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Immersion as Convergence: How Storytelling, Interaction, and Sensory Design Co-Produce Museum Virtual Reality Experiences

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Abstract

Cultural heritage institutions today are experiencing a digital transformation. Virtual Reality (VR), with the promise of immersive and interactive features, has drawn the attention of artists and curators. Some prior museology research has attempted to investigate digital innovations like virtual museums and VR-based exhibits to present the best of museum experiences; however, existing systematic research on the topic of interactive narrative experience with immersive VR technologies is rare. This paper reports on an original research project to understand the emergent issues concerning immersion, interactive and narrative in museum experience design. This research used multiple case studies, Claude Monet: The Water Lily Obsession; We live in the Ocean of Air; Mona Lisa: Beyond the Glass; Curious Alice. In total, 22 semi-structured interviews were conducted with VR experts and museum curators to understand the motivation of the designers and developers. This research hopes to contribute to the digital revolution of museums, providing a foundation for curators and artists who are interested in using VR technologies in exhibitions.

Keywords: virtual reality; museum experience; immersion; interactive narrative; storytelling

1. Introduction

Over the past decade, Virtual Reality (VR) and broader Extended Reality (XR) technologies have reshaped how cultural heritage institutions engage audiences, transitioning museums from static repositories of artefacts into participatory, experiential environments. 2016 was considered as "The Year of VR" [1]. This was the year that VR technologies took a leap forward with the emergence of consumer systems such as the Sony PlayStation PSVR, Oculus Rift and HTC Vive. Following these developments, the expansion of immersive technologies has become a major talking point for people inclined to represent, diffuse and access information via new media forms [2,3].

Museums, as knowledge institutions, have long been entrusted with the dual mission of preserving collective memory and educating the public [4]. The accelerating digital transformation of the cultural sector has triggered a re-evaluation of how these missions are fulfilled. The integration of immersive technologies, interactive interfaces, and multisensory design has initiated a global movement toward the digital museum revolution, where curation increasingly involves experimentation, participation, and emotional engagement. From early experiments in digital visualisation and 3D scanning [5,6] to the multisensory integration of immersive displays [7], museums have embraced technologies that merge

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education, interactivity, and affective experience. This "digital museum revolution" signals a paradigm shift in curatorial practice, one that aligns with what Hein [8] calls the museum in transition, where audiences become co-constructors of meaning rather than passive observers. As Song and Evans [9] observe, XR enhances museum curation and exhibition practices by providing new dimensions for interacting with museum objects, enabling artefacts to be reinterpreted as digital "things" that embody Heidegger's fourfold (Earth, Sky, Mortals, and Divinities) within phenomenological encounters. In this framework, visitors become active agents (mortals), their gestures and movements enact Earthly practice, imagination and projection form the Sky, and affective or spiritual resonance reveals the presence of the Divinities.

This convergence reflects a wider shift in visitor expectations. The traditional model of passive observation is increasingly replaced by a desire for interactive participation, multisensory feedback, and personalised engagement [10]. Responding to this change, curators and artists are now reimagining museum exhibitions as immersive narrative environments, where storytelling, co-creation, and embodied interaction are central to interpretation [11,12]. These developments align with contemporary museological discourse on participatory design, affective learning, and digital empathy [13,14].

Building on these philosophical and practical insights, the paper examines how storytelling, interactivity, and immersion intersect in the design and experience of museum-based VR exhibitions. It seeks to address the following research question: How can storytelling and interactivity co-produce immersion in museum-based VR exhibitions? To explore this question, the study adopts a qualitative, phenomenologically informed approach combining multiple case studies and expert interviews [15,16]. Four VR projects were selected for analysis, Claude Monet: The Water Lily Obsession, Mona Lisa: Beyond the Glass, Museum of Other Realities, and We Live in an Ocean of Air. Together, these cases represent a spectrum of narrative, sensory, and interactive modalities in contemporary museum practice. By synthesising theoretical reflection with empirical observation, this paper aims to contribute to the ongoing digital transformation of museums, offering both conceptual insight and practical guidance for curators, designers, and cultural technologists working at the intersection of technology and cultural heritage.

2. Literature Review

2.1. Theoretical Foundations of Virtual Reality and Immersion

Numerous definitions of VR have appeared over the past three decades. VR has been defined as "a computer-generated, interactive, three-dimensional environment in which a person is immersed" [17]; a technology that provides "a more intimate interface between humans and computer imagery" [18]; Muhanna [19] argues that "virtual reality is an integration of several elements", including a virtual world (medium), immersion, feedback, interactivity and participant. More comprehensively, Lanier [2] offers more than 50 definitions of VR in his book The Dawn of the New Everything, which refers to multiple VR use cases in different contexts.

The unique nature of VR contributes to the special characteristics of VR experience. Immersion, as Evans [3] argues, is a unique selling point of VR. Engaging with VR has often been considered an immediate gateway to the experience of feeling immersed. There is a need to understand what an immersive experience is though in VR. Immersion was defined by Jerald [20] as presence, the subjective feeling of 'being there'. It refers to the sensation of being at another artificial place, and users can get a feeling of being 'transported' to another world. According to Shin [21], "immersion and presence are terms used to describe an experience in which the line between reality and imagination is blurred". In psychology, the

term immersion is used to describe a state of mind in which the participants are "completely involved in something while doing the action(s)" [19].

According to Carrozzino and Bergamasco [22], there are three levels of immersion: Non-immersive, Low Immersion and High Immersion. Non-immersive applications refer to laptops, tablets or smartphones. People just interact with the screen but cannot get a sense of immersion; Low immersion systems include Augmented Reality (AR) systems and hand-immersive workbenches. By using AR, 3D virtual objects can be put into the physical world, which breaks the barrier between physical and digital. However, low immersion systems could not allow users to achieve a full range of body movement, hence, users could not get a feeling of being completely immersed. High immersion systems such as a CAVE (cave automatic virtual environment) uses virtual reality technologies, combining stereoscopic projection (on four to six surfaces), 3D graphics, 3D sounds and other elements to build a full immersion system. Therefore, participants can achieve full-body movement and interact with the virtual objects in a virtual environment.

Based on the work of Nakatsu and Tosa [23] and Ermi and Mäyrä [24], Muhanna [19] proposed different groups of classification of immersion: passive immersion, active immersion, and sensory immersion, challenge-based immersion, and imaginative immersion. More specifically, for the first group, interaction is the key to distinguish these two forms of immersion. Passive immersion, like watching a movie, demands no interaction between the users and the media. While active immersion, like a VR experience, demands an interaction between the users and the system. Sensory immersion refers to sensory stimulation offered by VR systems, including visual, audio, haptics, and even taste execution. In addition, imaginative immersion could emerge when participants absorb in a story, and they start to use their imagination. Imaginative immersion could evoke a subjective feeling of participation, so that users could empathize with the characters in the story, which makes the experience become more emotional. In line with the notion of sensory immersion and imaginative immersion, the empirical research of Evans [3] explained the use of different elements to create immersion as a convergent assemblage: sight, vision and visual design; sound and audio; touch and haptics, and the use of narrative and story in creating sensory and emotional immersive VR experiences.

2.2. Immersive Storytelling and Digital Museology

The convergence of digital technology and museology has initiated a profound shift in how cultural institutions communicate meaning. Traditional exhibition models centred on passive observation are giving way to interactive storytelling, co-creation, and participatory engagement [25]. Within this transformation, transmedia storytelling (TMS), as theorised by Jenkins [26], has emerged as a framework for narrating across multiple media platforms to foster audience immersion and emotional resonance. In museum contexts, TMS expands curatorial practice beyond the physical gallery, creating interlinked experiences that traverse digital, spatial, and social interfaces [27].

The global digital revolution has profoundly reshaped museological practice. Notably, a museological project, Mu.SA 'Museum Skills Allica' (2016–2019), examined the digital transformation of the museum and its digital future, involving professionals from 10 popular international museums (i.e., the Louvre Museum, The Victoria and Albert Museum and National Museum Wales). The report of this project, 'Museum of the Future', emphasizes the revolutionary role of VR and AR technologies and game design in the field of cultural heritage. This shows how immersive and interactive exhibitions and installations have been pivotal in reconsidering curation practices [25]. This participatory model echoes Gröppel-Wegener and Kidd's [14] immersive storytelling framework, which categorises

museum visitors as active participants: audiences, interactants, players, or collaborators, rather than passive spectators.

Scholars have increasingly recognised that immersive storytelling in VR functions not merely as visual spectacle but as a mode of cultural translation and ethical engagement. Bevan and Green [28] conceptualise VR nonfiction as a mediography that reconstructs lived realities through affective realism, while Bevan et al. [29] describe VR as the ultimate empathy machine for its ability to evoke perspective-taking and emotional understanding. Similarly, Brown et al. [30] and Hürst et al. [31] demonstrate how mixed-reality systems support collaborative sense-making, extending the social and dialogical dimensions of exhibition design. Together, these studies reveal that XR storytelling transforms the museum from a site of observation into a relational medium, where emotion, narrative, and embodiment coalesce into new forms of cultural experience.

2.3. Applications of VR in Museum Practice

Scholars have since categorised VR applications in museums into three main forms: virtual museums, VR installations, and VR applications [11,32]. In the 1990s, the virtual museum was created as 3-D simulations in the form of CD-ROMs. One notable case is Apple Computer's 'Virtual Museum' that could be played by QuickTime VR software [32,33]. Today, most physical museums have an online presence, that can assist in solving the issue of too many items in collections but limited physical spaces. This also provides easy access for the public living far away from the museum. Outstandingly, the Google Arts & Culture institution has produced more than three thousand 360 virtual museum views online. Wearing a Google Cardboard (Google Inc., Mountain View, CA, USA) or a Head-Mounted Display (HMD) VR headset like Oculus Rift(Oculus VR, Menlo Park, CA, USA), users could discover a 360-degree museum view in a fully immersive experience. Particularly, there are some online-only museums, for example, the Universal Museum of Art (UMA) and the Kremer Museum, which are exclusively accessible through VR technologies. Moreover, according to Roussou, "VR installations (in the form of exhibits) and VR applications (in the form of 'experience') are increasingly considered by museums as an effective way to attract and educate visitors" [23]. Those VR installations and VR applications are supplements rather than the substitute of the physical museums, with the ability to introduce the historical or scientific information of museum permanent collections.

A successful example is A Journey Inside Paintings and Calligraphy–VR Art Exhibition at the National Palace Museum, from October to December 2018. Wearing HTC Vive VR headsets, visitors were placed in another world of ancient Chinese art and calligraphy, appreciating the artworks in a very different way to a traditional exhibition. Additionally, as part of the Modigliani exhibition at Tate Modern, the VR experience Modigliani VR: The Ochre Atelier immersed museum visitors in the final studio of Modigliani. Through the VR installation, visitors could see some details of Modigliani's work, get a sense of the environment, or even interact with some objects inside of the virtual studio [34]. When considering those immersive VR installations and VR applications as part of museum experience, it is necessary to explore their impacts on museum visitors and determine whether they have fulfilled the mission of the museum: providing education and entertainment for visitors. For example, the project of Historic Royal Palaces: The Lost Palace is an 'experiential resurrection' of its spaces and stories, an immersive heritage experience, which won the Museums + Heritage Award for Innovation in 2017 [35]. Here, individuals who came to palaces were able to explore the historical scene of Whitehall Palace in the time of the 17th century. It is worth noting that this project is regarded as a new VR attraction. Unlike traditional VR that displays the visual scene in a screen device, this experience told stories only with sound. By holding a piece of burnt wood (an instrument used to track

the body movement of people) and wearing headphones, people listen to the historical story of the Whitehall Palace and interact with the characters with the burnt wood. In this vein, participants could get a sense of immersion by both stepping in the physical place and imagining a virtual place.

3. Immersive Storytelling Experience Research Framework

The museology research of Gröppel-Wegener and Kidd [14] also discusses the idea of convergence while discussing the topic of creating immersive storytelling experiences in museums. Gröppel-Wegener and Kidd [14] propose a framework that breaks down the experience of immersion into different 'layers', organising them in four 'orientations': participant, process, creation, and story. The original emphasis of theirs is shown as below:

- Participant—where we are interested in the roles, identity, and agency of people participating, whether that be as audience, users, guests, etc.
- Process—where we are interested in the development of the story, and the experience and role of people who 'tell' and 'make' it, including both original 'creator' and others involved in its production.
- Creation—where we are interested in how the story is told amongst other things through space and the senses.

At the intersections of all these orientations we have:

- Story—where we are interested in the properties of the story told and experienced.

Firstly, participants refer to people who take part in the immersive experience. This conceptualisation specifically explores the role and agency of participants, their motivations, as well as the ways that they access the experience. As Gröppel-Wegener and Kidd [14] describe people who are called as participants show a more active role than those referred to as audiences. It is important to find an appropriate lexicon to define their roles, for example, Visitor, Player, Interactant, Collaborator, User and so on. This illustrates their agency "as to what they can and cannot do or how actively they participate" [14]. The use of participant allows for an exploration of the motivation of participants is to understand the reason why people choose to take part in this experience. In terms of how they experience it, this layer is to identify 'practices of consumption', exploring the ways that participants access the experience, including place, price, time-duration, solo or group [14]. The second concept of the process is to investigate the role and motivation of creators, as well as their creative process. Key here, as Gröppel-Wegener and Kidd [14] propose, "is a consideration of whether, why, and how a creative process worked with immersion in mind". In other words, the identity and motivation of creators influence the way in which they create and produce an experience, which may be related to their cultural backgrounds, or artistic inspirations. The genre choice and design process of creators that determines how participants would take part in the experience. Hence, there is no doubt that the ambitions of creators and their design process should be considered when the research analyses the immersive experience.

Thirdly, creation according to Gröppel-Wegener and Kidd [14] refers to "the orientation of the creation looks at both the design and the manifestation of the experience". The layer in this orientation includes the topic and themes of the experience; the use of space (site-flexible, site-generic, site-specific/designed, layout and spatial arrangement); the use of senses (sight and visual, sound and auditory, touch and tactic, proprioception and kinaesthetic modes, sensory consistency of the story world). The creation orientation illustrates the physical aspects of the experience, analysing those layers above, individually or collectively, could help to investigate the level of immersion of the designed experience. Finally, the story occurs at the intersection of the orientations of participant, process and

creation. A story could be considered as "a series of events or happenings" as well as "a mission or a design principle" [14]. In the context of the story, five layers have been suggested to be paid attention to, including "the narrative and its 'backstory', the plot and linearity of the story told, characters and performance, as well as adaptive characteristics" [14]. This framework inspired our research to investigate complex immersive storytelling experience layer by layer, examining their differences and similarities, discovering how these layers work together to achieve an immersive narrative system.

4. Research Methods and Procedures

This study adopted a qualitative multi-case design grounded in content analysis and expert interviews. The aim was to explore how storytelling and interactivity intersect to shape immersive experiences in VR-based museum contexts.

Firstly, the research utilised multiple-case studies to provide a context for collecting and reporting data, and to give a full account of the complete case-study stories. Four representative cases (shown in Table 1) were purposefully selected to capture the spectrum between narrative-driven and interaction-driven immersion in museum-related VR experiences. The first two are 360-degree VR films that narratively reconstruct the artists' lives and creative processes, whereas the latter two are multisensory and highly interactive installations that allow participants to explore artworks through embodied engagement and sensory stimulation, such as sound, touch, and movement, thereby deepening the sense of immersion and interactivity.

Table 1. Overview of the Four VR Museum Case Studies.

Case Study	VR Project (Year)	Type of Experience	Main Narrative	Key Interaction and Sensory Features
Case 1	Claude Monet: The Water Lily Obsession	360° cinematic VR experience in-gallery	Monet's life, perception, and creative process in Giverny	Spatial immersion; ambient sound; guided biographical narration. Still exhibited worldwide, considered a benchmark VR/art installation.
Case 2	Mona Lisa: Beyond the Glass	360° VR experience accompanying exhibition	Material, historical, and cultural context of the Mona Lisa	High-resolution 3D scans; close visual inspection; immersive audio. Continues to be cited as the Louvre's flagship digital interpretation project.
Case 3	The Museum of Other Realities	Multiplayer social VR museum	Exploration of VR-native artworks and abstract worlds	Free navigation; avatar interaction; exploration of 3D installations. Continues to operate with regular updates; widely used as a museum XR reference case.
Case 4	We Live in an Ocean of Air	Location-based multi-user VR installation	Human–nature interdependence and environmental storytelling	Biometric sensors; free movement; real-time visualised body data. Continues to tour galleries and be analysed in museum studies research.

Firstly, Case 1 is an eight-minute VR experience by Lucid Realities, exhibited at the Musée de l'Orangerie. Using HTC Vive headsets, visitors step into Monet's Giverny garden

and studio, experiencing the sensory environment that inspired Monet's Water Lilies. Through spatial immersion, sound design and biographical narration, the VR work offers an empathetic understanding of Monet's artistic process and complements the physical exhibition by creating an intimate, emotionally engaging encounter with the painter's world. Case 2 is the Louvre's first VR experience, developed with Emissive VR and HTC Vive Arts. Released alongside the Leonardo da Vinci exhibition. Using high-resolution scanning, 3D modelling and immersive sound, the experience reveals hidden layers of the Mona Lisa, including underdrawings, pigment structures and conservation findings. It also reconstructs the painting's cultural and historical context, offering viewers an intimate, research-based encounter with one of the world's most studied artworks. Case 3 is a multiplayer virtual museum dedicated to VR-native artworks. Artists use tools such as Tilt Brush to create three-dimensional installations that visitors can walk through, manipulate or inhabit. MOR functions as a social, ever-evolving space where users explore abstract worlds, attend live events and interact with others. It exemplifies how VR can redefine exhibition practices and expand artistic possibilities beyond physical constraints. Finally, Case 4 is a multi-user VR installation by Marshmallow Laser Feast. Participants wearing HTC Vive Pro headsets (HTC Corporation, Taoyuan City, Taiwan) and biometric sensors freely navigate a virtual Sequoia National Park. Their breath, movement and heartbeat are visualised in real time, creating a shared, responsive environment. The experience blends environmental storytelling with embodied interaction, highlighting human–nature interdependence through immersive, data-driven aesthetics.

Although the selected cases span 2018–2022, they represent the most influential and internationally recognised museum-based VR experiences of the past decade. As experts noted in interviews, the field evolves slowly because large-scale museum VR installations require multi-year development cycles; therefore, these cases remain methodologically and technologically representative of state-of-the-art immersive museum practice.

Throughout the research process, detailed observation results, including the researcher's experience and perceptions were recorded in a field notebook. 22 semi-structured interviews were conducted with industry experts. To select a representative sample, the researcher used LinkedIn as a sample frame which contains a global network of professionals. By using purposive sampling and snowball sampling as sampling methods, the researcher identified and recruited 22 participants, 11 female and 11 male. The sample included 15 participants based in Europe, 3 in the United States, 2 in Canada, and 1 in Asia. Each participant was assigned a numerical identifier (e.g., Participant 1) and a pseudonym to ensure confidentiality. All participants provided written informed consent prior to participation.

A series of 21 open-ended questions was devised, anticipating detailed narratives that echo the extensive experience of designers and professionals in the field, thereby facilitating a rich discourse on the pertinent themes. The questions drew partially on Gröppel-Wegener and Kidd's [14] immersive storytelling framework, enabling the researcher to explore themes of immersion, interactivity and narrativity across the four selected XR cases. It should be noted that the conversation was allowed to diverge to encapsulate follow-up questions that seek to attain a deeper understanding or elucidate specific insights, manifesting a dynamic and collaborative exploration of the complex landscape at hand.

In the analysis stage, the data were categorised, reviewed, and systematically coded. Field notes, diary entries, and recorded interviews were analysed using thematic analysis to identify recurring patterns related to immersion, usability, interaction, and interpretation [15]. To support this process, NVivo 11, one of the leading Qualitative Data Analysis Software (QDAS) tools, was used for data storage, organisation, and coding. During theme selection, a set of predefined, deductive codes such as immersion was initially applied to

guide the analysis and reflect key theoretical concepts embedded in the semi-structured interviews. Subthemes were then developed inductively from participants' descriptions of their XR experiences and were organised as child nodes within NVivo. This combined deductive–inductive approach enabled both theory-driven and data-driven insights to emerge, ensuring a rigorous interpretation of how Gen Z users engaged with each XR case.

5. Results

5.1. Narrative Immersion and Empathetic Understanding

The two cinematic VR experiences, The Water Lily Obsession and Mona Lisa: Beyond the Glass, demonstrate how narrative immersion in museums relies on emotional pacing, storytelling coherence, and sensory framing rather than on interactivity. In The Water Lily Obsession, the viewer journeys through Monet's water garden and studio while the narrator recounts his deteriorating eyesight and his friendship with Clemenceau; the transition from vibrant colour to monochrome, coordinated with a shift in musical tone, scaffolds empathy and situates the visitor inside Monet's perceptual world [36]. This resonates with work on narrative immersion as an affective-cognitive state produced by the orchestration of multimodal cues [37] and with museum storytelling scholarship that emphasises pacing, structure, and interpretive voice as core to visitor meaning-making [14,38,39]. As one of our interviewees (Rob, VR expert) noted, "more technology doesn't mean more immersion. . . emotional engagement is what makes us remember our stories," an observation aligned with experience-design perspectives in cultural settings where carefully staged encounters, not technical novelty, drive memorability [40,41].

In Mona Lisa: Beyond the Glass, the museum assumes the role of storyteller through poetic narration, voiceover, and spatial proximity to the famous painting. Participants can observe the brushstrokes, explore da Vinci's sketches, and encounter a three-dimensional avatar of the sitter. This intersection of artistic intimacy and digital mediation bridges what Kidd [39] terms the "new mediascape" of the museum, where curators design experiences that merge authenticity, emotion, and technological novelty. According to one UX designer, Laura, "people go to museums not just to learn something factual, but to feel something real." This statement resonates with Anderson et al. [42], who identify emotional salience as one of the most powerful mediators of learning in museum contexts.

Several interviewees across XR and museum fields observed that the term "immersion" has become conceptually diffuse. Aaron described it as "a much bigger word, a much bigger phenomenon than virtual reality," while Noah noted that it has become "a buzzword used for all kinds of things." Kate, an XR artist, proposed a more precise understanding, defining immersion as "a human experience where you feel wrapped, mentally or physically, by a story or by an artistic vision." Her definition aligns with Evans's [3] view that immersion emerges from the interrelation of visuals, sounds, narratives, and tactile perception. Interviewees also distinguished immersion from realism. Aaron argued that immersion "is not just a visual trick" that replaces reality, while Noah cautioned that when virtual simulations "try too closely to imitate reality, it becomes off-putting." In The Water Lily Obsession and Mona Lisa: Beyond the Glass, the stylised, painterly aesthetic avoids this pitfall and creates interpretive empathy. Narrative immersion in these cases depends not on mimetic fidelity but on the visitor's focused attention and emotional identification with the artist's world.

5.2. Sensory Interaction and Multisensory Coherence

Whereas narrative immersion depends on story and empathy, multisensory installations such as We Live in an Ocean of Air and The Museum of Other Realities demonstrate how bodily participation generates affective and social presence. In We Live in an Ocean

of Air, participants wear headsets and biosensors that track breath and heartbeat. Their physiological data are visualised as luminous particles and pulsing light, synchronising the body with the rhythm of the virtual forest. Jamie, a VR project operations manager, explained that "smell enhances realism, but touch creates the biggest emotional response." The installation transforms the act of breathing and movement into a shared narrative of life, encouraging empathy between humans and nature. The sound design, recorded in Sequoia National Park and composed by environmental artist Mileece I'Anson, deepens this effect by allowing participants to "hear plants talk to each other." This finding echoes Ceccacci et al. [43], who argue that haptic feedback in virtual museums enhances emotional memory retention and user satisfaction by anchoring sensory experience to tactile realism.

Similarly, The Museum of Other Realities provides a social and architectural experience that depends on sensory integration. Visitors enter a luminous, shifting digital museum where gravity and scale are fluid. Tutorials such as "Social Ray," "Teleport Up," and "Talk to Stranger" teach users to navigate through embodied gestures. Avatar customisation, achieved by interacting with virtual cubes, allows users to construct their visual identities, reinforcing embodiment within the virtual world. Franco, a VR designer, compared this process to theatrical scenography, stating that "in theatre they change the stage; in VR, we can change the entire environment and take everyone along the journey." This dynamic spatial play corresponds to Jung et al. [44], who found that VR and AR in museum contexts enhance visitors' sense of wonder and self-directed exploration through spatial and sensory affordances.

Audience responses to these installations reveal generational and social variations. Jamie observed that children "walked around to explore the virtual world," while younger adults showed curiosity and confidence. Older visitors required more reassurance, sometimes holding hands to build trust. Penny noted that "young people immediately were attracted to the VR experience because they are used to this sort of thing," while Bella found that AR screens worked best as "family experiences" that encourage group conversation. These observations align with [42], who demonstrated that social interaction and shared affect are key mediators of learning and enjoyment in museum environments. They also reflect Kidd's [39] notion of the "social museum," in which interactivity, conversation, and co-presence reshape the visitor's role from observer to participant.

5.3. Participant Agency, Collective Presence, and Audience Diversity

Agency in immersive museum experiences manifests through both individual control and collective participation. In We Live in an Ocean of Air, agency is enacted through movement, breathing, and interaction with others. Participants see their breath merge with others' luminous trails, transforming the exhibition into a collective organism. Jamie explained that curiosity was essential to this design: "When people put on the VR headsets, they are in a refreshed environment, and they regain their curiosity, which plays a really important role in exploring and learning." This sense of embodied co-creation corresponds to Giaccardi's [45] concept of participatory heritage, where visitors become active meaning-makers through sensory engagement and social interaction. The installation also exemplifies Gröppel-Wegener and Kidd's [14] argument that motivation and self-initiated exploration determine immersion, visitors should actively "buy into" the experience for emotional investment to occur. As Jung et al. [44] observe, such autonomy enhances perceived presence and learning, reinforcing the link between agency, affect, and engagement.

In The Museum of Other Realities, agency takes a more deliberate form. Users learn to navigate freely, teleport between rooms, and join others in conversation. The experience is highly interactive but also demands self-regulation, as the absence of spatial hierarchy can

cause disorientation. Developers addressed this by teaching "social verbs" that guide users to build their own sense of agency. Ethan, a museum digital manager, described similar concerns in physical museums, where VR and AR projects were designed as "conversation starters" while ensuring visitor flow. Laura, a UX researcher, added that museums attract both "older user bases between 30 and 45" and families with children, requiring diverse design strategies. Tiffany, an exhibition assistant, emphasised "community work" through workshops that enable visitors to co-create content related to exhibitions. These examples show that agency in immersive storytelling extends beyond virtual interactions to participatory design and community engagement.

Interviewees also highlighted the limitations of immersive technologies. Bella and Noah expressed concern that VR could distract visitors from physical artefacts, and Quill described some installations as "dust noise" that disrupts focus. Bella suggested that fully immersive experiences may require separate quiet spaces to maintain concentration. Economic and accessibility barriers remain significant; Gabriel hoped that immersive systems would become "cheaper and more inclusive." Despite these constraints, museums are increasingly shifting toward participatory models. Mia observed that institutions are moving "from collection-first to audience-first," while Bella noted that her museum is "becoming a more participative community." This evolution aligns with Kidd [39] and Mateos-Rusillo and Gifreu-Castells [46], who describe the contemporary museum as a collaborative interface rather than a site of authority—an institution that negotiates meaning through co-presence and dialogue.

Across the four case studies, a continuum emerges between narrative immersion and interactive agency, and between solitary empathy and collective participation. The Water Lily Obsession and Mona Lisa: Beyond the Glass cultivate introspective emotional immersion through storytelling and aesthetics, whereas We Live in an Ocean of Air and The Museum of Other Realities transform this immersion into embodied and social experience. The interview data reveal that audience diversity, spanning age, motivation, and technological familiarity, shapes how each layer of immersion is experienced. Ultimately, successful immersive storytelling in museums depends on balancing narrative focus [38], multisensory coherence [43,47], and accessible social agency [9,45] to engage diverse publics and foster shared cultural presence.

6. Discussion

This study applied Gröppel-Wegener and Kidd's [14] "immersive storytelling experience" framework to analyse how storytelling and interactivity co-produce immersion in four museum-based VR projects. By examining the orientations of Participant, Process, Creation, and Story, the discussion connects the empirical findings from narrative, sensory, and participatory dimensions to the theoretical understanding of convergence between artistic intention, technological design, and audience experience converge, as shown in Figure 1.

Across all cases, the four orientations did not operate as separate layers but as interdependent components that shaped one another. Participant agency was continually influenced by Process decisions such as narrative pacing, levels of guidance, or the extent of interaction, while Creation, through sensory design and spatial coherence, determined how participants interpreted and enacted the story. At their intersection, Story emerges as both the outcome and the organising principle of these interactions. Building on Gröppel-Wegener and Kidd's [14] immersive storytelling framework, this study develops a synthesised convergence model derived from comparative case analysis and practitioner interviews. Rather than treating Participant, Process, Creation, and Story as analytical layers, the model conceptualises immersion as an emergent condition produced through

their dynamic interdependence across different forms of museum-based VR experience (see Figure 2). Figure 2 synthesises the empirical findings by visualising immersion as a convergent relationship between Participant, Process, Creation, and Story rather than as discrete experiential layers. The diagram illustrates how these orientations align more tightly in narrative-driven VR experiences and become increasingly open and exploratory in interaction-led installations.

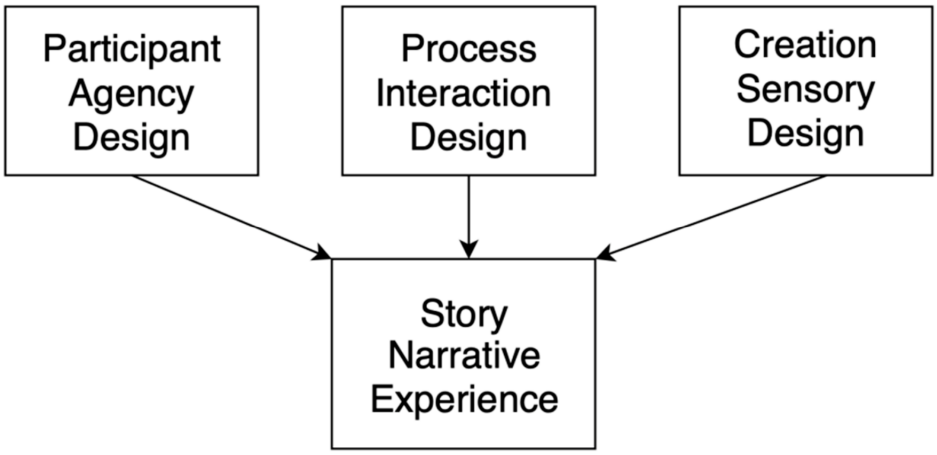

Figure 1. Immersive Storytelling Framework (adapted from Gröppel-Wegener & Kidd [14]). This diagram visualises the four orientations—Participant, Process, Creation, and Story—and the relational intersections that structure immersive museum experiences.

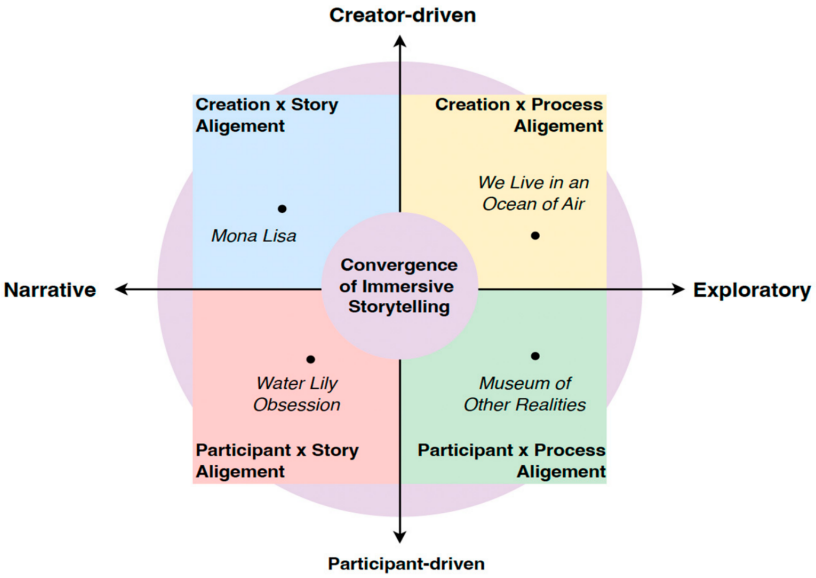

Figure 2. Convergence of immersive storytelling in museum-based virtual reality experiences.

This conceptual diagram illustrates how Participant, Process, Creation, and Story operate as interdependent orientations rather than sequential layers. Narrative-driven experiences such as Mona Lisa: Beyond the Glass and The Water Lily Obsession demonstrate tighter convergence through creator-led storytelling, while interaction-driven installations such as We Live in an Ocean of Air and The Museum of Other Realities exhibit more exploratory, participant-led configurations of immersion. When the orientations aligned, the empirical findings show that when these orientations aligned, as in the controlled narrative of Mona Lisa or the embodied coherence of We Live in an Ocean of Air, participants experienced a clearer and more emotionally resonant story. Where they diverged, as in The Museum of Other Realities, the story became more exploratory, fragmented,

or dependent on individual interpretation. The results demonstrate that immersion is not a singular technological effect but a relational condition emerging from the dynamic interactions among creators, participants, and the multisensory environments that mediate their encounters.

The participant orientation concerns the role, identity, and agency of people who engage with immersive experiences. Across all four cases, participants were not passive audiences but active contributors to meaning-making. In The Water Lily Obsession and Mona Lisa: Beyond the Glass, emotional empathy and aesthetic curiosity defined the visitor's engagement, while in We Live in an Ocean of Air and The Museum of Other Realities, agency expanded through bodily and social interaction. The interview data confirm that participation was shaped by curiosity, comfort with technology, and social context. As Jamie explained, participants "regain their curiosity" when entering a refreshed environment, and as Tiffany described, museums increasingly "aim at different groups of the population" through participatory programming.

These findings align with Gröppel-Wegener and Kidd's emphasis on participant motivation and practices of consumption, such as duration, cost, or group setting. Younger visitors were attracted to novelty and interactivity, whereas older visitors valued continuity with familiar art forms. In this sense, the participant layer also reflects cultural accessibility: successful immersive storytelling must account for varying technological literacies and emotional expectations. The installations that invited participants to act, touch, and move transformed them from viewers into collaborators, fulfilling the framework's call for an expanded lexicon of engagement that includes players, interactants, and co-creators.

The process orientation explores how creators conceptualise and construct immersion. The interviews reveal that artists, curators, and technologists deliberately approached design as an affective and cognitive process rather than a purely technical one. In The Water Lily Obsession, the creative team used painterly abstraction and temporal rhythm to convey Monet's perception, thereby situating the visitor within his sensory experience. In Mona Lisa: Beyond the Glass, curators used a controlled narrative voiceover to preserve institutional authority while humanising the historical figure. These examples show that creative processes are guided by distinct intentions, artistic empathy in one case, curatorial education in the other, that determine how immersion unfolds.

For the installation works, We Live in an Ocean of Air and The Museum of Other Realities, the creative process prioritised embodied and social design. Developers framed sensory integration as a form of empathy training, in which participants experience interconnectedness with other humans or with nature. Jamie's comment that "touch creates the biggest emotional response" illustrates how process decisions concerning haptic feedback and sound design serve emotional communication rather than spectacle. The MOR developers similarly viewed "social verbs" such as teleporting and greeting as essential to constructing shared agency. These processes reflect Gröppel-Wegener and Kidd's argument that creative practices are motivated by the desire to "work with immersion in mind," and that such motivations influence both the form of the experience and the user's role within it.

The creation orientation focuses on how immersive experiences are manifested through sensory design, spatial configuration, and the aesthetic consistency of the story world. The analysis of We Live in an Ocean of Air shows that sensory coherence produces what Evans [3] terms an "emergent property of presence." The transformation of physiological data into visual and auditory feedback created a sense of unity between participants and their surroundings. Similarly, The Museum of Other Realities redefined spatial perception by enabling users to experience scale, gravity, and materiality in new ways. Franco's description that "we can change the entire environment and take everyone along the

journey" illustrates how spatial fluidity and sensory harmony encourage users to construct meaning through embodied exploration.

In the cinematic experiences, creation manifests through aesthetic minimalism rather than sensory abundance. Both The Water Lily Obsession and Mona Lisa: Beyond the Glass used controlled visual pacing, subtle soundscapes, and limited spatial mobility to guide attention and sustain focus. The resulting experiences demonstrate that immersion can emerge equally from sensory restraint as from sensory intensity. These findings extend the creation orientation by showing that coherence, rather than complexity, determines the quality of immersion. The museum's spatial and sensory design must therefore balance spectacle with clarity, enabling visitors to remain emotionally and cognitively anchored within the story world.

The story orientation lies at the intersection of participant, process, and creation, and concerns the properties of the story told and experienced. Across the four cases, storytelling functioned as the connective tissue that linked emotional empathy, sensory coherence, and interactive agency. The Water Lily Obsession and Mona Lisa: Beyond the Glass exemplify narrative-driven immersion in which visitors are guided through linear plots grounded in biographical and historical narratives. We Live in an Ocean of Air and The Museum of Other Realities represent more open-ended, participatory stories where meaning is co-created through interaction and collective presence.

The convergence of narrative and interactivity reveals a key shift in museum practice. Instead of separating interpretation from participation, immersive storytelling unites them into a continuous experience of discovery. As Aaron observed, "immersion is not just replacing the real world but activating your brain in different ways." The story becomes both a journey and a design principle, as Gröppel-Wegener and Kidd describe, encompassing not only what is told but also how it is told and lived. Through this convergence, museums move from didactic presentation to experiential narrative, inviting visitors to inhabit the story world and, in doing so, to contribute to its meaning.

7. Conclusions

This study demonstrates that immersion in museum-based virtual reality (VR) is a convergent phenomenon that arises from the interdependence of participants' embodied presence, creators' intentions, multisensory design, and narrative coherence. Applying Gröppel-Wegener and Kidd's [14] four-orientation framework, the analysis highlights how these dimensions operate in concert. The participant orientation accounts for the diversity of audience engagement and agency; the process orientation elucidates the creators' intentions and production logic; the creation orientation focuses on the spatial, sensory, and material design of immersive environments; and the story orientation integrates these layers into a coherent interpretive system. Immersive convergence is achieved when emotional storytelling, embodied interaction, and coherent sensory design collectively transform both perception and understanding. Such convergence also redefines the role of the museum. Rather than serving merely as a repository of objects or static knowledge, the immersive museum becomes a relational medium in which human experience, technological mediation, and cultural meaning intersect. By situating VR and XR practices within a museological framework, this study moves beyond technologically deterministic accounts and emphasises the experiential, participatory, and ethical dimensions of digital heritage storytelling.

To answer our primary research question 'How can one create an effective immersive interactive narrative experience in museums with virtual reality?', the analyses of the four cases have illustrated different ways of using VR to present cultural content and form museum experiences. Notably, the main focusing message of each museum exhibition will

be the influencing factors in determining the choice of VR technologies. Importantly, our research proposes that storytelling can enforce imaginative immersion and evoke emotional engagement of participants; external stimulates like sound, smell and touch can promote sensory immersion; and embodied and spatial interaction can be achieved when participants can interact with the virtual objects or other people's avatars. There are different elements could be considered to create an immersive storytelling experience, varying from the role of participant, the space design, the use of senses to the use of narratives. It is necessary for creators to have a clear objective in mind, when creating the experience layer by layer, and then finally to achieve a successful immersive interactive narrative experience. This paper overall presents how to shift the visitors' museum experience from passive observation to active engagement, illustrating a design idea of an immersive interactive narrative experience. This research shows how the nature of VR (i.e., immersion, interactivity) may affect a museum visit and also explores to what extent does VR help with the narrative of museum contents. By articulating immersion as a convergent relationship between participant agency, creative process, sensory design, and narrative form, this study offers a transferable conceptual model that can inform the design and critical evaluation of future museum-based VR experiences.

This research has two limitations. Firstly, while conducting auto-ethnographical participation, researchers are the primary data collection instrument; their perceptions are shaped by their personal value and assumptions. It is therefore essential to acknowledge this potential bias, since different coders may categorise or prioritise themes in distinct ways. Secondly, due the limited number of case studies and interviews, the study may not provide sufficient and exhaustive results and generalisation is limited. Building on these limitations, future research could empirically validate the proposed framework through larger-scale studies that incorporate quantitative or mixed-method designs. For example, statistical analysis of user experience scales, controlled experiments comparing different VR narrative strategies, or multimodal analytics, such as eye-tracking, could test the relationships suggested in this study. Further research could also use questionnaires and interviews to assess the impressions and behaviour of participants with regard to the VR experiences. With the combination of design analysis and participant research, future research could develop a clear model of the most salient interaction strategies and propose more effective experience design and narrative strategies for museum-based exhibitions.

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