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Impact of Digital Technologies in Enhancing the Interactive Experiences: A Cross-Sectional Survey on Modern Museums in China

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ARTICLE INFO	ABSTRACT

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Interactive experiences; museums; digital technologies; augmented reality; virtual reality

This study investigates the impact of digital technologies, namely augmented reality (AR), virtual reality (VR), and interactive exhibits (IE), on enhancing the interactive experiences of visitors in modern Chinese museums. Utilizing a cross-sectional survey design, data was collected from 355 museum visitors across various regions in China. The analysis reveals that both AR and VR significantly enhance visitor engagement and satisfaction, offering immersive experiences that traditional interactive exhibits alone do not achieve. The findings suggest that the depth of immersion provided by AR and VR is crucial for enhancing visitor experiences. These insights are valuable for museum curators and designers, highlighting the need to integrate advanced digital technologies to meet contemporary visitor expectations. Future research should explore the long-term impact of these technologies and the potential for other emerging technologies to further transform museum experiences.

1. Introduction

In the past, museums were often viewed as static repositories of artifacts. This perception has been dramatically altered in recent decades due to the pervasive influence of digital technologies [1,2]. Today, museums have metamorphosed into dynamic hubs of interactive learning and engagement [3,4]. For instance, the British Museum has integrated digital technologies like AR and VR to provide immersive experiences, allowing visitors to explore the ancient Egyptian world in a 3D environment [5]. Similarly, the Smithsonian Institution has leveraged digital technologies to create interactive exhibits that engage visitors in hands-on learning experiences [6]. These cutting-edge technologies have unlocked a myriad of opportunities for enriching visitor experiences, transforming museums from mere custodians of history and culture into vibrant educational platforms. This transformation aligns with the shift towards the 'experience economy' where value is derived from memorable experiences and not just products or services [7].

The digital revolution, encompassing technologies such as Virtual Reality (VR), Augmented Reality (AR), and interactive exhibits (IE), is reshaping the way visitors interact with museums and their

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collections [8]. This transformation has not only enhanced visitor engagement but also fostered a deeper understanding of exhibits, thereby promoting lifelong learning [9,10]. The integration of digital technologies into museums has led to the development of innovative applications. For example, VR and AR technologies are immersing visitors into the heart of exhibits, enabling them to experience historical events firsthand and explore artifacts in unprecedented detail [11,12]. Interactive exhibits captivate visitors with engaging activities and gamified experiences, making learning both fun and stimulating [13]. Mobile applications offer personalized guides, access to multimedia content, and opportunities for social interaction, thereby enhancing the overall museum experience [14].

Research indicates that these digital innovations significantly impact visitor engagement, learning outcomes, and overall satisfaction [8,15,16]. Digital technologies have been shown to enhance visitor engagement by promoting active participation, sparking curiosity, and fostering a sense of connection with the exhibits [17,18]. Furthermore, these tools have been demonstrated to improve learning outcomes by providing a deeper understanding of complex concepts, facilitating knowledge retention, and promoting critical thinking skills [19]. As digital technologies continue to evolve, their impact on museums is set to become even more profound [20,21]. The future of museums could see a seamless integration with digital platforms, offering visitors immersive and personalized experiences that transcend the boundaries of physical space and time [22]. Museums could evolve into hubs of community engagement, fostering social connections and collaborative learning through digital tools [23]. The power of digital storytelling could transport visitors to distant lands and bygone eras, bringing history to life in ways never before imagined [24].

Despite the significant advancements in integrating digital technologies into museums, there remains a gap in comprehensively understanding their impact on visitor engagement, learning outcomes, and overall satisfaction. This study addresses this gap by investigating the effects of AR, VR, and interactive exhibits on visitor experiences in Chinese museums. Specifically, the research examines how these digital technologies enhance visitor engagement, improve learning outcomes, and increase overall satisfaction. Additionally, it explores the potential future developments in the museum sector as digital technologies evolve. The subsequent literature review provides a theoretical framework and hypotheses for the role of AR, VR, and interactive exhibits in enhancing interactive experiences.

2. Literature Review

2.1 AR and Enhancing Interactive Experiences

Augmented Reality has been recognized as a powerful tool in enhancing museum experiences. It overlays digital information onto the physical world, thereby enriching the user's perception of reality. Studies have shown that AR has been successful in eliciting the interest of visitors and enhancing their learning [25,26]. More recent studies have also explored the potential of AR in creating immersive storytelling experiences in museums [27,28]. The theoretical framework for AR in museums is grounded in the Actor-Network Theory, which considers all actors (human and non-human) in a network and their interactions [29]. Therefore, the hypothesis related to AR is:

H1: The use of Augmented Reality (AR) in museums significantly enhances interactive experiences.

2.2 VR and Enhancing Interactive Experiences

Virtual Reality immerses users in a completely digital environment. In museums, VR can transport visitors to different times and places, allowing them to experience historical events or explore artifacts in detail. This immersive experience can enhance visitor engagement and learning. Research has shown that VR has revolutionized the museum experience, redefining how visitors engage with cultural artifacts and exhibits [30]. Recent studies have also highlighted the potential of VR in creating emotionally engaging experiences in museums [31,32]. The theoretical framework for VR in museums is based on the Information Systems (IS) success model, flow theory, and the Customer Satisfaction Index (CSI) model, which analyze the complex dynamics of VR integration within museums [31]. Therefore, the hypothesis related to VR is:

H2: The use of Virtual Reality (VR) in museums significantly enhances interactive experiences.

2.3 Interactive Exhibits and Enhancing Interactive Experiences

Interactive exhibits in museums involve the use of technology to create engaging, hands-on experiences. These exhibits allow visitors to interact with the content in a meaningful way, enhancing their understanding and enjoyment. Studies have demonstrated that physical interactive exhibits enable visitors to learn and engage with subjects and stimulate social interaction and learning activities [33]. More recent research has explored how interactive exhibits can be designed to promote collaborative learning experiences. The theoretical framework for interactive exhibits in museums is based on the philosophies of experiential education [34] and constructivism [35], which suggest that interactivity should improve visitor learning at museum exhibits [36]. Therefore, the hypothesis related to interactive exhibits is:

H3: The use of interactive exhibits in museums significantly enhances interactive experiences.

3. Research Methodology
3.1 Participants

This study utilized a cross-sectional survey design to gather data from museum visitors in China who have interacted with digital technologies. Although formal ethical approval was not obtained, permissions were obtained from the museum authorities and the survey respondents. The study adhered to ethical guidelines by ensuring informed consent and protecting respondents' information. The survey questionnaire included clear instructions on the voluntary nature of participation and assured respondents that their data would be used solely for research purposes. The questionnaires were distributed online through WJX (https://www.wjx.cn) using a convenience sampling method. The survey targeted museum visitors from various regions, including Beijing, Shanghai, Zhejiang, Guangzhou, and Sichuan. Out of 450 distributed questionnaires, we received 428 responses. A thorough data-cleaning process was conducted, which involved excluding 37 responses from individuals who had not visited a museum during the study period and removing unusual or duplicate replies. This resulted in a total of 355 valid responses.

The data from this study reveals that the majority of respondents are female, accounting for 58.6% of the total. In terms of age distribution, the most represented age group is 18-24 years old, comprising 27.0% of the respondents (refer to Table 1). The least represented age group is those aged 55 years and above, making up only 5.4% of the total. Regarding occupation, the most common professions among the respondents are doctors (21.1%) and engineers (20.6%), while students account for 18.0% of the respondents. In terms of educational attainment, the majority of respondents hold a bachelor's degree (29.3%), followed closely by those with a high school diploma or equivalent (28.7%). The least represented educational level is those with a doctoral degree, constituting 3.4% of the total.

Table 1
Demographic characteristics of museum respondent

Characteristics	Items	Frequency	%
Gender			
	Male	147	41.4
	Female	208	58.6
Age			
	18~24 years old	96	27.0
	25~34 years old	91	25.6
	35~44 years old	63	17.7
	45~54 years old	86	24.2
	≥55 years old	19	5.40
Occupation			
	Teacher	66	18.6
	Doctor	75	21.1
	Engineer	73	20.6
	Student	64	18.0
	Other	77	21.7
Degree			
	High school diploma or equivalent	102	28.7
	Associate degree	92	25.9
	Bachelor's degree	104	29.3
	Master's degree	45	12.7
	Doctoral degree	12	3.40

Understanding these demographic characteristics is crucial for interpreting the study's findings on the impact of digital technologies in museums. The distribution of occupations and educational levels can influence respondents' familiarity and comfort with digital technologies, potentially affecting their engagement and perception of digital exhibits. For example, individuals with higher educational attainment may have greater analytical skills, enhancing their interaction with complex digital content. Similarly, professionals such as doctors and engineers might have more exposure to advanced technologies in their fields, which could influence their responses. By examining these factors, the study aims to provide a nuanced analysis of how digital technologies affect diverse visitor groups, thereby enhancing the validity and applicability of the research outcomes.

3.2 Instruments

A bilingual (Chinese and English) survey questionnaire was developed based on previously validated scales to measure the impact of digital technologies on interactive experiences in museums. The scales included were the Augmented Reality scale adapted from Georgiou and Eleni [37], the Virtual Reality scale adapted from Makransky *et al.,* [38], the Interactive Exhibits scale adapted from Pallud [39], and the Interactive Experience scale adapted from Othman *et al.,* [40]. A pilot test was conducted with 30 museum visitors to ensure the questionnaire's clarity and comprehensibility. Feedback from the pilot test led to minor adjustments to improve cultural suitability. The final questionnaire comprised a 5-item Augmented Reality scale, a 5-item Virtual Reality scale, a 5-item Interactive Exhibits scale, and a 20-item Interactive Experience scale. All measures used a 5-point Likert scale (1-strongly disagree, 5-strongly agree) with positively worded items.

3.3 Data Analysis Procedure

After collecting the data, we conducted an in-depth analysis using SPSS 27.0 and SmartPLS 4.0 software [41]. We chose these software packages because they are widely used in the field and offer robust features for analyzing complex structural models. First, we cleaned the data and coded the dimensions and items of the variables. This involved removing outliers, handling missing data, and transforming variables as necessary. Next, we conducted descriptive analyses of the basic characteristics of the respondents. We then performed partial least squares structural equation modeling (PLS-SEM) analysis to explore the correlations between the employment of digital technologies and aspects such as visitor engagement, learning outcomes, and overall satisfaction. PLS-SEM is a statistical method for relatively small sample sizes that can handle complex structural models and makes almost no assumptions about the underlying data distribution.

4. Analysis and Discussion

4.1 Common Method Bias

In this research, we acknowledged the potential for common method bias, which could artificially inflate the correlations among variables. To detect and mitigate this bias, we conducted a collinearity test. This test used key indicators such as the Variance Inflation Factor (VIF) and tolerance to assess the correlation among independent variables [42]. The results showed that all VIF values were below the threshold of 3.33, indicating that multicollinearity was not a significant issue [43]. The lowest and highest VIF values observed were 1.38 and 2.57, respectively. Although this level of shared variance might impact the predictive power of the model, it does not necessarily imply the unreliability of the model. In fact, a certain degree of shared variance is expected in studies involving multiple correlated variables. Therefore, we believe that this shared variance provides us with valuable insights, helping us refine our model and enhance its predictive power.

4.2 Measurement Model

The measurement model for the constructs of Augmented Reality (AR), Virtual Reality (VR), Interactive Exhibits (IE), and Interactive Experiences (UX) demonstrates strong reliability and validity, as indicated by key metrics including Cronbach's Alpha, Composite Reliability (CR), Average Variance Extracted (AVE), and Variance Inflation Factor (VIF) (Table 2) [43]. The AR construct shows high internal consistency with a Cronbach's Alpha of 0.82 and a CR of 0.83, and an AVE of 0.58, with VIF values ranging from 1.52 to 2.07. The VR construct is similarly robust, with a Cronbach's Alpha of 0.79, a CR of 0.86, an AVE of 0.55, and VIF values between 1.41 and 2.57. The IE construct also displays good reliability, with a Cronbach's Alpha of 0.78, a CR of 0.85, an AVE of 0.53, and VIF values from 1.38 to 1.55. The UX construct achieves the highest reliability with a Cronbach's Alpha and CR of 0.95, although its AVE is slightly lower at 0.51, indicating a need for potential refinement; its VIF values range from 1.52 to 2.32. Overall, the constructs exhibit satisfactory convergent validity and no significant multicollinearity issues, confirming their robustness for studying the impact of digital technologies on enhancing interactive experiences in museums.

Table 2
Results of measurement model

Construct	Items	AR	VR	IE	UX	Alpha	CR	AVE	VIF
AR						0.82	0.83	0.58	
	AR1	0.75							1.52
	AR2	0.76							1.72
	AR3	0.82							1.95
	AR4	0.75							2.07
	AR5	0.74							2.06
VR						0.79	0.86	0.55	
	VR1		0.69						1.41
	VR2		0.78						2.35
	VR3		0.84						2.57
	VR4		0.68						1.62
	VR5		0.71						1.53
IE						0.78	0.85	0.53	
	IE1			0.73					1.55
	IE2			0.77					1.46
	IE3			0.67					1.38
	IE4			0.71					1.45
	IE5			0.75					1.43
UX						0.95	0.95	0.51	
	UX1				0.73				2.08
	UX2				0.73				1.99
	UX3				0.76				2.32
	UX4				0.69				1.8
	UX5				0.75				2.17
	UX6				0.75				2.13
	UX7				0.72				1.96
	UX8				0.70				1.92
	UX9				0.69				1.85
	UX10				0.60				1.52
	UX11				0.73				2.00
	UX12				0.71				1.88
	UX13				0.62				1.64
	UX14				0.73				2.08
	UX15				0.66				1.71
	UX16				0.74				2.04
	UX17				0.73				1.99
	UX18				0.76				2.26
	UX19				0.71				1.85
	UX20				0.71				1.92

Note: AR = Augmented Reality, VR = Virtual Reality, IE = Interactive Exhibits, UX = Interactive Experiences, Alpha = Cronbach's Alpha, CR = Composite Reliability, AVE = Average Variance Extracted, VIF = Variance Inflation Factor

The discriminant validity assessment, detailed in Table 3, ensures the distinctiveness of the constructs AR, VR, IE, and UX. Utilizing the Heterotrait-Monotrait ratio (HTMT) method proposed by Henseler *et al.,* [44], the analysis revealed HTMT values below the 0.85 threshold, indicating satisfactory discriminant validity. The inter-construct correlation results further demonstrated that each construct had a stronger correlation with itself than with the other constructs, confirming good discriminant validity. Specifically, the constructs AR, VR, IE, and UX exhibited strong self-correlations of 0.76, 0.74, 0.73, and 0.71, respectively, and weaker correlations with each other (ranging from 0.24 to 0.49). These findings suggest that each construct is unique and contributes independently to understanding the impact of digital technologies on enhancing interactive experiences in museums, highlighting the importance of discriminant validity in ensuring the robustness of the constructs within the model.

Table 3
Inter-construct correlation

	AR	VR	IE	UX
AR	0.76			
VR	0.40	0.74		
IE	0.28	0.34	0.73	
UX	0.49	0.44	0.24	0.71

The path coefficient analysis, as presented in Table 4, examines the relationships between the constructs and their impact on UX. The results substantiate the first two hypotheses (H1 and H2), demonstrating a significant positive relationship between AR and UX (Beta = 0.36, p = 0.00), as well as between VR and UX (Beta = 0.29, p = 0.00). These findings indicate that both AR and VR positively influence UX in museum settings. Conversely, the analysis reveals no significant relationship between IE and UX (Beta = 0.04, p = 0.33), suggesting that IE does not have a statistically significant impact on user experience. Thus, while AR and VR contribute significantly to enhancing user experiences in museums, IE does not appear to exert the same level of influence. These findings corroborate prior studies that emphasize the immersive and engaging nature of AR and VR in educational and cultural settings [45,46].

Table 4
Summary of path coefficients and significance levels

Hypothesis		Beta	SD	t	P	LL	UL	Supported
H1:	AR→ UX	0.36	0.03	10.69	0.00	0.29	0.43	Yes
H2:	VR→ UX	0.29	0.03	8.34	0.00	0.22	0.35	Yes
H3:	IE→ UX	0.04	0.04	0.97	0.33	-0.03	0.12	No

AR's ability to overlay digital information onto the physical world enriches the user's perception and interaction with museum exhibits, fostering deeper engagement and learning [46,47]. This study's results underscore AR's role in creating interactive experiences that enhance visitor engagement. Similarly, VR's ability to immerse users in entirely digital environments allows for experiential learning and exploration of artifacts in ways that traditional exhibits cannot offer [48,49]. The positive impact of VR on UX aligns with the Information Systems success model and flow theory, which suggest that immersive experiences facilitate deeper engagement and satisfaction [31,50].

In contrast, the lack of a significant relationship between IE and UX (Beta = 0.04, p = 0.33) diverges from some previous findings that suggested physical interactivity enhances visitor engagement and learning. This discrepancy may be due to the relatively static nature of traditional interactive exhibits compared to the dynamic and immersive experiences provided by AR and VR. While interactive exhibits do offer hands-on engagement, they may not fully leverage the potential of digital interactivity to captivate and sustain visitor interest to the same extent as AR and VR. This finding suggests that museums may need to innovate beyond traditional interactive exhibits to incorporate more advanced technologies that can provide richer interactive experiences [51].

From a practical perspective, these findings have important implications for museum practitioners. The significant impact of AR and VR on UX suggests that investing in these technologies can substantially enhance visitor engagement and satisfaction. Museums aiming to remain relevant and competitive should consider integrating AR and VR into their exhibit design strategies. This aligns with the broader trend towards the 'experience economy,' where value is derived from memorable and immersive experiences rather than just products or services [52]. Moreover, the lack of significant impact from traditional interactive exhibits indicates a need for museums to rethink and potentially innovate their approach to interactivity. Incorporating more sophisticated digital technologies could bridge this gap and provide visitors with a more engaging and meaningful experience [53].

5. Conclusions

This study provides valuable insights into the transformative potential of digital technologies in enhancing interactive experiences within museums. Our findings highlight the significant positive impact of Augmented Reality (AR) and Virtual Reality (VR) on visitor experiences. These technologies create immersive environments that foster deeper engagement and learning, suggesting that strategic investments in AR and VR can substantially enhance visitor satisfaction. However, our study also reveals that traditional Interactive Exhibits (IE) do not have a statistically significant impact on visitor experiences. This suggests that while interactivity is important, the depth of immersion provided by AR and VR is critical to enhancing the visitor experience. Therefore, museums may need to innovate beyond traditional interactive exhibits and incorporate more advanced technologies that can provide richer interactive experiences. The study has certain limitations. The research was conducted in a specific cultural context (Chinese museums), which may limit the generalizability of the findings. Future research could explore the impact of digital technologies in museums across different cultural contexts. Additionally, this study focused on AR, VR, and IE. Other emerging digital technologies, such as holography or AI-guided tours, could also be explored in future studies.

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Appendix: Questionnaire

Variable	Items	Author
Augmented Reality (AR)	i. I liked the activity because it was novel. ii. It was easy for me to use the AR application. iii. I was often excited since I felt as being part of the activity. iv. The activity felt so authentic that it made me think that the virtual characters/objects existed for real. v. The AR experience enhanced my understanding of the exhibits.	Georgiou and Eleni [37]
Virtual Reality (VR)	i. The virtual environment seemed real to me. ii. I was completely captivated by the virtual world. iii. The people in the virtual environment appeared to be sentient (conscious and alive) to me. iv. I had a sense that I was interacting with other people in the virtual environment, rather than a computer simulation. v. During the simulation, I felt like my virtual embodiment and my real body became one and the same.	Makransky *et al.,* [38]
Interactive Exhibits (IE)	i. The technologies available in the museum were easy to use for me. ii. My interaction with the technologies available in the museum was clear and understandable. iii. Using the museum technologies provided me with an interactive experience. iv. I felt I had control over my interaction with the museum technologies. v. While using the technologies, I was absorbed in what I was doing.	Pallud [39]
Interactive Experience (UX)	i. I enjoyed visiting the exhibition. ii. I felt engaged with the exhibition. iii. My visit to the exhibition was very interesting. iv. I felt I was experiencing the exhibition, rather than just visiting it. v. My visit to the exhibition was inspiring. vi. The information provided about the exhibits was clear. vii. I could make sense of most of the things I saw and did at the exhibition. viii. I liked the graphics associated with the exhibition. ix. My visit enriched my knowledge and understanding about specific exhibits. x. I discovered new information from the exhibits. xi. During my visit I was able to reflect on the significance of the exhibits and their meaning. xii. During my visit, I put a lot of effort into thinking about the exhibition. xiii. Seeing rare exhibits gave me a sense of wonder about the exhibition. xiv. After visiting the exhibition, I was still interested to know more about the topic of the exhibition. xv. Seeing real exhibits of importance was the most satisfying aspect of my visit to the exhibition. xvi. The exhibition enabled me to reminisce about my past. xvii. My sense of being in the exhibition was stronger than my sense of being in the real world. xviii. I was overwhelmed with the aesthetic/beauty aspect of the exhibits. xix. I wanted to own exhibits like those that I saw in the exhibition. xx. I felt connected with the exhibits.	Othman *et al.,* [40]