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A STUDY ON THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN INTERACTIVE MUSEUM DISPLAYS AND VISITOR PERCEPTION

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Abstract

This study aims to explore the application of artificial intelligence (AI) in interactive museum displays and its impact on visitor perception. With the rapid advancement of technology, museums are gradually incorporating AI technology to enhance visitor experiences, providing more diverse and personalized interactive content. However, how these technologies affect visitor perception and overall experience still requires in-depth research. To address this issue, this study systematically collected expert opinions and employed the KANO model for classification and analysis. Firstly, through expert interviews and literature review, this study identified key dimensions, including interactivity, educational value, immersion, entertainment, and satisfaction. These dimensions reflect the critical perceptual factors of visitors when engaging with AI-driven interactive displays. Subsequently, this study utilized the Evaluation Grid Method (EGM) to refine and assess these dimensions, ensuring the comprehensiveness and depth of the research. During the research process, experts provided valuable insights and suggestions, helping to further understand the practical applications and challenges of AI technology in museum displays. Following this, the study used the KANO model to classify these dimensions, identifying which attributes have a decisive impact on visitor satisfaction. Through this process, the study will analyze the key factors of AI technology in enhancing visitor interactive experiences. This study provides valuable insights for museum managers and designers, helping them more effectively apply AI technology in future exhibit designs to enhance overall visitor experiences. By deeply understanding the application of AI technology in museums and its impact on visitor perception, museums can more effectively attract and retain audiences, achieving both educational and entertainment goals.

Keywords: Artificial Intelligence, Museum, Interactive Design, Evaluation Grid Method, KANO Two-Dimensional Quality Mode

Introduction

In the development of contemporary museums, the application of artificial intelligence (AI) technology has become a significant trend. With the rapid advancement of technology, AI not only enhances the interactivity and personalization of exhibition content but also profoundly changes the visitor experience. As museums are crucial institutions for cultural heritage and education, effectively applying these new technologies to further enhance visitor satisfaction and experience has become a focal point for researchers and practitioners. However, existing research on the specific applications of AI in museums and its impact on visitor perception remains insufficiently systematic.

The motivation of this study is to fill this research gap by exploring the application of AI technology in interactive museum displays and its impact on visitor perception. We aim to reveal, through in-depth analysis and systematic research, the specific roles AI technology plays in improving display effectiveness, educational value, and entertainment, as well as the challenges it faces in practical application. These research findings will help museum managers and designers better understand and apply AI technology, thereby enhancing the overall visitor experience.

This study aims to answer several core questions: Firstly, what are the specific applications of AI technology in interactive museum displays? Secondly, how do these applications affect visitors' perception and overall experience? To address these questions, this study employs expert interviews and literature review to establish the main research dimensions, including interactivity, educational value, immersion, entertainment, and satisfaction. These dimensions are intended to reflect the key perceptual factors of visitors when using AI-driven interactive displays.

Subsequently, this study utilizes the Evaluation Grid Method (EGM) to refine and assess these dimensions, ensuring the comprehensiveness and depth of the research. On this basis, the Kano quality model is applied to classify these dimensions, identifying the attributes that have a decisive impact on visitor satisfaction. Through this systematic research, this thesis aims to provide valuable guidance for museum managers and designers, helping them more effectively apply AI technology in future exhibition designs to achieve both educational and entertainment goals, thus attracting and retaining more visitors.

Literature Review

Interactive Museum Design and Artificial Intelligence

With the advancement of technology, museums are no longer just places for static displays of artifacts but have become spaces filled with interactive and innovative educational and entertainment experiences. The application of interactive design in museums aims to enhance visitors' experiences, making it not only a process of acquiring knowledge but also a comprehensive sensory experience. Dal Falco and Vassos (2017) proposed that

modern museum experience design should adopt a contemporary narrative approach, establishing deep connections between exhibits and visitors through interactive design, thereby increasing visitor engagement and satisfaction.

The introduction of Artificial Intelligence (AI) technology has further propelled the development of interactive design in museums. AI can provide personalized interactive content based on visitor behavior and preferences, enhancing the educational value and entertainment of the exhibits. Pisoni et al. (2021) emphasized the importance of human-centered AI in designing accessible cultural heritage, pointing out that AI technology can analyze visitor data to offer customized tour routes and interactive experiences, thus improving visitor satisfaction.

In practical applications, Cai et al. (2023) studied the use of AI interactive devices based on database management systems in the multidimensional design of museum exhibition content, finding that AI technology can effectively organize and display a large amount of cultural data, making it easier for visitors to access information and enhancing the interactivity and educational value of exhibitions. Additionally, Zhao et al. (2022) explored the application of digital twin technology combined with AI and 5G technology in the art design of digital museums, which can create highly immersive virtual exhibition spaces, making visitors feel as if they are in real historical scenes, further enhancing the immersion and realism of the experience.

Recuero Virto and López (2019) highlighted the core role of robots, AI, and service automation in museums, demonstrating how these technologies can provide more convenient and efficient visitor experiences through automated services and interactive robots, thereby improving overall service quality and visitor satisfaction.

Ismail (2021) offered a modern perspective on the application of AI and emerging technologies in museums and cultural heritage, emphasizing the potential of these technologies in innovating exhibition content and enhancing visitor interaction. Wang (2021) studied the digital design of smart museums based on AI, indicating that AI technology can optimize content management and visitor interaction, enhancing the overall visitor experience.

Hijazi and Baharin (2022) conducted a systematic literature review to evaluate the effects of digital technologies on visitor experiences in digital museums, highlighting the critical role of technological innovation in improving visitor satisfaction. Lai (2022) explored the integration of virtual and physical museums in the post-pandemic era, suggesting that AI technology can provide more flexible visiting options in new environments.

Lastly, Cheung (2022) conducted a case study on the digital archive of artifacts at the National Palace Museum, exploring the establishment and opening of museum collection interpretation data, emphasizing the importance of digital technology in the preservation and display of cultural heritage.

Overall, the application of AI technology in interactive museum design offers new opportunities to enhance visitor experiences. It not only increases the interactivity and personalization of exhibition content but also provides valuable visitor data through advanced data analysis and machine learning technologies, helping museum managers better understand

visitor needs, thereby optimizing exhibition design and management strategies. The application of these technologies enhances the educational and entertainment functions of museums and promotes the preservation and dissemination of cultural heritage.

Evaluation Grid Method (EGM)

Attractiveness represents the subjective preferences of consumers, which mainly stem from their value judgment system. This judgment system is derived from consumers' sensory reception, psychological decision-making, and sociological and artistic evaluation. Kelly (1955) proposed the psychology of personal constructs, emphasizing how individuals construct their world through personal experiences and perceptions, providing a theoretical basis for understanding consumers' value judgment systems. Sanui (1996) further introduced the Evaluation Grid Method (EGM) and applied it to the visualization process of user requirements.

The EGM research method is divided into two main steps. The first step is the evaluation of the target object, which requires answering whether the object is liked or disliked. The second step involves clarifying the meaning of the response through additional questions and integrating the respondents' answers, then analyzing the attractive elements of the product to consumers and creating the relevant structure grid diagram. This method emphasizes how consumers' subjective preferences influence their decision-making process.

Wang (2008) analyzed artificial expressions based on Kansei engineering, pointing out that in terms of EGM, interviews must mainly focus on highly involved groups. By comparing various features from actual user behavior cases, true and credible evaluations and opinions are collated. This method allows for the integration of the corresponding relationships between abstract feelings and specific conditions, which were difficult to capture in the past.

Through EGM, researchers can gain an in-depth understanding of consumers' perceptions of specific products or services and identify which features and attributes are attractive to consumers. This method is significant not only in the design and development of new products but also in helping companies better meet consumer needs and enhance market competitiveness. As a systematic method, EGM provides an effective framework for analyzing and understanding consumers' subjective preferences, thereby offering valuable insights for product design and marketing.

Kano Model

To address the shortcomings of the linear hypothesis, Kano (1984) proposed the Kano model with the core concept of "psychological quality," emphasizing a "two-dimensional" perspective to interpret the relationship between product quality and satisfaction (Figure 1). The linear (one-dimensional) model suggests that satisfaction with a certain quality element increases or decreases proportionally with the adequacy of the quality. However, in reality, this rule does not apply to all quality factors. The two-dimensional quality challenges this view, suggesting that satisfaction may not necessarily increase when all quality factors are in place. Sometimes, dissatisfaction may occur, or satisfaction may not necessarily be related to quality (Kano, Seraku, Takahashi, & Tsuji, 1984).

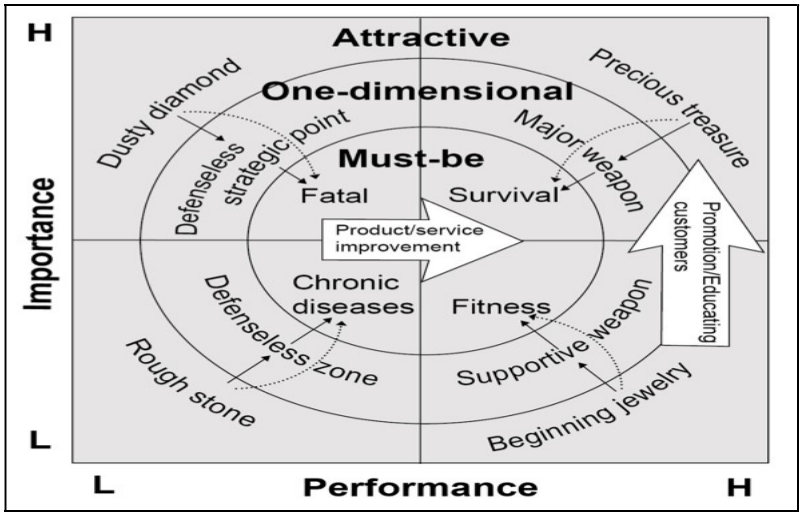

Figure 1: Kano Model

A simple method to identify different Kano categories (such as one-dimensional quality, attractive quality, and must-be quality) is to use the Kano questionnaire (Kano et al. , 1984). In this questionnaire, customers indicate whether they feel satisfied or dissatisfied with a given situation. First, a situation assumes the quality (criterion) is present or sufficient. The second situation assumes the quality is absent or insufficient. Customers must choose one of the aforementioned feeling responses again. By combining these two answers in the Kano evaluation table (Table 1), the product criteria can be identified as attractive quality, must-be quality, one-dimensional quality, indifferent quality, or reverse quality (Chen & Li, 2008).

Matzler and Hinterhuber (1998) pointed out that integrating Kano's model of customer satisfaction into quality function deployment can make product development projects more successful. Their research shows that identifying and classifying product attributes is crucial for enhancing customer satisfaction and product success. Ting and Chen (2002) explored the asymmetrical and non-linear effects of store quality attributes on customer satisfaction, emphasizing the different roles of various quality attributes on customer satisfaction.

Anderson and Sullivan (1993) studied the antecedents and consequences of customer satisfaction, highlighting the importance of customer satisfaction for firm performance. Mittal, Ross, and Baldasare (1998) investigated the asymmetric impact of positive and negative attribute-level performance on overall satisfaction and repurchase intention, finding that negative experiences have a more significant impact on customer satisfaction and loyalty.

Through these studies, it is evident that the Kano model plays a crucial role in understanding the complex relationship between customer satisfaction and product quality. It not only helps businesses identify key quality elements affecting customer satisfaction but also provides an effective method for optimizing product design and improving service quality.

Table 1. Kano Evaluation Table

Product Criteria/attributes		Insufficiency				
		Satisfied	It should be that way	I am indifferent	I can live with it	Dissatisfied
Sufficiency	Satisfied	Q	A	A	A	O
	It should be that way	R	I	I	I	M
	I am indifferent	R	I	I	I	M
	I can live with it	R	I	I	I	M
	Dissatisfied	R	R	R	R	Q

(A-attractive, O-one-dimensional, M-must-be, I-indifference, R-reversal, Q-questionable)

RESEARCH METHODS

The first phase of this study employed the Evaluation Grid Method (EGM) from Kansei engineering. In-depth interviews were conducted with five experts, three of whom have over 20 years of experience in spatial design and two who are exhibition planning and design professionals. The goal was to explore which cultural exhibition space designs could elicit emotional attractiveness from the audience. The EGM interview method is divided into three parts: original reasons, concrete matters, and abstract reasons. After identifying the original reasons, the method delves upwards into abstract feelings and downwards into concrete matters (Chen & Li, 2008). By organizing the interview content and drawing structural diagrams, the study ultimately summarized the charm element evaluation grid for the application of artificial intelligence in interactive museum displays and its impact on visitor perception.

The second phase of the study involved quantitative analysis. Based on the results of the preliminary EGM interviews, the Kano quality model was applied to investigate the use of artificial intelligence in interactive museum displays and its impact on visitor perception. The objective of this phase was to determine whether there are nonlinear relationships among visitor preferences for AI applications in museum interactive displays. The Kano quality model helps identify which attributes have a decisive impact on visitor satisfaction and analyzes these attributes' asymmetric and nonlinear characteristics.

This research method combines qualitative and quantitative analysis. It provides an in-depth understanding of experts' insights into cultural exhibition space design and validates and expands these insights through quantitative analysis. Thus, it comprehensively explores the impact of artificial intelligence applications in interactive museum displays on visitor perception.

FINDINGS

EGM Interview Results

Based on the interviews with five experts, a comprehensive analysis was conducted using the EGM evaluation structure diagram. This study aims to explore the application of artificial intelligence in interactive museum displays to enhance visitor experience, educational effectiveness, and immersion.

Firstly, interactivity is considered a crucial factor in increasing visitor engagement. The interviewed experts emphasized that personalized experiences, immediate feedback, and interactive games are key elements in attracting visitors. Technologies such as touch screens and interactive projections allow visitors to directly interact with exhibits, increasing the interactivity and fun of the visiting process. Additionally, the design of personalized experiences and immediate feedback can provide customized content based on visitor reactions and interests, significantly enhancing visitor satisfaction and engagement.

In terms of educational value, knowledge acquisition, expert commentary, and multilingual support are considered core factors in enhancing the educational value of displays. Experts pointed out that audiovisual materials and expert commentary enable visitors to understand the display content more deeply, enhancing learning outcomes. Meanwhile, multilingual support design can meet the needs of visitors from different language backgrounds, expanding the museum's audience and educational impact.

Regarding immersion, VR experiences, surround sound, and role-playing are essential methods for creating a sense of being there. Experts believe that these technologies can simulate real historical scenes or scientific phenomena, allowing visitors to feel an immersive experience during their visit. The design of surround sound and role-playing further enhances visitor immersion and emotional resonance, enabling them to experience the display content more profoundly.

Considering interactivity, educational value, and immersion, this study found that emotional resonance and innovative display techniques are key factors in enhancing visitor satisfaction and memorable points. Experts emphasized that the emotional resonance and commemorative value of the displays allow visitors to feel profound cultural meanings and personal emotional touches during the visit. The application of innovative display techniques brings unique visual and sensory experiences to the exhibition, further enhancing visitor satisfaction and the depth of the visiting experience.

Figure 2, the EGM evaluation structure diagram, shows the correlations between these key factors. Based on the above results, this study suggests that when designing interactive museum displays, attention should be paid to multi-level interaction, rich educational content, and immersive experiences, emphasizing the application of emotional resonance and innovative display techniques. This will help enhance the visitor experience, allowing them to gain knowledge, feel the depth of culture, and leave lasting memories during their visit.

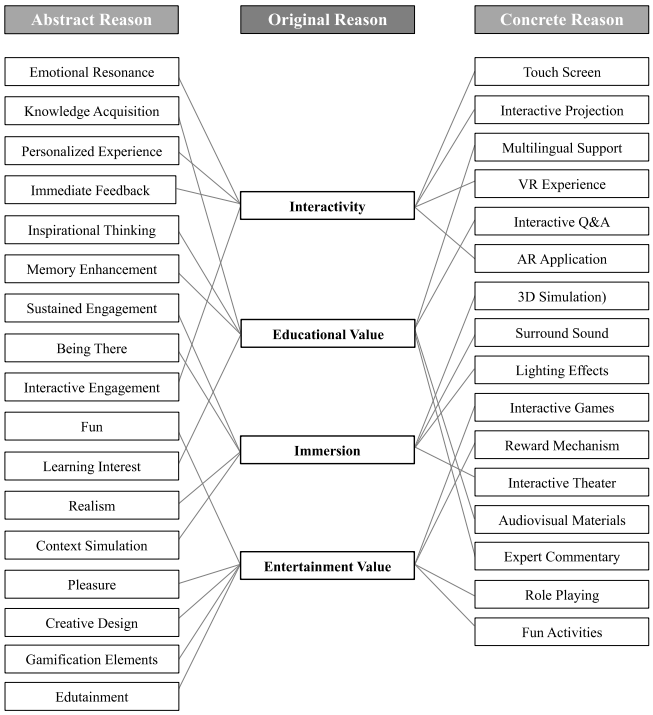

Figure 2: EGM Diagram

Kano Statistical Results

Reliability Analysis.

This study employs purposive sampling and snowball sampling. Purposive sampling involves the researcher subjectively and intentionally selecting the samples needed for the study based on specific research needs. Snowball sampling, on the other hand, is characterized by the network relationships among respondents, hence it is also known as network sampling. In this study, 105 valid questionnaires were collected. The results of the questionnaire were analyzed using the statistical software SPSS. 17 for reliability testing. The Cronbach's α value for the overall Kano questionnaire was 0. 876, indicating a very high level of reliability.

Attributes	Cronbach's α for forward items after item deletion.	Cronbach's α for reverse items after item deletion.
01. Personalized Experience	0. 877	0. 871
02. Immediate Feedback	0. 877	0. 867
03. Touch Screen	0. 876	0. 866
04. Interactive Projection	0. 877	0. 865
05. Interactive Games	0. 877	0. 865
06. Educational Value	0. 876	0. 865
07. Knowledge Acquisition	0. 876	0. 866

08. Expert Commentary	0. 876	0. 866
09. Multilingual Support	0. 879	0. 864
10. Audiovisual Materials	0. 876	0. 865
11. Immersion	0. 877	0. 865
12. Being There	0. 877	0. 863
13. VR Experience	0. 879	0. 866
14. Surround Sound	0. 878	0. 867
15. Role Playing	0. 881	0. 868
Overall assessment	0. 877	0. 866

Kano Analysis Findings.

This study classifies and analyzes the quality elements of interactive museum displays based on the KANO model. The KANO model identifies the impact of each quality element on visitor satisfaction through categories such as Must-be (M), One-dimensional (O), Indifferent (I), Attractive (A), Questionable (Q), and Reverse (R) attributes.

According to the results presented in Table 3, the majority of quality elements are classified as Attractive attributes (A). These elements significantly enhance visitor satisfaction, and their presence directly influences the overall experience of visitors.

For instance, personalized experiences provide customized content tailored to the individual needs and preferences of visitors, thereby increasing their engagement and satisfaction. Immediate feedback responds to visitors' interactions in real-time, providing instant gratification. The use of touch screens and interactive projection technologies creates more dynamic and engaging display effects, enhancing interactivity and enjoyment. Interactive games further elevate the entertainment value of the exhibits, allowing visitors to learn and explore through play.

Expert commentary and multilingual support offer professional and diverse information, ensuring that visitors from various backgrounds can fully understand the exhibit content. Audiovisual materials, presented through multimedia formats, enrich the sensory experience of visitors. Immersive experiences and the feeling of being present in real historical or scientific scenes deepen the impact and appeal of the exhibits. VR experiences and surround sound technology create a highly immersive environment through virtual reality and all-encompassing audio effects. Role-playing elements enable visitors to assume specific roles, providing a deeper understanding and engagement with the exhibit content.

These Attractive attributes are classified as such because they have a nonlinear impact on visitor satisfaction. When these elements are present, visitor satisfaction increases significantly, but their absence does not drastically reduce satisfaction. This nonlinear relationship indicates that the presence of these elements greatly enhances the visitor experience, but their absence does not have an equally negative impact on satisfaction.

On the other hand, two quality elements are classified as One-dimensional

attributes (O), including educational value and knowledge acquisition. These elements are crucial for enhancing the educational value and knowledge level of visitors and have a linear impact, meaning that as these elements improve, visitor satisfaction correspondingly increases. Educational content aims to enhance learning outcomes and cultural literacy, while knowledge acquisition involves providing rich informational content that allows visitors to gain a deeper understanding of the exhibit themes. The linear relationship of these elements indicates that their absence directly leads to visitor dissatisfaction.

Notably, the study did not identify any Must-be attributes (M). This may be due to the fact that interactive museum display designs focus more on innovation and appeal rather than basic infrastructure and services. Additionally, the widespread availability of basic facilities in modern museum displays means that they do not significantly influence visitor satisfaction.

In summary, the study suggests that museums should prioritize Attractive attributes when designing interactive displays to maximize visitor satisfaction and enhance the overall experience. At the same time, ensuring the high quality and adequacy of One-dimensional attributes such as educational value and knowledge acquisition is essential. By optimizing these key quality elements, museums can provide a rich cultural experience while creating engaging interactive exhibits.

Table 3: Percentage Distribution of Kano Quality Attributes

Attributes	M	O	I	A	Q	R	Kano
01. Personalized Experience	1. 05	13. 65	25. 20	56. 70	11. 55	2. 10	A
02. Immediate Feedback	2. 10	22. 05	10. 50	66. 15	8. 40	1. 05	A
03. Touch Screen	6. 30	25. 20	15. 75	55. 65	5. 25	2. 10	A
04. Interactive Projection	4. 20	24. 15	14. 70	60. 90	5. 25	1. 05	A
05. Interactive Games	1. 05	23. 10	16. 80	63. 00	4. 20	2. 10	A
06. Educational Value	9. 45	46. 20	17. 85	33. 60	3. 15	0. 00	O
07. Knowledge Acquisition	7. 35	50. 40	6. 30	43. 05	3. 15	0. 00	O
08. Expert Commentary	4. 20	25. 20	21. 00	55. 65	3. 15	1. 05	A
09. Multilingual Support	9. 45	31. 50	26. 25	39. 90	3. 15	0. 00	A
10. Audiovisual Materials	4. 20	28. 35	23. 10	48. 30	3. 15	3. 15	A
11. Immersion	6. 30	22. 05	14. 70	61. 95	4. 20	1. 05	A
12. Being There	2. 10	34. 65	8. 40	60. 90	3. 15	1. 05	A
13. VR Experience	3. 15	17. 85	16. 80	67. 20	3. 15	2. 10	A
14. Surround Sound	2. 10	25. 20	16. 80	57. 75	5. 25	3. 15	A
15. Role Playing	0. 00	12. 60	33. 60	52. 50	3. 15	8. 40	A

Conclusion

This study, based on the KANO model, classifies and analyzes various quality elements in interactive museum displays, revealing their impact on visitor satisfaction. The results indicate that elements such as personalized experience, immediate feedback, touch screens, interactive projections, interactive games, expert

commentary, multilingual support, audiovisual materials, immersion, being there, VR experiences, surround sound, and role-playing are classified as attractive quality elements. These elements have a significant nonlinear impact on enhancing visitor satisfaction, meaning that their presence greatly increases satisfaction, while their absence does not significantly reduce it. In contrast, educational value and knowledge acquisition are classified as one-dimensional quality elements. These elements have a linear relationship with visitor satisfaction, meaning that as these elements improve, visitor satisfaction correspondingly increases.

Comprehensive analysis suggests that museums should prioritize attractive quality elements in designing interactive displays, as these elements can greatly enhance visitor satisfaction and experience. At the same time, the high quality and adequacy of one-dimensional quality elements such as educational value and knowledge acquisition should be ensured to meet visitors' educational needs.

Recommendations

1. Strengthen Attractive Quality Elements: Museums should focus on enhancing attractive quality elements such as personalized experiences, immediate feedback, and interactive technologies in their display designs. These elements significantly boost visitor satisfaction and engagement. Advanced interactive technologies like VR experiences and surround sound should be actively introduced to create highly immersive environments.

2. Enhance Educational Value and Knowledge Acquisition: While ensuring that the display content is highly educational and knowledge-rich, museums should combine expert commentary and multilingual support to further improve visitors' learning outcomes and cultural literacy. Providing multimedia audiovisual materials can enrich the presentation of display content and attract visitors from diverse backgrounds.

3. Innovative Display Design: Continuously explore innovative display design methods by incorporating elements such as interactive games and role-playing into the exhibits. This enhances visitor participation and interaction. Museums should continuously optimize display content and forms based on visitor feedback to maintain freshness and appeal.

4. Emphasize Basic Infrastructure: Although the study did not find necessary quality elements (M), museums should not neglect the quality of basic infrastructure and services. Ensuring a comfortable and convenient environment can enhance the overall visitor experience.

By following these recommendations, museums can simultaneously increase visitor satisfaction and achieve dual goals of education and entertainment, thereby enhancing their influence in cultural dissemination and education.

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