
Spatial Augmented Reality: Redefining Immersive Visitor Experiences in Cultural Institutions

Abstract

This paper investigates the transformative role of Spatial Augmented Reality (SAR) in redefining visitor experiences within cultural institutions. Drawing on a narrative analysis of 27 immersive museum and exhibition experiences across 18 countries, the study refines the typology of communal and multisensory immersive environments. It highlights the critical role of sensory layering, spatial interaction, narrative storytelling, and advanced technologies in crafting emotionally resonant and memorable experiences. The research introduces a contextual model comprising an Experience Mapping Interface, Design Attribute Database, Narrative Builder, and Evaluation Framework to guide the design and evaluation of immersive environments. By bridging technological innovation with academic inquiry, the study lays the foundation for future longitudinal research into the cognitive, emotional, and social impacts of SAR. It also emphasizes the need for inclusive, sustainable, and culturally sensitive design standards as SAR continues to reshape public engagement with heritage, art, and storytelling in tourism and cultural sectors.

Key Words *Spatial Augmented Reality, Immersive Experiences, Cultural Institutions, Multisensory Engagement, Narrative Storytelling, Visitor Interaction*

Track *Technology and Innovation*

Focus of Paper *Theoretical/Academic*

Introduction

In recent years, the landscape of artistic expression, storytelling, and visitor engagement has been dramatically transformed by the advent of immersive technologies providing new opportunities and challenges to tourism and leisure business operators. The proliferation of larger-scale immersive experiences, such as those seen in Sphere, Luminiscence, Borderless, the Tutankhamun Exhibition, and Van Gogh immersive shows, as well as innovative restaurant concepts like Cosm or dining experiences like Sublimotion, Ultraviolet, and Alchemist, highlights a significant shift in the market. No longer are these immersive experiences confined to theme parks, luxury brands or national showcases; they are becoming accessible to a broader audience, driven by advancements in display, and projection technologies as well as control and content manipulation software.

At the same time, majority of the existing immersive technology, and experience research has focused on individual experiences through handheld (AR) devices or head-mounted (VR/XR) devices and therefore do not entirely capture the essence of present Spatial Augmented Reality (SAR) used in these larger-scale immersive experiences. Providing unforeseen opportunities for narrative storytelling, SAR incorporates the built environment, interior design, elements, and artifacts with additional layers of multisensory stimuli such as sounds, scents, images, graphics, and videos (Bimber & Raskar, 2005). Moreover, with the recent developments in sensor technologies, content manipulation software, and generative artificial intelligence, this combination of technologies allows people to interact with these enhanced elements both individually and within groups, creating a more holistic and communal experience.

The rapid evolution of immersive technologies, particularly Spatial Augmented Reality (SAR) and multisensory applications, calls for a comprehensive understanding of the typologies and dynamics that define these experiences. As immersive environments become more prevalent across cultural institutions and commercial venues, it is essential to investigate the variables that shape visitor engagement—ranging from sensory stimuli and technological integration to the interplay between narrative, space, and social interaction. This growing complexity introduces new skill sets, managerial strategies, and business opportunities, highlighting the need for scholarly inquiry into this expanding field. Building on the experience design framework proposed by Li et al. (2023), this study offers a narrative analysis of 27 immersive museum and exhibition experiences as an initial phase of a broader research project. The aim is to refine and update the typology of communal and multisensory immersive environments. Ultimately, the paper seeks to develop a contextual model that not only guides the creation of impactful and memorable visitor experiences but also lays the groundwork for a research tool and future longitudinal studies on the lasting impacts of immersive technologies in tourism and cultural engagement.

Literature Review

Over the past years, advances in immersive technologies, most notably spatial augmented reality (SAR) and generative artificial intelligence, have reshaped how artists and cultural institutions construct, and audiences engage with experiential works. Scholars have begun to map both the sensory affordances and the design principles underpinning these environments, revealing a complex interplay between technology, narrative, and visitor perception. However, much of the existing research has focused on individual experiences through handheld (AR) devices or head-mounted (VR/XR) devices, which do not entirely capture the essence of SAR (Loureiro et al., 2023). For example, a systematic review of immersive technology in tourism highlights rapid growth in VR/AR use for destination marketing, heritage interpretation, and pre-visit familiarization. Wei et al. (2022) and Yung and Khoo-Lattimore (2019) map out key application areas, from 360° site previews to multi-sensory heritage experiences—and identify challenges around technological accessibility and integration with existing visitor services. Post-COVID studies further emphasize that embedding AR-based storytelling into guided tours can accelerate the recovery of museum tourism, meet diverse visitor needs, and boost overall engagement.

Correspondingly, Obrist (2021) contends that current human–computer interfaces under-exploit modalities beyond sight and sound, and he argues for the systematic incorporation of touch, taste, and olfaction to deepen immersion and emotional resonance. Building on this premise, Guo et al. (2023) demonstrate in a controlled museum-setting experiment that layered visual and auditory cues significantly boost visitor satisfaction and perceived presence, suggesting that these two sensory channels remain foundational even as additional modalities are added. Together, these studies underscore a sensory-centric approach to designing digital exhibitions and shows, where complementary stimuli work in concert to sustain attention and facilitate memory formation.

Through a bibliometric survey of museum-based immersive technologies, Li et al. (2023) identify five thematic clusters ranging from VR- and AR-enhanced heritage tourism to storytelling in virtual heritage spaces, and highlight gaps in scholarship, particularly around scalable VR applications for inclusive access.

Chang (2021) examines how cognitive load and cultural framing shape audience responses in both science and art contexts, finding that interactive technologies coupled with rich cultural signifiers foster deeper reflection and learning. Popoli and Derda (2021) shift the focus to the production side, advocating for cross-disciplinary collaboration and narrative-driven co-design processes to replace passive, encyclopaedic exhibitions with participatory, visitor-centred experiences. Extending this collaborative ethos, Beale et al. (2022) document experimental partnerships between regional museums and digital designers, revealing that local institutions can serve as fertile testbeds for iterative innovation in media form and practice.

Empirical research consistently links immersive engagement metrics to downstream behavioural intentions. Beck et al. (2022) demonstrate that interactive VR experiences at heritage sites significantly elevate visitors' intentions to revisit and to recommend the site, compared to traditional guided tours. By applying Expectation–Confirmation and Cognition–Emotion–Behaviour frameworks (e.g. Schaffer et al., 2024), scholars have begun to operationalize 'stickiness' and 'referral' as measurable constructs, showing that cognitive perceptions (e.g.,

perceived value, ease of use) and emotional responses (e.g., satisfaction, cultural identity) jointly predict recommendation behaviours in both on-site and online museum contexts.

In parallel, Li and Huang (2023) introduce an experience-design framework grounded in four pillars: story, space, technology, and interactivity, and validate its efficacy through several case studies of large-scale art installations. Their work provides a practical starting point for curators seeking to move beyond novelty toward meaningful, repeatable design patterns.

To translate these insights into actionable tools, Li and Huang's (2023) four-pillar design framework, namely story, space, technology, interactivity, can be adapted to include evaluation metrics aligned with tourism outcomes (e.g., Net Promoter Score, revisit rates, learning assessments). Moreover, integrating in-situ data collection (surveys, physiological sensors, beacon-based dwell-time tracking) enables venue managers to benchmark sensory engagement and narrative effectiveness against key performance indicators like satisfaction and recommendation intent.

Despite robust evidence supporting the potential of immersive technologies to enhance visitor experiences, several critical research gaps remain. Notably, there is a lack of longitudinal studies assessing the sustained behavioural and cognitive impacts of these experiences, as well as a need for standardized evaluation protocols that enable meaningful cross-site comparisons. Similarly, recent work by Santoso et al. (2022) highlights the importance of multisensory extended reality (XR) in shaping the tourism experience journey, emphasizing its holistic and communal nature. Their findings suggest that sensory-rich environments influence visitor engagement and destination perception across various stages of the experience. Similarly, Loureiro et al. (2023), while focusing on traditional AR/VR, identify multisensory engagement and social interaction as emerging frontiers in immersive experience research, calling for deeper exploration of how such technologies affect emotions, engagement and group dynamics.

Collectively, these contributions underscore the centrality of multisensory feedback, narrative coherence, and participatory design in creating impactful and memorable experiences. However, mainstream VR/AR research continues to focus predominantly on individual use cases, such as head-mounted displays and personal devices, overlooking the communal, spatially shared nature of SAR installations. Unlike solo VR experiences, multisensory SAR environments foster collective presence, emotional resonance, and shared memory formation. These qualitative differences point to the need for distinct theoretical and methodological approaches tailored to communal SAR experiences.

Addressing these gaps will require interdisciplinary research that bridges human-computer interaction, visitor behaviour, and experience design. Future studies should aim to integrate additional sensory modalities at scale, adapt design frameworks across diverse institutional contexts, and develop validated tools to evaluate both cognitive and affective outcomes. Longitudinal research is especially needed to assess the lasting impacts of SAR on learning, satisfaction, and cultural accessibility, ultimately informing the development of more inclusive and socially engaging immersive environments.

Research Methodology

Acknowledging the research gaps presented in the recent literature, this study employs a narrative research methodology to explore the self-promoted qualities and features of various attractions. Narrative research methodology is a qualitative approach that focuses on the stories and experiences of individuals, providing a deep understanding of the subject matter (Andrews et al., 2025).

The analysis is based on a curated dataset of descriptive texts from immersive museum websites. Each entry includes a summary of the experience and a list of attributes. A qualitative narrative analysis was conducted to identify thematic patterns and experiential dimensions. Data Collection was conducted from 25 immersive attractions in 18 different countries. The data consisted of self-promoted narratives. Promotional materials, brochures, websites, and social media posts from the attractions were collected using Manus.im artificial intelligence, to understand how they present themselves. A thematic analysis of the narratives was conducted using

NVivo software, identifying recurring themes and features in the self-promoted narratives. The interpretation of the analysed narratives followed the rules of narrative construction. This method constructs a cohesive narrative that integrates different perspectives, providing insights into the authenticity and reliability of the developed contextual model (Holley & Colyar, 2009).

Findings

The analysis of immersive museum experiences reveals a strong emphasis on multisensory engagement. For instance, Luminiscence *'captivates visitors with 360-degree projections and 3D spatialized music, creating a complete sensory immersion within a sacred monument'*. Similarly, Arte Museum Dubai *'enhances the experience with orchestral music and delicate scents, transcending language and cultural boundaries'*. The Museum of Ice Cream offers a *'playful environment where visitors can engage their senses of taste, touch, and sight, creating joyful and memorable moments'*. These examples highlight the importance of incorporating multiple sensory modalities to create a rich and engaging visitor experience. The implication for future research tools is the need for a sensory mapping component to help designers plan and evaluate multisensory layers effectively.

Many immersive experiences rely heavily on spatial interaction and physical movement, which are central to fostering a deep sense of presence and engagement. At teamLab Planets, for instance, *'visitors navigate barefoot through water and mirrored floors, emphasizing full-body immersion and sensory engagement'*. Similarly, teamLab Borderless features *'artworks that respond dynamically to visitor movement, creating an environment that is constantly shifting in response to spatial interaction'*. At Future World in the ArtScience Museum, interactive *'climbing installations introduce height-related challenges, adding a layer of physical exertion and spatial awareness'*. These examples highlight how spatial interaction and physical stimuli are not merely aesthetic choices but fundamental components of immersive design. As such, there is a growing need to develop methods for systematically measuring the influence of these spatial dynamics, both to ensure safety and to optimize the emotional and cognitive impact of immersive environments.

Narrative storytelling plays a central role in many immersive experiences, often evoking emotions such as awe, introspection, and joy. Breathscapes, for example, *'combines guided meditation with philosophical narration, creating a tranquil and introspective environment'*. The Van Gogh & Rembrandt exhibition *'uses historical storytelling through letters and light to connect visitors with the artists' lives and works'*. Meow Wolf *'offers surreal, kaleidoscopic storyworlds that invite visitors to explore and interact with imaginative environments'*. These examples highlight the importance of narrative design frameworks and emotional impact assessment in research tools to support the creation of emotionally resonant experiences.

Cutting-edge technologies are a defining feature of many immersive experiences. Artechouse showcases *'digital art innovation, pushing the boundaries of what is possible with technology'*. The Sphere in Las Vegas offers *'immersive concert footage with advanced projection, creating unforgettable views and experiences'*. The Tutankhamun Exhibition uses *'holographic projections and digital reconstructions to bring ancient history to life'*. These examples demonstrate the need for a technology inventory and compatibility matrix in research tools to help designers integrate and evaluate the latest technological innovations.

Conclusions

This study has illuminated the richness and diversity of immersive experiences emerging across cultural and entertainment contexts. Through narrative analysis of 27 immersive attractions, it becomes evident that these experiences are not only technologically sophisticated but also deeply sensory, spatially dynamic, and emotionally resonant. Unlike traditional VR/AR applications that often prioritize individual engagement through head-mounted displays, Spatial Augmented Reality (SAR) environments foster shared, communal experiences that are co-created by visitors within space. These are not fleeting visual impressions, but holistic, multi-dimensional encounters shaped by the interplay of light, sound, movement, and narrative.

The proliferation of large-scale immersive experiences, such as Sphere, Luminiscence, and Van Gogh: The Immersive Experience, underscores a critical shift in how SAR is applied in leisure and entertainment. These

environments reveal a set of emerging dimensions that remain underexplored in current academic literature: narrative integration, multisensory layering, AI-driven personalization, and communal dynamics. While industry innovation accelerates, academic frameworks have yet to catch up, leaving a gap in understanding how these experiences function, impact, and evolve.

To address this, the study proposes a conceptual research model for immersive SAR experiences, comprising four interrelated components: the Experience Mapping Interface, Design Attribute Database, Narrative Builder, and Evaluation Framework. Together, these tools support a more rigorous, interdisciplinary approach to studying immersive environments—not merely as technological spectacles, but as cultural interfaces that mediate meaning, memory, and social interaction.

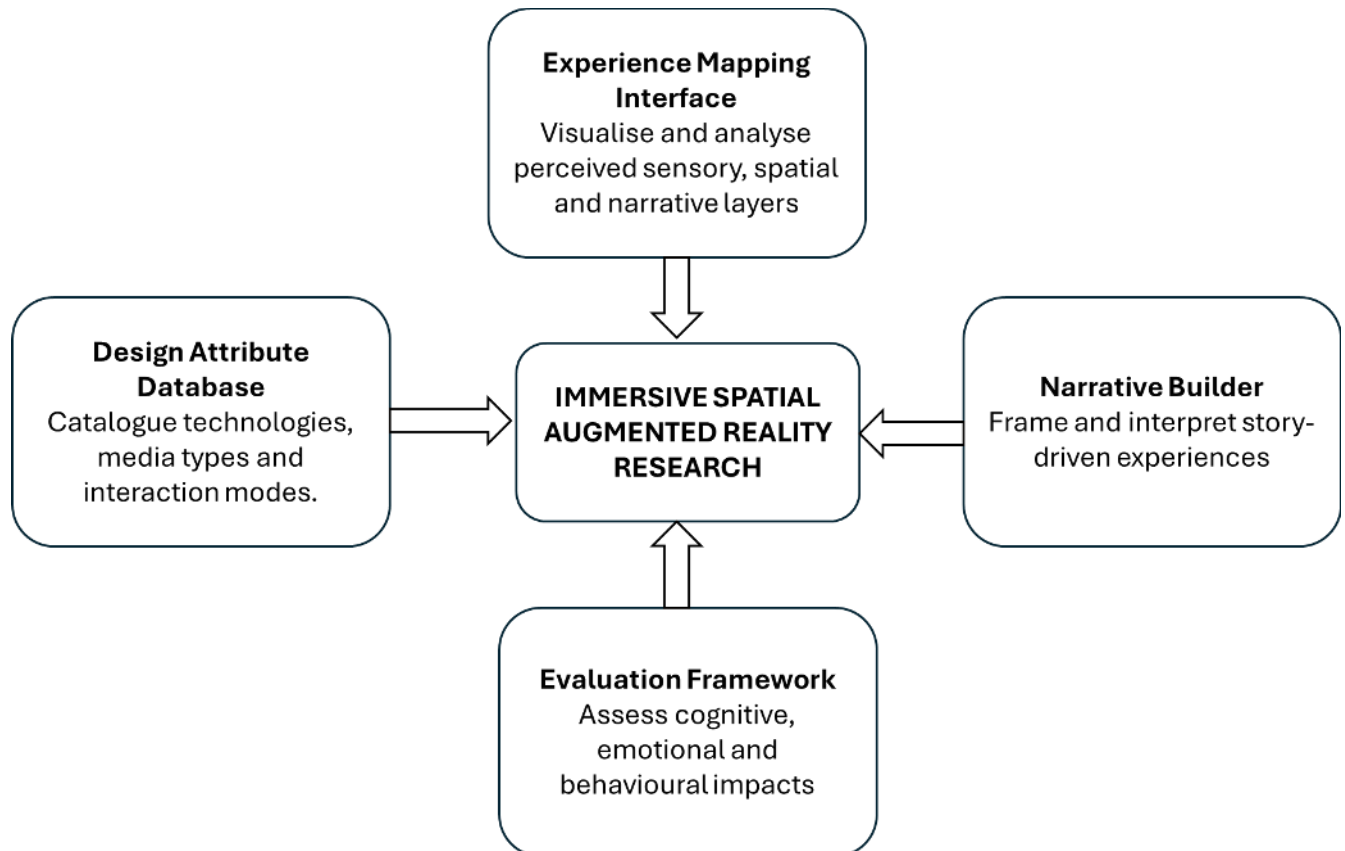


Figure 1 Proposed conceptual research model for Immersive SAR Experiences

The findings also highlight the need for new research methodologies that account for the multisensory, adaptive, and communal nature of SAR experiences. Future studies should prioritize:

- Validated metrics for immersive satisfaction, emotional resonance, and social connectedness.
- Mixed-methods approaches that capture both measurable outcomes and affective dimensions.
- Longitudinal research to explore how immersive environments influence memory, cultural attachment, and tourism behaviours over time.

Moreover, the ethical and cultural implications of SAR, ranging from authenticity and inclusivity to commercialization—demand thoughtful consideration. As SAR continues to reshape public spaces and cultural heritage sites, it is imperative to develop design standards that ensure accessibility, sustainability, and cultural sensitivity.

In conclusion, this study lays the groundwork for a more inclusive, evidence-based understanding of immersive experiences. By bridging the gap between technological innovation and academic inquiry, the proposed model offers a foundation for designing the next generation of immersive environments, ones that inspire, educate, and connect through shared, sensory-rich storytelling.

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