exhibits, and 3 immersive audiovisual spaces. New multimedia technologies, such as virtual reality, 360VR, and physical interaction, are not prominently applied and are categorized as interactive exhibits. Therefore, the Yangzhou Grand Canal Museum (GCM) was selected as a comparative case due to its application of immersive media technologies.

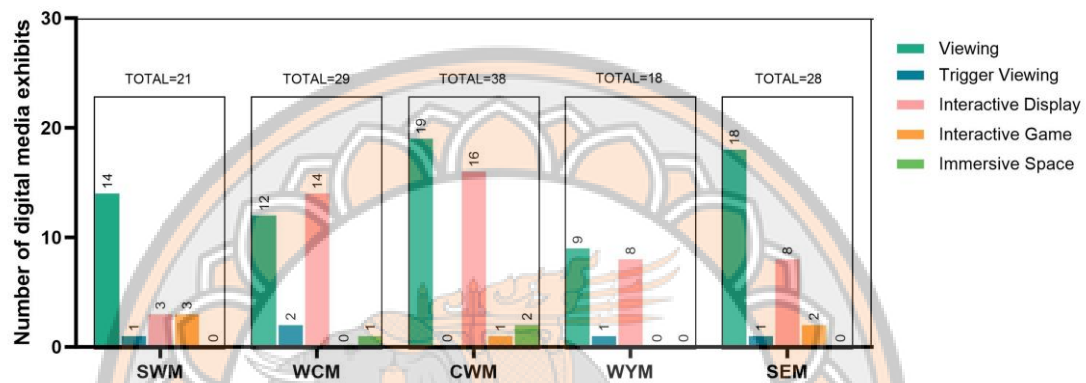


Figure 15 The distribution of digital exhibits based on interactive formats and quantities across five museums

These museums demonstrate various intersection points where exhibitions interact with diverse digital media. **Table B1** shows these digital media and device characteristics.

Case study: five museums

Five museums jointly recorded the environmental features and design features of 135 digital displays. Under the factor A11-interaction form, 72 items were classified as viewing-based (53.33%), 5 as trigger-viewing (3.70%), 49 as interactive display (36.30%), 6 as interactive gaming (4.44%), and 3 as immersive space (2.22%). The statistical findings suggest that viewing-based digital media exhibits remain the dominant form in modern Chinese new museums.

Based on the ranking of each factor's importance and preliminary on-site environmental observations, the researchers conducted a cross-tabulation analysis in SPSS V27.01 using the A11 -Interaction format from the second-tier A1 display configuration, along with third-tier indicators including A12 -Primary digital media equipment, A13-Sensory engagement formats, A21 -Clear signage or explanation systems, A22 -Explicit themes, A23 -Visual language style, A24 -Color contrast, A33-

Narrative types, and B12- Digital exhibit's structural and positional relationship within its parent exhibit. The statistical results were visualized using GraphPad Prism 10.1.2.

The results of the analysis in **Figure 16** indicate that at the A1 level, the main types of digital devices are still Information booths, touchscreens, indicators, and projectors. Since the chosen permanent gallery is a comprehensive history and city culture one, instead of a specialized interaction or children's museum, the application of new technological methods is limited. Among the virtual reality technologies widely mentioned in the literature, such as XR and VR, only one instance was identified. At the CWM, there is a digital exhibition featuring virtual imaging, which is currently damaged and under repair. The SEM employs some new media materials as display mediums, such as directly projecting visual interpretations of exhibits onto showcase glass panels instead of using traditional wall-mounted televisions. Under indicator B12, a small number of interactive exhibits are located along secondary exhibition routes, surrounded by no exhibition content or related information, or positioned above, below, or to the side of primary exhibition content. These digital exhibits primarily consist of interactive query devices.

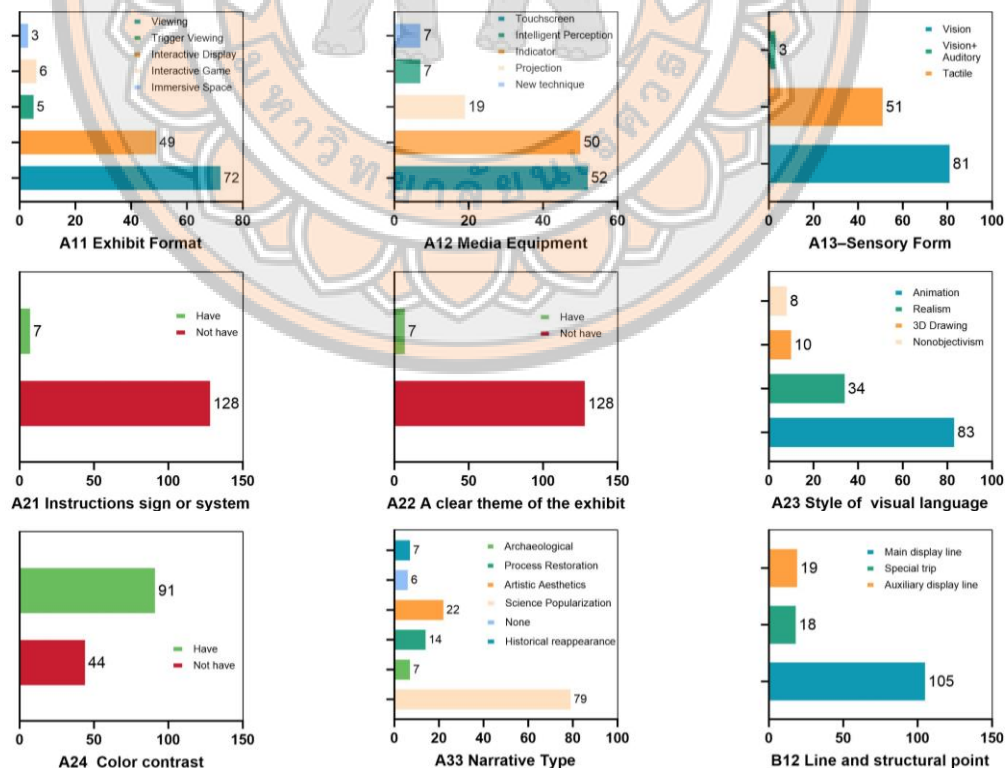


Figure 16 Main feature and description of digital media exhibits

The findings suggest that the digital presentation shown in the five museums is mainly science storytelling-focused. This is a narrative type that has been proven in literature review to effectively enhance visitor (user) experience and fully leverage the advantages of digital intervention technology (Tong, 2020; Liu, 2020). In Chapter VI, this study will continue to explore the design features and environmental characteristics of digital displays and exhibits that exhibit high appeal to different types of visitors.

Comparative study: Immersive Digital Interactive Exhibition in China Yangzhou Grand Canal Museum (GCM)

The Grand Canal Museum, situated in the picturesque city of Yangzhou, is dedicated to exhibiting the rich cultural legacy of the Grand Canal from Beijing to Hangzhou. The museum incorporates an array of digital exhibits, offering visitors a distinctive and engaging digital interaction and visiting experience (Li, 2022). Over the past two years, the Grand Canal Museum has always been among the most-visited museums in China. It attracts a wide range of people, such as local people, young people, and those passionate about cultural tourism, as well as museum lovers of different ages. The inquiry mainly concentrated on the “Boats on the Canal” gallery, which combines digital display and cultural traditional exhibition for culture. The entire exhibition hall is designed as a canal scene and ship interior, featuring distributed touch inquiry screens (Y4-1), augmented reality interactive screens (Y4-2), and interactive screens inside the cabin (Y4-3), along with a VR experience of the spacecraft interior deck and panoramic view (Y4-3). Detailed issues and obstacles will be described in the next section on physical environment evaluation results.

(2) Barriers and Limitations in Exhibition Environment Containing Digital Media of the Museums

Case study: five museums

Suzhou Museum (West) (SWM)

The Suzhou Museum West Campus is situated in Suzhou City. The museum not only showcases the historical civilization and non-material cultural legacy of the Suzhou area (old Suzhou), but also offers in-depth interpretations and vivid presentations of traditional crafts and cultural heritage through digital media technologies. Although Suzhou is a renowned tourist city, the main visitor groups of this museum still consist of residents, out-of-town tourists, and youth study groups, failing to attract a large number of non-local visitors. The investigation took place in both the International Co-operative Gallery and the Suzhou Historical Gallery. **Figure 17** provides a layout view of

the history gallery, along with a schematic highlighting the pertinent problem areas. Within the Suzhou History Gallery, digital media applications feature audio-visual spaces, an interactive screen for query or game, as well as ancient artistic scenarios. The main problem is the low utilization rate and overall attractiveness to all visitors.

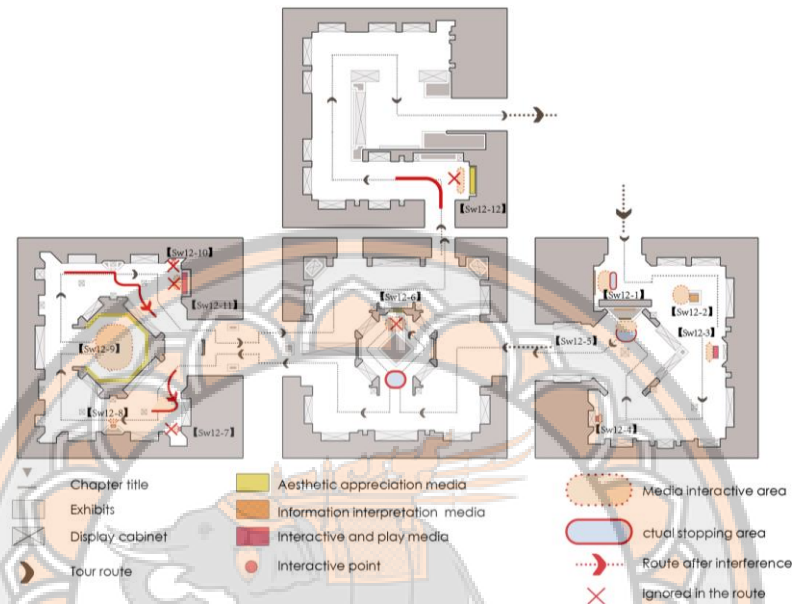


Figure 17 The layout and pertinent problem areas of the Suzhou History Gallery

The Historical Gallery has several issues, which are indicated schematically in **Figure 17**. Specifically: (1) The digital exhibits are commonly placed at the back of the primary path or in the corners of the display cases, which tend to be missed by the majority of visitors, as evidenced by the numbers SW12-1, SW12-6, SW12-9, and SW12-10, illustrated in **Figure 17**; (2) The positioning and high degree of the display equipment and interactive screens are unsuitable, hindering visitors' ability to interact with them, as exemplified in **Figure 18(a)**; (3) There is an abundance of vague information disseminated by digital media, which complicates the extraction of practical information and the comprehension of exhibition contexts. As depicted in **Figure 18(b)**, the video showcases the artistic scenes, which are abstract, which complicates the process of understanding its underlying purpose for the audience. As depicted in **Figure 18(c)**, the projection showcases the activities of craftsmen at work; nonetheless, the display cabinet positioned in front hinders the visibility of the projection, thereby complicating visitors' ability to focus on the projection.

The International Co-operative Gallery serves as a global exhibition venue, collaboratively curated and executed by the Suzhou Museum in partnership with the British Museum. Currently showcased is "King of Assyria: Ashurbanipal,"

which comprehensively blends digital imagery, video, and interactive features to convey the content. The primary limitation was that the digital interaction displays caused congestion and interrupted visitors' visiting routes.



Figure 18 Photo description of the problems in the West Campus of Suzhou Museum

Upon analyzing the layout depicted in **Figure 19**, it is evident that the animation wall labeled SW9 - 1 is located on the left-hand side near the main entrance. This placement results in congestion at the entrance when over five people stop to view the exhibit. The video displays identified by the numbers SW9-4 and SW9-7 in **Figure 19** also present a comparable issue: those displays contain content that introduces history and cultural relic knowledge, requiring visitors to remain and watch, which leads to congestion when there is a high volume of people. In other areas, the two primary audio-visual spaces within the exhibition receive minimal visitor traffic. Visitor feedback indicates that the key reasons are: (1) insufficient lighting, and (2) the prolonged display of content and visuals that lack relevance to everyday life and necessitate a specialized knowledge background for comprehension.

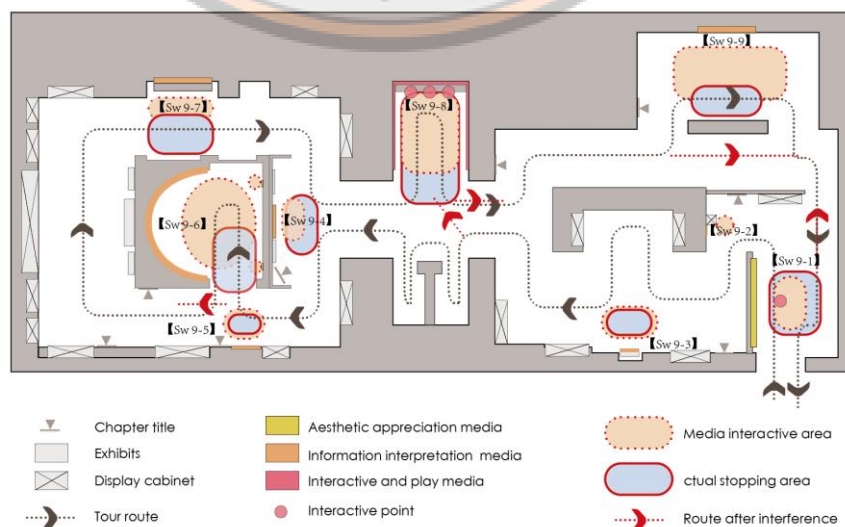


Figure 19 The layout and pertinent problem areas of the International Gallery

Museum of Wu in Suzhou (WCM)

The Museum of Wu is situated in Suzhou, China, exhibiting the historical culture and natural resources of the Wu region and dynasty. Similar to the SMW, although positioned as a tourist museum, the primary visitors to the Museum of Wu are residents rather than large numbers of tourist visitors. This survey was conducted in Basic Exhibition Galleries No.1 and No.3, revealing key issues including inadequate maintenance due to poor location selection of digital exhibits, malfunctions in digital media equipment, and insufficient recognition of exhibits. The specific problems are summarized into the following five points:

First, the positioning of digital exhibits or devices is often in corners or behind main information walls, lacking signage or introductions, which results in them being overlooked by visitors. For instance, the exhibits W17-2, W17-3, and W17-4 in **Figure 20** are three different digital interaction exhibits that are placed behind the visitor's visiting path after being combined, falling beyond the conventional implementation scope. W17-3, located in a dimly lit corner, is a physical interactive exhibit lacking clear signage. As shown in **Figure 21(a)** and (b), there are no signs or operational notices around the exhibits and displays. Even visitors who notice it struggle to recognize its interactive features.

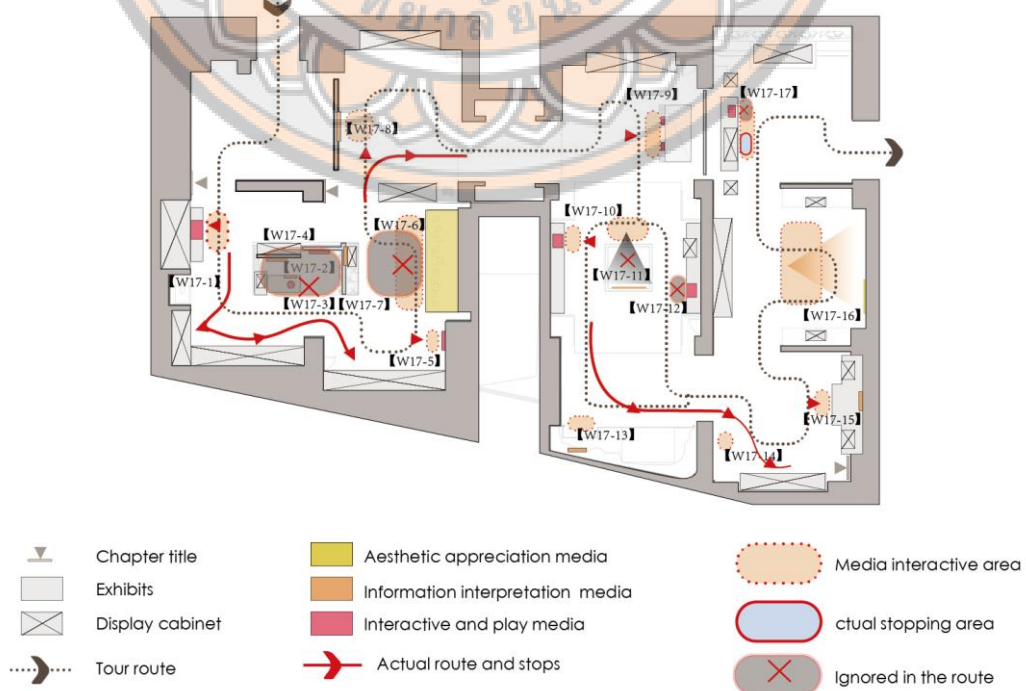


Figure 20 The layout and pertinent problem areas of the Galleries No.1



Figure 21 Photo description of the Exhibition Galleries No.1

Secondly, interactive exhibits are blended with art exhibits, lacking a clear distinction. In Basic Exhibition Galleries No. 3, as illustrated in **Figure 22**, the child-friendly design theme and style lead adults to ignore these small, cute interactive buttons, making it difficult to identify the function of interactive media exhibits. As illustrated in **Figure 21(c)**, individuals visiting the interactive wall (W12-7) need to activate the “light points” for touch on the wall, after which the corresponding content projection of animation starts. Nonetheless, the miniature “light points” on the wall are challenging to identify. The unpredictability of such touch off further caused various exhibits which are not interactive, like the one designated W11-* in **Figure 21(d)**, to be erroneously perceived as interactive by visitors, leading to them being yanked forcefully.

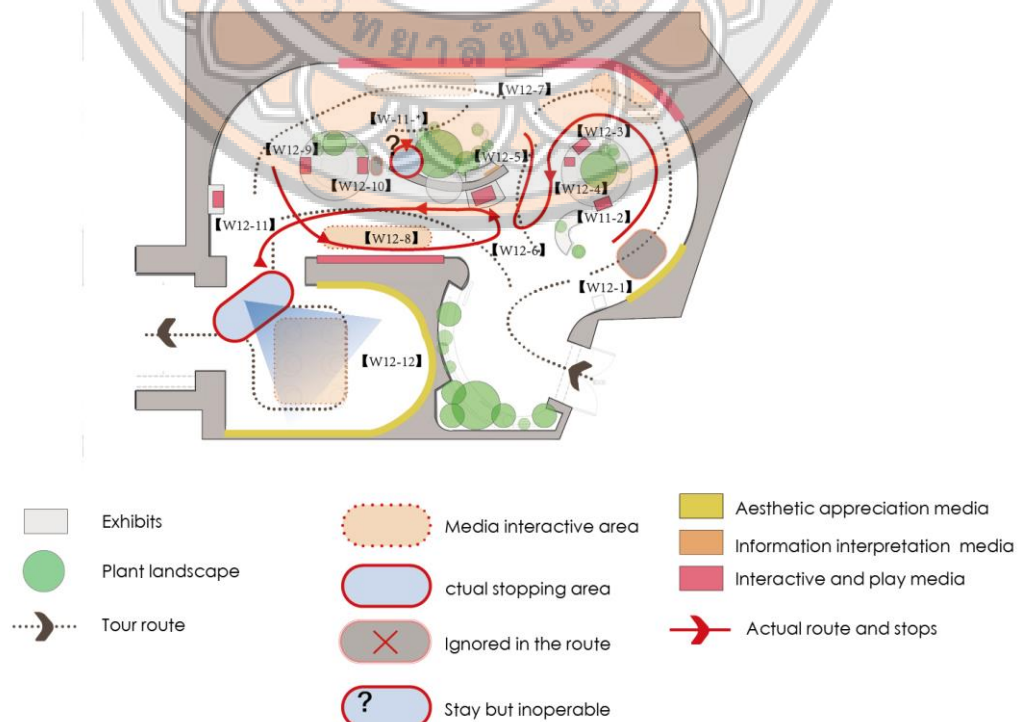


Figure 22 The layout and pertinent problem areas of the Galleries No.3

Fourth, the positioning of the digital media space is illogical, leading to congestion. As illustrated in **Figure 21(e)**, the immersion cinema (W12-12 in **Figure 22**) is situated at the exit of the gallery. Even though the video room features a dedicated area and cushions, numerous visitors still congregate at the entrance to watch. Despite having its own dedicated space and seating cushions, numerous visitors congregate at the entrance to observe. And the fifth, the exhibit is devoid of a switching function of language and visual explanatory icons, which prevents foreigners from operating it and comprehending its functions.

Jiangnan Water Town Culture Museum of China (CWM)

The Jiangnan Water Town Culture Museum (CWM), situated in Hangzhou, utilizes a range of modern multimedia technology and artistic settings to showcase the cultural heritage of water towns instead of conventional display boards. The survey findings reveal that the main visitors consist of undergraduate, local older adults, and family groups, while the exhibition appears to be unattractive to cultural tourists. As illustrated in **Figure 23**, the CWM features a total of 42 digital exhibits and displays, densely positioned with a randomized visitation path and lacking a fixed path. This configuration led to a confusing visiting route, leading to the oversight of the majority of exhibits by visitors. Additionally, the disjointed content structure undermines the attractiveness of the exhibition. There exist several problems with the exhibition environment, detailed as follows:

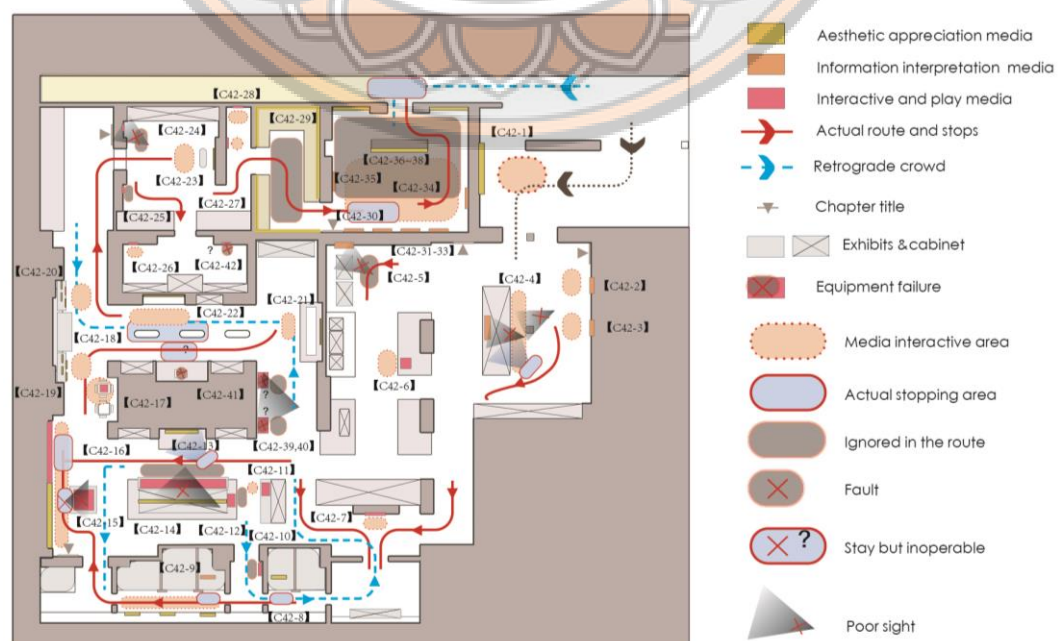


Figure 23 The layout and pertinent problem areas of the exhibition in the CWM

Firstly, the mismatch in height and positioning complicates the visibility of the digital exhibits in **Figure 24(a)**. The video devices and projections placed for numbers C42-4, C42-5, and C42-14 fall outside a reasonable field of vision, rendering the content screens less noticeable to visitors. And, interactive tables and screens, including exhibits C42-24, C40-25, and C42-39, are spread across different corners, which makes it difficult to draw attention. Secondly, the NO. C42-15 and NO. C42-14 are tables for interaction; however, the information and image aren't placed within an ideal view range, and there is no explicit notice of operation, causing them to be overlooked by visitors. **Figure 24(b)**, when visitors try to click on the desktop screen, they can't see the full screen. Third, the big interactive screen, C42-16, is devoid of interactive guidance; as a result, while it attracts some visitors, many are oblivious to its touch capabilities, as depicted in **Figure 24(c)**. Fourth, the content of digital media often lacks effective information communication, leading to visitors being disinclined to linger. Exhibits C42-1, C42-23, C42-29, and C42-30 through C42-38 are situated in pathways that visitors must traverse. These exhibits feature art pictures or videos for arts are artistic appreciation with no explanatory knowledge or information, resulting in few visitors pausing to view them, as illustrated in **Figure 24(d)**. The area where C42-34~38 is situated encounters a comparable problem: numerous media and large screens show videos devoid of informative content or perspectives, which makes it hard for individuals to stay and watch.

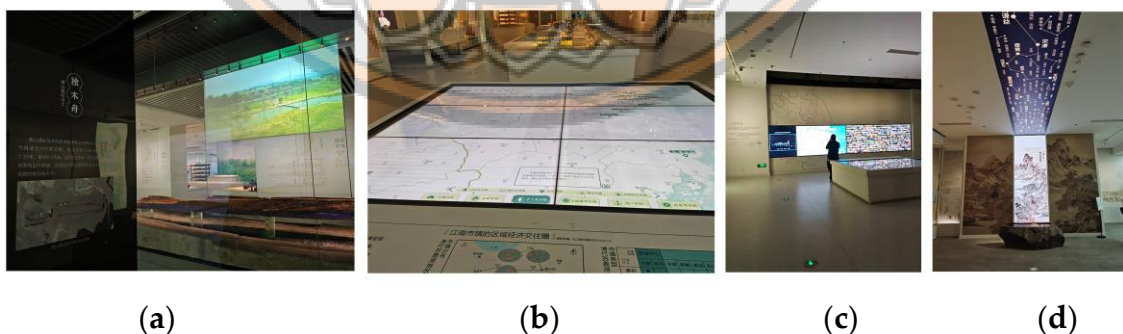


Figure 24 Photo description of the Jiangnan Water Town Culture Museum

Wu-Yue Culture Museum (WYM)

The Wu-Yue Culture Museum was inaugurated in 2024, featuring digital interaction, cinemas, a multiplayer interactive screen, and various other digital media technologies to showcase cultural relics and historical heritage. Survey findings

reveal a wide array of visitors to the museum, encompassing visitors for tourism, students from Hangzhou's universities, families, and older adults in the local community. The key issues facing the Wu-Yue Culture Museum primarily center on the placement and substance of the digital displays and exhibits, which are elaborated upon in the following sections.

Initially, the positioning, elevation, and arrangement of the media exhibits are flawed. In **Figure 25**, Y18-6 and Y18-10 interact with the spectators and the surrounding exhibits, having a mutual influence on each other. Additionally, the illumination and shadows cast by the media exhibits Y18-2, Y18-6, and Y18-10 adversely affect the neighboring physical exhibits. The height of Y18-16 is not favorable for viewing, as depicted in **Figures 26(a)** and (b). Secondly, within the immersive cinemas NO. Y18-1, NO. Y18-9, and NO. Y18-10, the films' content exhibits similarity, and the level of content interpretation remains uniform. These films are all historical overviews, lacking deeper content exploration, which leads to a diminished attraction for the large film concluding the exhibition, thereby drawing fewer visitors. Thirdly, the media exhibits a lack of operational instructions, leading visitors to either ignore them or get confused. For instance, the interactive screen of NO. Y18-15 is hidden inside ship landscaping, positioned among other exhibits without any clear guidance, as depicted in **Figure 26(c)**. The interactive table for Y18-17 and the magic screen for Y18-18 are situated outside the main exhibition hall, close to the exit, lacking proper operational instructions, leading to the majority of visitors simply passing by. However, subsequent interviews with visitors revealed that the interactive magic screen was the most highly regarded media exhibit, as it allows visitors to inquire and acquire information not covered in the exhibition's physical space, as evidenced in **Figure 26(d)**.

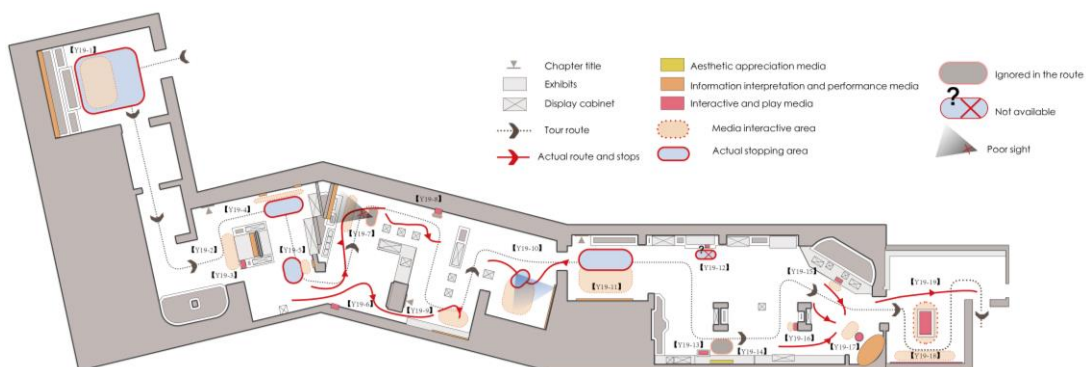


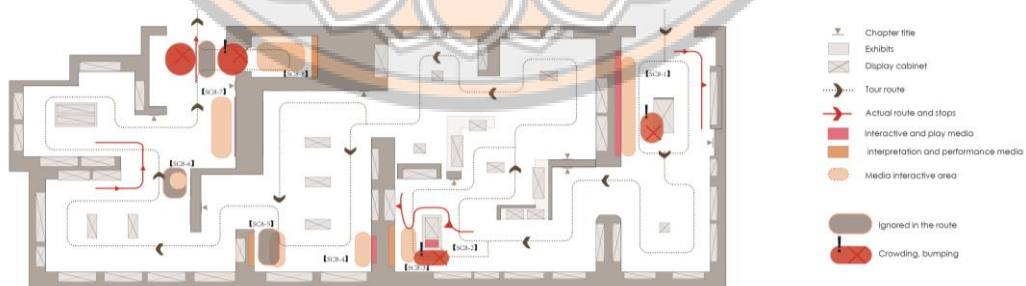
Figure 25 The layout and pertinent problem areas of Wu-Yue Culture Museum



Figure 26 Photo description in Wu-Yue Culture Museum

Shanghai Museum -East Campus (SEM)

The SEM, the latest ancient Chinese art and heritage museum, opened in 2024, and focuses on being a “visitor-friendly museum” and a “digital intelligence museum.” It attracts a large number of residents and cultural tourism enthusiasts of all ages. The digital interpretation in the SEM highlights a comprehensive interpretation of heritage, encompassing the historical background and craftsmanship of the artifacts. The digital interpretation emphasizes the production process and utilizes 3D modeling technology to achieve a three-dimensional presentation of the heritage, a unique approach that stands in stark contrast to the other four museums. The results present the survey evaluation outcomes of four galleries at the Shanghai Museum: the Chinese Numismatics Gallery, the Ancient Chinese Jade Gallery, the Ancient Ceramics Gallery, and the Ancient Chinese Bronze Gallery. **Figure 27** illustrates the spatial layouts of the four exhibition halls along with the distribution of digital exhibits and identified issues.



(a)

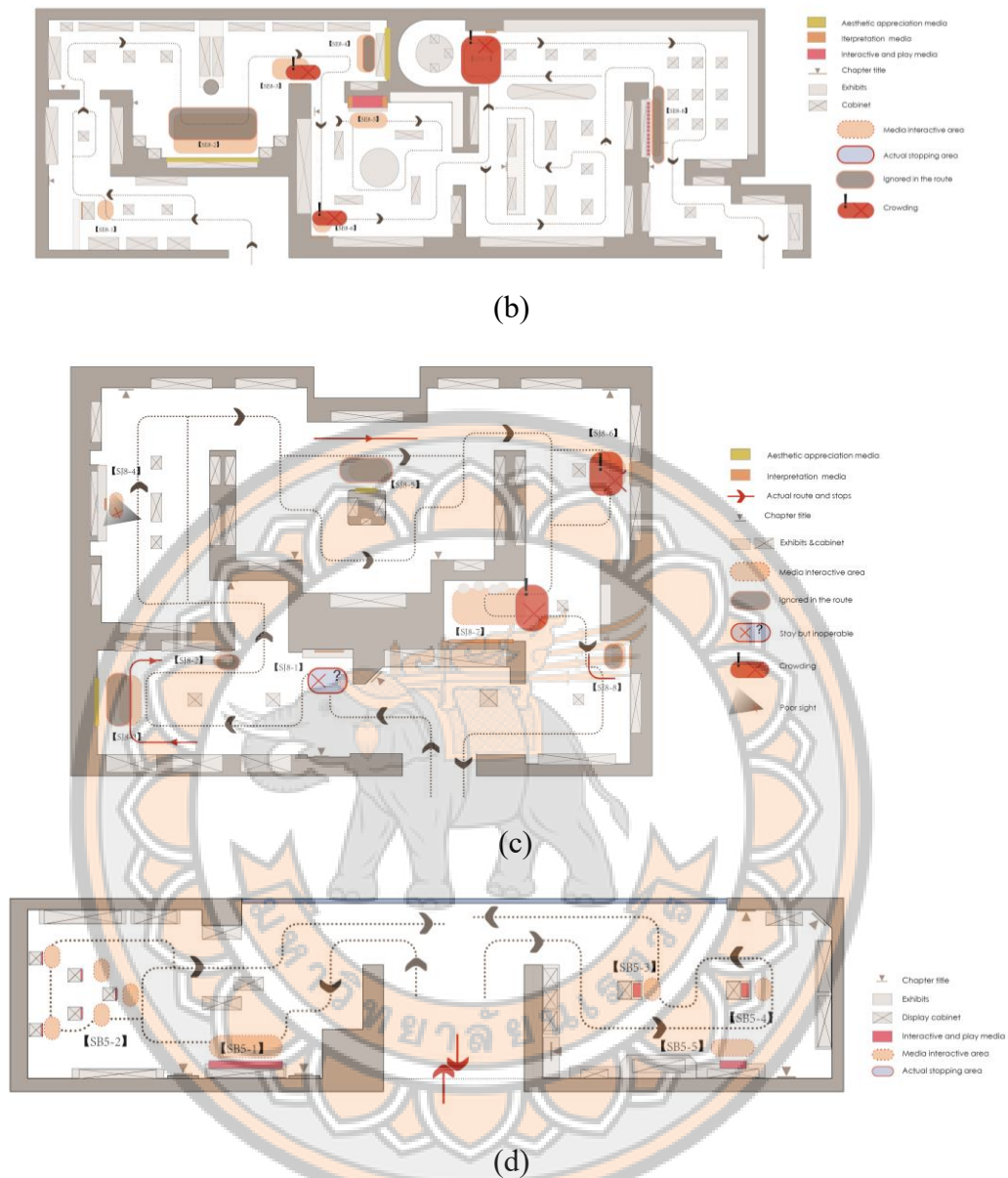


Figure 27 The layout and pertinent problem areas of the 4 galleries in the SEM

The most distinctive feature of the digital media interaction at the Shanghai Museum East is the comprehensive interpretation of cultural relics exhibits and heritage, which includes the historical background and craftsmanship of the artifacts. The touch screen for professional knowledge explanation seems to have been deliberately downsized and placed on one side of the display case, providing professional or interested visitors with a way to search for information. However, this also raises issues: the unreasonable location and spatial scale have led to congestion among the crowd.

In the environmental measurements of the museum, the issues identified also include the following three points: 1) Most digital media interactions are far from the main route, which makes them easy to overlook by visitors. As shown in **Figure 27(a)**, the positions marked by SC8-6 and SC8-8, and exhibit SJ8-8 in **Figure 27 (b)**; the area of these digital exhibits is situated beside the visiting path, and visitors won't actively head to this area. 2) The spatial scale is unreasonable, causing congestion. As shown in **Figure 28 (a) and (b)**, the location is SC8-8 in **Figure 27 (a)** and SE8-6 in **Figure 27 (b)**. 3) Artistic or a lack of relevant interpretation of the exhibits leads to communication barriers. As shown in **Figure 28 (c)**, the interactive query desktop, SB5-1 in **Figure 27 (d)**, is attractive to tourists to stay and watch due to its vivid painting style and procedural content interpretation. However, due to the lack of operation instructions, a large number of visitors think it is not interactive. 4) The interpretation of exhibits is too artistic or lacks relevant interpretation, forming a communication barrier. As shown in **Figure 28(d)**, the projection exhibits that SJ8-3 is an animated creation based on the prototype of the “jade cong” artifact, but it is overly abstract, making it difficult to comprehend. Additionally, due to the lack of explanatory information, visitors speculated whether it could be triggered by touch; the digital projection content is challenging to understand.

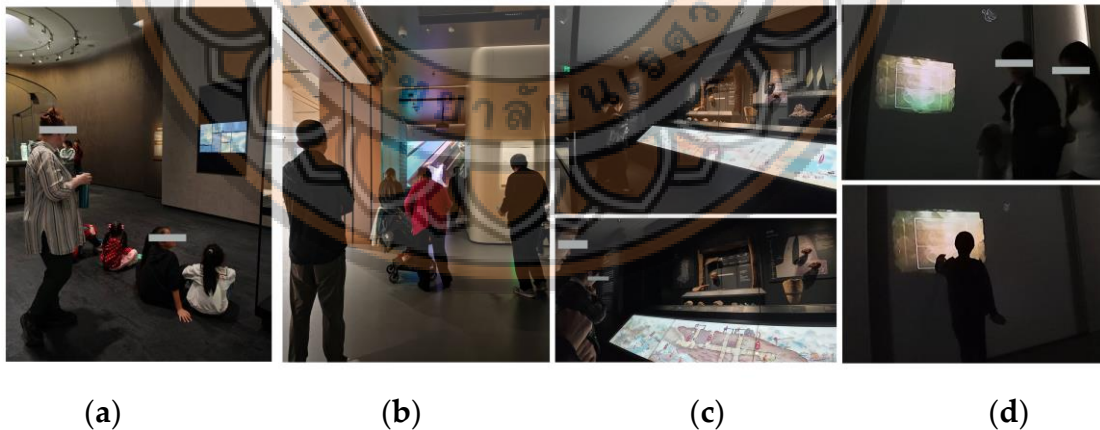


Figure 28 Photo description in the Shanghai Museum -East

Comparative study: Immersive Digital Interactive Exhibition in China Grand Canal Museum (GCM)

The examination of the China Grand Canal Museum centered on the gallery “Boats on the Canal”. As depicted in **Figure 29**, the gallery employs a two-tiered space spanning fourteen meters to segment the exhibition into two primary zones: the lower level, dedicated to the historical narrative of boats and a model showcase, and

the upper level, designed for the spaceship-themed experience. The key challenges encountered by the "Boats on the Canal" exhibition involve the spatial scale, the diminished utilization of digital media, the absence of designated areas for media interaction operations, and the congestion resulting from the use of digital media. Further identified concerns are outlined subsequently.

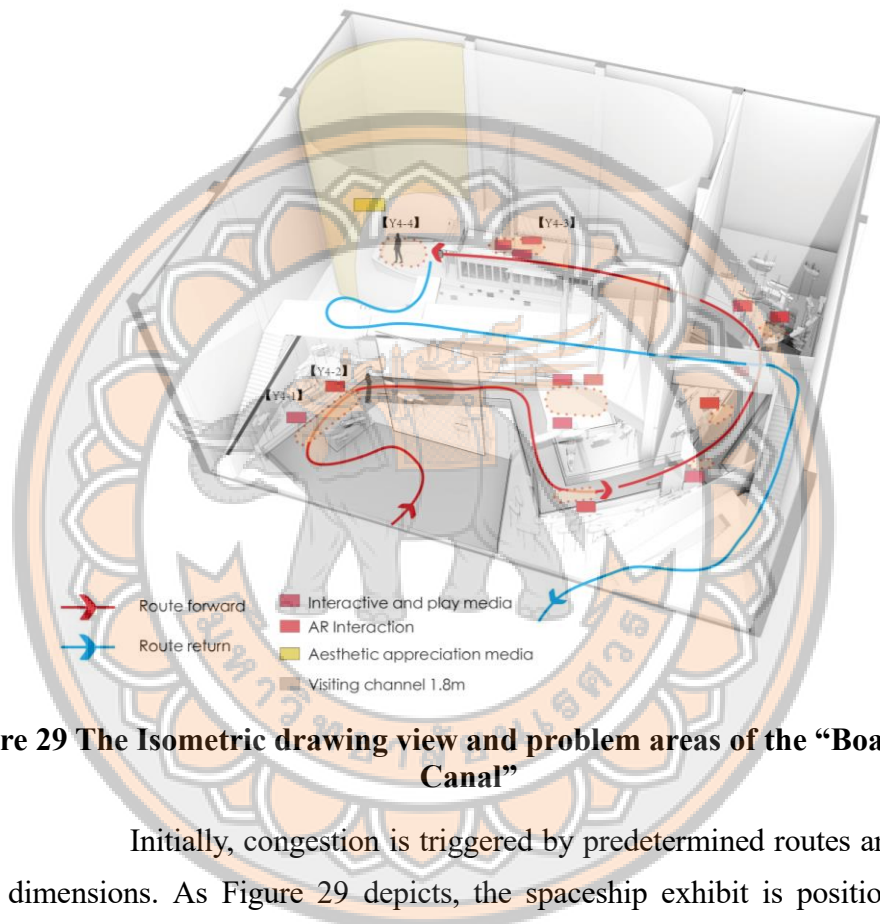


Figure 29 The Isometric drawing view and problem areas of the “Boats on the Canal”

Initially, congestion is triggered by predetermined routes and confined spatial dimensions. As Figure 29 depicts, the spaceship exhibit is positioned on the building's upper level. Visitors need to pass through the exhibition area on the first floor in order. They are compelled to traverse a solitary pathway, which is merely 1.8 meters wide. This scenario introduces an additional concern: touch query screens (Y4-1) and AR interactive screens (Y4-2) are arranged at small intervals on both sides of the 1.8-meter-wide walkway. Visitors often struggle to complete reading the content, capture photos for keepsakes, and engage with interactive devices when the passage, measuring 1.8 meters in width, is packed with numerous individuals. **Table 33** compares the desired scenario with the actual exhibition site. Additionally, according to the on-site survey, most tourists were impressed by the space-themed dual-screen VR experience

and 5G video. However, some elderly tourists and motion sickness sufferers admitted that although these experiences were attractive, they did pose challenges.

Table 33 Comparison of the design scenario with the real-world conditions

The Design image of the desired scenario	The actual exhibition site
	
	

5.3 Result of the 7UD Checklist Evaluation of the exhibition environment

Upon completing an access audit of seven galleries within six museums by utilizing the UD evaluation checklist, the collected data were input into SPSSv27 for descriptive analysis. As shown in Table B2, Appendix B, this process produced the UD scoring rate for each digital exhibit and the UD scoring of six museums.

As seen in **Figure 30**, on the whole, the Shanghai Museum East has a relatively good performance in terms of 7UDs scoring rate, especially in UD3 and UD4 indicators, significantly higher than the other four museums. On the contrary, despite the Jiangnan Water Town Culture Museum of China (CWM) having the most digital devices and attempting to disseminate cultural heritage through digital interpretation, its 7UDS scoring rate is the lowest. This indicates that the CWM has the most problems and obstacles in digital interpretation. the Wu-Yue Museum has a high overall score rate but a lower score rate for UD3-Simple and Intuitive Use. The scoring rates of the Wu Culture Museum in Equitable Use (UD1), Simple and Intuitive Use (UD3), and

Perceptible Information (UD4) are lower. The China Grand Canal Museum has obtained remarkably better outcomes for UD3; nevertheless, its UD1 score ratio is the lowest.

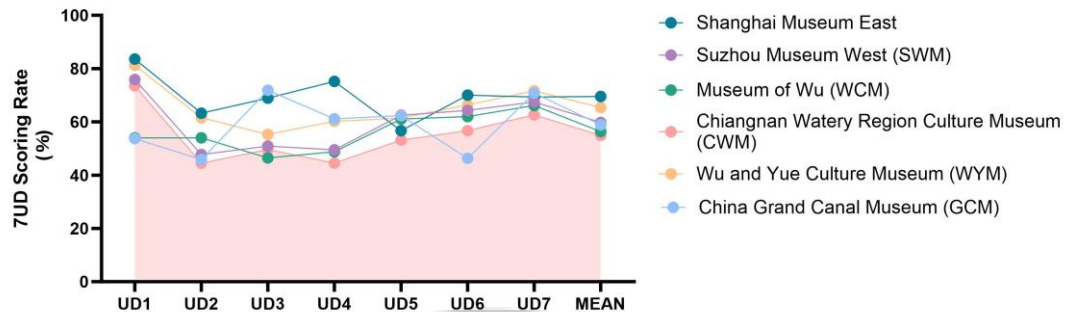


Figure 30 The 7UD Scoring Rates and Comparison of Six Museums

(1) Five museums: The 7UD Checklist evaluation results

To further examine the relationship between the digital design elements and the universal design, the 7UD evaluation results of the 135 group exhibits were recoded according to the classification of digital media exhibit configurations. The score ranges and their interpretations are as follows: 0-20% indicate a “Failed” level, meaning the exhibit does not comply with UD principles; 20%-40% indicate a “Poor” level, meaning the exhibit barely complies with UD principles; 40%-60% indicate a “Fair” level, meaning the exhibit complies with UD principles; 60%-80% indicate a “Good” level, representing compliance with UD principles; and 80%-100% indicate an “Excellent” level, representing strong compliance with UD principles. In this study, the “Good” and “Excellent” levels are considered as the tiers where digital interpretation exhibits meet the principles of Universal Design.

Figure 31(a) shows that the 7UD scoring rates for the five major types of digital interpretation are all within the “Fair” level, with only the UD1 indicator performing well with “Good”. This indicates that most visitors can participate equally in digital interpretation and presentation. However, for digital interpretation within the context of immersion spaces, the UD4 and UD5 indicators are rated as “Poor,” indicating that visitors struggle to clearly understand the purpose and significance of the digital devices. Additionally, the space may evoke feelings of threat and insecurity among visitors.

Specifically, within the array of digital interpretation exhibits, UD1 exhibited a notably high level of adherence, with 94.3% of digital displays and exhibits aligning with UD1 (Excellent and Good). In contrast, UD2 (29.6%), UD3 (43.2%), and UD5 (45.5%) all recorded percentages below 50%. Only sixteen digital exhibits satisfied

all seven universal design principles, accounting for 18.18% of the total. Conversely, three exhibits failed to meet any of the seven principles, representing 3.40% of the total. As shown in **Figure 31(b)**, the digital displays and exhibits showcased across the three museums predominantly adhere to universal design, ranging from Fair to Good, suggesting considerable scope for enhancement.

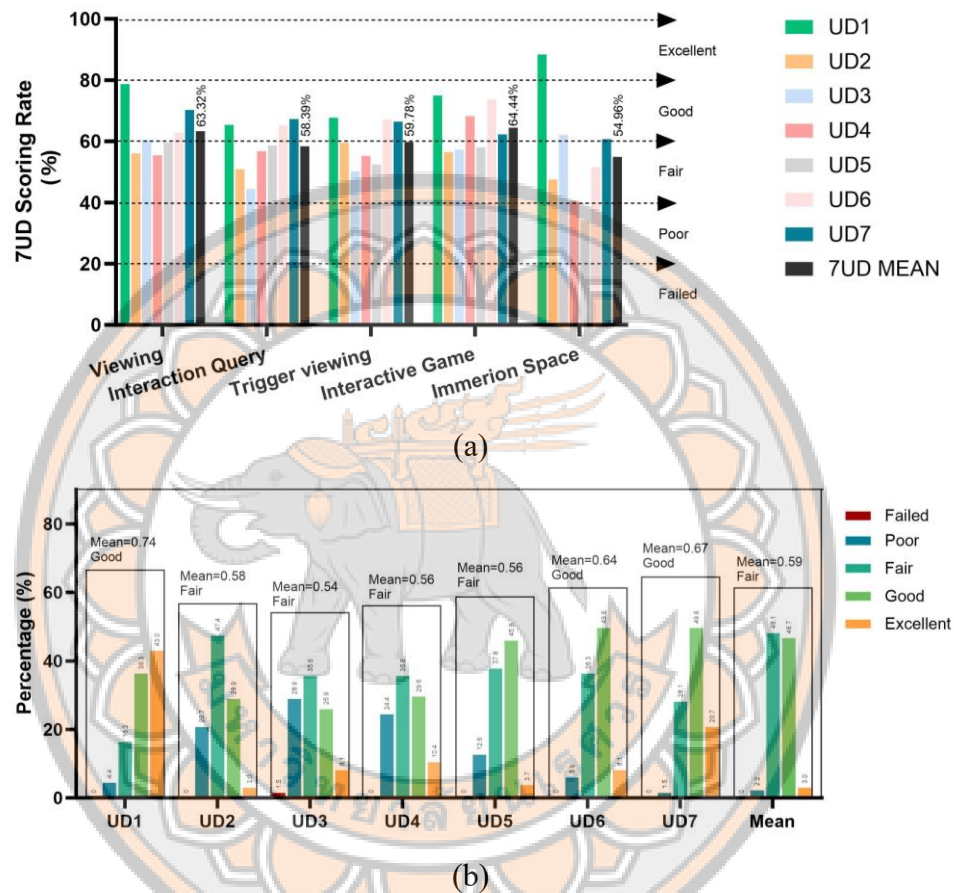


Figure 31 The 7UDs scoring rates for the five types of digital media exhibits

The specific results analysis of the five museums is as follows:

Suzhou Museum (West) (SWM)

The historical exhibition hall in the Suzhou Museum West showcases the regional culture and urban heritage of the Suzhou area, consisting of 12 digital interpretation devices. The international exhibition hall is currently hosting an exhibition titled “King of Assyria: Ashurbanipal,” which tells the story of the heritage and culture related to Ashurbanipal and his Assyrian empire, featuring 9 digital interpretation devices. In this museum, the forms of digital exhibits include film and television spaces, knowledge point explanations, query displays, interactive games, and art installations. **Figure 32** shows that the overall 7UD score rate of the SWM is

in the “Fair” level, with the lowest 7UD scoring rate for viewing type and trigger viewing type, which is in the “Poor” level. The 7UD scoring rate for the type of interactive game is higher compared to other digital devices.

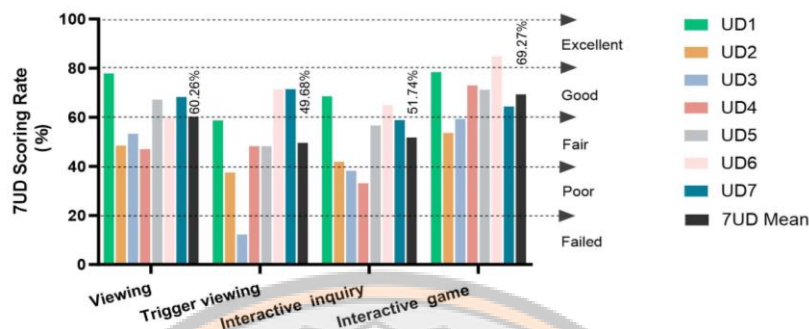


Figure 32 The 7UD scoring rates of digital interpretation in SWM

The issue with digital interpretation in the history gallery lies in the insufficient utilization rate of digital devices. Inspections revealed that the scoring rates for indicators UD2, UD3, and UD4 were notably low, manifested as: a lack of flexible and diverse interpretation methods, insufficient prominent explanations and signage, high difficulty in content recognition, image playback potentially being mistaken for touchscreen operations, and artistic scenes, videos, or projections being more easily overlooked by visitors. The two viewing spaces in the international gallery were mostly ignored by visitors, accompanied by low scores for indicators UD2, UD3, UD4, and UD6. The specific analysis is as follows:

The digital media at the Suzhou Museum West is exhibiting subpar performance in three key areas: UD2, UD3, and UD4. When it comes to addressing the needs of diverse visitor groups, there's a remarkable shortage of support for older visitors, children with family visitors, and those people who with special needs. (1). Firstly, due to the winding route design, when tourists choose their own tour routes according to their preferences, it will lead to an incomplete experience of the exhibition structure. Moreover, family tourists with children and teenage student groups will change their visiting routes due to the attraction of digital interactive exhibits and cross with the crowd. The bulk of digital media exhibits in the SWM are centered around knowledge, frequently devoid of varied formats that cater to the needs of the elderly, children, and foreign visitors. Most digital displays mainly function as content playback mechanisms, offering abstract material or simple lists of informational points, which also fall short in providing diverse formats to effectively reach the elderly, children, and foreign visitors. (2). Secondly, the displays associated with the UD3 indicator are devoid

of the necessary operational guidelines and explanatory content. Furthermore, the inadequate lighting conditions hinder child, elderly, and foreign visitors lacking professional expertise from accessing and comprehending the information. (3). Thirdly, consider the Perceptible Information (UD4); the materials on display are highly professional and difficult to learn, which is challenging for children for children, seniors, and international visitors in acquiring pertinent information.

Museum of Wu in Suzhou (WCM)

The Museum of Wu is situated in Suzhou, China. Although the museum is designed to be a cultural tourism attraction, the majority of its visitors are residents, and it lacks sufficient appeal for tourists. The Archaeological Heritage Gallery showcases the archaeological records and heritage remains of the ancient Suzhou area. There is a total of 17 digital devices within the gallery. The Natural Heritage Gallery showcases the natural resources and intangible heritage, featuring a total of 12 digital devices. The forms of application of digital interpretation technologies in WCM include immersion spaces, AR interaction, entity interaction, viewing videos, sensor projections, and artistic scenes. As shown in **Figure 33**, under the evaluation of the 7UDs evaluation checklist, the digital interpretation with all types of WCM shows weaknesses in 7 indicators of UD7s. In the context of UD1, there are distinct levels of challenges faced by foreign, child, and older adults. The exhibition is devoid of English directional signs and visitor management systems, which hinders visitors from accessing information efficiently. The digital devices feature a notably child-like design, which discourages senior visitors from interacting with them. Concerning Simple and Intuitive Use (UD3) and Perceptible Information (UD4), the digital interpretation within the Museum of Wu lacks clear explanations of its functions and operations, frequently triggered by unintended touches from child visitors.

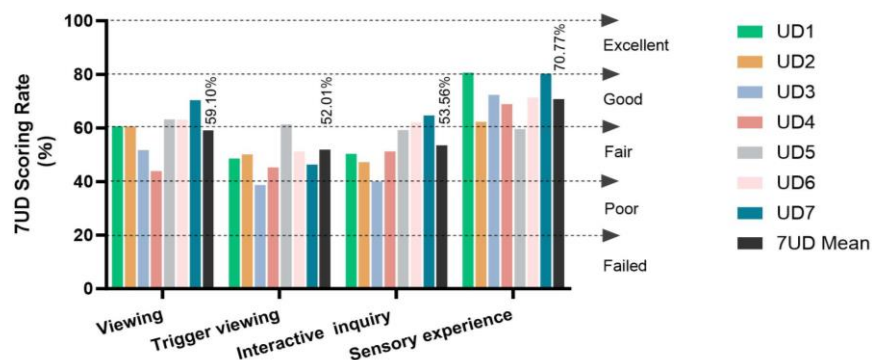


Figure 33 The 7UD scoring rates of digital interpretation in WCM

Firstly, UD1 encounters diverse obstacles for not Chinese tourists, child, and any type of adult. The lack of English signage and visual navigation system hindered visitors from effectively obtaining information. The displays for interaction, characterized by a distinctly child-oriented design, dissuade elderly visitors from interacting with them. (2) Secondly, issues with the UD2 indicators encompass neglect stemming from the improper positioning of digital devices and the inability to effectively identify these devices. In addition, digital displays and exhibits provide only one mode of operation, and many are located behind the main tourist path. Visitors have to actively seek them out to get a rich experience. Unfortunately, with the exception of dedicated museum lovers, few visitors are willing to interact with media exhibits. (3) Thirdly, concerning the indicators for UD3 and UD4, the digital exhibits are deficient in clear functional descriptions and operational guidance. Interaction devices are frequently triggered by accidental touches from child visitors or when parents guide their children in exploration. Thirdly, regarding UD3 and UD4, due to digital displays and exhibits lacking description and operation instructions, the devices are often triggered by accidental touch by children, visitors, or parents guiding their children to engage in interaction. Furthermore, the content within the interpretation and display of the media exhibits is excessively specialized, lacks logical consistency, and is inadequately aligned with the exhibition's framework. Visitors across various demographics, including the elderly, families, couples, and middle-aged individuals, have expressed challenges in comprehending the media.

Jiangnan Water Town Culture Museum of China (CWM)

The Jiangnan Water Town Culture Museum of China (CWM), situated in Hangzhou, China, showcases the cultural heritage of the water town through modern digital interpretation technologies, including artistic scenes. The museum primarily attracts college students from the surrounding area and local middle-aged and elderly families, lacking sufficient appeal to tourists. The Jiangnan Water Town Culture Museum of China stands out among the six museums for having the highest count of digital media exhibits, featuring an impressive array of 42 digital devices. These devices are densely arranged, leading to a dispersed visitor flow and the absence of a predefined path. This arrangement has consequently resulted in a disorganized visitor flow, causing many devices to be missed by visitors. Moreover, the densely distributed digital devices are mostly query screens, query desks, and static videos. As shown in **Figure 34**, the scoring rates (38 group digital media exhibits) for 7UD are low, with significant

deficiencies in UD2, UD3, UD4, and UD5 indicators, all being below 40%. The scoring rate of the UD3 indicator for the interaction game and the UD5 indicator for sensory immersion space is below 20%, which is considered “Failed”.

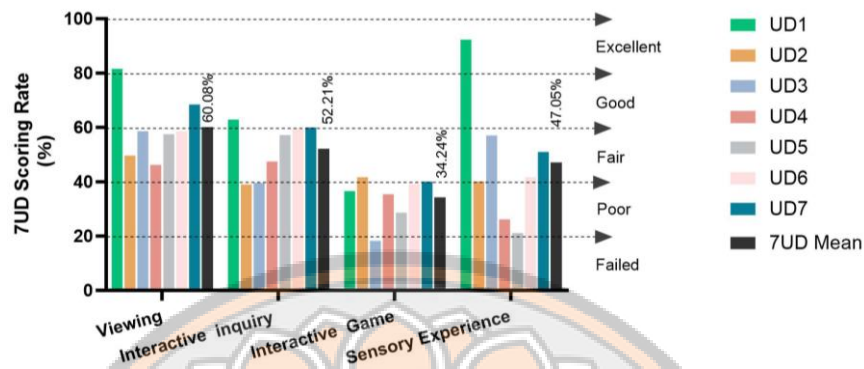


Figure 34 The 7UD scoring rates of digital interpretation in CWM

The Jiangnan Water Town Culture Museum of China received the lowest scores in the 7UD Checklist assessment among the six museums evaluated. Except for UD1, the museum scored the lowest on all six Universal Design (UD) indicators. Additionally, its score for UD5 was notably lower than those of the other four museums. (1) Firstly, the digital exhibits, considered for UD1, are devoid of English explanations, making it challenging for foreigners to grasp the meaning of the exhibits. In addition, some interactive exhibitions presented in a desktop form are difficult for child visitors and people with disabilities to access. (2) Secondly, for Flexibility in Use (UD2), the exhibition design of scattered visiting paths and a dense arrangement of media exhibits. Tourists are prone to getting lost in the process of changing their routes at will. This, however, results in certain exhibits being bypassed and some visitors becoming disoriented. Additionally, certain digital media installations are situated in out-of-the-way corners, frequented primarily by those with specialized interests, such as undergraduate students and museum-loving lovers. (3) Thirdly, in the indicator of Simple and Intuitive Use (UD3), the interaction displays are missing instructions and visual icons, thereby hindering easy understanding and operation for visitors across all categories. (4) Fourth, the material presented in UD4, the digital media exhibits are abstract and devoid of distinct information points, which hampers the ability of visitors from all backgrounds to maintain focus. In addition, the interaction exhibits, displays, or screens do not meet ergonomic standards, so that visitors can only discover and participate in the interactive experience when they are deeply exploring. (5) Fifth, consider Tolerance for Error (UD5); there are no error

alerts for incorrect actions in the interactive exhibits, which often results in repeated touching and unconscious repetitive actions by child and student visitors. In interactive displays and exhibits, there are no error alerts for incorrect movements, which often leads to children visitors repeatedly touching and unconsciously repeating the movements. In the two immersive audiovisual spaces, overly dim lighting and enclosed large-screen environments may cause discomfort to visitors of different types, leading them to leave. Additionally, it's worth noting that the Jiangnan Water Town Cultural Museum has a higher failure rate of digital media equipment compared to the other museums in this study.

Wu-Yue Culture Museum (WYM)

The Wu-Yue Culture Museum, newly established in 2024, incorporates digital interpretation technologies, including intelligent sensing, interactive inquiry, and audio-visual spaces, to vividly display cultural heritage and history. There is a total of 19 digital media exhibition items in the museum, one of which is damaged. As shown in **Figure 35**, the 7UD scoring rates (18 digital media exhibits) for the UD2, UD3, UD4, UD5, and UD6 indicators of viewing digital devices are all below 60%. The specific issues manifest as the unsuitable placement of the devices, causing impacts on surrounding exhibits, such as blocking traffic and creating reflections. Additionally, the discomfort of the viewing space and excessive physical exertion are due to inappropriate viewing distances and scales.

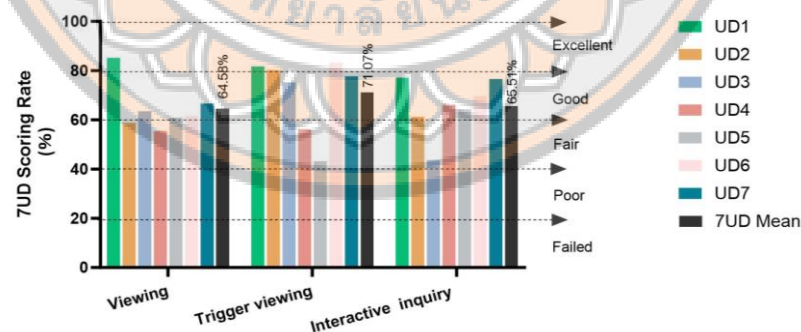


Figure 35 The 7UD scoring rates of digital interpretation in Wu-Yue Museum

The Wu-Yue Culture Museum has achieved notably higher scores across all 7UD indicators. And among the five museums, UD1 boasts the highest score rate. There are two factors underlying this analysis: at the first, the digital displays and exhibits are positioned at crucial points within the space layout, showcasing a spatial and operational scale that are properly balanced, making them accessible for

participation by visitors of diverse backgrounds; secondly, the content of digital media presentations, which visually elucidate archaeological knowledge, is appropriate for viewing by visitors of all types, irrespective of the difficulty level. Despite this, the digital exhibits in the Wu-Yue Culture Museum continue to present several current situations that are not in alignment with the 7 principles of UD: (i). Ambiguous operation instructions and obscure labels hinder the comprehension of the functions of the media exhibits; (ii). The excessive height and oversize of digital devices lead to more significant physical strain on visitors. and (iii). The incorrect positioning of digital displays and exhibits results in a negative effect on neighboring objects or exhibits.

Shanghai Museum East Campus (SEM)

From the data in **Table 37** and **Figure 30** it can be seen that the overall 7UD score rate for the Shanghai Museum East is 69.57%, and according to the classification of grades where every 20% is level, it falls into the Good category (UD score rate of 60%-80%), indicating that it has relatively well met the principles of Universal Design.

As shown in **Figure 36**, the overall scoring rates of the four digital interpretation methods all fall within the “good” range, with UD1 scoring above 80%. This indicates that the digital media interactions at the Shanghai Museum East Branch can provide objective conditions for participation by different types of visitors, demonstrating excellent accessibility performance. In particular, the UD3 and UD4 metrics show that visitors can clearly understand the purpose and content of the digital interpretations. However, the scoring rates of the UD5 and UD2 indicators are insufficient: Visitors may encounter varying degrees of obstacles during their participation in digital interpretation, such as sudden program interruptions, crowded spaces, etc. This indicates that while the location and format of the digital exhibits do not pose accessibility barriers for visitors, there remains a lack of user-friendliness in terms of flexibility, perceptibility, and fault tolerance. For example, elderly visitors may perceive these digital media as irrelevant to the exhibition content, and the crowded environment may not be suitable for their visit was the conclusion drawn from the first phase of the survey.

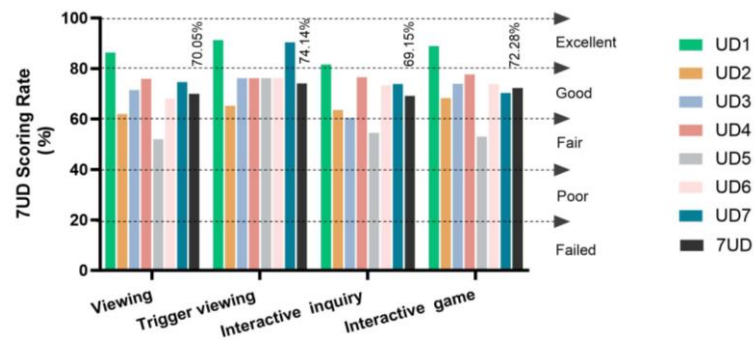


Figure 36 The 7UD scoring rates of digital interpretation in SEM

Further analyze the four galleries of the Shanghai Museum in detail. The 7UD Checklist Evaluation results for the four galleries are relatively balanced, all reaching the “Good” level, as shown in **Figure 37(b)**. The UD scoring rates for the Ancient Chinese Bronze Gallery, Ancient Chinese Jade Gallery, Chinese Numismatics Gallery, and Ancient Ceramics Gallery are 72.07%, 68.87%, 68.50%, and 71.57% respectively. Among them, the Ancient Chinese Bronze Gallery has the highest comprehensive UD scoring rate, reaching 72.07%. Environmental measurement results based on design elements in Stage 1 of the research also indicate that the Bronze Hall has relatively fewer environmental barriers and restrictions.

As can be seen from **Figure 37(a)**, among the four galleries in the Shanghai Museum East, the 7UD Checklist Evaluation results of the Ancient Ceramics Gallery are significantly different. In particular, the scoring rates of UD5, about tolerance rate, are notably insufficient compared to other galleries; whereas the scoring rate for UD3, about operational simplicity, is significantly higher than the other three galleries. This indicated that the digital media interactions in the Ancient Ceramics Gallery can provide good perception and operational instructions for visitors of different types, with excellent accessibility performance, and the primary obstacles and barriers are inappropriate exhibit placement and spatial dimensions, which lead to crowd congestion and safety hazards. The gallery with similar issues also includes the Chinese Numismatics Gallery. The main barriers to interaction are interruptions or restrictions during the interactive participation process, which is consistent with the findings of the first phase environmental inspection.

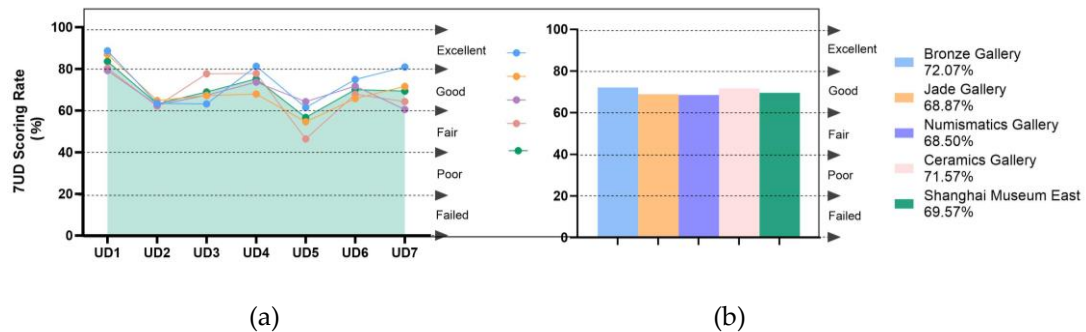


Figure 37 The UD score rates for the four galleries in Shanghai Museum East

(2) Comparative study: China Grand Canal Museum (GCM)

As illustrated in **Figure 38**, the GCM exhibits poor performance in UD1 (score rates = 53.71%), UD2 (score rates = 45.82%), and UD6 (score rates = 46.34%). In terms of catering to the demand of various visitors, an inadequate provision for single middle-aged and older adult visitors. (i). Firstly, within the UD1, the restricted and crowded watch area leads visitors to experience a sense of insecurity. Additionally, the novel digital techniques tend to be unacquainted or disconcerting. (ii). Secondly, within the scope of the UD2, the space is designed with a single fixed access to the site, requiring visitors to move along with the crowd and adhere to the set route. As visitor numbers swell, the practicality of pausing to thoroughly examine the exhibits correspondingly declines. (iii). Thirdly, regarding the UD5, the ambient lighting is dark and dim, and the space for interaction and operations is confined, which complicates the accessibility of interactive facilities. Owing to the singular route highlighted in UD2, visitors are unable to pause flexibly and engage in exploration, leading to extended walking distances and diminished visitation comfort.

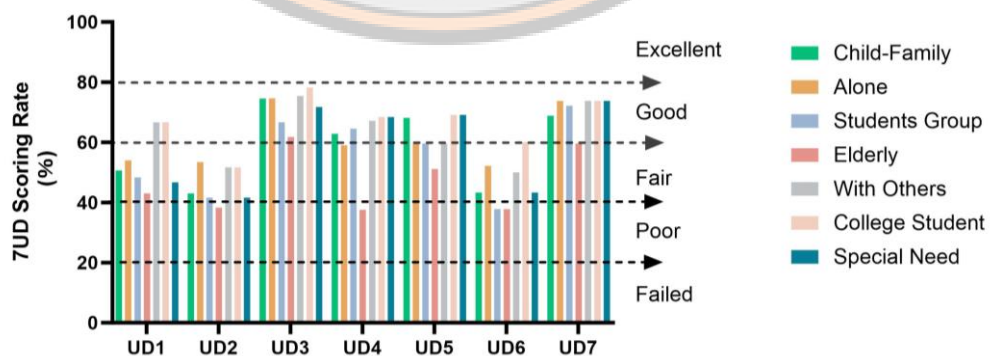


Figure 38 The 7UD scoring rates of digital interpretation in GCM

By analyzing the increase in the UD score rate of the Grand Canal Museum, it can be concluded that, based on new digital technologies such as XR and

VR, issues and obstacles are prone to arise in UD1, UD2, and UD6, which are significantly influenced by the personal factors of visitors. Therefore, it is necessary to fully consider the needs and characteristics of different visitors during the design process, as well as how to align them with universal design principles to reduce visitation barriers. This finding supplements the previous research results.

5.4 Results of Visitor Interviews

To explore further the factors that influence visitors' engagement and their experiences during actual visits to exhibitions, a group of 94 visitors near the exit of the museum's main exhibition hall was randomly selected for interviews. Through in-depth one-on-one conversations, researchers not only mapped out their movement patterns during the exhibition but also captured key insights: challenges they faced, memorable experiences, and anticipated future visits. A significant number of participants in this study struggled to understand professional terms such as "digital interpretation," "interaction," and "experience." Therefore, the focus was primarily on their statements and expressions rather than posing overly specialized questions. Their engagement with the digital exhibit was largely random, with a greater emphasis on comfort, safety, and content presentation methods. This research compiled the interview transcripts, identified key terms, and synthesized perspectives from several key dimensions: basic information, operational experiences (highlighting both challenges and advantages), viewpoints, and recommendations.

(1) Basic information

Among the 94 participants in the interview, 63 were female (67.02%) and 31 were male (32.98%). Among them, 11 were parent-child families, 18 were couples, 15 were solo visitors, 17 were university students, 13 were middle school students, 16 were elderly individuals, and 6 were foreigners. The question about the motivation and purpose of visiting revolves around such questions as: "Do you visit museums often?" and "What brings you to this museum?". Among the visitors to the question, the three main answers were: "leisure and relaxation, casual stroll", "specially visiting museums during travel", and "museum enthusiasts". It is noteworthy that very few visitors mentioned "learning," with the closest expression being "seeing things they haven't seen before."

(2) Experience: obstacles and benefits

By asking questions such as "Have you seen a digital exhibit or display?" "Do you like digital exhibits?" and "Are you ready to participate in a digital interactive device?" This study gathered information on visitors' receptiveness to digital interpretation

and their instinctive reactions during their museum visit. The overall sentiments of the interviewees regarding the different types were: they deemed it acceptable, with key phrases such as "engaging format," "engaging content," "easy operation," "beneficial for visits," and "knowledge enhancement." Only 11 respondents expressed clear dissatisfaction with digital media interpretation, mainly due to "lack of professionalism", "poor production quality" and "lack of participation". One senior visitor and two middle-aged visitors stated that they would not give particular attention to digital media and were indifferent to its quality. Furthermore, several participants noted that, in contrast to digital interpretation, they placed greater emphasis on physical objects.

Operational-level inquiries encompass: "Have you seen or participated in a digital exhibition?", "What difficulties have you encountered in the process of operation?", and "Do you realize this is interactive?" An interesting trend emerged when analyzing the interview data: While 75.53% of respondents (N=71) said "digital exhibition is good," their reasons were somewhat unclear. Nevertheless, when the conversation shifted to challenges or recommendations concerning its usage, these participants displayed a marked increase in enthusiasm. The key phrases include "lack of explanation," "uncertain how to do it," "the content unrelated to the theme of the exhibition," "overcrowded," and "not appropriate for me." Several older persons also commented, "These activities are meant for the youth; I don't care about them, and I won't engage in interactions." "As we're aging, we're unfamiliar with how these things function. We simply observe what we can grasp and won't trouble ourselves with learning how it works." In contrast, highly educated seniors and those with extensive museum visiting experience remarked, "I find the interaction quite straightforward. Despite being over 60, I experience no difficulty whatsoever".



Figure 39 High-frequency feature word analysis

Figure 39 showcases the frequency count of keywords obtained from the interviews. The findings from the high-frequency feature word analysis, conducted through semi-structured interviews, are documented in Appendix B, Table B3.

5.5 Summary

Analysis of physical environments in museums and their alignment with key factors for effectively integrating digital technologies to promote museum tourism

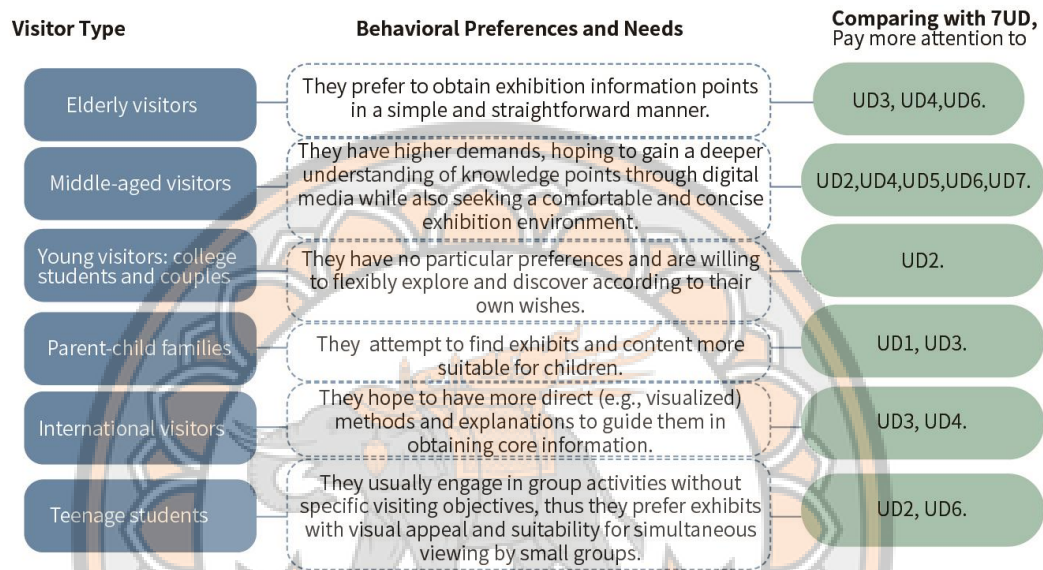


Figure 40 Alignment of physical environment assessments and visitor interviews

By environmental measurement and assessment, combining and comparatively analyzing data from visitor interviews, this study examines the different visiting obstacles presented by digitally-intervened exhibition environments across six museums in three aspects: Physical Environment, Information Environment, and Interactive Environment. Identified the existing issues in digital exhibits and media design for museums and the supply-demand relationship with visitors, as shown in **Figure 40**. And the specific findings are summarized in Appendix B, Table B4.

The results show that among the UD evaluations, the exhibits with a UD score rate below 50% overlap with the problematic exhibits identified in the environmental survey. As shown in **Table B5**. Additionally, it was discovered that the correlation between visitor behavior and the exhibition environment, as augmented by UD7 reviews, corresponds to the findings from visitor interviews. Therefore, it is concluded that utilizing UD principles can address existing issues in exhibition design, thereby enhancing visitor interest and interaction.

CHAPTER VI

RESULTS OF OBJECTIVE 3

6.1 Overview

Objective 3 aims to investigate museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital media technologies in exhibitions. Data analysis and results presentation are divided into four parts: the first part is the survey results on the attractiveness of digital media exhibits based on the IAE scale. The second part is the visitor experience survey results. The third part presents the results of the correlation analysis between UD, attractiveness, and visitor experience. The research at this stage was conducted at the Suzhou Museum West, the Wu Culture Museum, the Jiangnan Water Town Museum, the Wu and Yue Culture Museum, and the Shanghai Museum East Branch, investigating the characteristics, visiting behaviors, and experiences of different types of visitors. The participants were in Sample Group 3 and Sample Group 4. The results are analyzed as follows:

6.2 Results on the Attractive Power of Digital Exhibits Based on the IAE Scale

(1) Descriptive analysis of statistical results

Through the systematic data collection using the IAE Scale, this study ultimately observed and recorded 138 group digital media interaction and interpretation exhibits and 6,024 visitors' AP quantitative data from the IAE Scale. In SPSS 27.0.1, the raw data were used for further descriptive statistical analysis, resulting in (i). The mean IAE score of digital interpretation devices for each museum, (ii). The score distribution and the proportion of the visitors, and (iii). The mean IAE score of each type of digital interpretation device for various target audiences.

Table 34 Summary of IAE scores for five museums, $p < 0.001$

IAE	SWM		WCM		SME		CWM		WYM		TOTAL	%
0	513	50.30%	719	54.60%	560	36.89%	623	63.40%	638	53.70%	3058	50.80%
1	265	26.00%	373	28.30%	448	29.51%	220	22.40%	264	22.20%	1577	26.20%
2	190	23.60%	200	17.00%	394	33.60%	128	14.20%	244	24.00%	1146	23.00%
3	51		24		116		12		42		243	
Total	1019		1316		1518		983		1188		6024	
+1	67	6.60%	35	2.7%	132	8.70%	51	5.20%	34	2.90%	319	5.30%
Mean	0.85		0.67		1.13		0.5727		0.7517		0.82	
SD	1.06467		0.8666		1.10913		0.88005		0.95728		1.00629	

In this phase, only digital devices with an average score of 2 or higher are considered to have attracted visitors' attention, thereby achieving the desired effect of the

digital interpretation device being attractive to the visitor, as determined by this research study. Regrettably, none of the museums surveyed achieved a score of 2. **Table 34** displays the IAE scores for digital interpretation in five museums. The results indicate that only the Shanghai Museum East attained a mean score of 1.13, and among its visitors, only 33.60% scored 2 or higher.

Based on the key factors influencing visitor interest and interaction identified in Objective 1, the characteristics of digital exhibits are comprehensively described in the following section. For instance, display configurations categorized as viewing-type digital exhibits can be classified as science-popularization interpretive viewing digital media exhibits, artistic-aesthetic viewing digital exhibits, audiovisual spatial digital exhibits, etc. Graphs were plotted using GraphPad Prism 10.1.2 to visually demonstrate the attractiveness of digital exhibits with different design features, as well as their appeal to different types of visitors, shown in **Figure 41**.

Only the digital interpretations of interactive games have an IAE score exceeding 1 point, indicating that content interaction games are more appealing to visitors than click-through games, as evidenced by the higher IAE. In the digital interpretation devices of the viewing type, the IAE score of the viewing space is significantly higher than other types, while the AP of the viewing-art and aesthetic category is far below the average level (MEAN=0.52).

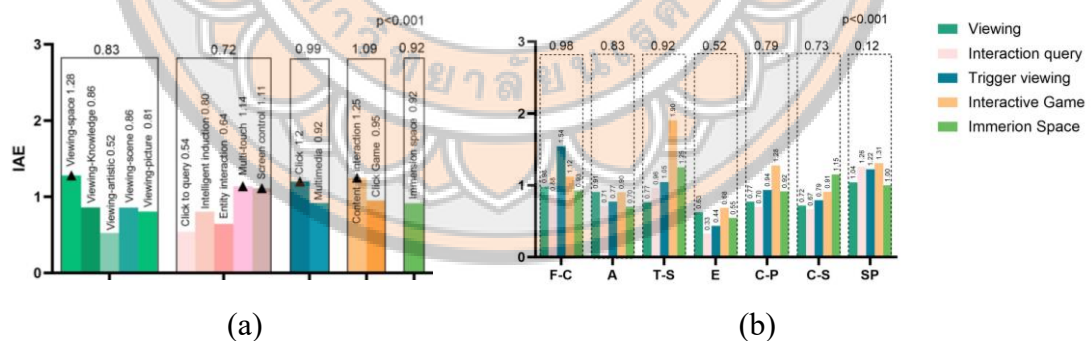


Figure 41 Results of IAE scores for five museums. (a) IAE scores of different types of digital exhibits; (b) IAE scores of digital exhibits with different visitors

Analysis of the IAE Scale results for each of the five museums

To further identify the correlations among various factors, an in-depth analysis was conducted on five museums.

Suzhou Museum West (SWM)

In SWM, the IAE Scale recorded a final observation of 1019 visitors, with details and IAE scores listed in **Table 35**.

Table 35 Summary of IAE scores for Suzhou Museum West, $p < 0.001$

IAE	Historical Exhibition		International Exhibition Hall		TOTAL	%
0	236	52.30%	277	48.80%	513	50.30%
1	126	27.90%	139	24.50%	265	26.00%
2	83	18.40%	107	18.80%	190	23.60%
3	6	1.30%	45	7.90%	51	
Total	451		568		1019	
Wow	22	4.88%	45	7.90%	67	6.60%
IAE Mean	0.74		0.94		0.85	
SD	0.92087		1.15485		1.06467	

In terms of the AP of digital devices, over half of the visitors (76.3%) scored 1 or below on the IAE scale, indicating that their interaction with digital devices ranges from “ignore” to “attend”. In Figure 42(b), among the 21 digital interpretation devices, only the mean IAE score of the viewing-knowledge category digital devices reached 1 point. Two digital devices have achieved a score of 2: the animation viewing space of SW12-8 at the History Gallery and the painting interaction game of SW9-8 at the International Gallery. Based on the observations, it was found that although most visitors approached to watch SW12-8, few people would watch the animation until the end. This indicates that while the SW12-8 installation has its appeal, it is difficult to maintain continuous viewing. No. Sw9-8 painting interaction game device, with 86% of visitors successfully participating and showing obvious wow moments during the interaction. However, most elderly visitors (75%) and single middle-aged visitors (68.8% visitors ignored or briefly viewed the device without participating. Figure 42 (a) shows the IAE scores and heatmap of various target groups at SWM. Through detailed analysis, the characteristics of digital exhibits with high attractiveness scores for different demographic groups were identified.

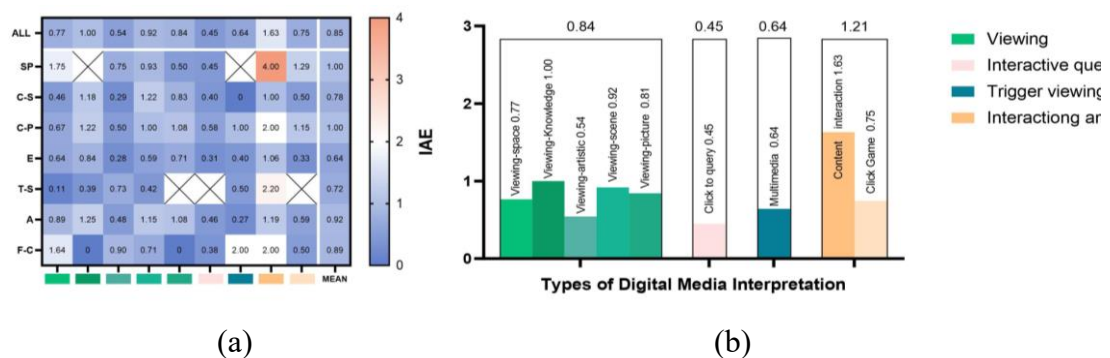


Figure 42 The IAE scores for different types of digital interpretations with different visitors in SWM. (a) The IAE scores and heatmap of various target groups. (b) The IAE scores for different types of digital interpretations.

Museum of Wu in Suzhou (WCM)

The Wu Culture Museum is a museum highly praised by professionals (Chen, 2023), yet even on Saturdays, the number of visitors remains few, with the main visitors being elderly people and couples. Two galleries recorded a total of 1,316 visits throughout Saturday and Sunday. The results of **Table 36** show that only 17% of the visitors scored 2 points or more, indicating that their visiting behavior falls between “Engage” and “Successful Engage”, and half of the visitors (54.6%) are at the level of “ignore”. In particular, the mean IAE score for interaction devices is 0.57, with little difference in the AP between click-based interactions, intelligent sensing interactions, and physical entity interaction; only a significant increase in AP is observed for visitors from Parent-Child families, shown in **Figure 43**.

Table 36 Summary of IAE scores for Museum of Wu, $p < 0.01$

IAE	Archaeology Exhibition Hall		“WU WIND” Exhibition		TOTAL	%
0	381	54.30%	338	55.00%	719	54.60%
1	233	33.20%	140	22.80%	373	28.40%
2	83	11.80%	117	19.10%	200	17.00%
3	5	0.70%	19	3.10%	24	
Total	702		614		1316	
+1	14	2.00%	21	3.40%	35	2.66%
IAE Mean	0.61		0.7362		0.67	
SD	0.72242		0.96027		0.8666	

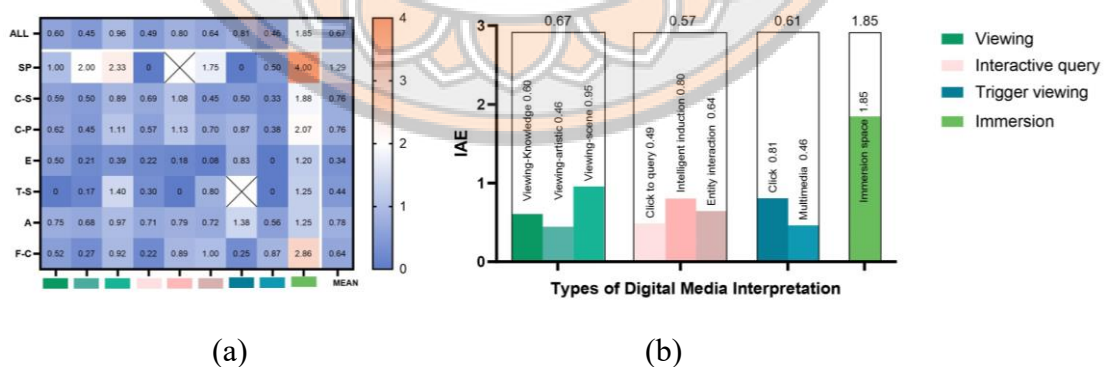


Figure 43 IAE scores for different types of digital interpretations with different visitors in WCM. (a) The IAE scores and heatmap of various target groups. (b) The IAE scores for different types of digital interpretations.

Jiangnan Water Town Culture Museum of China (CWM)

The CWM features a total of 42 digital interpretation devices, which recorded 983 visitor instances during the recorded period, Saturday. Within this time

frame, no teenage students were present in the gallery. From the IAE scores in **Table 37**, only 14.2% of the visitors achieved a score of 2 or above. Among them, 33.57% were parent-child families, and 28.57% were companion-type visitors. In the gallery, the IAE scores for digital interpretations of various types are all below 1 point, with the highest score being 0.66 for the viewing type. The IAE score for interaction games is only 0.26, indicating that almost no one will notice this device. As can be seen from **Figure 44**, among the four types of digital interpretations, the types of visitors attracted and engaged are mainly parent-child families and companion-type visitors, while in the interactive query category, middle-aged visitors who visit alone are more willing to discover and participate in interactions (16.95%).

Table 37 Summary of IAE scores for CWM, $p < 0.001$

IAE	Viewing		Interaction Display		Interaction Game		Sensory Immersion		TOTAL	%
0	283	56.70%	241	67.30%	33	78.60%	66	78.60%	623	63.40%
1	138	27.70%	58	16.20%	7	16.70%	17	20.20%	220	22.40%
2	72	15.60%	53	16.50%	2	4.80%	1	1.20%	128	14.20%
3	6		6		0		0		12	
TOTAL	499		258		42		84		983	
+1	30	6.00%	18	5.00%	0	0.00%	3	3.60%	51	5.2%
IAE	0.66		0.56		0.2619		0.2619		0.5727	
SD	0.90043		0.9232		0.54368		0.54039		0.88005	

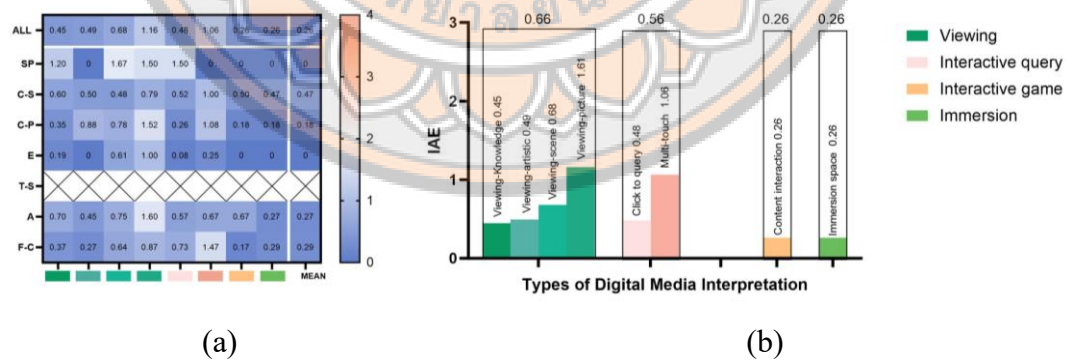


Figure 44 IAE scores for different types of digital interpretations with different visitors in CWM. (a) The IAE scores and heatmap of various target groups. (b) The IAE scores for different types of digital interpretations.

Wu-Yue Culture Museum (WYM)

The digital interpretation and presentation devices at the WYM are concentrated in the historical gallery, which recorded 1,188 visitors. On the Saturday of the survey, there were no teenage student visitors. From **Table 38**, it can be seen that the

Viewing- Intelligent Sensing category digital devices have a higher IAE score, with an average of 1.4, and 44.20% of visitors scored 2 or above. The IAE score for interaction query devices is relatively low, with a score of only 0.59. From the IAE scores of various types of visitors in **Figure 45**, it can be seen that the AP among different types of digital interpretations at the WYM varies significantly. Viewing-space and viewing-knowledge categories have higher AP to visitors of various types. On the other hand, viewing artistic scenes and viewing image playback categories have lower AP.

Table 38 Summary of IAE scores for WYM, $p < 0.001$

IAE	Viewing		Interaction Display		Interaction Game		TOTAL	%
0	322	51.20%	293	63.10%	28	29.50%	638	53.70%
1	161	25.60%	85	18.30%	25	26.30%	264	22.20%
2	132	22.20%	79	18.50%	23	44.20%	244	24.00%
3	14		7		19		42	
Total	629		464		95		1188	
+1	19	3.00%	10	2.20%	5	5.30%	34	2.90%
Mean	0.77		0.59		1.4		0.7517	
SD	.92771		0.88447		1.18860		0.95728	

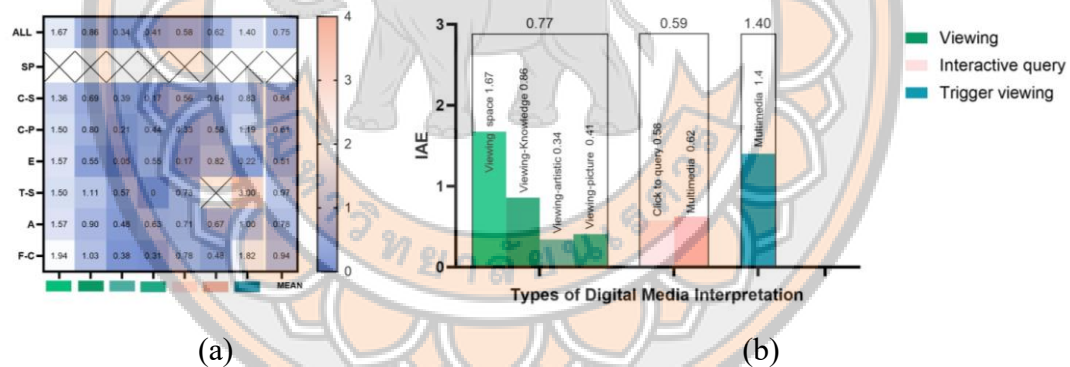


Figure 45 IAE scores for different types of digital interpretations with different visitors in WYM. (a) The IAE scores and heatmap of various target groups. (b) The IAE scores for different types of digital interpretations.

Shanghai Museum East Campus (SEM)

In the four galleries of SEM, a total of 1518 visitors' behavior was recorded by the IAE scale. The observation location in the Ancient Chinese Bronze Gallery is located on the second floor of the gallery, not including the four knowledge-viewing devices on the first floor, as there are interpretation devices of the same type and function set up in the Ancient Chinese Jade Gallery. As can be seen from **Table 39**, among the four galleries, only the Ancient Chinese Bronze Gallery had more than half of its visitors (66.3%) with an IAE score of 2 or above, indicating that they were

between “Engage” and “Successful Engage”. There are 74% of visitors rate 1 point or below in The Ancient Chinese Jade Gallery, indicating that the majority of visitors do not notice digital interpretation or are not attracted enough to stop and stay, while the main type of digital interpretation in the Jade Gallery is of the viewing type, especially those with a viewing-artistic screen. As can be seen from **Figure 46**, among the visitors who scored 2 points or more at SEM, the largest proportion is families with children (44.92%), followed by young students (43.09%).

Table 39 Summary of IAE scores for SEM, $p < 0.01$

IAE	SB5		SE8		SC8		SJ8		TOTAL	%
0	16	16.84%	165	31.90%	166	35.20%	213	49.10%	560	36.89%
1	16	16.84%	177	34.20%	147	31.10%	108	24.90%	448	29.51%
2	45	47.40%	138	26.70%	129	27.30%	82	18.90%	394	33.60%
3	18	18.90%	37	7.20%	30	6.40%	31	7.10%	116	
Total	95		517		472		434		1518	
+1	35	36.80%	46	8.90%	34	7.20%	17	3.91%	132	8.70%
IAE Mean	1.4		1.18		1.12		0.88		1.13	
SD	1.30397		1.07136		1.06490		1.04381		1.10913	

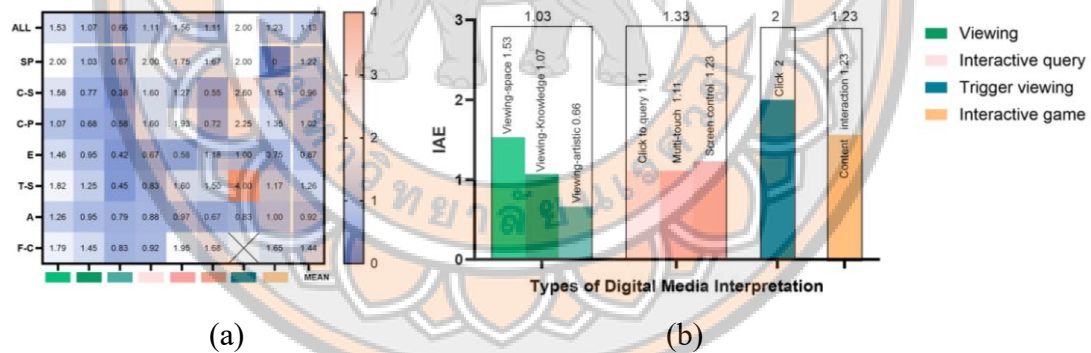


Figure 46 IAE scores for different types of digital interpretations with different visitors in SEM. (a) The IAE scores and heatmap of various target groups. (b) The IAE scores for different types of digital interpretations.

(2) Comprehensive analysis of the IAE Scores of the five museums

Through bivariate analysis, it was found that the A11-Interactive form of the exhibit, viewing, interactive, or play, does not have a significant impact on AP. Instead, the A33-narrative type of content interpretation and presentation indicates that certain elements within the interpretation type significantly affect the IAE score ($P < 0.001$), as shown in **Table 40**. The C23- identity of the visitor, the visitor's approach or avoidance behavior, has no significant impact on the production of

involvement, including learning behavior, communication behavior, photography behavior, and other moments presenting immersion and pleasure, during the visit.

Table 40 Bivariate analysis results

	A11	A22	A23	A24	A33	B12	Visito r	IAE Based	IAE +1
A11	1								
A22	-.059**	1							
A23	-.113**	.186**	1						
A24	.036**	-.022	0	1					
A33	.175**	.082**	-.035**	0.005	1				
B12	.070**	.186**	-.213**	.039**	-.053**	1			
Visitor	.034**	0.012	-.0015	0.021	0.002	.026*	1		
IAE Based	-0.003	-.209**	0.012	-.077**	-.041**	-.127**	-.080**	1	
IAE +1	.038**	-.079**	.043**	-.035**	-.035**	-.070**	0.008	.384**	1
Mean	0.006	-.204**	0.02	-.077**	-.044**	-.129**	-.069**	.978**	.569** 1

** At the 0.01 level (two-tailed), the correlation is statistically significant.
* At the 0.05 level (two-tailed), the correlation is statistically significant.

The findings support further research. Based on the results of Objective 1, the top ten factors were selected according to the importance of indicators and elements influencing visitors' interest and engagement: A23-Style of visual language, A33-The narrative type of content, B12-Location and structural point, A22-A clear theme of the exhibit, A24-Color contrast, A11-Interactive form of the exhibit. A comprehensive comparison of Objective 2's environmental measurements and visitor interview results, as well as the current phase's observations on attractiveness and involvement, indicates that the main media devices-such as new technologies, multi-touch screens, and clear exhibition instructions-along with digital exhibits featuring spacious spatial configurations and reasonable scales, are more effective in attracting visitors. Therefore, in this phase's analysis, the following factors were incorporated: A12-Main media equipment, A21-Instruction sign or system, and B3-Spatial Configurations/ Exhibit Scale (B31-Independent digital space, B32-Have spacing with other exhibits, B33-Large digital media installations, B34-No independent properties). Cross-tabulation and correlation analyses were conducted with the attractiveness scores of each digital exhibit.

Figure 47 shows that digital exhibits with attraction scores ranging from 2 to 3 exhibit the following characteristics: triggering viewing, utilization of new media technologies, colors harmonizing with the environment, and clear and specific display

themes. The visual language employs a 3D drawing style to showcase internal structures or processes, with the exhibits located along the main exhibition line or within independent digital audiovisual spaces. Regarding the interpretation system dimension, 135 sets of digital interpretations almost entirely lack explanatory systems, making them unsuitable as criteria for judging attraction. However, based on visitor interviews, unclear or absent interpretation systems indeed negatively impact the visiting experience. Although the influence of B12-Location and structural point ($p=0.08>0.05$) on attractiveness is not significant, it can still be observed from the statistical data that digital exhibits located on auxiliary display lines with no relevant display content nearby mostly received attractiveness scores of 0-1. Meanwhile, B3 Spatial configuration and exhibit scale of digital exhibits showed no significant impact on attractiveness.

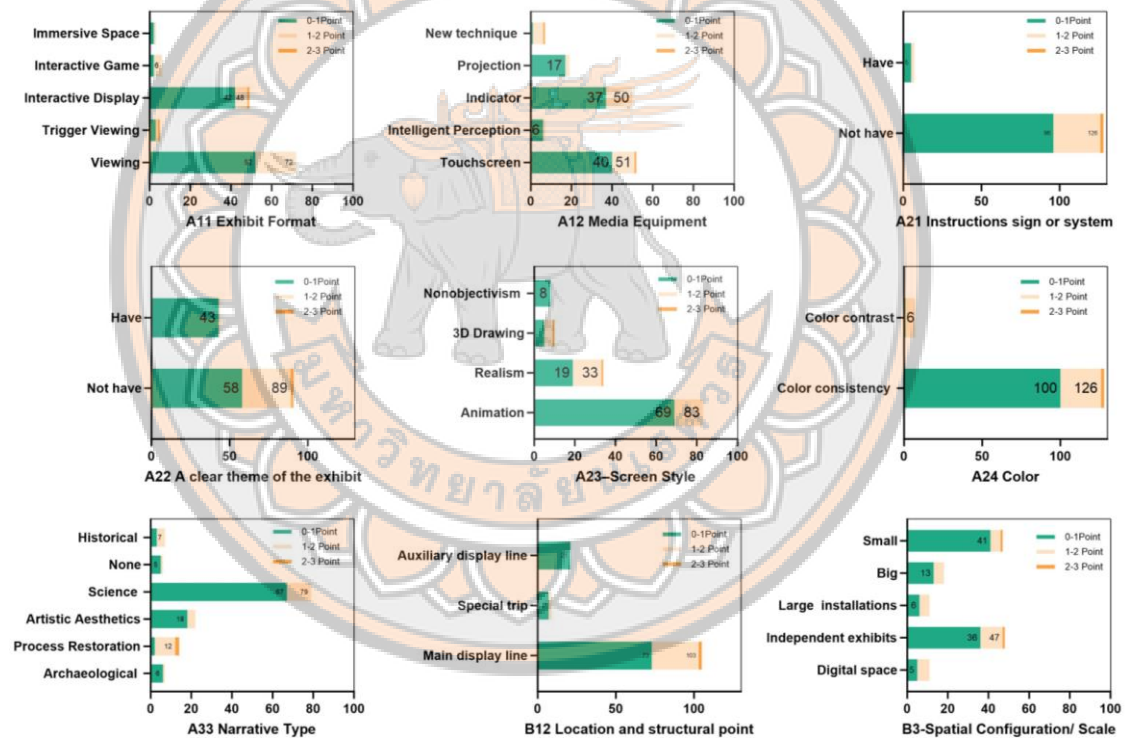


Figure 47 The relationship between main factors and visitor AP (IAE scores)

6.3 Correlation analysis: Attractive Power (AP) with 7UD

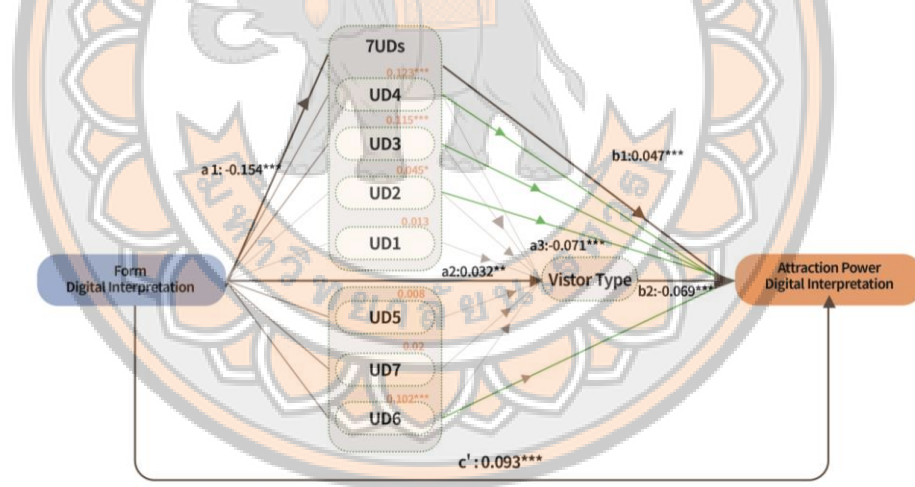
To further interpret the relationship between the 7UD scoring rate and AP, the raw data from the two-stage evaluation were combined and analyzed in SPSS 27.0.1. The digital interpretation format factors were used as the independent variable, and linear regressions were performed separately for the 7UDs score rates, visitor types, and IAE scores. The results are shown in **Table 41**.

Table 41 Linear Regression Analysis of Digital Formal, 7UDs, Visitors, and IAE

Predictor variables	Model 1 (7UD)				Model 2(Visitor)				Model 3 (IAE)			
	β	se	Bete	t	β	se	Bete	t	β	se	Bete	t
Type	-0.004	0	-0.154	12.027**	0.015	0.006	0.032	2.496**	0.01	0.003	0.039	3.131**
7UDs					-1.252	0.226	-0.071	-5.542***	3.054	0.114	0.047	26.743**
Visitor									-0.037	0.007	-0.069	-5.367**

*** At the 0.001 level (two-tailed), the correlation is statistically significant.
 ** At the 0.01 level (two-tailed), the correlation is statistically significant
 Type = Digital interpretation and presentation Type; Visitor = Visitor Type

When using the 7UDs scoring rates as a mediating variable, the regression coefficient is significant ($p < 0.001$), but the β is negative, and $a*b$ and c' are of different signs, indicating the presence of mediating suppression. The same situation occurs when establishing a model with visitor type as a mediating variable, which also suggests that both UD and visitor type play a part in mediating, as can be seen in the model in **Figure 48**.

**Figure 48 Path diagram of Digital Interpretation Formal, 7UDs Score, Visitor Types, and IAE Score**

Further regression analysis on the 7UDs indicators revealed that, in the interaction between digital interpretation format factors, 7UDs, and visitor types, the regression coefficients for UD3, UD4, and UD6 indicators are significant. In other words, the satisfaction levels of UD3, UD4, and UD6 within the 7UDs significantly influence the intensity of the attractiveness of digital interpretation. The data is presented in **Table C1**.

6.4 Results Analysis of the Questionnaire Survey

The objective of the questionnaire survey is to investigate the experiences of different types of visitors with digital interpretation, with the sample group consisting of various types of visitors to the case museum. A total of 238 questionnaires were distributed to visitors who had completed their museum visits in the lobby of the five museums. Following the screening of pre-survey questions, individuals lacking a conceptual understanding of digital interpretation and those who did not visit the target case gallery were excluded, yielding 139 valid questionnaires. The analysis of the questionnaire results is divided into three parts: Demographic and Motivation Analysis; Descriptive Analysis -exploring the needs and characteristics of different types of visitors, and Factor Analysis - the correlation between various variables.

(1) Demographic Analysis

The demographic data shown in **Table 42** indicates that participants from five museums consist of males (30.2%) and females (69.8%), and the majority are young visitors aged between 18-35 years old (57.6%), with younger visitors and elderly visitors accounting for 7.9% and 5.0% respectively. The educational background of those with a university degree or above accounts for 86.3%. It should be noted that in this survey, the proportion of foreign visitors to the museum was significantly low, and female visitors outnumbered male visitors significantly. During the 10-day survey period, no visitors with disabilities or those with mobility impairments were present.

Table 42 Demographic Analysis Results

Gender	%	Age	%	Education	%	Nation	%
Male	97(69.8%)	14-17	11(7.9%)	Undergraduate	89(64.0%)	China	134(96.4%)
Female	42(30.2%)	18-35	80(57.6%)	Graduate	31(22.3%)	Russia	1(0.7%)
		36-60	41(29.5%)	Technical secondary	7 (5.0%)	Iran	1(0.7%)
		60+	7(5.0%)	Middle school	12(8.6%)	Thailand	3(2.2%)

(2) Visit Purpose and Motivation Analysis

The main types of visits for young and middle-aged visitors are companions with others and individual visits, with the purpose often being hobbies and interests; young people are also the main group that visits museums four or more times a year, accounting for 72.5%. Most teenage visitors participate in group activities, with 81.9% of them visiting museums 0-3 times a year, primarily due to school requirements, unrelated to personal interest. Elderly visitors are mostly

engaged in tourism behaviors with relatives (57.1%), while some are occasional behaviors of local elderly people (28.6%). Shown in **Table 433**.

Table 43 The main types of visitors

Visitor type	%	Visiting Purpose	%	Engage	%
Companion	51(36.7%)	Hobbies and Interests	64(46%)	0-1/Year	26(18.7%)
Alone	45(32.4%)	Profession and Major	17(12.2%)	2-4/Year	73(52.5%)
Child-Family	30(21.6%)	Unintentional Act Without a Purpose	11(7.9%)	Over 4/Year	40(28.8%)
Student Group	13(9.4%)	Tourism	42(30.2%)		
		Others	5(3.5%)		

To explore the impact of museum exhibition environments on AP, the questionnaire also conducted a survey and analysis of the motivations of different visitors. Through the results of the Chi-square goodness-of-fit test, there is a significant inconsistency in the visiting motivations among visitors of different age groups ($p < 0.05$), and the visiting motivations also show a significant inconsistency among visitors of different types ($p < 0.05$).



Figure 49 Motivations for visiting among visitors of different ages and types

The results, as shown in **Figure 49**, indicate that “MO4-Leisure and relaxation” and “MO5-Gaining knowledge” are the two main motivations for visitors

to visit museums, followed by “MO3-Museum lovers” and “MO9-Special exhibition content”. MO3 stands out among individual visitors, and the motivations for child-family are diverse, among which the motivations of “MO7-Improving parent-child relationships” and “MO8-Children’s recreational education” are significantly different from other visitors.

(3) Analysis results of factors affecting visitors’ experience

At the visceral level, 2 questions to investigate the favorability of different types of visitors towards digital interpretation technology. The mean score for the item “I am willing to participate in digital interaction” is 3.38, indicating a lack of intention to deliberately engage in digital interpretation devices. The mean score for the item “I am satisfied with digital interpretation” is 3.58, which falls between neutral and satisfied. The results of the cross-tabulation test indicate that the age of visitors does not have a significant impact on their engagement willingness and favorability. In contrast, the type of visitor has a more significant impact on favorability and willingness to interact with digital interpretation, with parent-child families and student groups being more inclined to actively participate in digital interactions.

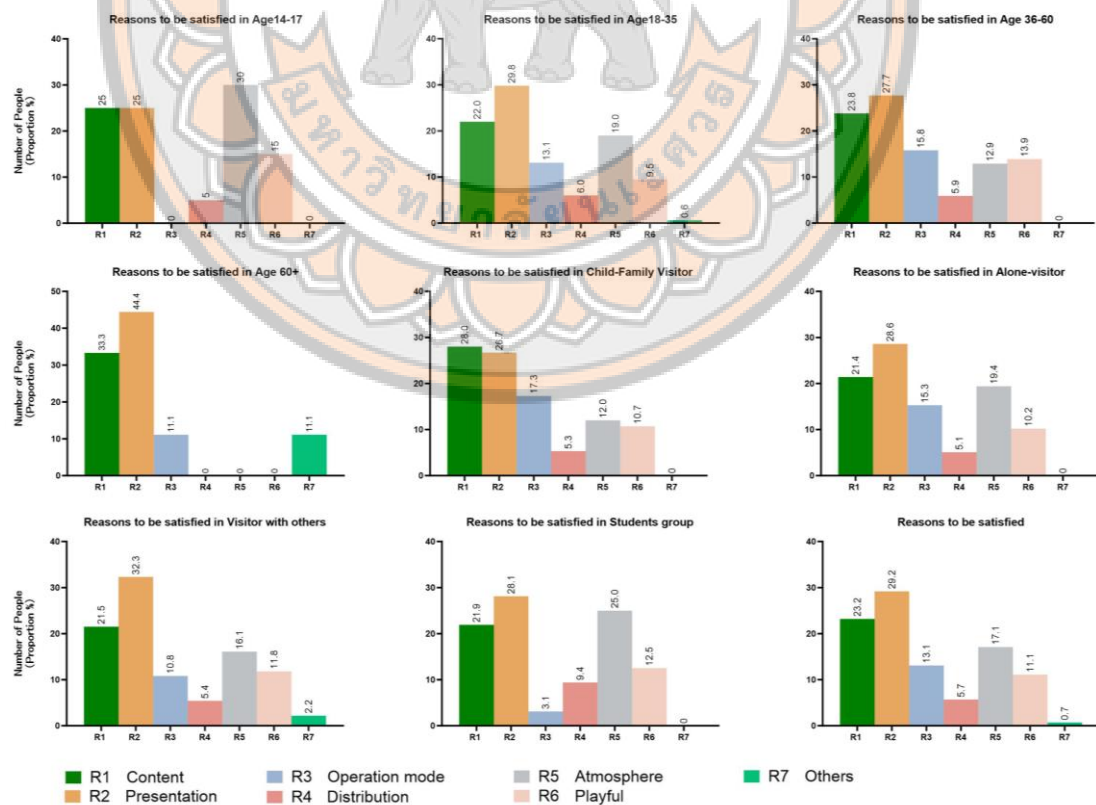


Figure 50 Reasons to be satisfied with digital exhibits

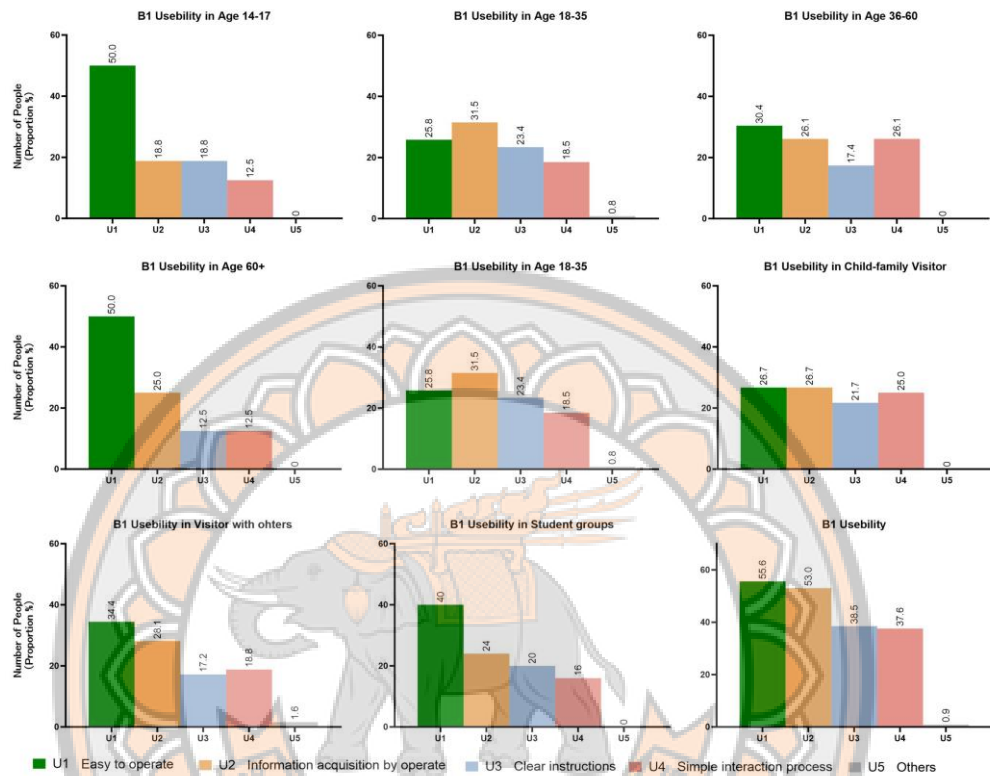
The questionnaire investigated the reasons for the composition of participants' favorability. The type of visitor has a significant impact on favorability, with $p < 0.05$. As shown in **Figure 50**, visitors of different ages and types are all satisfied with the "R1-content and knowledge of interpretation and presentation technologies" and "R2-ways of using digital media technologies to explain history and culture." However, younger visitors (14-17 years old) are relatively more concerned about the exhibition atmosphere created by digital media.

At the behavioral level, the questionnaire surveyed visitors' satisfaction with operability, content perceptibility, and entertainment, as well as the related reasons, as shown in **Figure 51**. Age did not have a significant impact on any of the three dimensions at the behavioral level; visitors of different ages and types were more focused on the information conveyed by digital interpretation, namely "digital media vividly recreates historical scenes and culture" (77.6%) and "digital technology helps me better understand knowledge" (63.6%).

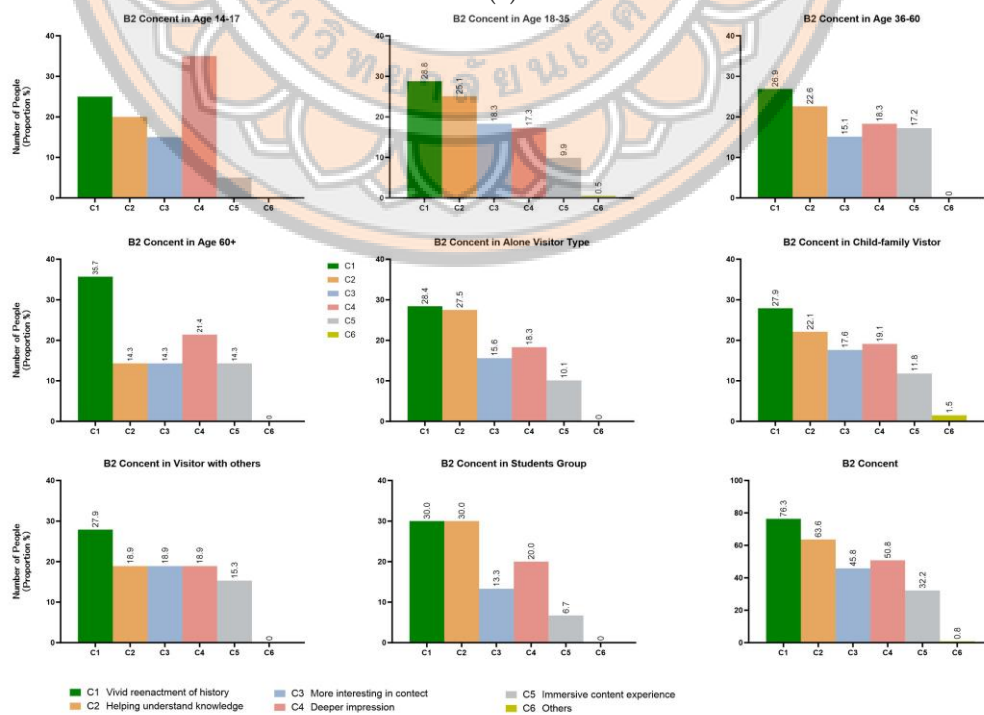
The type of visitor influences the evaluation results of operability and entertainment. In terms of operability, 55.6% of the participants chose "digital devices are easy to operate," while individual visitors prefer to "obtain desired information through digital devices". In terms of entertainment, 66.7% of the participants chose "The way history is presented on digital interpretation devices is interesting," followed by "gamification elements helping to better understand the knowledge." Parent-child families and student groups are more satisfied with the entertainment aspect of digital devices. Elderly visitors are more satisfied with "personalized historical and cultural experiences" and "immersive experiences." However, professional visitors rate the three dimensions lower, especially in terms of entertainment, and they are more focused on the acquisition of information in terms of operability.

At the reflective level, the score for the item "C1-Digital Interpretation Helps Me Achieve the Expected Visit Experience" is 3.49. The meaning is that visitors' attitude lies somewhere between indifference to digital interpretation and achieving the expected. In the item "C5-Digital device interfering with my visit", Mean=3.68, the digital interpretation device neither causes serious interference with the visit nor has a positive impact. This is consistent with the results at the visceral level: museum visitors do not care about digital devices and are basically satisfied. The result of the question "C2-I am willing to recommend this museum to others for reasons with digital interpretation" with a mean of 3.27 indicates that among the reasons why visitors would

recommend the museum to others, there are almost no reasons related to digital interpretation. In other words, digital interpretation does not become a reason for participants to recommend the museum to others.



(a)



(b)

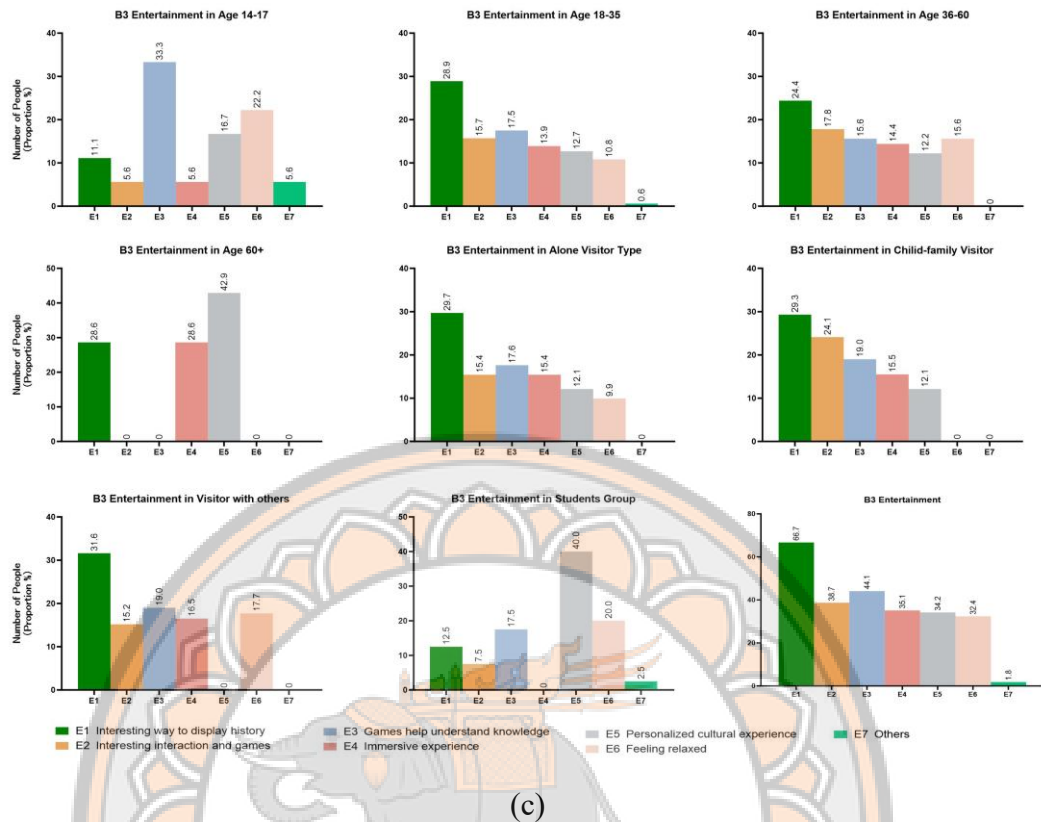


Figure 51 Analysis of the behavioral dimension results of visitor experience in the questionnaire survey. (a) Statistical results of the B1- Usability dimension. (b) Statistical results of the B2-Concent dimension. (c) Statistical results of the B3- Entertainment dimension.

This survey analyzed the digital devices with which visitors were dissatisfied. 47 participants believed there were no unsatisfactory digital devices. Therefore, a total of 92 participants made 202 choices on this issue. The results are shown in **Figure 52**. 44.1% of the participants chose “N2-Crowded, too many people operating,” and 34.4% of the visitors chose “N6-No knowledge and content.” Elderly visitors believe that “N1-operation is difficult” and “N8-content is unrelated to the exhibition.” Furthermore, participants who selected “other” provided answers such as “the content of digital interpretation is not deep enough” and “the format is not designed for me.”

Furthermore, the questionnaire also investigated whether visitors had visited all digital interpretations and presentations, with 78.4% of participants choosing “No, only part of them.” The main reasons included “Not interested in the format of interpretation (42.2%)” “Did not deliberately miss, some devices were not seen (41.3%)” “The interactive form was not suitable for participation (37.6%)” “Crowded, difficult to approach (33.0%)” and “Not interested in the content of the digital interpretation(32.1%).”

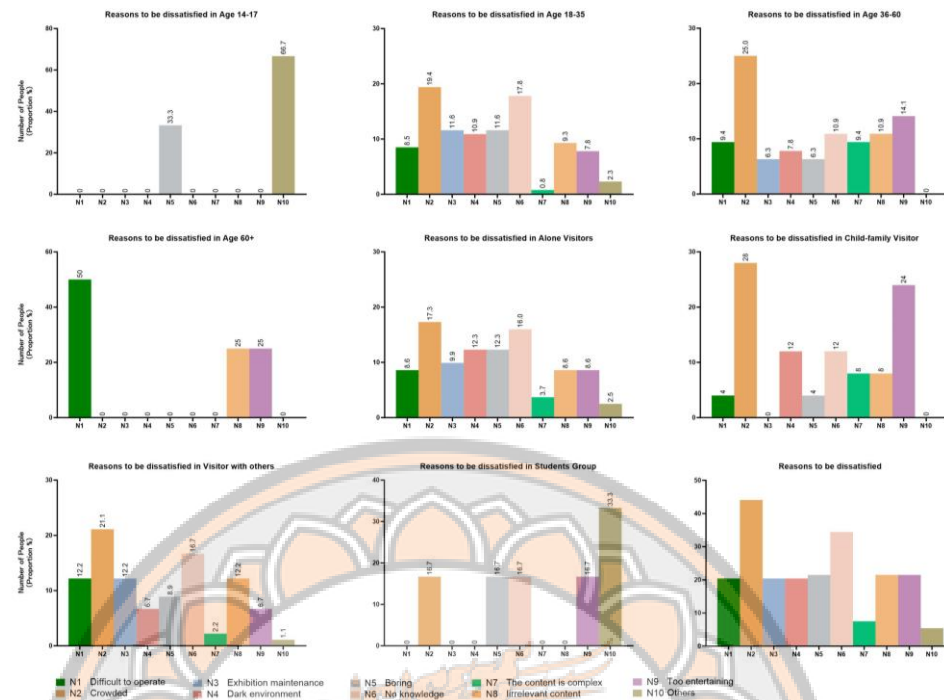


Figure 52 The reasons for dissatisfaction for different ages and types of visitors

6.5 Summary

Analysis of museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital technologies in exhibitions

The evaluation results of this phase's IAE scale indicate that the application effect of digital technology did not meet expectations. 77% of visitors either ignored it or noticed, but it was difficult to engage, while only 4% of tourists successfully operated or viewed the complete interpretation. The operational approach of digital interpretation has no significant impact on attractiveness, whereas the form of heritage content interpretation is significantly correlated with attractiveness. This aligns with the findings of the questionnaire survey. Whether the cinema space or the form of the display affects visitors' participation is not the determining factor; rather, it is the interpretive format, such as artistically aesthetic films or knowledge-based explanations inversely influences visitors' willingness to engage. This aligns with the perspective presented in the literature review by Liu (2020), where visitors exhibit a greater anticipation for novel interpretations of information facilitated by digital technologies, or the subsequent evocation of memories, as further elaborated by Chen (2023). Furthermore, the content of digital technology selected by visitors under the "Negative Impact Visit" option was unattractive and caused environmental interference with surrounding exhibits, which aligns with the findings from the Case Study of Objective 2. The results support further analysis.

CHAPTER VII

RESULTS OF OBJECTIVE 4

7.1 Overview

Objective 4 aims to propose strategies for effectively utilizing digital media technologies in museum exhibitions to enhance visitor engagement and promote museum tourism in China. The results are divided into two parts. The first part is to propose design guidelines based on the results of objectives 1-3. The second part is to verify the effects of museum exhibition schemes designed according to the design guidelines through image stimulus questionnaires. Participants were the sample group 5. The results are as follows.

7.2 Generation Image Questionnaire of Design Characteristics and Factors of Digital Museum Exhibits that Effectively Motivate Visitors' Interest and Interaction

(1) Summary of results for Objectives 1-3

Among the factors influencing visitors' interest and interaction, the most significant are design elements, including visual materials, exhibit configurations, and content frameworks. Specifically, the narrative type within the content framework, the explanatory system in visual materials, and the interactive formats and participant numbers in exhibit configurations are particularly crucial. Following these are visitor-related factors, encompassing behavioral preferences, behavioral characteristics, and individual traits. Among these, the identity characteristics within behavioral traits, as well as cognitive and physical attributes within individual characteristics, are relatively more important. The seven universal design principles can be used to accommodate the physical and psychological attributes of diverse visitors, thereby enhancing their engagement with digital interactions. Lastly, there are physical environmental factors, including the floor plan and layout, lighting and ambiance, spatial configuration, and exhibit scale. Among these, streamlined circulation routes, digital displays positioned along primary exhibition pathways, large standalone digital installations, as well as comfortable lighting and ambiance, are particularly effective in capturing visitors' attention.

However, the interpretation of content and the comfort level of the environment determine whether visitors are willing to stay, engage in interactions, and leave with a profound impression. Research findings indicate that environmental

characteristics can be reformative by adhering to seven universal design principles to increase visitor diversity by meeting their demand, providing both the objective conditions and psychological satisfaction for visitor engagement, such as accessibility, convenience, safety, and so on. Further enhancements in display configuration, visual materials, and content framework design can satisfy visitors' touring needs and psychological fulfillment, thereby elevating interaction and experience. The ultimate goal is to enhance visitor interest and interaction through digital interventions, consequently promoting the overarching objective of museum tourism.

(2) Design images in the simulation questionnaire

Based on the summary of the previous step, the study obtained: Factors influencing visitor interest and interaction; 2) Key factors and mechanisms that can influence the exhibition environment and visitor interest; 3) Exhibition features that can enhance visitor interest and interaction. In the end, 11 factors and characteristics were identified which need to evaluation from image questionnaire: Usability for all(U1); Flexibility in engagement(U2); Clear communication, easy to see, easy to understand(U3); Perceptible information(U4); Security(U5); Comfortable and low physical effort(U6); Approach and use size(U7); For multiple people to participate(F1); Strong visual impact(F2); More involved and excited(F3); Vivid and interpretable(F4). A questionnaire with 10 images was designed to evaluate the above 11 factors on the visitors' interest, interaction, and satisfaction, as shown in **Figure 53**.



Figure 53 The images in the questionnaire

(2) Expert group evaluation of the image questionnaire

Based on the characteristics of museum exhibitions under digital technology interventions that can enhance the interest and engagement of different types of visitors, and incorporating the 7 principles of Universal Design, we utilized the computer graphics software SketchUp for drafting and obtained the 10 renderings shown in **Figure 12**. The purpose is to interview three experts, shown in **Table 9**, for interviews through an image stimulation survey format, to obtain their attitudes towards the design concepts and forms of this type. The image stimulation questionnaire is shown in APPENDIX A, Table A4.

The results show that the three experts expressed support for the form of image simulation and put forward relevant views. Both support implementing universal design principles, believing that inclusive design is currently underrepresented in museum exhibitions in China, and this should be given more attention in exhibition design. Moreover, regarding the ten major characteristics, expert A believes that more formal design elements should be incorporated into the format, as their management experience indicates a growing demand among museum visitors for "check-in" opportunities. If there is no eye-catching form or technology, it will be difficult to attract tourists. Secondly, it should visually and formally reflect distinctive regional characteristics, rather than being a generic design style applicable to all museums. On this point, the expert B, who has experience in museum exhibition design and construction, expressed their agreement. They believe that during project presentations, impressing clients with inclusive design is not an easy task, and the first step to getting a proposal approved is identifying the cultural characteristics of the museum (including but not limited to cultural resources, heritage resources, tourism resources, and humanistic resources, etc.). The exhibition format and visual effects must first meet the cultural interpretation requirements of the museum. Secondly, the concept of inclusive design or universal design may require systematic training for designers or the leading role of project leaders.

7.3 Results of Image Stimulation Questionnaire Survey

(1) Basic Information

The survey was conducted on July 19 and 20, 2025, at the "Old Door East Scenic Area" in Nanjing, especially at the entrance of the Nanjing City Wall Museum, where questionnaires were distributed electronically. The purpose was to investigate the preferences of different types of visitors for digital exhibition design schemes

completed according to design guidelines. A total of 420 visitors were invited to participate in the questionnaire survey, with 60 participants in each group (a total of seven groups, see **Table 44**. Which means there are a total of 420 questionnaires that were distributed in this study. In SPSS 27.0.1 software, the cross-tabulation was used to eliminate the responses that were significantly inconsistent with the age and visitor type, such as those who were 14-17 years old but chose the visiting type of college students. After excluding, 410 valid questionnaires were collected, and the data were shown in **Table 44**. The participants included 171 males and 239 females, with 374 Chinese individuals and 36 foreign nationals. Age distribution showed: 67 participants aged 14-17, 146 participants aged 18-35, 134 participants aged 36-60, and 63 of them aged over 60. Complete data are provided in Appendix D1.

Table 44 The number of participants and the number of valid questionnaires

Age	Visitor Type														Total
	A	F-C		Cp		Ts		E		Cs		Sp			
14-17	0	0	1	1	0	0	56	56	1	0	2	0	10	10	67
18-35	25	25	23	23	25	25	0	0	0	0	55	55	18	18	146
36-60	35	35	36	36	35	36	3	0	0	0	0	0	28	28	134
60+	0	0	0	0	0	0	1	0	59	59	3	0	4	4	63
Total	60	60	60	60	60	60	60	56	60	59	60	55	60	60	420/410

FC - Family with children**A** - Alone visitors (18-60); **Ts**- Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment).

(2) Result Analysis

Results of Design Images Satisfaction Evaluation

This section contains a satisfaction assessment of 10 design images. Each image involves three dimensions: satisfaction, interest, and interaction. In addition, each image involves 1-2 environmental feature dimensions, that is, the digital exhibition features emphasized by this image, which can enhance visitors' interest and interaction. And each dimension was measured using a 5-point Likert scale, in which 5=Mostly, 4=Very, 3=Moderate, 2=Slightly, 1=Not at all. When the design feature dimension score is between 4 and 5 points, it is considered that this design feature is clearly reflected, and the satisfaction, interest, and interaction dimension scores are considered to be valid. As shown in the **Figure 54**. The statistical results show that the evaluation scores of each dimension of the 10 images ranged from 4.18 to 4.83 points, which means that the participants were able to perceive the design features conveyed by the design images well and believed that such designs could enhance their interest and interaction.

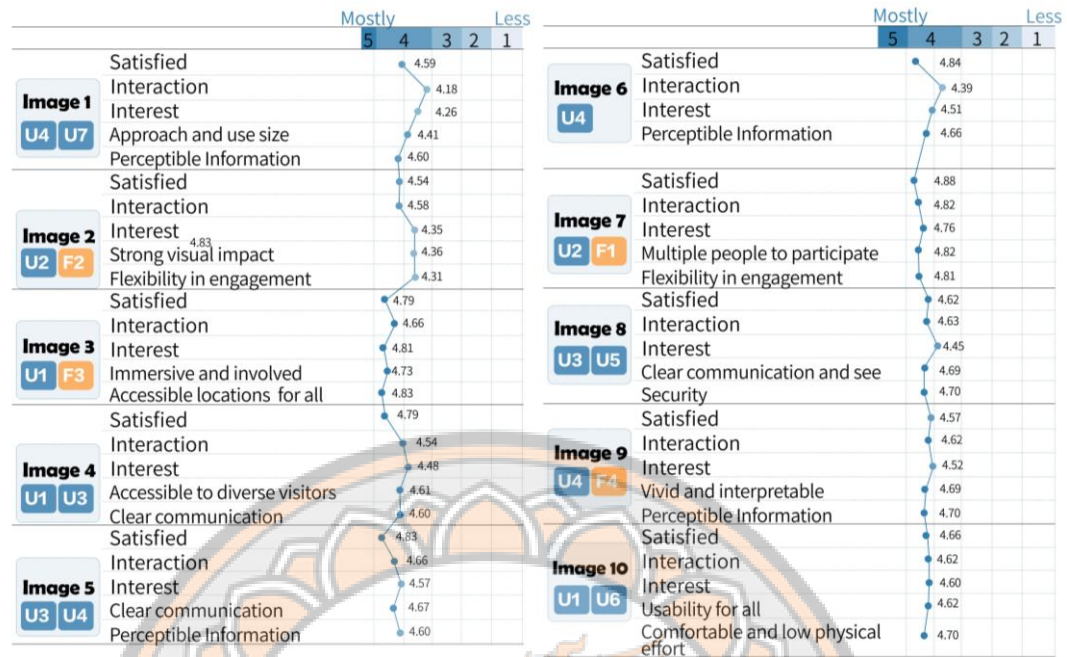


Figure 54 Average score statistics analysis- Every indicator of each image

The specific results of ten Images are analyzed as follows:

Image 1



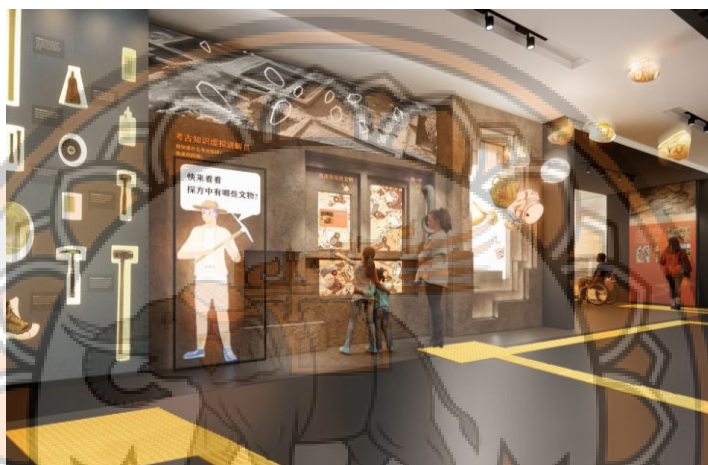
Figure 55 Image 1 in “Questionnaire of Museum Design Satisfaction Evaluation”

The features evaluated in Image 1, Figure 55, were “Approach and Use Size” and “Perceptible Information”, with average scores of 4.42 and 4.60, **Appendix D2**. That is, participants thought that the design image was very good in terms of approach and use size, and had very good perceptible information. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.59, 4.18, and 4.26, respectively. The evaluation results of different types of visitors are shown in **Table 45**. That is to say, different types of visitors felt particularly satisfied and very satisfied with the design of Image 1, which could improve their interest and interaction.

Table 45 The evaluation results of Image 1 based on different types of visitors

Image 1	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.62	4.70	4.60	4.70	4.61	4.49	4.42	4.59
Interest	4.23	4.23	4.25	4.16	4.22	4.11	4.07	4.18
Interaction	4.40	4.27	4.27	4.20	4.29	4.27	4.13	4.26

FC - Family with children **A** - Alone visitors (18-60); **Ts**- Teen-agers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 2**Figure 56 Image 2 in “Questionnaire of Museum Design Satisfaction Evaluation”**

The features evaluated in Image 2, **Figure 56**, were “Visual Impact” and “Flexibility in Engagement”, with average scores of 4.36 and 4.31, **Appendix D2**. That is, participants think that the design image has a very good visual impact and a very good flexibility in engagement. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.54, 4.35, and 4.58, respectively. The evaluation results of different types of visitors are shown in **Table 46**. That is to say, various types of visitors felt particularly satisfied and very satisfied with the design of Image 2, which could improve their interest and interaction.

Table 46 The evaluation results of Image 2 based on different types of visitors

Image 2	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.55	4.47	4.47	4.52	4.64	4.60	4.52	4.54
Interest	4.70	4.63	4.52	4.57	4.59	4.44	4.57	4.58
Interaction	4.25	4.40	4.32	4.29	4.36	4.53	4.35	4.35

FC - Family with children **A** - Alone visitors (18-60); **Ts**- Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

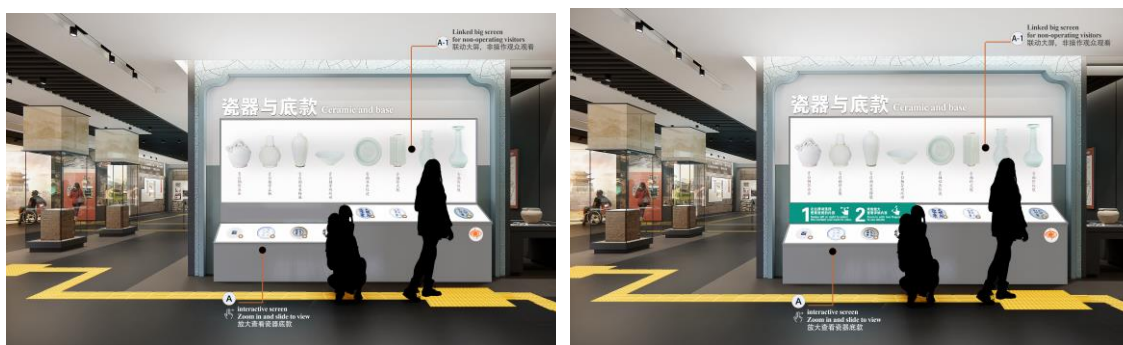
Image 3**Figure 57 Image 3 in “Questionnaire of Museum Design Satisfaction Evaluation”**

The features evaluated in Image 3, **Figure 57**, were “Immersive and Involved” and “Accessible locations and the Space”, with average scores of 4.73 and 4.83, respectively, Appendix D2. That is, participants found the design image to be very immersive and expressive of very good accessible locations and the space. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.79, 4.81, and 4.66, respectively. The evaluation results of different types of visitors are shown in **Table 47**. That is to say, various types of visitors felt particularly satisfied and very satisfied with the design of Image 3, which could improve their interest and interaction.

Table 47 The evaluation results of Image 3 based on different types of visitors

Image 3	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.87	4.82	4.78	4.70	4.81	4.78	4.77	4.79
Interest	4.80	4.80	4.65	4.66	4.71	4.84	4.70	4.66
Interaction	4.62	4.62	4.80	4.84	4.85	4.67	4.77	4.81

FC - Family with children **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 4

(a) Old design

(b) New design

Figure 58 Image 4 in “Questionnaire of Museum Design Satisfaction Evaluation”

The features evaluated in Image 4, **Figure 58**, were “Accessible to Diverse Visitors” and “Clear Communication, Easy to see, and Easy to Understand,” with average scores of 4.61 and 4.60, respectively, as shown in Appendix D2. That is, participants believe that the new design image, **Figure 58(b)**, is very good to meet the requirements of being accessible to diverse visitors and very clear communication, easy to see, and easy to understand compared with the old design, **Figure 58(a)**. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.79, 4.48, and 4.54, respectively. The evaluation results of different types of visitors are shown in **Table 48**. That is to say, various types of visitors felt particularly satisfied and very satisfied with the design of Image 4(b), which could improve their interest and interaction.

Table 48 The evaluation results of Image 4 based on different types of visitors

Image 4	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.82	4.85	4.75	4.71	4.78	4.80	4.83	4.79
Interest	4.43	4.48	4.48	4.48	4.51	4.45	4.50	4.54
Interaction	4.63	4.52	4.50	4.57	4.54	4.60	4.40	4.48

FC - Family with children; A - Alone visitors (18-60); Ts- Teenagers student group; E - Old adults; Cp - Visit with friends/relatives (18-60); Cs - Undergraduate/postgraduate students (in studying). Sp - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 5

The features evaluated in Image 5, **Figure 59**, were “Clear Communication, Easy to see, and Easy to Understand” and “Perceptible Information,” with average scores of 4.67 and 4.60, respectively, as shown in Appendix D2. That is, the participants believed that compared with the old design, **Figure 59(a)**, the new design image, **Figure 59(b)**, showed very clear communication, easy to see, easy to

understand, and very good perceptible information. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.83, 4.66, and 4.57, respectively. The evaluation results of different types of visitors are shown in **Table 49**. That is to say, various types of visitors felt particularly satisfied and very satisfied with the design of Image 5(b), which could improve their interest and interaction.

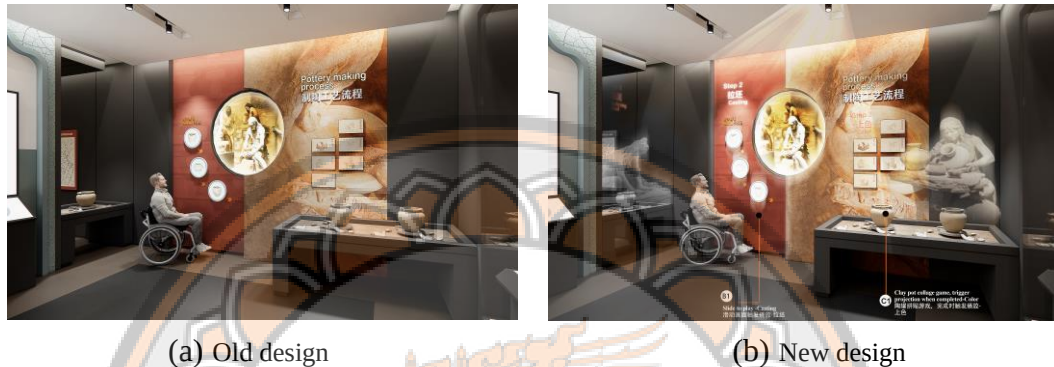


Figure 59 Image 5 in “Questionnaire of Museum Design Satisfaction Evaluation”

Table 49 The evaluation results of Image 5 based on different types of visitors

Image 5	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.80	4.80	4.87	4.89	4.78	4.84	4.85	4.83
Interest	4.65	4.65	4.68	4.79	4.66	4.62	4.55	4.66
Interaction	4.60	4.63	4.68	4.48	4.63	4.44	4.53	4.57

FC - Family with children; A - Alone visitors (18-60); Ts - Teenagers student group; E - Old adults; Cp - Visit with friends/relatives (18-60); Cs - Undergraduate/postgraduate students (in studying). Sp - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 6



Figure 60 Image 6 in “Questionnaire of Museum Design Satisfaction Evaluation”

The feature evaluated in Image 6, **Figure 60**, was “Perceptible Information”, with average scores of 4.66, **Appendix D2**. That is, the participants

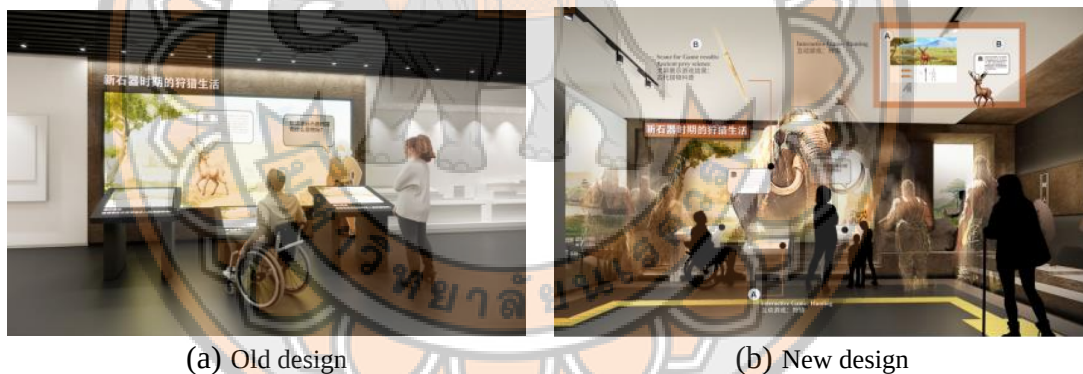
agreed that compared with the old design, **Figure 60(a)**, the new design image, **Figure 60(b)**, showed very good perceptible information. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.84, 4.39, and 4.51, respectively. The evaluation results of different types of visitors are shown in **Table 50**. That is to say, different types of visitors felt particularly satisfied and very satisfied with the design of Image 6(b), which could improve their interest and interaction.

Table 50 The evaluation results of Image 6 based on different types of visitors

Image 6	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.80	4.77	4.80	4.82	4.88	4.93	4.88	4.84
Interest	4.50	4.28	4.48	4.43	4.31	4.38	4.35	4.39
Interaction	4.48	4.62	4.45	4.50	4.46	4.55	4.52	4.51

FC - Family with children; A - Alone visitors (18-60); Ts- Teenagers student group; E - Old adults; Cp - Visit with friends/relatives (18-60); Cs - Undergraduate/postgraduate students (in studying). Sp - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 7



(a) Old design

(b) New design

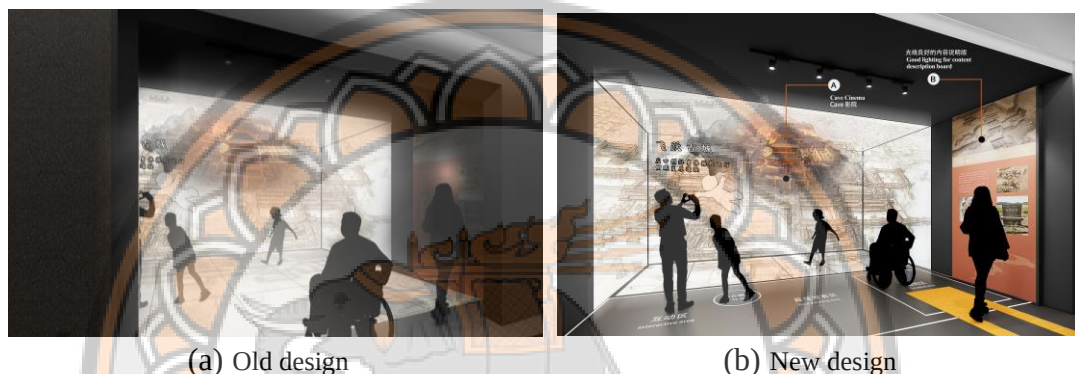
Figure 61 Image 7 in “Questionnaire of Museum Design Satisfaction Evaluation”

The features evaluated in Image 7, **Figure 61**, were “Multiple people to Participate” and “Flexibility in Engagement”, with average scores of 4.82 and 4.81, Appendix D2. That is, participants believe that the new design image, **Figure 61(b)**, is very good to meet the requirements of multiple people to participate and reflects the very good flexibility in engagement compared with the old design, **Figure 61(a)**. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.88, 4.82, and 4.76, respectively. The evaluation results of different types of visitors are shown in **Table 51**. That is to say, different types of visitors felt particularly satisfied and very satisfied with the design of Image 7(b), which could improve their interest and interaction.

Table 51 The evaluation results of Image 7 based on different types of visitors

Image 7	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.88	4.88	4.90	4.80	4.92	4.93	4.87	4.88
Interest	4.82	4.82	4.83	4.84	4.80	4.82	4.85	4.82
Interaction	4.78	4.78	4.75	4.82	4.73	4.75	4.77	4.76

FC - Family with children; **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 8**Figure 62 Image 8 in “Questionnaire of Museum Design Satisfaction Evaluation”**

The features evaluated in Image 8, **Figure 62**, were “Clear Communication, Easy to See” and “Security”, with average scores of 4.62 and 4.45, Appendix D2. That is, participants believe that, compared with the old design, the new design image, **Figure 62(b)**, is very good for clear communication, easy to see, and provides very good security. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.62, 4.45, and 4.63, respectively. The evaluation results of different types of visitors are shown in **Table 52**. That is to say, different types of visitors felt particularly satisfied and very satisfied with the design of Image 8, which could improve their interest and interaction.

Table 52 The evaluation results of Image 8 based on different types of visitors

Image 8	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.68	4.70	4.63	4.59	4.63	4.64	4.50	4.62
Interest	4.58	4.75	4.52	4.63	4.59	4.55	4.62	4.63
Interaction	4.47	4.30	4.68	4.55	4.39	4.45	4.45	4.45

FC - Family with children; **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 9**Figure 63 Image 9 in “Questionnaire of Museum Design Satisfaction Evaluation”**

The features evaluated in Image 9, **Figure 63**, were “Exciting” and “Perceptible Information”, with average scores of 4.57 and 4.62, Appendix D2. That is, participants thought that the new design image, **Figure 63(b)**, was very exciting and had good perceptible information compared to **Figure 63(a)**, which is the old design. The average scores of “Satisfaction”, “Interest”, and “interaction” items were 4.57, 4.62, and 4.50, respectively. The evaluation results of different types of visitors are shown in **Table 53**. That is to say, different types of visitors felt particularly satisfied and very satisfied with the design of Image 9(b), which could improve their interest and interaction.

Table 53 The evaluation results of Image 9 based on different types of visitors

Image 9	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.62	4.58	4.55	4.62	4.54	4.62	4.88	4.57
Interest	4.60	4.62	4.72	4.58	4.61	4.58	4.58	4.62
Interaction	4.63	4.58	4.43	4.55	4.54	4.55	4.53	4.52

FC - Family with children **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Image 10

The features evaluated in Image 10, **Figure 64**, were “Usability for All” and “Comfortable and Low Physical Effort”, with average scores of 4.62 and 4.70, Appendix D2. That is, participants agreed that the design image was a good example of usability for all and very comfortable, and very low physical effort. The average scores of “Satisfaction”, “Interest”, and “Interaction” items were 4.65, 4.62, and 4.60, respectively. The evaluation results of different types of visitors are shown in **Table 54**. That is to say, different types of

visitors felt particularly satisfied and very satisfied with the design of Image 10, which could improve their interest and interaction.



Figure 64 Image 10 in “Questionnaire of Museum Digital Design Satisfaction Evaluation”

Table 54 The evaluation results of Image 10 based on different types of visitors

Image 10	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Satisfaction	4.77	4.63	4.52	4.80	4.66	4.60	4.58	4.65
Interest	4.67	4.77	4.62	4.71	4.54	4.45	4.57	4.62
Interaction	4.57	4.67	4.73	4.71	4.58	4.47	4.50	4.60

FC - Family with children **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Comprehensive analysis of ten Images

Further analysis found that Image 7 received the highest satisfaction and Interest rating, which contains fact or F1, for multiple people to participate, and UD2, Flexibility in engagement. Image 3 received the highest interaction rating and contains indicator F3, more involved and exciting, and features of UD1. As shown in the **Figure 65**, the top 3 images in satisfaction score featured the indicator F1, UD2, UD3, UD4; the top 3 images in interest dimension featured the indicator: F1, F3, UD1, UD2, UD3, UD4; the top 3 images in interaction score featured the indicator: F1, F3, UD1, UD2, UD6.

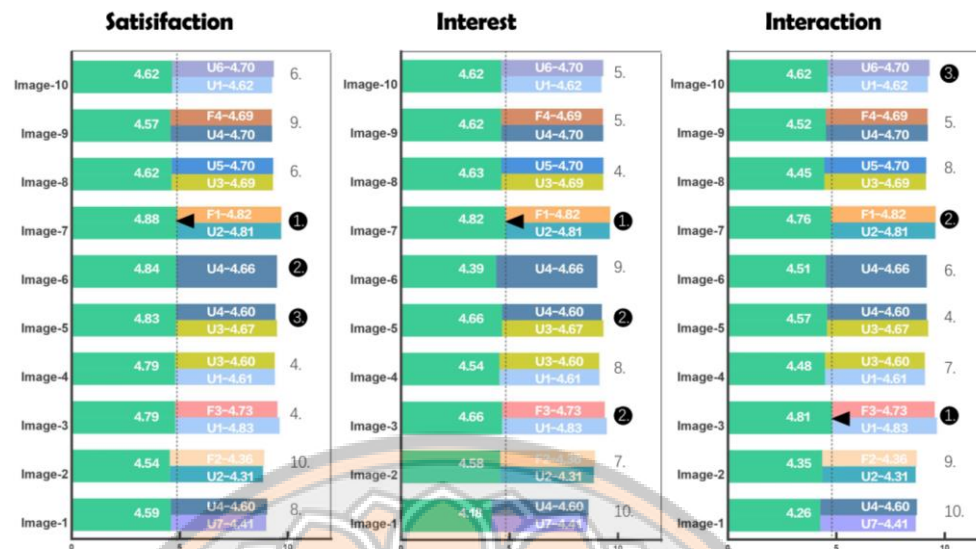


Figure 65 The results of the comparative analysis regarding key factors

Results of Overall Satisfaction and Preference Evaluation

The results of **Table 55** show that in the item-Q1 "whether they satisfied with the design of museum digital exhibits that can be participated in by all types of visitors.", the average score of 7 groups of visitors is between 3.98 and 4.43, which means that no matter what type of visitors agree with and am satisfied with, the score is between "Mostly satisfied" and "very satisfied". Only the parent-child family group scored an average of 3.98, which is below the 4 mark on a scale of satisfaction and very satisfaction. In the item-Q2 of "whether they are interesting in visiting such a designed museum, when they see recommendations for such museums (design in 10 Images) on social media or in travel promotions ", the average score of 7 groups of visitors ranged from 4.03 to 4.30, which means that the interesting and willingness of any type of visitors is between "Mostly interesting" and "Very interesting". In the item-Q3 of "whether such digital exhibits in museums (design in 10 newly designed Images) can enhance their interaction and experience during museum visits", the average score of 7 groups of visitors ranged from 3.97 to 4.33, which means that the level of perception in "Interaction" of any type of visitors is between "Mostly interaction" and "Very interaction". Only the special needs group (Foreigners, people with physical disabilities, poor eyesight, or hearing) scored 3.97 points, meaning they thought the level of interaction in the design was between "Very interaction" and "Moderate interaction " for them. The overall results show that the

target audiences (museum visitors) are satisfied with the design (shown in 10 Images). They agreed that such a design would increase their interest and interaction.

Table 55 Statistics results of “Satisfaction”, “Interest”, and “Interaction”

	Visitor Type							Mean
	A	F-C	Cp	Ts	E	Cs	Sp	
Q1-Satisfaction	4.43	3.98	4.35	4.02	4.31	4.07	4.00	4.17
Q2-Interest	4.30	4.08	4.22	4.05	4.03	4.18	4.13	4.14
Q3-nteraction	4.33	4.02	4.18	4.14	4.29	4.24	3.97	4.17

FC - Family with children; **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

7.4 Utilization Guidelines

Based on the factors influencing visitors' interest and engagement, this study proposes application guidelines for museum exhibition design under digital technology intervention, consisting of the following three parts: (i) exhibition design principles under digital technology intervention; (ii) Universal Design paradigm: how digital design meets universal design; and (iii) Ten features of digital media interpretation and interaction exhibits that attract the interest and interaction of different types of visitors.

PART 1: Exhibition Design Principles under digital technology intervention to motivate visitors' interest and interaction in cultural tourism museums

Full-process and multi-disciplinary collaborative digital media interpretation and interactive design for museums

Through theoretical research and case studies, we have concluded that the impact of digital technology on visitor interest is based on visitors' perception of the exhibition environment. Design factors, environmental factors, and visitor factors collectively determine visitor behavior and experience. Therefore, digital media design should be considered from the very beginning of the exhibition project planning. That is, starting from project initiation and preliminary market research, to content planning, experience construction, then to exhibition layout and spatial planning, and finally to the configuration of digital exhibits and interactive content. This involves a multidisciplinary and multidimensional co-influencing mechanism. **Figure 66** displays the design process checklist.

understand the characteristics and needs of the target visitors—for example, motivations and behavioral preferences, behavioral characteristics and identity traits, personalized features, etc. **Figure 67** illustrates the considerations for the target visitors of the tourist museum in the “Utilization Guideline handbook”.

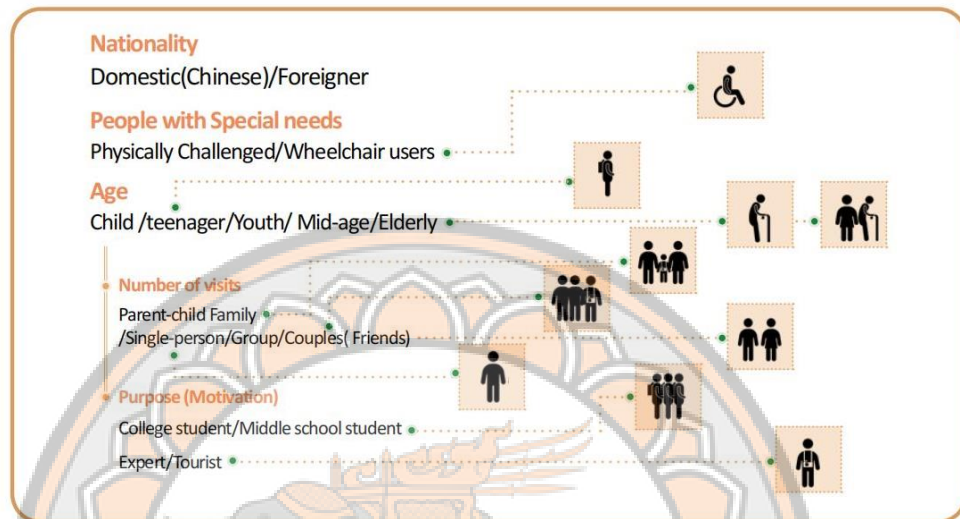


Figure 67 The considerations for the target visitors of the tourist museum

Under the visitor-centered design principle, another crucial concept is the “Visitor Pathway to Experience”. Visitors walk into the museum with excitement and longing for cultural heritage, hoping to engage in personalized ways of interaction and go sightseeing across time and space. The result is an inspiring, exciting, and intellectual challenge. Technology is not simply an auxiliary component of well-crafted and thriving tourism experiences; it needs to be conceived from a holistic perspective to be successfully integrated into the experience, a unique cultural and learning experience exclusive to museums, distinct from other leisure and tourism products.

PART 2: Criteria for an inclusive museum for people with disabilities

Based on the 'Museum for All' philosophy and human-centered design paradigm, this design guide incorporates Americans with Disabilities Act (ADA) compliant principles to ensure equal visitor accessibility for people with disabilities. These principles are developed through cross-departmental collaboration and applied throughout the entire exhibition lifecycle, from planning and content design to environmental and experience design. **Figure 68** shows seven criteria and the standard of barrier-free design in the guidebook.

Advice: The inclusive design through multi-department collaboration.



Criteria Checklist		Failed	Fair	Good
1.	Museums should provide visitors with three options: Braille, embossed text, or large font.			✓
2.	Educational materials of 3D exhibits replicas . Audio and tactile guides are provided for blind visitors.	✓		
3.	Accessibility facilities for visually impaired and impaired vision, such as tactile paving.	✓		
4.	Diverse ways to experience sensory action to enhance their interactive experience.		✓	
5.	Barrier-free access from the museum entrance to the exhibition.			✓
6.	Generous room design, the exhibit features a viewing area at the front for wheelchair users to navigate.	✓		
7.	Exhibit height is suitable for wheelchair users, but children and shorter people also benefit from it.		✓	

Figure 68 Criteria for an inclusive museum for people with disabilities

PART 3: Universal Design paradigm-using 7 principles of Universal Design in digital interpretation and interactive design

In the digital interpretation and interactive visiting process of museums, the usability of digital exhibits is crucial, while the accessibility of the exhibition environment and the perceptibility of the information environment are equally important. A comprehensive visitor experience strategy should be adopted from the initial stages of project planning. During the planning phase, fully consider the needs of different user groups to ensure that information, services, and spaces are accessible to everyone (including vulnerable groups). Therefore, this study recommends incorporating the seven principles of universal design during the design stage to identify numerous universal solutions at the planning stage. In other words, the exhibition environment, digital interaction formats, and digital content design should all adhere to universal design principles, providing equal service and access possibilities for all visitors. **Table D1** demonstrates how the exhibition environment, digital interaction formats, and digital content comply with universal design principles.

PART 4: Ten design features of museum exhibitions under digital technology intervention that can enhance interest and interaction among different types of visitors

Based on satisfying the seven universal design principles, this guide proposes ten key characteristics of museum exhibition design under digital technology intervention that can enhance visitor interest and interaction. These ten characteristics are based on the top ten influential factors identified in the research findings that affect visitor interest and engagement: visual materials-labeling system, theme, narrative form, location and nodes, main equipment, capacity, content framework, exhibit scale, lighting ambiance, and visitor flow. **Figure 69** illustrates the feature description diagram drawn in the design compass.

Feature 1: An intuitive instruction system that anyone can understand.

Feature 2: Clear and understandable theme, visitors can quickly judge its value.

Feature 3: Procedural and lifelike narrative forms for historical representation, avoiding repetitive exhibits. Obscure and difficult to comprehend. Narratives detached from daily life. Visitors of all cognitive levels can understand and acquire effective information.

Feature 4: Located within the main exhibition framework, the content is connected in front and back, with major routes and lines of sight

Feature 5: The main form of the equipment should be novel and multi-sensory, but not too complex. Novel things attract visitors' interest.

Feature 6: At least three people should be able to operate or observe simultaneously. When a visitor is operating, other visitors should also be able to access information. Avoid congested environments.

Feature 7: The content framework should have clearly identifiable value guidance, and the information load should not be overloaded or too little.

Feature 8: The scale of the exhibit should not be too small, and there should be an appropriate distance between other exhibits to avoid congestion or excessive content load. Based on meeting the first 7 characteristics, large exhibits with independent spaces will attract more visitors.

Feature 9: Comfortable lighting and acoustic environment, free from glare with optimal reading sightlines. The creation of any ambiance must prioritize the effective dissemination of information.

Feature 10: Concise visiting route with minimal physical exertion. The main exhibition content should be arranged along a concise route, while auxiliary and extended routes should be designed for professional and exploratory visitors.

Design Feature 2

Clear and understandable theme, visitors can quickly judge its value

Explanation:

· By integrating modeling and projection, the exhibit visually demonstrates the three stages of ancient pottery-making: clay preparation, wheel throwing, and glazing.
· Interactive screens allow visitors to explore different content through multi-touch interfaces.
· The hands-on interactive games require no complex controls, enabling participation from all visitors.

Design Feature 4

Located within the main exhibition framework, the content is connected in front and back, with major routes and line of sight.

Explanation:

· Eye-catching and intuitive titles to indicate the main content displayed by visitors.
· Use virtual portrait navigation to attract the interest of visitors with questions.
· Relatively independent digital equipment. Use color to indicate the importance of content and the connection between previous and subsequent content.

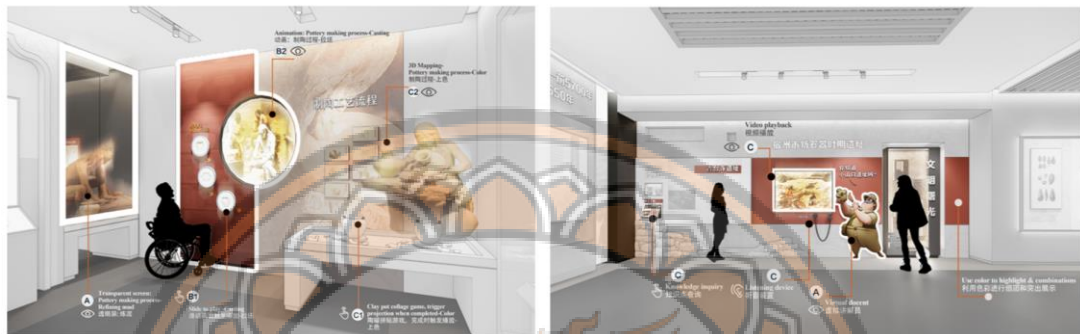


Figure 69 The image description of the ten features for enhancing visitor interest and interaction of digital exhibits proposed in the “Utilization Guideline”

CHAPTER VIII

CONCLUSIONS

By collecting all the data, the researchers obtained guidelines and strategies consistent with the research objectives. This study aims to investigate the factors influencing the interests and interactions of different types of visitors in museum exhibition design under digital media technology intervention, and further explores strategies for effectively utilizing digital media technology in museum exhibitions to enhance engagement among diverse visitor groups, ultimately promoting the development of China's museum tourism industry. The objectives of this study primarily focus on the following four aspects:

(1) To analyze the factors and principles for integrating digital media technologies into museum exhibition design to enhance visitor interest, engagement, and interaction, thus promoting museum tourism.

(2) To examine the physical environments of popular museums in China and evaluate their alignment with key factors for effectively integrating digital intervention techniques to promote museum tourism.

(3) To investigate museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital intervention techniques in museum exhibitions.

(4) To propose strategies for effectively utilizing digital intervention techniques in museum exhibitions to enhance visitor interest and interaction and promote museum tourism in China.

8.1 Conclusions of four Research Objectives

The research findings of the four objectives can be summarized as follows:

Objective 1: To analyze the factors and principles for integrating digital media technologies into museum exhibition design to enhance visitor interest, engagement, and interaction, thus promoting museum tourism.

(1) Conclusions of the systematic literature review results

This paper explores the factors influencing visitors' interest and interactive behaviors in museum exhibitions under the intervention of digital media technologies. Bitgood (2003) proposed that the factors affecting visitors' behaviors and experiences include design, environmental, and visitor factors. Museum communication theory

posits that exhibition designers in museums re-encode exhibition information and present the content through design language and visual materials, while visitors decode this information to acquire knowledge (Huang, 2017; Sun, 2017). The exhibition space serves as a carrier for information dissemination and a venue where audiences acquire information and interact with it. Designers must not only alter spatial elements such as form, structure, and color to create intuitive, vivid, systematic, easily understandable, and engaging visual spatial forms, but also present the displayed information to the audience in a planned, purposeful, and logically coherent manner, thereby fulfilling the exhibitor's communication objectives (Sun, 2017).

The environmental behavior theory posits that visitors receive signal stimuli (including psychological and physiological environments) in museum exhibition settings (Ken, 2013; Li, 2021; Wu, 2014; Zhang, 2018), which are processed through their perceptual systems, leading to various behavioral responses such as approach behaviors and avoidance behaviors (Li, 2021). Both environmental factors and visitor characteristics jointly influence the outcomes of these responses. The attention-value model theory in museum audience research posits that visitors search for exhibits in the environment that can capture their attention, aiming to expend minimal effort while achieving maximum gains, based on their motivations and visit purposes (Bitgood, 2013; Ceccarelli et al., 2024; King et al., 2025; Vázquez, 2016).

Therefore, based on museum communication theory, environmental behavior models, visitor attention models, and visitor experience (UX) theory, the behavior and reactions of visitors in a museum exhibition environment are influenced by exhibition design factors, including exhibit design, spatial form design, visitor flow design, content design, and visual communication design; environmental characteristic factors, including physical environments such as accessibility, legibility, comfort, and convenience, informational environments such as readability, learnability, and benefit, and psychological environments such as aesthetics and cultural significance; as well as visitor factors, including demographic characteristics, behavioral preferences, and spatial perception, among others. **Table 25** The factors influencing visitor behavior and exhibition effectiveness from the literature review shows the results of this phase.

(2) Conclusions of expert interview

After evaluation by three experts on factors influencing visitors' interest and interactive behaviors through the literature review, the experts concluded that visual materials such as color, display configuration, and content presentation affect

visitors' interest and interactive behaviors. Furthermore, the experts suggested that since this research ultimately aims to discuss design guidelines for museum exhibition design, it is necessary to define the intersections of information spaces and psychological environments and translate them into design language. Consequently, psychological environmental factors were transformed into design factors and physical environmental factors, while psychological environmental factors were converted into observational indicators for evaluation.

Ultimately, the factors and indicators influencing visitors' interest and interaction were identified, comprising 9 dimensions and 29 indicators across design factors, environmental factors (physical), and visitor factors. Additionally, the evaluation and inspection methods for each indicator were established. See **Figure 14** and **Table A1**.

(3) Conclusion of AHP

The purpose of AHP is to, from the experts' perspective, 1) preliminarily determine the weights of various factors affecting visitors' interest and participation, to assist in further validation. 2) Compare with the results of visitor surveys to identify potential breakthroughs for enhancing visitors' interest and participation. Through expert scoring and weight analysis, the top ten factors influencing visitors' interest and interaction were ultimately identified, as shown in **Table 56**.

Table 56 The top 10 factors with the highest weight

1 st Layer	W	2 nd Layer	W	pW	3 rd Layer	W	pW		
A- Design Features	0.428	A1-Exhibit Configuration	0.301	0.129	2	A11 Interactive form of the exhibit	0.306	0.039	6
		A2-Visual Materials	0.411	0.176	1	A22 Clear exhibit theme	0.252	0.044	4
						A23 Style of visual language	0.326	0.057	1
						A24 Color contrast	0.219	0.039	6
		A3-Content Framework	0.288	0.123	4	A33 The content narrative type	0.467	0.057	1
B- Environm ental Features	0.225	B1-Layout /Path	0.349	0.079	8	B12 Location and structural point	0.573	0.045	3
C- Visitor Features	0.317	C2-behaviorChar acteristics	0.272	0.086	6	C23 The identity of the visitor	0.461	0.040	5
		C3- Personal Features	0.442	0.140	3	C31 Cognitive feature	0.363	0.051	2
						C32 Museum-visiting / year	0.318	0.044	4
						C33 Physical feature	0.319	0.045	3

(4) Results summary of objective 1

First, there are 29 indicators under the factors of design, environmental, and visitor features that were found to affect the interest and interaction of visitors. Second, the top ten factors are: A23, style of visual language; A33, the narrative type of content; C31, Cognitive Characteristics; B12, Location and structural point; C33 Physical feature; A22, Clear exhibit theme; C32, Museum-visiting /year; C23, The identity of the visitor; A24, Color contrast; A11, Interactive form of the exhibit.

The results of the study identify the factors that influence the behavior of visitors in the digital interactive exhibition environment. In this phase, not only are the design factors considered, but also the environmental factors related to the digital interpretation equipment and the visitor characteristics. Experts believe that design features ($W=0.4278$) are more important than visitor features ($W = 0.4588$), which are more important than environmental features ($W = 0.2552$). This slightly differs from previous research findings. Wu (2012) proposed that among all factors, environmental and visitor factors served as the primary influences. It was also found that experts from different disciplines had different emphases on different factors.

Objective 2: To examine the physical environments of popular museums in China and evaluate their alignment with key factors for effectively integrating digital media technologies to promote museum tourism.

(1) From Step 1: Environment measurement based on design elements

The current application forms and design Features of digital Technology in museums

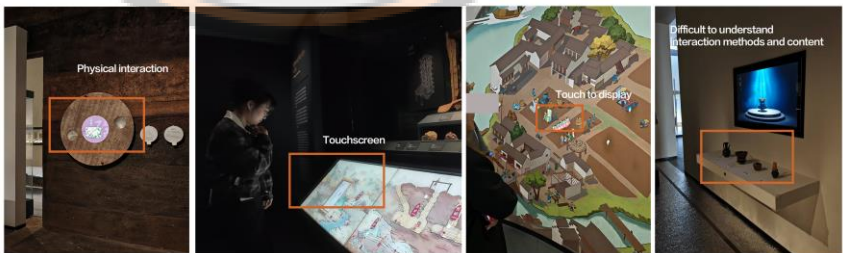
Statistics on digital media exhibits in China's five most popular newly-built museums over the past five years reveal that existing digital displays remain predominantly viewing-oriented and interactive inquiry-based. New technologies widely discussed in literature as capable of enhancing visitor engagement and experience, such as VR and XR (Chen, 2023; Cipparrone et al., 2025; Li, 2022; Mason, 2020; Ning et al., 2023; Wang, 2015), are relatively underutilized. In terms of digital interpretation content, most exhibits prioritize popular science and documentary formats, while approaches like scene narration and historical reconstruction (Chen, 2023; Kasemsarn et al., 2023; Tong, 2020) are less frequently employed. Meanwhile, scene reconstruction, narrative design, and digital storytelling methods, extensively recognized in academic research as beneficial for enhancing visitor experience design, show relatively limited application. The utilization of digital technologies to create

environments and atmospheres is also a primary direction in the current digital exhibition design at the China Tourism Museum, which is consistent with the perspective put forward by Owell & Kokkranikal (2015) in the literature review, stating that experiencing the entire museum environment is more attractive than the exhibits inside the museum. **Table B1** demonstrates the main forms of digital media interaction and technological equipment currently existing in Chinese museums. **Figure 16** displays the relevant design features based on 10 key weighting factors.

Conclusion of barriers and limitations in the museum exhibition environment containing digital media

The researcher evaluated and documented the physical environments of six museums through exhibition traverses and on-site environmental recordings. The identified issues include: (i). a lack of specific guidance information or poor placement, (ii). obstacles in primary circulation spaces and excessive crowding that reduce visitation efficiency, (iii). poor spatial ambiance and difficulty in content recognition exacerbating the aforementioned problems, leading to unsatisfactory exhibition environments composed of digital media interactions, (iv). unappealing digital content, and (v). Inappropriate scale and placement of interactive consoles are causing participation difficulties. As shown in **Table 57**. This is consistent with the problems raised by Huang(2014), Lo et al.(2023), Wu(2012), Kasemsarn et al.(2025), and Ken (2003,2006) in their research: at the beginning of digital exhibit design, there is a lack of research on the needs and behavioral characteristics of different visitors.

Table 57 Description of environmental assessment based on the design factors

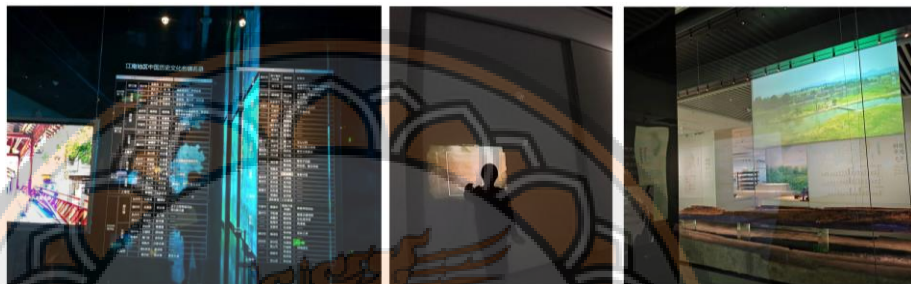
Obstacle	Image description
(1)	
Lack of specific guidance information or poor placement.	

(2)



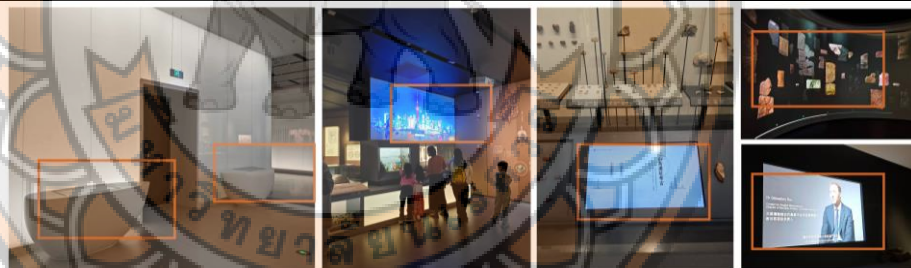
Obstacles in primary circulation spaces and excessive crowding that reduce visitation efficiency

(3)



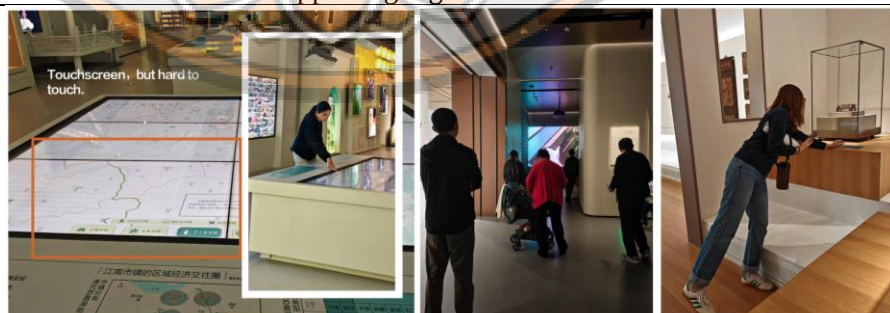
Poor spatial ambiance and difficulty in content recognition exacerbate the aforementioned problems, leading to unsatisfactory exhibition environments composed of digital media interactions.

(4)



Unappealing digital media exhibits.

(5)



Inappropriate scale and placement of interactive consoles are causing participation difficulties.

(2) From Step 2: Physical environment measurement based on the 7UD checklist evaluation

Conclusion of the 7UD checklist evaluation in six museums

The evaluation results through the UD checklist revealed that digital components with more issues and barriers corresponded to lower UD score rates. The findings also demonstrated distinct behavioral preferences and tendencies among different types of visitors. For instance, parent-child families placed greater emphasis on the entertainment value of formats and operational accessibility, explained by UD1, UD2, and UD3. However, all visitor types prioritized the readability of exhibition content and perceptual information-UD4.

The recognized problems encompass the deficiency of precise guiding information or the inadequate positioning of digital media within the exhibition setting, barriers in the main communication areas, and excessive crowding, which collectively lower the effectiveness of visits (Ken, 2003; Lo et al., 2023; Wu, 2014). Additionally, the poor spatial atmosphere and the difficulty in identifying content exacerbate these problems, leading to a dissatisfying exhibition environment affected by digital media interactions (Chiang, 2022; Li, 2021). The findings, derived from the assessment of the UD7 checklist, revealed that the integration of digital media with environmental composition, characterized by a greater number of issues and obstacles, is associated with lower UD scoring rates. The results also show different behavioral preferences and tendencies among various types of visitors (King et al., 2025; Li, 2021; Liu, 2020). For instance, parent-child families focus more on the entertainment value of the form and the ease of operation. (Li & Luo, 2024; Shiang et al., 2015) - explained for UD1, UD2, and UD3. However, visitors of different types are all more concerned with the readability- UD1, UD3, and perceived information (Kasemsarn et al., 2025)-UD4 of the exhibition content.

(3) From Step 3: Visitor interview in museum exhibition sites

Conclusion of the visitors' interview and comparative analysis

It was further found through random interviews with on-site visitors that the behavioral traits of different visitors differ. Older audiences prefer to obtain exhibition information points simply and directly (Kasemsarn et al., 2025), focusing on UD3, UD4, and UD6. Middle-aged audiences possess elevated expectations, desiring an enhanced comprehension of knowledge points via digital media, alongside an exhibition environment that is both comfortable and succinct (Liu, 2020). They pay more attention to UD2, UD3, UD4, UD5, UD6, and UD7. Young audiences, including

college students and couples, lack specific preferences and are inclined to explore and discover flexibly in line with their interests (Chen, 2005; Liu, 2020; Gofman et al., 2011), paying more attention to UD2. Parent-child families attempt to find exhibits and exhibition content more suitable for children (Lo et al., 2023; Su, 2019), with their focus on UD1 and UD3. International audiences hope for more direct (e.g., visual) methods and explanations to guide them in accessing core information (Kasemsarn et al., 2025), as both Chinese culture and Chinese characters make it difficult for them to quickly comprehend, namely UD4 and UD3. Teenage students usually engage in group activities without specific visiting objectives, thus preferring exhibits with visual appeal and suitability for small-group simultaneous viewing (Lai & Qian, 2015; Liu, 2020; Tessa et al., 2010). They pay more attention to U6 and UD2.

These findings are consistent with the results of the 7UD checklist evaluation. Therefore, introducing the 7 universal design principles into museum exhibition design can help mitigate environmental barriers, thereby enhancing visitor engagement.

(4) Results summary of objective 2

Through the study of the above three steps, we have obtained the alignment between the physical environment and the key factors that affect the interest and interaction of visitors.

Through comparative analysis of environmental assessment results and 7UD checklist evaluation findings, six museums revealed additional digital media-related issues during environmental inspections. These problems became particularly evident when 7UD scores were low, indicating consistency between the audit results and environmental assessment outcomes. For example, in the Culture of Wu Museum, issues like disorganized exhibition routes and low utilization of digital media exhibits failed to attract visitors to linger. By analyzing the UD principles, we can identify the underlying causes corresponding to UD2, UD3, UD5, and UD6. In the Wu-Yu Museum, problems such as visitor flow interference with neighboring exhibitions and poorly positioned exhibits that failed to draw crowds can be explained through UD2, UD3, and UD4.

By comparing the results of visitor interviews with expert evaluations, it was found that from the visitors' perspective, whether a digital exhibit has a clear explanatory system and whether it can convey content from different dimensions compared to physical exhibits are crucial factors in their decision to engage with digital interactions. However, the visual language and interactive forms of digital exhibits have little impact on visitors. Instead, whether the visual language and interactive forms align with the 7UD principles

affects visitor engagement. The results further support the use of seven universal design principles to enhance visitor engagement and provide specific directions, shown in **Figure 68**. Details are provided in **Table B6**.

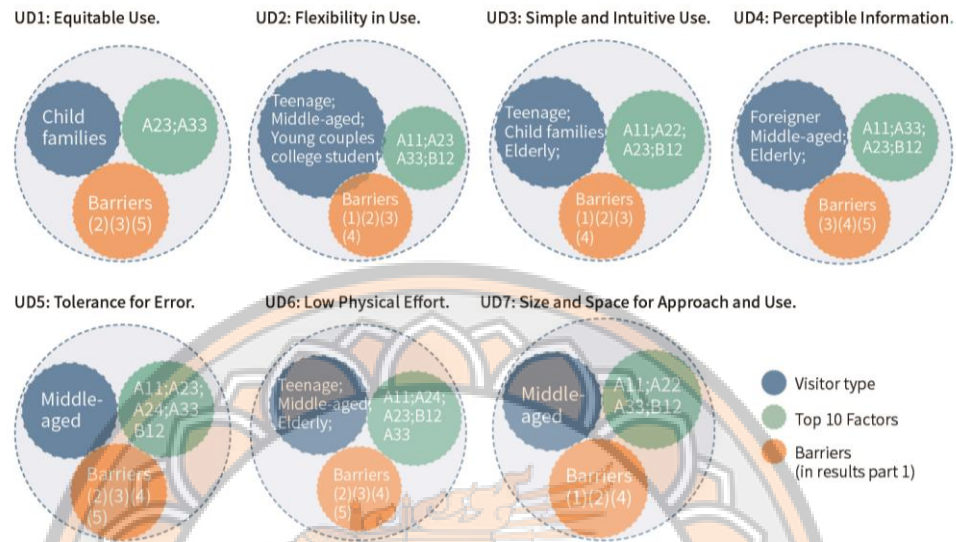


Figure 70 The association between environmental barriers, design factors, 7UD, and visitor characteristics

This environmental assessment integrating universal design principles provides visitors with a method to construct behavioral experiences while considering both physical and psychological environmental factors. It connects exhibition designers' concepts with visitors' behavioral responses and experiences. Through this assessment, constructors can identify which museum exhibition resources and initiatives significantly impact visitors and propose corresponding improvement suggestions. Objective 2 proposes methods to enhance visitor engagement from the perspective of addressing visitation barriers, but we still do not know which factors can attract visitors' attention and interaction interest. This is precisely the issue that Objective 3 needs to address.

Objective 3: To investigate museum visitors' behaviors and needs regarding their engagement, interest, and interaction with digital media technologies in exhibitions.

(1) From Step1: Non-contact behavior observation by the IAE scale

Conclusion of the findings from the "Attractive Power" survey

The IAE evaluation results indicate that the application of digital interpretation technology has not achieved the expected outcomes (Lo et al., 2023). 77% of

visitors either ignore the displays or notice them but struggle to be engaged, while only 4% of visitors successfully interact with or watch the complete interpretation. Digital exhibits scoring 2-3 on the attractiveness scale share the following characteristics: triggered viewing, novel media technology, color schemes harmonizing with the environment, and clearly defined thematic presentations. Their visual language employs 3D rendering to showcase internal structures or processes. Although the spatial configuration and scale of the B3 digital exhibits show no significant impact on attractiveness, behavioral observation statistics still reveal that digital exhibits located on auxiliary display lines, with no relevant surrounding content, lack appeal. Conversely, exhibits positioned on primary display lines or within dedicated digital audiovisual spaces are more likely to attract visitor engagement and prolonged stays (Bitgood, 2019).

(2) From Step2: Correlation analysis

By comparing the attraction results with the UD results, it was found that devices with low scores in the UD evaluation corresponded to lower attraction scores. This outcome highlights the positive influence of UD fulfillment (i.e., environmental factors) on attraction. However, the results also revealed that some digital interpretations with high UD scores exhibited low attraction. Further regression analysis of the formal factors of digital interpretation, visitor factors, UD factors, and attractiveness scores revealed that visitor type serves as a potential mediator linking attractiveness to digital interpretation, exhibition performance, and universal design principles. The form of digital interpretation devices showed no significant impact on attractiveness; for instance, whether the space was a cinema or a display format did not influence visitor participation. Instead, the form of interpretation, such as artistically aesthetic films or knowledge-based explanations, inversely affected visitors' engagement (Ceccarelli et al., 2024; Li & Ito, 2023; Liu, 2020). Meanwhile, the fulfillment rate of UD emerged as a key variable influencing participation across different visitor types, with UD3, UD4, and UD6 playing pivotal roles.

After the analysis of the previous stage, it was discovered that the digital interpretation with the same type can result in opposite AP, which proves that AP is related to UD and is significantly positively influenced by the UD3, UD4, and UD6 indicators. Figure 15 illustrates this phenomenon. **Figure 69** demonstrates this phenomenon. It is also found that even when UD is well implemented in digital interpretation devices, they can still experience low AP. This is because certain factors within the formats of digital interpretation play a decisive role. The phenomenon was

corroborated through the VX questionnaire survey, which revealed that visitors of different types exhibit different behavioral preferences. However, their satisfaction with the digital interpretation is based on whether the digital device effectively and vividly interprets the heritage and historical knowledge (King et al., 2025; Liu, 2020).

There are researchers have pointed out that the behavior of museum visitors is closely related to their learning motivation. In other words, the visitors of museums generally have a motivation and need for learning (Huang, 2014; Kasemsarn et al., 2023; Lu et al., 2018; Mason, 2020; Zhang, 2018). a finding that is consistent with the results of this study. And precisely for this reason, some digital interpretation devices, despite performing well on all 7UDs indicators, still lack attraction power to visitors.

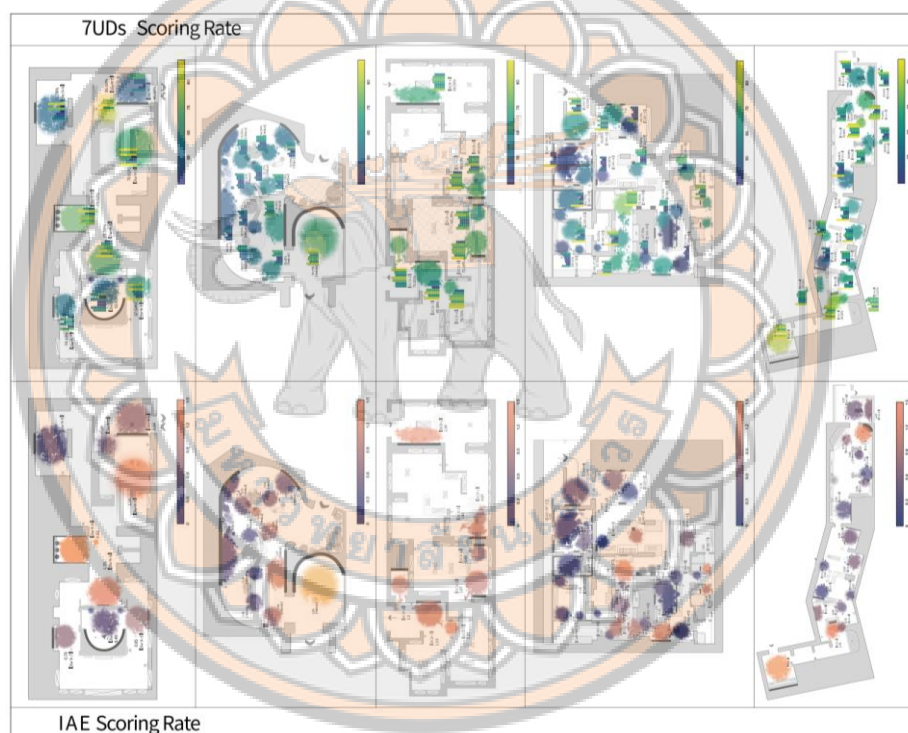


Figure 71 The visual comparison of scoring rates between 7UDs and IAE

(5) From Step 3 : Visitor experience survey in six museums by using user experience questionnaire

Conclusion of Visitor Experience Results

Based on visitor behavior observation, this study further analyzed post-visit experience questionnaires to identify preferences for digital interpretation among different types of visitors from perceptual, behavioral, and reflective dimensions (Liu, 2020). The results are as follows: Although visitors of different types exhibit varying motivations for visiting, including learning, leisure, and aimless relaxation behaviors,

the influencing factors demonstrate consistency. Environmental accessibility and content interpretability account for a significant proportion, while entertainment relevance is minimal (Liu, 2020; Zhang, 2018). Tourists believe they do not deliberately engage in digital interpretation. Whether digital media is prominently positioned and whether the visual content is clear of which relate to the exhibition-determines whether they stay (Bitgood, 2013; Vázquez, 2016). This aligns with the attractiveness evaluation results: the form of interaction does not affect attractiveness, whereas content and UD (Universal Design) do. Regarding content satisfaction, visitors of different types all selected “vivid recreation of historical scenes” and “better understanding of key points.” Elderly audiences additionally chose “lifelike scenarios,” while student audiences added “process-oriented interpretation.”

The results from this stage further confirm that the UD principles, particularly UD3, UD5, and UD6, have a significant impact on the attractiveness and engagement level of digital exhibits. Meanwhile, new digital technologies that eliminate complex operations (Kasemsarn et al., 2025; Ken, 2006; Su, 2019), along with lifelike, process-oriented, and scenario-recreating digital narratives located at key display nodes (Mason, 2020; Ning et al., 2023; Tong, 2023), are critical features for attracting visitors to stay and participate. The study also verifies that these characteristics can satisfy the interests and needs of various types of visitors.

(6) Results summary of objective 3

Through a comprehensive analysis of the three dimensions of UD, AP, and VX, it was found:

(1) Regardless of the form of digital devices, the elements related to “content interpretation” in the visual representation, information perception form, and interaction form presented by digital devices will attract visitors’ attention to a greater extent. For example, images with clear knowledge points are more attractive than those of an artistic aesthetic nature. Images for the process of creating heritage, conducting structural analysis, or the process of archaeology are more engaging than expert explanations or static displays (Kasemsarn, 2024; Liu, 2020; Tong, 2023).

(2) Different types of visitors tend to participate randomly when facing digital interpretation. In the face of the same digital interpretation, when visitors pass by, the screen presents a clear and closely related image to the exhibition content, and visitors often stop to watch; however, if the image happens to be a transitional content or an end scene, visitors usually walk straight past (Bitgood, 2013; Ceccarelli et al., 2024).

(3) In addition to the environmental factors involved in the 7UDs Checklist, during behavioral observations, it was found that when the position of digital interpretation is outside the content frame, it will be ignored by visitors. This is consistent with the survey results, where visitors place more emphasis on the content perception of the exhibition (Bitgood, 2019). Ideally, the theme of a museum should harmoniously integrate with digital technology to effectively convey the exhibition content, while providing an incredible experience for visitors during museum visits (Dong, 2024; Lu et al., 2018; Mason, 2020; Ning et al., 2023; Wang, 2015). This discovery can serve as a supplement to the 7UDs Evaluation Checklist-supplementing the consistency and structural aspects of the UD2 and UD4 indicators.

The results of this study emphasize the important role of content perception in digital interpretation.

Objective 4: To propose strategies for effectively utilizing digital media technologies in museum exhibitions to enhance visitor engagement and promote museum tourism in China.

(1) From Step 1 : Summary of results for Objectives 1-3

Key features of digital exhibits that attract the interest and interaction of different visitors.

The findings suggested that digital exhibits with high attractiveness possess the following characteristics: novel visual forms and media devices (A12), clear themes (A22), process and historical reconstructions in interpretation (A25), larger display scales (B34), low information load (A31), non-complex content (A32), spacious and comfortable environments (B31), and exhibit placement along primary visiting path (B12). Notably, digital interpretations of space, particularly those in a cinema-style format, are more appealing to elderly visitors.

The analysis of the correlation between AP and design elements revealed that neither the digital type (A11) nor the screen visual style (A23) significantly influenced visitor interest. According to attention model theory, visitors tend to prioritize exhibits that quickly capture attention and require minimal mental effort to maximize benefits. Museum visitors prioritize reducing cognitive load and seeking meaningful experiences over mere knowledge acquisition, which contrasts sharply with the learning-oriented behavior of cultural tourists. This phenomenon may be closely related to visitors' motivational patterns and environmental perception characteristics. Based on this, we conducted an in-depth exploration of the limitations

of digital interaction exhibits in museum exhibition environments and proposed corresponding solutions.

Design image questionnaire

Through objectives 1-3, we got that: Factors that influence visitor interest and interaction. Key factors and mechanisms that can affect the exhibition environment and visitor interaction. Exhibition features that enhance visitor interest and interaction. In the end, 11 factors and characteristics were identified. U1-Usability for all; U2-Flexibility in engagement; U3-Clear communication, easy to see; U4-Mostly perceptible information; U5-Mostly security; U6-Mostly comfortable and low physical effort; U7-Mostly approach and use size; F1-For multiple people to participate; F2-Strong visual impact; F3-More involved and exciting; F4-Vivid and interpretable. A questionnaire with 10 images was designed to evaluate the above 11 factors on the visitors' interest, interaction, and satisfaction.

(2) From Step 2: Image Stimulation Questionnaire

The results showed that if the museum's digital media could provide more display forms and more interesting historical knowledge introduction (Liu, 2020; King et al., 2025), and the exhibition with digital media intervention provide inclusive solutions for a diverse range of visitors (Kasemsarn et al., 2023), they would have a better experience: more interesting, more interaction, and more engagement.

The evaluation scores of each dimension of the 10 images ranged from 4.18 to 4.83, which means that the participants were able to perceive the design features conveyed by the design images well and believed that such designs could enhance their interest and interaction. From the perspective of overall satisfaction, the average score across all three dimensions reached 4 points, indicating satisfaction with the design and its ability to enhance interest and engagement. But, more attention should be paid to elderly, child-family visitors, and visitors with special needs, such as people with disabilities and foreigners.

(3) Results summary of objective 4:

How can proposed strategies utilizing digital media technologies be effective in museum exhibition design to enhance visitor interest, engagement, and interaction, thereby contributing to the promotion of tourism in museums?

Through a series of theoretical research and empirical investigation, the study first identified the factors that affect visitors' interest and interactive behavior: environmental factors, design factors, and visitor factors. The study identified the acceptance and adoption of digital technologies among different types of visitors.

Secondly, it found that the universal design paradigm could be incorporated into the design process to reduce barriers encountered by visitors in exhibition environments (Filová et al., 2022), particularly those caused by digital technologies. Through behavioral observation and experience survey, the exhibition features that can attract visitors' interest and interaction are determined (Bitgood, 2019; Huang, 2014; King et al. 2024), and these features can be realized by the 7 principles of Universal Design. In addition, the further influence relationship caused by visitors' characteristics is supplemented: attractive digital exhibit features based on the attention value model.

At this point, the study proposes design guidelines that can be used to enhance the interest and interaction of different types of visitors through digital media intervention. An effective digital design guide that enhances the appeal of digital technology and museum communication should include the following three components: Part 1 is Digital Technologies and Application Formats. Part two is a Design Framework and Process of Museum Digital Media Design. And part three is how to evaluate the design effect.

8.1 Discussion

Exploratory Research-Objective 1

In the existing research, the theories of museum exhibition design are mainly concentrated in the museum science, exhibition design, and digital media design. The theoretical aspects of visitor studies encompass: 1) In museum communication, visitors as receivers of information (Huang, 2017). 2) In environmental behavior studies, visitors' behavioral responses to environmental stimuli (Li, 2021). 3) From the perspective of digital design, visitors are users of digital products or devices (King et al., 2025; Liu, 2022).

Previous studies have pointed out that one of the reasons for the problems of digital exhibits in museum exhibitions is the lack of research on visitors' behavior (Ken, 2003). Therefore, this study examines museum exhibition design that incorporates digital media techniques within the theoretical framework of environmental behavior.

The key factors affecting the interest and interaction of visitors are discussed. Through a series of theoretical and empirical studies, it demonstrates that Universal Design can be effectively integrated into digital museum exhibitions to enhance visitor engagement and interaction, thereby promoting cultural tourism. Furthermore, in line with international design trends and the 'Museum for all' concept, this study builds upon existing theoretical frameworks by incorporating the Americans

with Disabilities Act (ADA) to establish accessibility standards for digital interactive and interpretive features in museum exhibition environments.

Empirical Research -Objective 2 and Objective 3

Through the evaluation of six museums from the perspective of visitors, the conclusions of previous studies are confirmed. 1) There are still a series of problems in the practical application of digital media techniques in museums, which have a certain negative impact on visitors' visits (Ken, 2003; Ning et al., 2022). For example, the congestion, the dimness, and the confusion of content caused by the digital media exhibits. 2) The digital media exhibits in the museum failed to achieve the desired impact (Lo et al., 2023). Among the five museums surveyed for digital exhibit appeal, only the Shanghai Museum's digital exhibits effectively attracted visitors to linger, with an appeal score of 1.13, above 1 (Attend). 3) Visitors are not willing to pay attention to the digital exhibits and participate in the interaction (Ceccarelli et al., 2024; Liu & Chang, 2024); digital interaction is more of a random behavior.

Based on Gap1: Through environmental surveys, this study addresses two key findings: 1) The design of digital interpretation and interaction in museums should be studied and designed within a broader exhibition context. 2) Applying the seven principles of Universal Design to resolve the problems and obstacles in the existing museum exhibitions, thereby enhancing visitor engagement and interaction. 3) Consider accessibility standards in digital design and focus on the rights of people with physical disabilities to visit.

Based on Gap 2: Through visitor investigation, this study addresses three key questions: 1) Emphasizing digital media exhibit features which can effectively stimulate visitor interest and foster interactive experiences. 2) Developing targeted design strategies based on visitor-centered evaluation findings to boost engagement across different museum visitors. Although some digital exhibits meet the universal design principles, they still fail to attract visitors because an attractive digital exhibit must satisfy both the physical characteristics of visitors and the psychological satisfaction, such as learning, exploration, and relaxation.

Generative Research: Objective 4

Firstly, the design of digital interpretation and interaction in museums should be studied and designed within a broader exhibition context. Museum exhibition design is a multidisciplinary collaborative process that integrates spatial planning, environmental creation, content presentation, and interactive experiences. Especially after the introduction

of digital media interaction, this collaborative relationship becomes even more complex (Mason, 2020; Phillips, 2011). The results also confirm that the layout design, content framework, space configuration, and the arrangement of digital equipment in the exhibition environment have caused the low space utilization and lack of attraction. The main reason is the lack of collaboration and overall planning in the initial design.

Secondly, museums should be designed for all demographics, taking into account the diverse interests, cognitive levels, and physical limitations of visitors to enhance the experience (Kasemsarn et al., 2023; Tešin et al., 2022). Integrating universal design principles into exhibition design (Filová et al., 2022) helps improve inclusivity and foster visitor diversity. Conducting visitor research is essential for museum designers (King et al., 2025).

Thirdly, evaluation of the exhibition after its completion is essential. Only through systematic and standardized evaluation can designers effectively identify the visitors' user experience and whether the design is effective (Li et al., 2024). This study confirms that the seven principles of UD can be used to predict problems in the exhibition environment, and verifies the feasibility and effectiveness of the evaluation framework through surveys of the five different types of museums, which can provide new evaluation methods for museum workers.

Utilization Guideline

The effectiveness of the design guide in enhancing visitors' interest, interaction, and satisfaction has been confirmed by the image questionnaire survey. While digital technology can attract visitors to museums, its effectiveness is also influenced by other factors, such as exhibition content. This requires a thorough analysis during the design phase. In addition, this design guide is based on international theories, including environmental behavior, attention value model, universal design, and the Americans with Disabilities Act. It is also a universal design guide targeting design thinking, design process, visitor research, and evaluation, and is therefore considered applicable to museum digital exhibit design beyond the Chinese region.

8.3 Research Contributions

(1). Through systematic literature review and expert evaluation, this study identified the factors that affect visitors' interest and engagement in museum exhibition environments with digital technology intervention and established the evaluation method based on these factors.

(2). Based on the results of the literature study, this study establishes the Post-Occupancy Evaluation (POE) framework for museum exhibitions containing digital

media. Through empirical research, this study identified barriers to digital technology adoption in existing museum exhibitions and proposed solutions by introducing seven principles of Universal Design. This provides a general framework and evaluation criteria for both theoretical research and practical design implementation.

(3). The study emphasizes the POE based on the visitor perspective through an integrated research methodology combining environmental measurements, behavioral observations (qualitative), and questionnaire surveys (quantitative). It further identifies characteristics that can attract visitors' interest and engage them with interactive digital interpretations and exhibits. This provides new approaches and methodologies for exhibition evaluation and helps to establish museums that serve all people.

(4). Proposed strategies for effectively utilizing digital media technologies in museum exhibitions to enhance visitor engagement and promote museum tourism in China. Through a systematic and process-oriented general design framework, this application guide can be applied to other regions and other types of museum exhibition design. Through systematic theoretical research and empirical investigations, this study innovatively integrates the Universal Design paradigm into museum exhibition design containing digital media technology. By applying the Attention Value Model, we propose a design framework that utilizes digital media interventions to enhance engagement and interaction for diverse visitor groups, thereby promoting cultural tourism development. Image simulation experiments confirm the framework's effectiveness in boosting interest across different visitor types, making it a valuable reference for exhibition design and implementation.

8.4 Limitations

The main goal of this study is to identify the elements that can motivate the interest and interaction of diverse visitors, as well as the underlying mechanisms of influence, thereby increasing museum visitors' engagement and experience. It also proposes principles and guidelines for museum exhibition design under the intervention of digital interactive technologies. During the research process, the researchers identified the following issues and limitations in the study:

(1) The disparity between theory and practice. This study investigates and categorizes the factors influencing visitor interest and interaction in museum exhibition design, incorporating digital technologies. It aims to identify the design and environmental characteristics that affect visitor Behavior and perception in exhibitions and digital media design, thereby facilitating effective communication between

designers and visitors. However, the study found discrepancies between the theoretical perspectives retained by experts and the visitor-centered POE survey results. This also explains why existing digital exhibits lack appeal. Curators or designers should understand the needs and characteristics of the target audience based on project features to refine and develop design outcomes, ensuring alignment with practical work requirements.

(2) Regarding the POE in this study. This serves as a recommendation and preliminary attempt for those interested in further exploring this field. Regarding the POE system developed in this study. This serves as a recommendation and preliminary attempt for those interested in further exploring this field. Secondly, although this study is based on the visitor's perspective, it is also an interdisciplinary research. Researchers with different professional backgrounds may affect the completeness of data collection, analysis, conclusions, and report writing. The classification criteria for design factors and environmental factors are based on a literature review and the five expert panel members in this study. However, during the actual case analysis, it was discovered that overlaps exist at the intersection points of information space, psychological environment, and physical environment, which may also lead to redundant variables with similar characteristics appearing in the dataset.

(3) During visitor interviews and questionnaire surveys, factors such as respondents' cognitive levels and prior museum visitation experiences can influence the survey results. For instance, elderly individuals unfamiliar with technology may lead to incorrect interpretations or misunderstandings. Most visitors tend to prefer colloquial and relatable descriptions. The survey revealed that female visitors outnumbered male visitors by a significant margin, and they demonstrated markedly more willingness to participate than their male counterparts. Therefore, surveyors should possess relevant skills to effectively extract key information from complex conversations while minimizing visitors' defensive attitudes to the greatest extent possible.

(4) The research subjects of this study are cultural tourism museums aimed at disseminating regional culture and historical heritage, targeting the general public from all walks of life. Applying these conclusions to industrial museums, science museums, or children's museums should be reconsidered based on exhibition content and function.

8.5 Suggestions

The design recommendations proposed in this study are based on the research findings and stem from a theoretical research perspective. Although the purpose of these design recommendations is to serve practitioners or those who are about to become museum builders or designers, we all recognize that in actual museum construction projects, museum administrators may influence the presentation of the design due to considerations of social factors, management factors, and other elements. Therefore, this design guide should be approached dialectically. Based on the research results derived from Objective 1-4, this study puts forward the suggestions about utilization guidelines of digital media intervention techniques in museum exhibition design for motivating visitors' interest and interaction, following five parts.

(1) Establish a universal framework based on factors influencing visitor interest and engagement

This universal framework for museum exhibition design encompasses a full process and multi-disciplinary collaborative digital media interpretation and interactive design for museums on how to utilize digital interventions to enhance visitor interest and interaction, aiming to assist exhibition designers and museum administrators in developing better museums that serve all visitors. Museum exhibition design is a multifaceted and collaborative process that integrates space, environment, content, and interaction. Especially when digital media interaction is included, the collaborative aspect becomes significantly more complex (Mason, 2020; Phillips, 2011). The results confirm that obstacles and problems within the exhibition environment, such as layout, content framework, space configuration, and the digital device's line, contribute to low utilization and a lack of appeal. The results show that limitations and obstacles in the physical environment, such as layout design, framework construction of content and theme, configuration of space, and digital equipment or devices' positioning, can lead to low utilization and interaction in the exhibition space, and dampen visitors' interest. This is attributed to insufficient collaboration and overall planning at the design's inception. Therefore, the universal framework proposed in this study to enhance visitors' interest and participation should include the design principles, design paradigms, evaluation processes, and multi-disciplinary team collaboration charters from visitor research, project development, and project evaluation. This universal framework aims to assist designers in creating museum exhibitions that better cater to the interests and interactive needs of diverse visitor groups.

(2) Visitor-Centered digital media design in museums

Museum is intended for everyone in society, and need to take into account the interests, behavioral preferences, and even physical limitations of diverse visitors to enhance the overall experience (Kasemsarn et al., 2023; Tešin et al., 2020). This study found that visitor characteristics are one of the important factors affecting visitors' interest and participation. The results indicate that the characteristics and needs of target groups should be fully considered in project development and exhibition design. For example, museums targeting local middle-aged and elderly audiences or family-oriented families should incorporate more concise and relatable content in their digital interpretation. When the target audience includes a large number of professional viewers, they should maintain lively and straightforward presentations while appropriately adding specialized content. For destinations primarily serving tourists, it's essential to enhance knowledge-based content with supplementary information about heritage tourism. Furthermore, this study demonstrates that the 7 principles of universal design should be incorporated into museum exhibition design (Filová et al., 2022) to foster inclusivity and diversity among visitors.

(3) Museum for all-Using Universal Design principles in digital design

The fundamental requirements for different types of museum visits remain consistent: safe and accessible environments (Ken, 2003), clear and concise information delivery (Kasemsarn et al., 2025), and engaging knowledge presentation (Su, 2009). Therefore, the 7UD principle can be considered as a foundation to enhance the digital interpretation appeal of exhibition environments when implementing interactive design. UD1: Everyone can participate in the digital device equally and safely. UD2: This digital device accommodates a broad spectrum of personal preferences and abilities, permitting visitors to choose among multiple route options, participation modes, sequences, and space-time configurations. UD3: Even if the visitor has varying levels of knowledge, language skills, or attention spans, this device is designed to be intuitively comprehensible, addressing the fundamental queries, "What is this? And what can I do with it?" at exhibitions. UD4: When combining different modes, communication of digital interpretation and presentation is effective. That is, clearly informing visitors of the information they are facing. UD5: The exhibition environment and digital devices are risk-free, without sensory overload. UD6: Comfortable movement, ergonomic solutions, minimize repetitive fatigue. UD7: Regardless of physical attributes, including body traits and abilities, suitable dimensions of space and physical environment should be provided

for proximity, interaction, and operation. Specifically, focus should be given to ensuring that UD3 and UD4 criteria are fulfilled within the context of digital interpretation.

(4) Museum for disability-Considerations of accessibility standards

Although the idea of "museums for all" is proposed in this study, the principles of universal design are introduced to achieve this goal. Museums designed for all users also accommodate individuals with disabilities and physical impairments, including wheelchair users, the blind, and the deaf. While universal design principles aim to meet the needs of users with diverse physical characteristics, practical design must still consider the specific needs of special groups. For instance, compliance with accessibility standards can be verified through the Americans with Disabilities Act (ADA) criteria. By implementing disability-friendly facilities in exhibition environments, museums can better achieve the "Accessibility and Usability for All".

Relevant studies in the literature review and ADA support this view, museum for disability. According to the current image simulation survey results, visitors are supportive of the accessibility facilities in museum exhibitions. However, the sample in this study lacks samples of people with disabilities, which is closely related to the construction status and policies of China's museums. Inclusive design is still in its infancy, and basic accessibility facilities are lacking in exhibition environments. This is also an area that needs further research in future studies.

(5) Focus on digital that prioritizes readability and clarity over novelty

Although the core of digital interpretation lies in utilizing advanced technologies to present cultural heritage, the focus should be on users rather than the technology itself (Mason, 2020). One of the distinguishing features of museums compared to other public spaces or tourism products is the dissemination of information (Zhang et al., 2018; Sun, 2017). Therefore, the effectiveness of exhibition information dissemination is one of the primary goals of digital interpretation and interactive exhibits, as well as one of the criteria by which museum visitors judge their appeal. For example, the application of digital interpretation technology should be considered when designing exhibition spaces, including the following aspects: the position of the interpretation device within the space, its connection with the preceding and following exhibition content, and the preservation of appropriate viewing/manipulation distance and space. Digital interpretation should not be used as a tool to fill blank exhibition walls. The ten design features of museum exhibitions under digital technology intervention, which are proposed in this study, will further elaborate on the characteristic that prioritizes readability and clarity.



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APPENDIX A Research Tools

Table A1 The factors and evaluation indicators at various levels, along with the relevant technical methodologies

1 st Layer	2 nd Layer	3 st Layer Indicators	7UDs
A- Design features	A1- Exhibit Configuration	A11 Form of digital interaction: 1. Viewing type; 2. Triggered viewing type; 3. Interactive Display type; 4. Interaction game type; 5. Immersive space type.	UD1; UD2; UD3; UD4; UD5; UD6; UD7
		A12 Main media equipment: 1. Touchscreen or multi-touch screen. 2. Intelligent sensing. 3. Display. 4. Projection. 5. New technologies including VR, XR, or 3d mapping, etc.	UD1; UD2; UD3; UD4; UD5; UD6; UD7
		A13 Sensory participation formats: 1. Visual, 2. Visual + Auditory 3. Tactile 4. Other Senses or Multi-sensory	UD5; UD6; UD7
		A14 Number of people the digital exhibit can accommodate simultaneously: 1.1 person. 2.1-2 People operating or viewing. 3.3-5 People simultaneously operating or viewing. 4. Group. (Capece et al., 2024; Chen, 2022; Dong, 2024; Furferi et al., 2024; Ken, 2006; Li, 2021; Li et al., 2024; Lo et al., 2023; Lu & Chen, 2018; Mason, 2020; Tong, 2020; Wang, 2015; Wu, 2012)	UD2; UD5; UD6; UD7
	A2- Visual materials	A21 Explicit signage or explanation systems	UD1; UD3; UD4; UD7
		A22 Clearly defined themes	UD3; UD7
		A23 Visual styles presented: 1. Realistic style; 2. Cartoon or Animation style; 3. 3d drawing style; 4. abstract art style	UD1; UD2; UD3; UD5; UD6
		A24 1. Contrast color, and 2. Harmonizing with surrounding colors (Bitgood, 2013; Chen, 2023; Chiang, 2022; de Borhegyi, 1963; Knez & Wright, 1970; King et al., 2025; Lu & Chen, 2018; Shiang et al., 2015; Tong, 2020; Vázquez, 2010; Ling & Guo, 2024).	UD5; UD6
	A3- Content Framework	A31 Information load: 1. High 2. Moderate 3. Low	UD3; UD4; UD5
		A32 Complexity of information: 1. Complex and difficult information. 2. Concise and easy information.	UD4; UD5; UD6; UD7
		A33 Narrative type: 1. Archaeological documentation; 2. Process interpretation and reappearance; 3. Historical reappearance (including historical scenes, historical stories, or architecture, etc.); 4. Science popularization; 5. Artistic appreciation; 6. Static image playback, non-narrative.	UD1; UD2; UD3; UD4; UD5; UD6; UD7

		Bitgood, 2009; Bitgood, 2013; Ceccarelli et al., 2024; Chiang, 2022; Kasemsarn et al., 2025; Liu, 2020; Ning et al., 2022; Tong, 2020;
		Method: Expert evaluation; Environment measurement; Exhibition Walkthrough; The 7UD Checklist Evaluation; Visitor interview
B1- Layout and Visiting Path	B11 Layout: 1. Fixed single flow path; 2. Flexible flow path; 3. Located in complex multi-corridor flow paths.	UD1; UD2; UD3; UD6
	B12 Exhibit layout location: 1. Located along the main exhibition route. 2. Situated on the special exhibition route 3. Positioned on secondary exhibition routes	UD2; UD5; UD6
		Bitgood & Huimei, 1992; Bitgood, 2013; Chiang, 2022; Ken, 2003; Mason, 2020; Wu, 2012; Zu, 2019
	B21 Dedicated lighting, projection, and other atmospheric elements.	UD1; UD5; UD6
B2- Lighting and Atmosph ere	B22 Consistent with the environment	UD1; UD5; UD6
	B22 Create a sound atmosphere	UD1; UD5; UD6
		Bitgood, 2013; Chen & Chang, 2009; Chiang, 2022; Ken, 2006; Phillips, 2011; Shaby et al., 2017; Vázquez, 2010; Wu, 2012; Zu, 2019.
	B31 Independent space	UD1; UD2; UD5; UD6; UD7
B3- Spatial Configur ation and Exhibit Scale	B32 There are partitions / separate desks/walls	UD1; UD2; UD5; UD6 UD7
	B33 Configuration: 1. Large-scale media installations; 2. Artistic installations; 3. Comprehensive scenes; 4. Independent digital device.	UD1; UD4; UD5; UD6; UD7
	B34 Not possess independent attributes: 1. Large indicator 2. Small indicator	UD1; UD2; UD3 UD4; UD6; UD7
		Bitgood 2013, Chiang, 2022; Huang, 2014; Ken, 2003; Lo et al., 2023; Miao et al., 2024; Vázquez, 2010; Wu, 2012.
B- Environmen tal features		Method: Environment measurement; Exhibition walkthrough; The 7UD Checklist Evaluation, Questionnaire, Scenario access exercise
C- Visitor features		C11 Demographic characteristics
		C12 Motivation
	C1 behavior preferenc e	C12 Purposes Chen, 2005; Jiang & Wen, 2020; Kasemsarn et al., 2023; Liu, 2020; Li, 2021; Li, & Ito, 2023; Powell & Kokkranikal, 2015; Wu, 2014; Wang & Chu, 2015; Zhang et al., 2018.
		Observation indicators: behavioral responses
	C2- behavior	C13 Visit the characteristics: alone or in a pair/group C22 Out-of-town visitors or local visitors

Characteristics	Chin, 1998; De Backe et al., 2015; Dong, 2024; Eldamshiry & Khalil, 2018; Kasemsarn et al., 2023; Liu, 2020; Li, 2021; Lo et al., 2023.
C3-personal characteristics	C31 Cognitive characteristics
	C32 The annual number of museum visits
	C33 Physical characteristics
	Dong, 2024; Kasemsarn et al., 2023; Kasemsarn et al., 2025; Liu, 2020; Norman, 1981; Tuomi et al., 2023.
Method: behavior observation; Visitor interview; Questionnaire;	

Table A2 Environmental evaluation checklist in the access audit based on the 7UD

7UD Evaluation Checklist										
Museum Exhibition Hall: SWM			Exhibit in the layout:							
Exhibit: SW9-1										
*Visitor types: FC - Family with children; A - Alone visitors (18-60); Ts - Teenagers student group; E - Old adults; Cp - Visit with friends/relatives (18-60); Cs - Undergraduate/postgraduate student (in studying). Sp - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)										
*Y -meets the requirements; N -does not meet the requirements; F -partially meets the requirements; O -element does not exist										
UD1: Equitable Use			Compliant	Visitor type						
Assessment content	Standard	Fc		S	Ts	E	Cp	Cs	D	
UD1-1 Can all visitors view/participate in/enter this exhibition area or space?	☐ There are enough access points to enter	Y N F O								
	☐ There are ramps and other equivalent entrances to enter at the same time									
	☐ Comply with the visual image and guidance of various types of visitors									
	The position of the exhibit will not be ignored because of the route choice									
UD1-2 Can all visitors have the same experience?	The presentation form is open to all types of visitors without specific requirements	Y N F O								
	The operation form is barrier-free and adjustable to accommodate different visitors									
UD1-3 Are the operations and content of the exhibit suitable for all audiences?	A good content structure can be viewed/understood without difficulty and does not require prior learning experience	Y N F O								
	It will not affect the operation, viewing and understanding of the exhibits because of the neglect of other exhibition contents									
	Visitors can get the information they need									

UD2: Flexibility in Use		Compliant	Visitor type							
Assessment content	Standard		Fc	S	Ts	E	Cp	Cs	D	
U2-1 Is the position of the items flexible?	Use activity partitions to connect or separate media exhibition space	Y N F O								
	Visitors can flexibly choose different routes and schedules									
	Flexible route choices will not affect the structure of the exhibition									
U2-2 Does the item provide multiple options for methods?	There are many ways to obtain information, such as interactive, audiovisual and touch	Y N F O								
	Subtitles or graphics allow people to choose to hear or read to understand the content									
	Help others understand the content while interacting									
	Visitors may withdraw from the visit									
U2-3 Is the position of the items flexible?	Visitors can choose to browse through the content, fast forward or play it back	Y N F O								
	Use activity partitions to connect or separate media exhibition space									
UD3: Simple and Intuitive Use		Compliant	Visitor type							
Assessment content	Standard		Fc	S	Ts	E	Cp	Cs	D	
U3-1 Is the location of the exhibit easy to reach and visit?	The location is clear and with guidelines	Y N F O								
	There are no obstacles, and the route is simple									
	Appropriate light and environment, easy to identify and read									
	High-contrast layout (Material comparison, color comparison)									
UD3-2 Are there clear instructions and introductions for the items?	The control button of the equipment is clear and intuitive	Y N F O								
	If so, indicate the length									
	There are exhibits and content introductions									
	A well-organized and clear display or description facilitates user access to operations									
UD3-3 Is the information easy to read and watch?	Information materials should be accompanied by color illustrations as easily readable information.	Y N F O								
	Multilingual selection/visual information									
	Appropriate layout, font, and picture									
UD3-4 Is the item operation simple?	There is not too much duplication	Y N F O								
	The operation button/device start is flexible									
	The operation meets visitors' expectations									
	There is clear operational feedback									

UD4: Perceptible Information		Compliant	Visitor type						
Assessment content	Standard		Fc	S	Ts	E	Cp	Cs	D
U4-1 Do the exhibits provide multisensory information to meet visitors with different senses and abilities?	Tactile information: tactile models and relief plans, acoustic information, etc	Y N F O							
	There are clear directions and entrance signs for visitors								
	Exhibits can be observed from a variety of distances and angles from multiple visual perceptions								
	text-to-speech system available								
U4-2 Can visitors clearly identify the exhibit?	The exhibits have obvious signs to identify the type, so that visitors can clearly identify the function of the exhibits	Y N F O							
	Exhibits have location and route signs in the exhibition hall								
	The prominent visual effect and form are easy to identify								
UD5: Tolerance for Error		Compliant	Visitor type						
Assessment content	Standard		Fc	S	Ts	E	Cp	Cs	D
U5-1 Do the exhibits contain hazards and obstacles?	There are no protruding objects, and the height of these objects ensures that all types of visitors will not touch them	Y N F O							
	Protect dangerous positions, table corners								
	The lower space of the ceiling is marked in a variety of ways on the stairs, ramps, or under the handrail of the beam.								
	No sensory overload (bright light, reflections on smooth surfaces, inappropriate contrast, color, noise).								
U5-2 Are there any safety tips on the checklist?	Indicate incorrect operations	Y N F O							
	Provide indications of areas where viewing is not recommended.								
	Interactive programs provide guidance when users make inappropriate choices								
UD6: Low Physical Effort		Compliant	Visitor type						
Assessment content	Standard		Fc	S	Ts	E	Cp	Cs	D
U6-1 Are the exhibits suitable and comfortable for all visitors?	Suitable space, non-slip surface, and handrail to reduce physical exertion	Y N F O							
	Show the proper size of the screen to avoid excessive focus								
	The location and scale of the exhibition facilities are reasonable, and the main information is in line with the best sight line and a reasonable operation height								
UD6-2	Easy-to-operate form, easy to achieve the	Y							

Do exhibits cause fatigue and excessive physical exertion in visitors?	operation, and reasonable force	N F O							
	The target information can be obtained without a long operation								
	The duration is appropriate to avoid watching and operating in the same posture for a long time								
UD6-3 Are there rest seats for exhibits that need to be viewed for a long time?	Provide suitable seats and space for all types of bodies	Y N F O							
	The rest position is arranged reasonably and will not affect other visitors								
	Provide suitable seats and space for all types of bodies								

UD7: Size and Space for Approach and Use		Compliant	Visitor type						
Assessment content	Standard		Fc	S	Ts	E	Cp	Cs	D
U7-1 Can the effective space radiated by the exhibit meet the requirements of operation/view?	Operation space and booth size according to the characteristics of each group	Y N F O							
	Important information is in the right place								
	There is enough space between the exhibits, such as between the digital and the physical exhibits, or explanatory information								
	An adjustable console or diversion space								
UD7-2 Whether the exhibit has an impact on the surrounding exhibition environment?	The entrance and circulation area allow free movement without congestion	Y N F O							
	The right space, audio, and light radiation will not affect the surrounding visit								
	The location is suitable and will not affect the visiting route of the exhibition								
UD7-3 Is the operation ergonomic? Does it meet the operational habits of different people?	Operation buttons. The desktop is easily accessible, allowing any sitting or standing user to comfortably access all components	Y N F O							
	Adapt to changes in hand and grip size.								
	Provide a clear view of important elements for any user sitting or standing.								

Table A3 The questionnaire used for the experience survey at the museum site

Satisfaction questionnaire of the museum's digital media interactive experience

Hello! I am a doctoral student at Naresuan University, Thailand. The study aimed to understand the views and preferences of different ages and cultural backgrounds about museum digital media interaction techniques. The information in this questionnaire is only for the purpose of the research and does not involve any commercial use. Please rest assured that the answer.

Q1: I have visited museums before. ☐ yes ☐ no

Q2: I know what digital media in the museum means. ☐ yes ☐ no

Q3: I was attracted by the social media hype about digital media shown. ☐ yes ☐ no

Part1 basic information						
Age: ☐ 14-17, ☐ 18-35, ☐ 36-60, ☐ 60+			Country: ☐ China ☐ Other:			
Gender: ☐ Male, ☐ Female, ☐ Other			Purpose: ☐ Professional ☐ Interest ☐ Tour			
Educational: ☐ Middle School ☐ University ☐ Graduate Student			Type of Visitor: ☐ Individual, ☐ Family, Parent-Child ☐ Partner\ Companion ☐ Student			
Visit the Museum Every Year: ☐ 0-1 ☐ 1-3 ☐ 4+			Information Sources: ☐ Recommended by Others ☐ Internet ☐ Teacher ☐ Pass By			
1. Why do I want to visit the museum--choose the most eligible options, no more than five						
☐ Enhance the Quality of Life; ☐ Experience New Things; ☐ Interest; ☐ Leisure and relaxation; ☐ Work or School Requirements; ☐ Improve Parent-Child Relationship; ☐ Get New Knowledge; ☐ Children's Leisure Education ☐ Special Exhibition Content ☐ Grinding Time ☐ Other:						
2. I am satisfied with the experience of the digital media interactive exhibition in the museum		☐ Very disagree	☐ Disagree	☐ Fair	☐ Agree	☐ Very Agree
(You can choose more)						
☐ I am satisfied with the content and knowledge presented by digital media ☐ I am satisfied with the way digital media is used to show historical culture ☐ I am satisfied with the way I operate the digital interactive device ☐ I am satisfied with the distribution and location of the digital media exhibition items ☐ I am satisfied with the atmosphere of the exhibition space presented by the digital media ☐ I am satisfied with the games and entertainment of digital media interaction ☐ Other: ☐ Not satisfied						
There are digital interactive exhibition items that I am not satisfied with ☐ Y; ☐ N						
These exhibition items are:						
The reasons are: (with multiple options)						
☐ Difficult in operation, difficult to understand the operation process; ☐ The environment is dim ☐ Crowded, too many people operate; ☐ Exhibit maintenance can not be used; ☐ bored. ☐ It is complex and difficult to understand; ☐ No knowledge of content. ☐ Too much entertainment; ☐ The content is irrelevant to the content of the exhibition ☐ other:						
4. I am satisfied with the availability/operability of digital media interaction in the museum		☐ Very disagree	☐ Disagree	☐ Fair	☐ Agree	☐ Very agree

The reasons are: (with multiple options) ☐ The operation of the digital interactive device in the exhibition is easy to operate ☐ I can get the information I want through the interactive media show item ☐ The interaction description is clear, and I can understand the interaction and participation methods of different digital exhibition items in a short time. ☐ I think the process of operating the interactive exhibition items is very simple. ☐ other: _____ ☐ Not satisfied					
There are digital exhibition items that I find difficult to manipulate or have little access to: Y N These exhibition items are _____ The reasons are: (with multiple options) ☐ The explanation is not clear; There are too many people operating. ☐ Exhibit maintenance should not be used; The lights are dim; The display form and content of the exhibition items are not designed for me, I am not suitable for operation / I find it difficult to operate. ☐ others: _____					
5. I am satisfied with the knowledge or content displayed in the digital exhibition in the museum	☐ Very disagree	☐ Disagree	☐ Fair	☐ Agree	☐ Very agree
The reasons are: (with multiple options) ☐ Digital media vividly reproduces the historical scenes and historical stories ☐ Digital media technology allows me to better understand the cultural knowledge points ☐ Digital technology has made me more interested ☐ In the process of participating in the digital media display, I have left a deeper impression on the content ☐ other: _____ : _____ ☐ Not satisfied					
6. I am satisfied with the entertainment of the digital media interactions in the museum	☐ Very disagree	☐ Disagree	☐ Fair	☐ Agree	☐ Very agree
The reasons are: (with multiple options) ☐ The way cultural history is presented through digital media is interesting ☐ The interaction and play process is fun; ☐ Digital media gives me an immersive experience ☐ The game factor makes the process of understanding the knowledge point more flexible ☐ Digital media provides me with a unique historical and cultural experience ☐ The entertainment and games brought by the digital interaction make me feel casual, relaxed ☐ other: _____ : _____ ☐ Not satisfied					
7. Digital interpretation and demonstrations brought me to visit expectations	☐ Very disagree	☐ Disagree	☐ Fair	☐ Agree	☐ Very agree
☐ leisure ☐ study ☐ parentage ☐ play ☐ other : _____					
8. I am willing to recommend museums to others, including digital media interaction	☐ Very disagree	☐ Disagree	☐ Fair	☐ Agree	☐ Very agree
9. I visited all the digital interactive exhibitions: Yes, I was involved in every media display; No, I have only participated in the interaction of some The reason why I only visited some of the digital exhibition items is: (optional) ☐ Not interested in the presentation content; ☐ Not interested in the interactive form. Interactive forms are not suitable for participation; ☐ Crowded, hard to approach. Maintenance of exhibits; ☐ Not deliberately omitted, because the position or way is not seen; I was pressed for time; ☐ I visited last time ☐ Fatigue has been produced ☐ other: _____					
10. The digital interactive exhibition items affected my visiting experience and did not achieve the expected effect: yes, no The reasons are: (with multiple options) ☐ Difficult to access and operate; ☐ Difficult to operate; ☐ The operation is simple and boring; ☐ Too much entertainment; ☐ The content is difficult and difficult to understand; ☐ I didn't learn anything. ☐ The digital media interactive exhibition item has influenced my visit to other exhibitions ☐ other: _____					

Table A4 Image stimulation questionnaire



Questionnaire of the Museum Digital Media Exhibit Design Satisfaction Evaluation

Hello! I am a doctoral student at Naresuan University, Thailand. The study aimed to understand the views and preferences of visitors of different ages and cultural backgrounds regarding museum digital media interaction techniques. The information in this questionnaire is solely for research purposes and will not be used for any commercial purposes. Please rest assured that the answer.

Part 1. Basic information

1. Age: ☐ 14-17, ☐ 18-35, ☐ 36-60, ☐ 60+ 2. Country: ☐ China ☐ Other:
3. Gender: ☐ Male ☐ Female, ☐ Other 4. Visit the Museum Every Year: ☐ 0-1 ☐ 1-3 ☐ 4+
5. Type of Visitor:
- ☐ Alone visitors (25-60), ☐ Parent-Child Family ☐ Visit with friends/relatives (18-60), ☐ Old adults,
☐ Teenager students group, ☐ Undergraduate/postgraduate students, ☐ Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)

Part 2. Design Images Satisfaction Evaluation

Below are 10 images in total, designed by the designer for the digital media exhibits of a tourism museum showcasing regional history and culture. Please make your selection based on your realistic attitude to help us evaluate the design, and the desired level of evaluation for the respondent is to view the newly designed (the picture below).

Image 1

This is the design of the interactive inquiry screen. In terms of content, the hierarchical inquiry progresses step by step, from simple to complex. In terms of form, the larger screen size and characters provide participation possibilities for those with poor vision. **Question:** Do you think this hierarchical, difficulty-based query and barrier-free design (the picture below) could improve your engagement? Please make a truthful choice:



Level of Perception	5	4	3	2	1	Level of Perception
	Mostly	Very	Moderate	Slightly	Not at all	
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Mostly approach and use size	☐	☐	☐	☐	☐	Less approach and Use size
Mostly perceptible Information	☐	☐	☐	☐	☐	Less perceptible Information

Image 2

This is a multisensory media interaction and Audio-visual combination exhibit. By incorporating technologies such as phantom imaging and 3D projection into the inquiry exhibits, new media technologies provide various visiting solutions for different visitors.

Question: Do you think such multi-sensory digital exhibits with strong visual impact (the picture below) have enhanced your willingness to engage? Please make a truthful choice based on the newly designed:

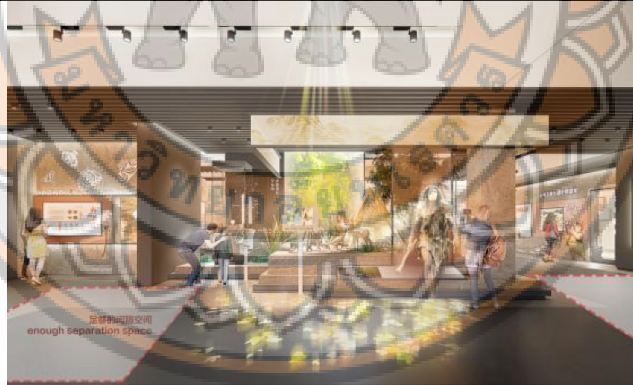


Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Strong visual impact	☐	☐	☐	☐	☐	Less visual impact
Mostly flexibility in engagement	☐	☐	☐	☐	☐	Less flexibility in engagement

Image 3

This is a large-scale immersive multimedia interactive installation, located in an easily accessible area, with the exhibit situated in a relatively independent space, providing ample interactive space for visitors with diverse needs. It will not interfere with surrounding exhibits.

Question: Do you think such a design that emphasizes a personalized experience can enhance your willingness to engage? Please make a truthful choice, based on the newly designed image (the picture below and additional video effects):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interest	☐	☐	☐	☐	☐	Less interest
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly immersive and involved	☐	☐	☐	☐	☐	Poor immersive and involved
Mostly accessible locations and the space	☐	☐	☐	☐	☐	Less accessible locations and the space

Image 4

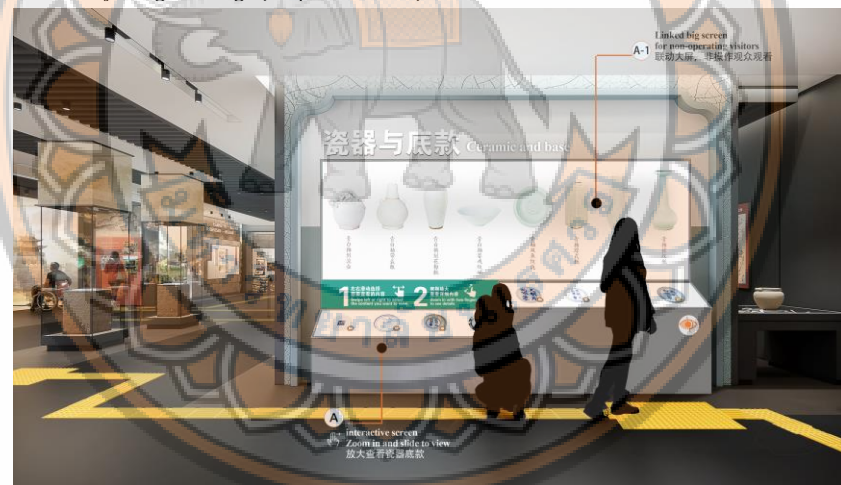
This is an interactive desktop in a museum.



The old design has without operation instructions [the picture above].

The picture below is the new design, where the designer has provided clear and accessible operation instructions, including an accessible color design. This is to ensure that visitors with any characteristics can easily access participation methods, and tactile models have been set up for those with visual impairments to usability for all with simple and intuitive use.

Question: Compared to the exhibit without operational instructions (the picture above), do you think the design with operational instructions (the picture below) is more likely to capture your attention and engagement? please make a truthful choice based on the newly designed image (the picture below):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Accessible to diverse visitors	☐	☐	☐	☐	☐	Accessible to limited visitors
Clear communication, easy to see, and easy to understand	☐	☐	☐	☐	☐	Unclear communication, difficult to see and understand

Image5

This is a set of digital media combinations in an audiovisual interactive format



The old design lacks an exhibit theme and content tips [see the picture above].

The picture below is the new design, where the designer has established a concise and prominent theme to enable visitors to obtain information, designed for simple and intuitive use, and provides perceptible information for everyone.

Question: Compared to the exhibit lacking thematic presentation (the picture above), do you think the design with clear themes (the picture below) would attract your willingness to engage? Please make a truthful choice based on the newly designed image (the picture below and additional video effects):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Clear communication, easy to see, and easy to understand	☐	☐	☐	☐	☐	Unclear communication, difficult to see and understand
Mostly perceptible Information	☐	☐	☐	☐	☐	Less perceptible Information

Image 6

This is a small-scale digital video for viewing.



The old design lacks color contrast [the picture above].

The picture below is the new design, where the designer used color contrast. To ensure content coherence, the design employs high color contrast (barrier-free color design) for content composition and emphasis, facilitating easy identification. It highlights perceptible information, ensuring that all visitors can equally, conveniently, and barrier-free access and utilize information under any circumstances.

Question: Compared to the design without color contrast (the picture above), do you think the design with color contrast (the picture below) is more likely to capture your attention and engagement? Please make a truthful choice based on the newly designed image (the picture below):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Mostly perceptible Information	☐	☐	☐	☐	☐	Less perceptible Information

Image 7

This is a large-scale digital interactive game exhibit.



The old design features an interactive table and display screens [the picture above].

The picture below is the newly designed image that simultaneously accommodates 3-8 participants. The designers have incorporated multiple forms of engagement, providing diverse participation options for different audiences, such as joining the game or watching immersive films.

Question: Compared to a relatively single digital interactive table (the picture above), do you think such digital interaction games with diverse forms of participation (the picture below) are more capable of indicating your willingness to engage? Please make a truthful choice based on the newly designed image (the picture below and additional video effects):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Mostly for multiple people to participate	☐	☐	☐	☐	☐	Less for multiple people to participate
Mostly flexibility in engagement	☐	☐	☐	☐	☐	Less flexibility in engagement

Image 8

This is an immersive audiovisual space.



The old design adopted dim lighting to highlight the light and shadow effects [the picture above].

The picture below is the newly designed image, where the designer adopted an open space entrance to ensure appropriate lighting. For visitors with different needs, optimal viewing areas were designated to avoid issues such as dim lighting, glare, and a sense of insecurity, to create a comfortable and safe environment.

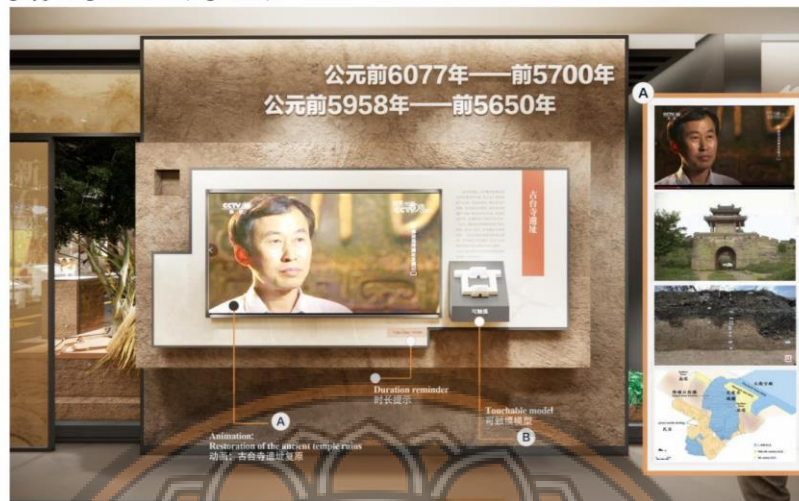
Question: Compared to the dim and cramped space (the picture above), do you think the design (the picture below), which ensures appropriate lighting and avoids glare, significantly, security enhances your willingness to engage? Please make a truthful choice based on the newly designed image (the picture below):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Clear communication, easy to see	☐	☐	☐	☐	☐	Less communicated, easy to see
Mostly security	☐	☐	☐	☐	☐	Less security

Image 9

This is a viewing-type digital video (big-scale).



The old design adopted a narrative structure with expert explanations [the picture above].

The picture below is the newly designed image, where the designer adopted a narrative framework combining procedural generation and scene restoration. This design is to enable viewers with different understanding abilities to see the construction process of the ancient city wall intuitively and vividly without having to spend too much time on operation and mental thinking, designed for perceivable Information.

Question: Do you think the newly designed (the picture below) can enhance your willingness to participate and help you better understand the content? Please make a truthful choice based on the newly designed image (the picture below and additional video):



Level of Perception	5 Mostly	4 Very	3 Moderate	2 Slightly	1 Not at all	Level of Perception
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Mostly exciting	☐	☐	☐	☐	☐	Less exciting
Mostly perceptible Information	☐	☐	☐	☐	☐	Less perceptible Information

Image 10

This is a viewing-type digital video. The designer placed the exhibit along the main visitor route and set up optimal viewing areas as well as assistive devices for visitors with different physical characteristics, while minimizing physical exertion as much as possible.

Question: Do you think such a design (the picture below) can enhance your willingness to engage? Please make a truthful choice based on the newly designed image:



Level of Perception	5	4	3	2	1	Level of Perception
	Mostly	Very	Moderate	Slightly	Not at all	
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction
Mostly interest	☐	☐	☐	☐	☐	Less interest
Usability for all	☐	☐	☐	☐	☐	Less usability for all
Mostly comfortable and low physical effort	☐	☐	☐	☐	☐	Less comfortable and low physical effort

Part 3. Overall Satisfaction and Preference Survey

1. I agree with and am satisfied with the design of museum digital exhibits that can be participated in by all types of visitors.

Level of Perception	5	4	3	2	1	Level of Perception
	Mostly	Very	Moderate	Slightly	Not at all	
Mostly satisfied	☐	☐	☐	☐	☐	Not at all satisfied

2. When I see recommendations for such museums (design in 10 Images) on social media or in travel promotions, I am interested in visiting.

Level of Perception	5	4	3	2	1	Level of Perception
	Mostly	Very	Moderate	Slightly	Not at all	
Mostly interest	☐	☐	☐	☐	☐	Less interest

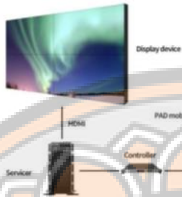
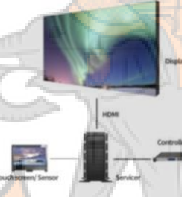
3. Such digital exhibits in museums (design in 10 newly designed Images) can enhance my interesting and interactive experience during museum visits.

Level of Perception	5	4	3	2	1	Level of Perception
	Mostly	Very	Moderate	Slightly	Not at all	
Mostly interaction	☐	☐	☐	☐	☐	Less Interaction

Thank you very much for your participation!

APPENDIX B Research results in Objective 2

Table B1 Forms of application of digital technology in museum exhibitions

Type	Description	
	Topological relationship diagram	Example of a photo from the exhibition
1 Viewing Based Type	Present the objects and content to the visitors through multimedia formats such as audio or video. The exhibits automatically play and demonstrate without requiring any visitor interaction, with no option to control playback progress (Lo et al., 2023; Wu, 2012). 	
2 Trigger Viewing Type	The exhibit is activated and triggered by visitors, with its dynamic process preset, and the visitors' actions will not affect the progression of the display (Lo et al., 2023). 	
3 Interactive Displays Type	An interactive system designed utilizing machinery, electrical power, and related technologies, where the visitors can not only interact with designed programs through a computer screen, but also with the exhibit responding differently based on the operator's input, with mutual feedback between the two (Huang, 2014). 	
4 Interactive Gaming Type	Applying gaming concepts, elements, or mechanics to interactive exhibits, visitors engage with various forms of participatory displays such as gaming programs, artistic creations, competitive games, and physically interactive games, allowing participants to acquire knowledge through gameplay (Li et al., 2024; Tong, 2020). 	

The information is aggregated into a complete spatial context, where interactive installations integrate emerging technologies with sensory experiences, aiming not only to provide visual experiences but also to deepen the audience's multi-sensory engagement through technology (Su, 2019; Tong, 2020).

5 Immersive
Spaces
Type

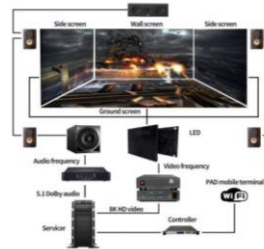


Table B2 Results Statistics of 7UD Evaluation Checklist

Museum	UD1*	UD2*	UD3*	UD4*	UD5*	UD6*	UD7*	Mean
SWM	75.93%	47.76%	50.93%	49.50%	62.49%	64.32%	67.53%	59.78%
SEM	83.59%	63.28%	68.88%	75.16%	56.68%	70.06%	69.35%	69.57%
WCM	56%	53.99%	46.5%	48.83%	61.07%	62.01%	66.17%	56.37%
CWM	73.56%	44.51%	49.67%	44.55%	53.16%	56.69%	62.6%	54.96%
WYM	81.24%	61.6%	55.27%	60.23%	61.44%	66.37%	71.70%	65.41%
	74.06%	58.29%	54.25%	55.65%	58.97%	63.89%	67.47%	61.80%
GCM	53.71%	45.82%	71.86%	61.15%	62.37%	46.34%	70.80%	58.86%

* UD1, Equitable Use; *UD2, Flexibility in Use; *UD3, Simple and Intuitive Use; *UD4, Perceptible Information; *UD5, Tolerance for Error; *UD6, Low Physical Effort; *UD7, Size and Space for Approach and Use.

Table B3 High-frequency word analysis based on semi-structured interviews

Category	Feature words/phrases	F	Remarks/examples
Feature words	Favorable	68	Thought digital media was good/ fine
	Diversified forms	53	Positive evaluation of digital interpretation
	Vivid content	40	Positive comments, such as “vivid picture”
	Environmental problems	39	Complain about dim lighting, crowded space, confusing routes, etc.
	Unwilling	35	Digital devices are complicated or uninteresting
	Novelty	28	Digital media is novel and interesting
	Simple content	20	Criticism of the lack of depth in multimedia content
	Overlook	19	Not paying attention to digital interpretation
	Not for me	16	Not suitable for the elderly/children
	Physical objects	15	Focus on physical objects
	Not interested	15	Not interested in digital interpretation

	Irrelevant content	10	Criticism of digital content is irrelevant to the exhibition
	Wasting of resources	8	Criticism of digital media
	Easy to operate	8	Simple to operate, and there are no obstacles
	Children	6	Controversy over interactive design for children
	Safe	5	Emphasize a safe and unblocked space
	Needs of the elderly	4	Elderly maladaptation problems, such as dizziness
	Unclear illustration	4	Interactive devices lack guidance
	Video playback/screen	5	Specific forms, such as video playback
Gender	Female	63	The respondents were mainly female (64.52%)
	Male	31	The proportion of respondents who are male is 35.48%
Forms of visits	Companionship	18	The family visit form is mostly used for residents
	Visit alone	15	Common among professional visitors
	With the kids	11	Take preschool children on a tour
	Study Group	6	Common forms of tourists (such as couples traveling, friends group leisure)
Motivation	Leisure and relaxation	15	Core needs are frequently mentioned by local tourists
	Cultural tourism	7	Core motivation of non-local tourists
	Learning	3	Mentioned by professional visitors
	Interesting	5	Museum enthusiasts

Table B4 Based on design elements and environmental factors, and the results of environmental measurement for six museums, combining and comparatively analyzing data from visitor interviews

Issues and obstacles	Visitor requirements description (excerpt)
B1 • The digital media exhibit is located at the back of the main route, and visitors will not go there proactively. • The digital media exhibit is located in a corner without exhibition content, outside the exhibition framework, and visitors will not actively go there.	• Middle-aged: I generally don't actively pay attention to this media. I prefer to focus my attention on the exhibits. • High school student: I wouldn't deliberately go over and poke these screens because I feel like they wouldn't give me the information I want. • University student: The environment is too dark, and I can't see the information on the wall. • University student: I haven't deliberately ignored it, but sometimes I just don't see these exhibits.
A1, A3, B1, B2, B3 • The inappropriate height and form of the media items will lead to visitors ignoring it. • The height of the media is too high, making it unsuitable for viewing.	

B2, B3 • The dim and cramped exhibition environment created by digital media is not conducive to information acquisition.

B3 • Influence the surrounding exhibits

- Dense arrangement of digital media, causing mutual interference.

- Middle-aged: I think digital media is interfering with my visit; its light is reflecting on the display cases.

A2 • Interactive exhibits lack relevant introductions and guidance. They are difficult to recognize, especially for older people and those who seldom visit museums.

- Younger: I didn't know this was interactive; he didn't give me a hint.
- Elderly: I don't know what this is; I think it's not interesting.
- Foreigner: I don't understand what this is.

B1, B2

- Traffic congestion
- Inappropriate spatial division leads to interference with the visitor flow.

- Middle-aged: I don't want to go there, there are too many people.
- Elderly: So many people, it's what young people like, but it's not suitable for me.

A2

- Interactive exhibits lacking interactive instructions can cause confusion among visitors.
- The interactive interface lacks a language conversion system or visual operation icons.
- Lack of guidance leads to children making random, unconscious touches and pats on digital media.

- Child: Can I play with this? Can I hit this? Does it move...
- Foreigner: I don't know what the meaning of this interaction is. Why should I click on it?
- Elderly: I'm not interested, I won't touch it.
- University student: Isn't this something that can be looked up? How come it can't be looked up?

A1, B1, B3

- Due to inappropriate scale or ergonomics, visitors are unable to view or participate.

- Parent-child: Some exhibits are not suitable for children to interact with; it is suggested that some that are suitable for children could be set up.
- Elderly: I think there are too many things for children in the museum, which we cannot use; it's a waste of resources. There should be more focus on the exhibits.
- University student: These interactions are too childish and meaningless, just for the sake of interaction.
- Elderly: I like that 5G panoramic experience, but I can't watch it; it makes me too dizzy. I hope more consideration is given to elderly people.

A2

- The faulty equipment was not repaired promptly.

- University Student: I don't care if these devices are broken, because they won't affect my visit.
- University student: Often, I see many attractive exhibits, but they are all closed and cannot be interacted with.

A2, A3	The content displayed is not directly related to the exhibition theme, and visitors cannot directly obtain useful information.	Middle-aged: I think most of the media are unrelated to the exhibition, and the content created is superficial, unable to help understand the exhibition.
A3	- The content displayed is a list and playback of information points, without expanding the content or providing a richer background introduction. - Content is specialized and lacks relevance to daily life, failing to resonate.	- Elderly: I have noticed these screens, but I find them uninteresting at a glance unless they remind me of something from the past. - High school student: I hope the explanation of knowledge points is more detailed, for example, this bronze ware, besides wanting to see its photo, I also want to know its manufacturing process.
A3	- The content displayed is abstract and overly artistic, causing visitors to feel confused. - The visual content is rough and lacks appeal.	- Foreigner: I don't know what this means. What is this picture? It's hard for me to understand. It seems unrelated to the exhibition. - University student: This presentation is not exquisite, and the interpretation of the content is insufficient. Museums should put effort into interpreting the content. - University student: I prefer exhibits that explain the process. I hope they can help understand the process, but the current exhibits are mostly about inquiry and entertainment. - Middle school student: I hope to see explanations of knowledge, but not just textual explanations; I hope for vivid explanations that are both graphical and textual. - Middle-aged: Some media is just for the sake of good visuals, but lacks knowledge content; I won't watch that, and I also think it's a waste.
A2, A3	- No clear knowledge points or information. - The interpretation of knowledge points is not lively, deep, and interesting enough.	

Table B5 The results of comparative analysis of environmental measurements, 7U Checklist evaluations, and visitor interviews

Problems and obstacles during the museum visit	People encountering obstacles							Complying with 7UD
	FC	A	TS	E	CP	CS	SP	
The location of the exhibit is hard to reach. Based on the form, it is believed that the exhibit is not designed for oneself.	×		×	×			×	Not UD1* Not UD7*
Due to the improper location/scale of the exhibit, it was not noticed and therefore ignored.	×	×	×	×	×	×	×	Not UD3* Not UD4*
Lack of explanation leads to neglect and loss of interest.		×		×	×	×	×	Not UD4
The lighting is dim and the environment is dark, making it difficult to read or causing discomfort to the eyes.	×	×	×	×	×	×	×	Not UD3 Not UD5* Not UD6*
The projection height is too high for comfortable viewing.	×	×	×	×	×	×	×	Not UD7
The operation interface is too high, making it difficult to operate.	×						×	Not UD6 Not UD7

Digital exhibits affect the surrounding exhibits, causing mutual interference.	×	×	×	×	×	×	×	Not UD2* Not UD7
Due to congestion, it results in a poor experience, even leading to abandonment of the visit.	×	×		×			×	Not UD5 Not UD7
Disorder in movement caused by the attraction of people to digital media	×		×		×	×	×	Not UD2 Not UD4
The operation instructions and trigger guidance are not clear, making it difficult to identify the functionality of the exhibits.		×	×	×	×	×	×	Not UD4
Meaningless actions such as repeatedly slapping or clicking.	×		×			×		Not UD4 Not UD5
The interaction cannot meet the expectations.		×	×			×		Not UD2 Not UD4
Equipment damage	×	×	×	×	×	×	×	Not UD3 Not UD5
The device is not responsive when starting up.	×	×	×	×	×	×	×	Not UD7
The film is too long, standing for a long time.	×			×				Not UD4 Not UD6
The content is abstract and artistic, making it difficult to understand its message.	×	×	×	×	×	×	×	Not UD4
The picture is not refined and lacks appeal.								
The content is too professional, with a dense amount of information that is difficult to accept in a short time.	×	×	×	×	×	×	×	Not UD3 Not UD4
Cannot obtain knowledge related to the exhibition	×	×	×	×	×	×	×	Not UD4

* UD1, Equitable Use; *UD2, Flexibility in Use; *UD3, Simple and Intuitive Use;
 *UD4, Perceptible Information; *UD5, Tolerance for Error; *UD6, Low Physical Effort;
 *UD7, Size and Space for Approach and Use.

Table B6 Conclusions of problem analysis, visitor behavior, and UD

Comparison Results of Visit Barriers, Visitor Needs, and 7UD	
Problems Analysis	Description and Comparison with 7UD
(1)- Lack of information guidance	• Visitors cannot recognize the theme and objective of digital exhibits, regarding them as having no relation to the exhibition. • The location of the digital exhibit diverges from the main content line. • Low-scale, minimal recognition • The operational guidelines and activation instructions lack clarity, which complicates the process of identifying the functions of the exhibits. Not meet UD2, UD3, UD7
(2)- Congestion	• Congestion caused by improper positioning • No suitable viewing space/operating space was reserved. • The insufficient spacing between digital exhibits and surrounding exhibits has resulted in intersecting visitor flows and congestion. • Spaces deemed unsafe and inaccessible, with audiences lingering in traffic passages, causing congestion. • Disruption in motion due to individuals' fascination with digital media.
With UD	Not UD1; Not UD2; Not UD3; Not UD5; Not UD6; UD7

(3)- Poor atmosphere	• An atmosphere that is excessively dim or overly packed is deemed unsafe. • Positioned along a secondary path, it necessitates extra walking to arrive at the destination. • Glare, noise, and other uncomfortable physical environments. • Dim lighting makes reading difficult or causes eye discomfort. • Circuitous and complex visitor circulation route.
With UD	Not UD1; Not UD2; Not UD3; Not UD4; Not UD5; Not UD6
(4)- Digital devices lack appeal	• In the same exhibition, digital interpretation featuring equivalent content and visual materials diminishes its appeal. • The digital exhibit is devoid of a distinct theme and is perceived as challenging to comprehend.. • The design of visual materials is deemed to be specifically targeted at young people or children. • The content is overly burdensome, making it hard to pinpoint crucial information.. • The material is intricate and deemed highly specialized, necessitating cognitive exertion. • The material is straightforward and deemed devoid of significance. • The content falls short of expectations; specifically, instead of providing contextual interpretations, it only showcases displays of physical exhibits. • Due to the exhibit's improper location and scale, it went unnoticed and was consequently ignored. • The content, being abstract and artistic, poses a challenge in comprehending its underlying message. • The image is unrefined and fails to attract interest.
With UD	Not UD2; Not UD3; Not UD4; Not UD5; Not UD6; Not UD7
(5)- The difficulty of operation	• The period is extended, and the absence of seating for rest results in undue physical strain. • Prolonged exposure to inappropriate lighting conditions can result in visual fatigue. • Requires sustaining a physically strenuous posture for prolonged durations, such as gazing upwards or stooping down. • Necessitates interactive engagement and is deemed unrelated to one's self. • The operating interface is too high, which makes it hard to operate. • The location is challenging to access. • The height of the projection is excessively elevated, making it uncomfortable for viewing. • Meaningless actions, such as persistently slapping or clicking. • Equipment Malfunction or the device fails to respond when initiating startup.
With UD	Not UD1; Not UD4; Not UD5; Not UD6

APPENDIX C Research results in Objective 3

Table C1 Regression analysis on the 7UDs indicators

	β	SE	Beta	t	p	95.0% confidence interval	
(constant)	-0.68	0.088		-7.729	0	-0.853	-0.508
Visitors	-0.024	0.007	-0.045	-3.679	0	-0.037	-0.011
UD2	0.34	0.137	0.045	2.475	0.013	0.071	0.608
UD1	0.083	0.1	0.013	0.837	0.403	-0.112	0.279
UD3	0.608	0.106	0.115	5.754	0	0.401	0.815
UD4	0.657	0.093	0.123	7.04	0	0.474	0.84
UD5	0.061	0.096	0.008	0.636	0.525	-0.127	0.248
UD6	0.716	0.116	0.102	6.169	0	0.488	0.944
UD7	0.151	0.117	0.02	1.296	0.195	-0.078	0.381

APPENDIX D Research results in Objective 4

Table D1 Design features that comply with the 7 principles of UD

Design suggestions in a museum exhibition based on 7UD	
Explain	Design suggestions
UD1 Equitable Use. Design to meet the needs of everyone.	
- Satisfy the needs of all different groups without exception. - Provide all users with the same usage method, otherwise an equivalent.	- Set up entrances and exits for digital exhibits that anyone can enter, rather than creating separate accessible solutions. - Digital exhibits should be located in a manner that is accessible to all, avoiding obstacles such as steps, narrow bridges, sunken areas, or other features that could impede the access of elderly or disabled individuals. - If possible, place the digital exhibits on the main exhibition line-visible and easy to find. Quick visitors will not miss the core content - Digital exhibits should have a visual identity and guidance that resonates with the psychological characteristics of different visitor types, while steering clear of overly entertainment-focused or childishly styled guidance.
UD2 Flexibility in Use. Design can adapt to many choices or methods, allowing visitors to choose from several route options, sequences, and spatial timings. Flexibility is also important for exhibits and exhibition spaces.	
Explain	Design suggestions
- The environment can adapt to a wide range of individual preferences and abilities. - Several means of vertical communication (using various methods to enhance accessibility)	- Multiple forms of information communication (including prominent location, language, visual icons, good lighting) - Considering the needs of various types of visitors, it is advisable to install displays of different sizes whenever possible. For instance, larger displays that align with the general public's cognition, along with attractive headline descriptions, should be provided. Moreover, alternative avenues for interpretation and inquiry should be provided for professional visitors.

to achieve the same purpose).

- Sit appropriate partitions and dividers for screening. Independent exhibits are more effective at capturing visitors' attention.
- Enough channels allow for flexible entry and exit.
- Set the route as simply as possible, with no more than three routes.
- Flexible routes also support the structure of the exhibition.
- Adopting a content framework that progresses from foundational to advanced levels can meet the needs of visitors with diverse backgrounds.

UD3 Simple and Intuitive Use. Intuitive moving and wayfinding are very important for every user.

Explain	Design suggestions
• Locations clearly highlighted • Self-explanatory solutions (Regardless of the user's experience, knowledge, language proficiency, or current level of attention, the design can be easily understood on how to use it.) • The means of helping in navigation are applied	• Set clear direction signs or maps in places that could potentially confuse. • The visual image of the digital interaction and devices should have a significant contrast with the surrounding environment. Create aesthetically pleasing and easily comprehensible logos and pictograms to aid in the recognition of the functions of digital exhibits for Visitors from different cultural backgrounds. • Signage should be eye-catching and prominent to accommodate visitors of all types and cultural backgrounds. • A clear theme should be established for the digital interpretation exhibit, closely connected with the main content of the exhibition. This ensures that visitors with varying abilities can understand the forthcoming content. The theme should be clear and succinct. • The location of the exhibit should be at important nodes of the content, with a clear content structure. • Strongly related to the surrounding exhibits in terms of logic or content, aiding understanding Reduce the complexity of the physical environment The open and simple visiting route will not miss the exhibition content or get lost because of digital exhibits • Color or materials contrast in specific digital exhibit regions. • Trigger keys are prominent and easy to activate. The consistency between the interactive form and the display content can avoid the confusion of visitors

UD4 Perceptible Information. When different modes are combined, communication is effective.

Explain	Design suggestions
• Multisensory information: Maximize the "readability" of basic information: Regardless of environmental conditions or the sensory abilities of the user, design can effectively communicate	• Indication of path location and space (informing the audience of their current location and the upcoming route, to prevent getting lost) • Equip digital interactive exhibits with concise, visual operation instructions. • Establish dedicated guidance instructions for visitors near digital exhibits, indicating that these are interactive digital displays that they can engage with. • Multilingual, easy to read, logos and pictograms. Tactile models

necessary information to the user. • Various forms and clear visibility Provide adequate contrast between essential information and its surroundings.	and relief maps, acoustic information, sign language, and tactile Latin and Braille - information that can be touched. • The content framework for digital interpretation organizes information by importance, with presentation methods requiring intuitiveness and conciseness. • Establish a content framework that aligns with the cognitive levels of visitors from various age groups, avoiding excessive difficulty or oversimplification, rather than emphasizing specialization. • Adopt a visual interpretation approach to present engaging and entertaining content within an appropriate duration, ensuring to avoid excessive cognitive load to maintain attention. • Through various communication methods to enable visitors to understand the content from different perspectives, avoiding repetitive content and narrative forms, and addressing the different visitors' needs for concise and intuitive information. • Exhibits can be observed from various distances and angles with multiple visual perceptions.
UD5 Tolerance for Error. The environment is risk-free, with dangers and errors minimized.	
Explain	Design suggestions
• No dangerous barriers Safe evacuation makes everyone feel safe with secure access • No sensory overload (intense light, reflections on smooth surfaces, inappropriate contrast, colors, noise)	• Digital interpretation exhibits should be placed along the main route, but not at traffic nodes, to prevent congestion. • There are no prominent objects in the environment; the height of these objects should ensure that all visitors will not come into contact with them. • Appropriate safe evacuation routes should be considered around the digital devices. • The surrounding environment of digital equipment should be safeguarded against potential hazards, such as dark environments, protruding obstacles, and narrow passages. • The media space should utilize glare-free spatial decorative materials. • A reasonable space ensures that visitors do not feel any danger or threat. • Considering the small spatial scale, the safety hazards it brings when there are too many people. • Spaces with lower ceilings, under stairs, or beams, are marked in various ways. • Set an error operation prompt for the visitors, especially for children. • Choose digital interaction devices and operationally simple configuration, which has a high fault tolerance, and is easy to maintain later on.
UD6 Low Physical Effort. The design should minimize fatigue and repetitive movements.	
Explain	Design suggestions
• Comfortable exercise/Ergonomic	• The digital display environment should have appropriate lighting, taking into account the visual characteristics of visitors,

solutions/Minimizes fatigue • Minimum physical effort required for manipulating internal components (reasonable operating force) • Opportunity for rest: Minimize sustained physical exertion.	especially elderly and children's audiences. Overly dim spatial conditions should not be created merely for atmospheric purposes. • Spaces with appropriate lighting, nonslip surfaces, and handrails can reduce physical exertion. • Digital media exhibits require appropriate lighting and an environment conducive to easy identification and reading. • Provide temporary seating for visitors, which should consist of chairs designed to accommodate the physical characteristics of elderly visitors. • Digital exhibits should be established in relatively independent spaces or locations to prevent interference with surrounding exhibits. • Low energy consumption operation console or device. • Comfortable operating, interaction time should not be too long. • Easy-to-operate exhibits and forms. • Avoid complex or fine operations • Sufficient space should be maintained between exhibits, such as the spacing between digital media and physical exhibits or explanatory information. Avoid information overload and an excessive cognitive burden.
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UD7 Size and Space for Approach and Use

These components are visible, accessible, and within reach for users standing or sitting, including those of various body sizes, such as children.

Explain	Design suggestions
• Provide sufficient space for the use of assistive devices or personal assistance: • Regardless of physical characteristics such as body size or ability, appropriate size and space will be allocated for approach, contact, and operation.	• Providing a suitable and comfortable viewing/experience space for non-operating users. • There is enough space between exhibits, such as between digital media and physical exhibits or explanatory information. • The height and position of the console should be such that anybody characteristic visitor can reach it. • Digital devices should be placed within the normal line of sight, not positioned above display cabinets, on the floor, or lower tabletops. • Visual elements are visible, accessible, and approachable to everyone. • Considering the operational characteristics of visitors with different physical attributes, such as Older visitors with reduced dexterity, the need for precise operations should be minimized.

Table D2 Demographic statistics results

Gender	%	Age	%	Visit Museum Frequency	%	Nation	%
Male	171(41.7%)	14-17	67(16.3%)	0-1/ Year	103(25.1%)	China	37(91.2%)
Female	239(58.3%)	18-35	146(35.6%)	2-4/Year	179(43.7%)	Other	36(8.8%)
		36-60	134(32.4%)	Over 4/Year	128(31.2%)		
		60+	63(15.4%)				

Table D3 Statistics results of features evaluated in ten Images based on “Visitor Type”

		Visitor Type							Mean
		A	F-C	Cp	Ts	E	Cs	Sp	
Image 1	Approach and Use Size	4.38	4.40	4.33	4.43	4.42	4.53	4.42	4.41
	Perceptible Information	4.55	4.52	4.55	4.66	4.53	4.76	4.63	4.60
Image 2	Visual Impact	4.32	4.35	4.47	4.46	4.31	4.40	4.22	4.36
	Flexibility in Engagement	4.43	4.18	4.28	4.34	4.34	4.36	4.23	4.31
Image 3	Immersive and Involved	4.82	4.75	4.72	4.70	4.76	4.80	4.60	4.73
	Accessible Locations and Space	4.78	4.85	4.83	4.89	4.83	4.85	4.80	4.83
Image 4	Accessible to Diverse Visitors	4.57	4.68	4.62	4.61	4.68	4.51	4.63	4.61
	Clear Communication, Easy to See, and Easy to Understand	4.65	4.50	4.58	4.61	4.68	4.58	4.58	4.60
Image 5	Clear Communication, Easy to See, and Easy to Understand	4.57	4.75	4.70	4.68	4.75	4.62	4.63	4.67
	Perceptible Information	4.63	4.57	4.63	4.61	4.51	4.71	4.55	4.60
Image 6	Perceptible Information	4.68	4.75	4.63	4.64	4.53	4.71	4.65	4.66
Image 7	Multiple People to Participate	4.83	4.75	4.78	4.89	4.83	4.87	4.82	4.82
	Flexibility in Engagement	4.87	4.77	4.78	4.89	4.73	4.82	4.83	4.81
Image 8	Clear Communication, Easy to See	4.65	4.70	4.75	4.75	4.69	4.71	4.60	4.69
	Security	4.63	4.75	4.78	4.68	4.69	4.69	4.70	4.70
Image 9	Exciting	4.63	4.72	4.58	4.64	4.83	4.71	4.65	4.68
	Perceptible Information	4.62	4.53	4.60	4.68	4.59	4.60	4.62	4.60
Image 10	Usability for all	4.70	4.63	4.57	4.57	4.66	4.58	4.65	4.62
	Comfortable and Low Physical Effort	4.78	4.70	4.72	4.79	4.51	4.73	4.65	4.70

FC - Family with children; **A** - Alone visitors (18-60); **Ts** - Teenagers student group; **E** - Old adults; **Cp** - Visit with friends/relatives (18-60); **Cs** - Undergraduate/postgraduate students (in studying). **Sp** - Visitors with special needs (foreigners, people with mobility difficulties, hearing/visual impairment, etc.)