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RECEIVED 05 March 2024

ACCEPTED 01 July 2024

PUBLISHED 18 July 2024

CITATION

Song Z and Evans L (2024), The museum of digital things: extended reality and museum practices.

Front. Virtual Real. 5:1396280.

doi: 10.3389/frvir.2024.1396280

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The museum of digital things: extended reality and museum practices

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This study presents a philosophical reconceptualisation of museums using phenomenological frameworks. It explores the role extended reality (XR) “things” play in the museum experience and studies how their function differs from traditional objects. Existing studies highlight the technological tools, solutions and various visitor experience modalities in the museum sector. However, only a few papers focus on the theoretical aspects of using XR in museums. This empirical study adopts a qualitative research methodology, and 22 semi-structured interviews with specialists in XR design and development, museum culture, curation and museum exhibitions are conducted. The findings suggest that XR enhances museum curation and exhibition practices by providing new dimensions for interacting with museum objects. This aligns with Heidegger’s “the thing” and “fourfold” concepts—the integration of mortals (i.e., museum visitors), earth (i.e., the activities participated in by the visitors), sky (i.e., the potentialities and ideas stimulated by the artefacts) and divinities (i.e., the visitors’ emotions while interacting with the exhibits). Therefore, these new interactions, enabled by XR, can accentuate the narratives attached to and the meaning of the artefacts within the digital museum space, facilitating new understandings and relationships with history due to the digitisation of objects. Furthermore, this can potentially impact XR’s use in developing multi-channel curation and multi-sensory visitor experiences in museums and cultural heritage institutions.

KEYWORDS

extended reality, museums, curation, user experience, phenomenology, revealing of things

1 Introduction

Curation and culture existed before anything became digital. Accordingly, museums are institutions that curate and contextualise major cultural artefacts and histories (Ch’ng et al., 2019, p.2). The term “curator” is a Latin word derived from “*curare*,” meaning “to take care of” (George, 2017, p. 10). This meaning is preserved in the modern definition of the word “curate,” which means to select, organise and look after the items in a collection or an exhibition. Culture and curation are intertwined; thus, curation happens within and through culture. For instance, curation often focuses on the preservation, safeguarding and documentation of the cultures people value. Spencer-Oatey (2012, p. 4) highlighted three fundamental levels of culture, including “(a) observable artefacts, (b) values and (c) basic underlying assumptions.” Specifically, the communities of particular cultures create cultural artefacts which include physical object layouts and patterns, technologies and arts. These artefacts are generally visible, often unintelligible, and have specific meanings to

which people attribute academic and cultural value. Furthermore, these underlying attributions relate to an individual's circumstances, relationships and social environment. Therefore, the objects cannot be separated from the culture in which they were created.

Presently, curators are questioning the objects and the meaning that they intend to obtain. This includes the values and assumptions behind these objects, and their potential arrangement with other objects to create a broader understanding. In contrast, Alsina (2010, p. 1) asserted that culture is a process where meanings are produced and exchanged instead of a static set of practices and interpretations. It is open to appropriation, negotiation and challenge according to the dynamic shifts in sociocultural contexts and the movement of people, information and products (Alsina, 2010, p.1). This suggests that culture is a dynamic system that provides an opportunity to question, reflect on, and change the nature of curation.

In the late 1960s, the use of technologies in museums evoked new connotations for culture and transformed curation practices, such as documenting traditional museum collections, developing innovations for exhibitions and enhancing visitor experience (Uzelac, 2010; Graham and Cook, 2010; Hein, 2014; Kidd, 2014; Ch'ng et al., 2019). Consequently, the world's sociocultural context experienced an intense transformation, leading to a new cultural paradigm called the "digital culture" (Alsina, 2010, p. 1). Deuze (2006) defined digital culture as the dynamic process of developing new values, practices and expectations with two key underlying assumptions: computerisation and globalisation. The author (Deuze, 2006, p. 67) suggested three key components of digital culture: remediation, bricolage and participation. This explained the shift from existing curatorial methods to digital collections and highlighted the adjustments required to establish digital curatorial approaches compared to analogue artefacts.

During recent decades, there has been a profound integration of technological innovations into museum curatorial methodologies and visitor engagement strategies (Ch'ng et al., 2019; Trunfio et al., 2022), with extended reality (XR) tools emerging as pivotal components for the evolution of digital museology (Bekele et al., 2018). XR is a collective term for virtual (VR), augmented (AR) and mixed reality (MR) technologies, which provide sensory experiences through various combinations of real and digital content. The renowned reality-virtuality continuum introduced by Milgram and Kishino (1994) described the distance between real and virtual environments, defining VR, AR, and MR. Within the continuum, AR is close to the real world and augmented virtuality (AV) is similar to the virtual environment. In addition, MR is an environment where real and virtual content coexist and interact in real-time. Jaron Lanier (2017) suggested more than 50 VR definitions, referring to multiple VR use cases in various contexts. Thus, Evans (2019, p.8) commented, "Lanier offers definitions that draw out the importance of cognition, perception, dreaming, existentialism and phenomenology in that VR emphasises the actuality of existing consciously, empathy and hallucinating." This indicates that VR offers a unique avenue for philosophical inquiry, allowing users to profoundly influence and enhance their understanding and interaction with the physical and virtual worlds. This philosophical and humanistic approach to understanding VR inspired this study's exploration of its experiential and existential aspects.

Immersive technologies are currently becoming pivotal in digital museology (Li et al., 2023). Bekele et al. (2018) highlighted the five main purposes for using AR, VR and MR in cultural heritage (CH):

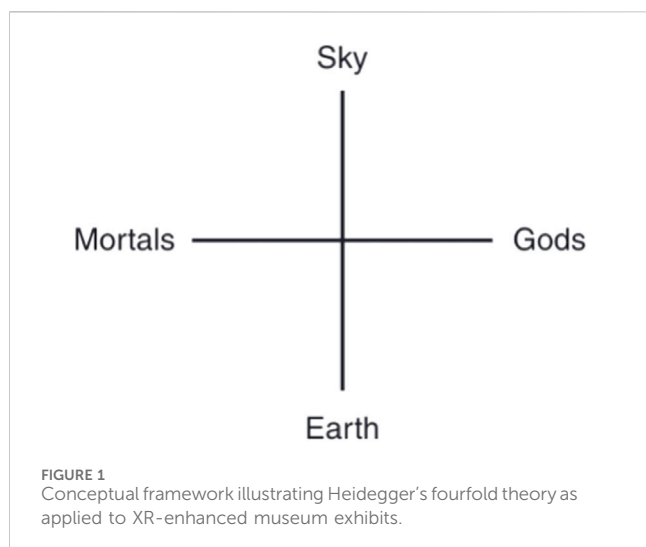
education, exhibition enhancement, exploration, reconstruction and virtual museums. On the one hand, AR blends the virtual and real to enhance art appreciation through interactive design (Md Nor and Abdul Razak, 2021). For example, users could interact with AR devices to receive location and user-aware digital information for physical exhibits (Panteleris et al., 2021). On the other hand, VR uniquely delivers information, broadening historical understanding with its direct user-technology interface. According to Roussou (2010, p. 247), "VR installations (i.e., exhibits) and applications (i.e., experience)" have become increasingly regarded by museums as an effective way to attract and educate visitors. By offering participants an extended set of digital interactions with the exhibition, these VR installations and applications help participants to effectively access and learn historical or scientific information about the museum's permanent collection. Furthermore, Li et al. (2023, p. 1) proposed that museum VR applications have the potential to revolutionize user experience and reform the landscape of exhibitions.

Several studies demonstrate the viability and reliability of immersive technologies for preserving CH (Gaitatzes et al., 2001; Xie et al., 2015; Bekele et al., 2018; Panteleris et al., 2021; Rzayev et al., 2019; González Vargas et al., 2020; Sun & Ch'ng, 2024). Particularly, researchers used VR and three-dimensional (3D) data acquisition techniques such as 3D scanning, printing and photogrammetry to build ancient artefacts for various CH purposes (Hermon and Kalisperis, 2011; Scopigno, 2012; Di Giuseppantonio Di Franco et al., 2015; Aicardi et al., 2018), such as creating virtual museums (Lepouras et al., 2004). Major AR application areas in CH include heritage data management and exploration, and enhancing the visitor experience (Wojciechowski et al., 2004; Damala et al., 2008; Kolstee and van Eck, 2011; Damala et al., 2012; Haugstvedt and Krogstie, 2012; Jevremovic and Petrovski, 2012; Panteleris et al., 2021; Rau et al., 2022). However, creating, sharing and preserving cultural memory may present challenges due to information overload. Also, many curators are sceptical about using technologies in the arts. One main reason is that multimedia applications tend to focus on the presentation and glamour of innovation instead of solving specific problems or preserving the exhibit content's intentions (Kelly et al., 2017).

Overall, existing literature highlight technological tools, solutions and various experience modalities. Evaluation processes, findings, and XR limitation cases in the museum sector are also highlighted (Ch'ng et al., 2019; Taormina and Bonini Baraldi, 2022). However, only a few studies focus on the theoretical aspects of XR use. This disparity presents an opportunity to explore the effectiveness of XR museum applications from a theoretical and philosophical perspective. To bridge this gap, this research adopts phenomenological frameworks to theoretically emphasise XR's operational success in CH applications.

2 Phenomenology, the thing, the fourfold and extended reality

Our proposed theoretical framework was derived from phenomenological theory. Phenomenology originates from the ancient Greek word φαινόμενον, phainomenon, which signifies "that which shows itself from itself" (Heidegger, [1962] 2019,



p. 51). Heidegger explained the meaning of the phenomenon concept (i.e., the showing-itself-in-itself) as “a distinctive way in which something can be encountered” (Heidegger, 2019, p. 55). As such, the phenomenological concept of phenomenon can be described as a way to show something in entities.

In museum settings, curators carefully select artefacts to form meaningful collections as part of the curation process. These artefacts are not regarded as individual pieces and “things” that contain cultural meaning. This inspired us to explore the intrinsic meanings of museum artefacts from a phenomenological perspective, focusing on Heidegger's ontological phenomenology. By doing this, this paper aims to highlight the significance of perceiving museum artefacts as technological entities and things endowed with fourfold characteristics. It also focuses on the transformation of museum spaces into culturally rich and meaningful places using XR technologies.

In Heidegger's subsequent philosophy, he questions the essence of human existence by considering the acts of building and dwelling. Heidegger famously stated, “to be a human being means to be on the Earth as a mortal. It means to dwell” (Heidegger, 2008, p. 325). For Heidegger, the concepts of dwelling and building are intricately interconnected, with the former serving as the purpose and the latter being the means to achieve it (Heidegger, 2008, p. 324). Moreover, dwelling is not considered a mere act of residing or staying; it is a profound engagement with the world. Heidegger articulated, “dwelling itself is always a staying with things,” emphasizing that in the act of dwelling, humans preserve and maintain the fourfold—the interplay of Earth, skies, mortals and gods, see Figure 1. It is through dwelling that we interact with and understand these elements. He further elaborated, “dwelling, as preserving, keeps the fourfold in which mortals stay in things” (Heidegger, 2008, p. 329). Essentially, humans transmit the core nature of the fourfold into the things with which they interact by dwelling, thereby preserving them (Heidegger, 2008, p. 329). As Heidegger proposed, “dwelling itself is always a staying with things” (Heidegger, 2008, p. 247). In this instance, the main focus is the concrescence of the fourfold (i.e., the Earth, skies, mortals and gods) (Heidegger, 2008, p. 321). The four elements' relationships are expressed as skies–earth and mortals–gods, and Ereignis (i.e., the

event) is the intersection of the four components (Evans, 2015, p. 63).

According to Heidegger (2008), when an object is truly a thing, it gathers the four integral parts of the fourfold. First, the Earth represents taking things, such as a family meal, for granted (Evans, 2019). The skies are the possibilities that come from these practices (i.e., a forward projection). Then, the gods signify the sense of being engaged in an action that occurs, which is the feeling of being a part of the activity. Finally, the mortals represent us, the human being or *Dasien* in Heidegger's words. Mitchell (2015, p. 4) noted that mediation and relationality are central aspects of Heidegger's philosophical approach to the concept of the thing.

Mitchell (2015, p. 7) suggests that the fourfold describes how things are structured and shows the relationships between things and the world beyond them.

The fourfold provides an account of the thing as inherently relational. Thanks to the fourfold, these things unfold themselves ecstatically, opening relations with the world beyond them. Unlike the self-enclosed object of modern metaphysics, the thing is utterly worldly, its essence lying in the relations it maintains throughout the world around it, the world to which it is inextricably bound. The world becomes the medium of the thing's relations. The fourfold is the key to understanding this streaming, mediated, relationality of finite, worldly existence' (Mitchell, 2015, p. 3).

In the current digital era, as Mitchell (2015, p. 7) explains, using a Heideggerian approach leads to the conclusion that the revealing of things in the world is influenced by technology due to its pervasiveness. In the context of this research, using immersive technologies changes the relationships of cultural objects with the world, transforming the status of the thing. This also affects the mediation and relationality of things enacted by the fourfold (Mitchell, 2015).

Furthermore, when an object “things” it gathers the four elements of the fourfold, which possess material and temporal aspects. For example, when an object does a thing, it pulls the past and the future into the present by connecting the material world to that event. In addition, objects do things by having a physical presence that we assemble around. Heidegger presented the jug example. A jug on the table gathers people around, bringing their past with them into the future projection within that present space. The thing's activity, in this instance, is creating a gathering. Evans (2015) argued that technological devices can create a gathering. In the past, people's ideas about places and future projections included potential activities and ambitions in the physical object's environment.

Beyond mere technological entities, museum artefacts retain the fourfold characteristics within the culturally rich and meaningful XR-enhanced spaces. Heidegger suggested that artworks possess a “thingly” character. At a basic level, artefacts and artworks in museums are objects that contain cultural meanings, and their overall *thingly* aspect is grounded in the potential artistic understanding of the artefact.

In museum curatorial practices, displaying the “thingness” of historical artefacts and artworks is essential. Comprehending the essence of art necessitates considering what constitutes a thing and its thingness. This can be examined by applying Heidegger's fourfold conceptual framework. In museums, curators deliberately select artefacts that can create gatherings. Thus, what the person

experiences as past information is always a projection of the future. Immersive tools, such as AR and VR, can enrich the four dynamics of thingness and amplify the multifaceted essence of the artefacts within the museum's digital domain. As a result, museums can be described as poetic worlds where visitors, curators, artefacts and the museum's physical space intertwine, revealing a place full of meaning and narrative.

Therefore, Heidegger's philosophy significantly influenced this research, providing the grounds to view museums not only as artefact storage, but also as realms where significant human encounters are crafted, expressed and exchanged. Thus, the thing and fourfold theories offer a profound framework for examining museum XR artefacts. This approach highlights the potential of museum items from diverse viewpoints, liberating them from their physical confines and facilitating their analysis within a broader thematic scope. As identified in this paper, these theoretical potentials can be realised by applying XR technologies.

3 Methods

3.1 Aims and research questions

This paper aims to explore the role XR objects play as things within the museum experience. It focuses on understanding how XR objects function differently from traditional ones. Ultimately, museum curators and XR practitioners examine how immersive technologies enhance the evolving digital CH landscape, improve the global accessibility of museum collections and analyse the demographics and museum audience preferences. This triggers further reflections on XR's future in the museum experience. Therefore, the research questions are:

- How do museums currently manage curation and enhance the visitor experience?
- How can using XR technologies enhance the intrinsic qualities of museum artefacts?

3.2 Research design

This study conducted semi-structured interviews with various experts in XR design, museum curation, and exhibition practices. The interviews were structured to cover several key themes: XR design strategies, museum curation and exhibition practices, and audience engagement. Particular queries focused on the difficulties of curating and presenting both traditional and XR art, the design procedures for XR apps, and the effects of XR on visitor experiences. This comprehensive approach allowed us to gather in-depth insights into the roles, challenges, and experiences of museum experts and XR practitioners (Creswell and Creswell 2018).

We used LinkedIn, which contains a global network of professionals, to select a representative sample. From October to December 2021, we identified and recruited 22 participants, including 11 males and females by using the purposive and snowball sampling methods. Fifteen participants were in Europe, three in America, two in Canada and one in Asia. The sample was defined using purposive and snowball sampling methods, ensuring

the selection of individuals with significant expertise and experience in XR design and development, museum culture, curation, and exhibitions. Inclusion criteria included having a minimum of 2 years of experience in their respective fields and a demonstrated history of working on projects involving XR technologies in museums. Participants were excluded if they did not meet these criteria or if they were unable to provide informed consent. The participants sampled had all had experience of working with or developing XR applications that were characterised by their ability to create immersive and interactive environments in museums. These applications varied from simple AR overlays that provided additional information about exhibits to fully immersive VR experiences that transported users to different historical periods or locations. The key characteristics considered were high levels of interactivity, realistic visual and auditory simulations, and the ability to engage multiple senses. The participants were assigned a code and pseudonym (e.g., Participant 1, Aaron). Accordingly, the target population comprised practitioners and experts in related fields, including curators, artists, XR developers and designers (See Table 1 for detailed participant information). Therefore, the 22 semi-structured interviews investigated VR and AR conception, creation and implementation by observing the preservation of museum research results within the design process¹.

Furthermore, the thematic interview data analysis identified significant patterns and themes, which were then synthesized to address the overarching research question (Braun and Clarke, 2006). Using thematic analysis, the interview data was classified into nine themes based on the interview questions and data collected throughout the interview.

4 Results

4.1 The current state of museums and their challenges

Traditionally, museum curators select, preserve, and curate cultural objects, displaying them to visitors for educational purposes. However, the artefacts are not self-explanatory. Therefore, providing sufficient information to introduce their social and historical background to museum visitors is essential (Pattakos et al., 2023). The participants in this research asserted that the amount of information requiring updates in museums is overwhelming. Owing to physical constraints, museums can only display a limited portion of their collections and provide insufficient labelling information. As a palaeontologist and museum curator, Bella ensures the scientific information behind artefacts, such as dinosaurs or paintings, is accurate. While Bella says the current museum exhibition barely assisted with updating her research because they are too static. She asserted that:

¹ The interview transcripts and additional resources used in this study are not included in the manuscript but are available upon reasonable request from the corresponding author.

TABLE 1 Category and distribution of interview participants.

Category	United Kingdom	Outside United Kingdom
Museum Curators	5	1
Exhibition Assistants	1	
Immersive Experience Designers	2	1
Immersive Technologists	1	
XR Developers	2	2
Museum Digital Program Manager	1	
VR Architects	1	
Cultural Heritage Lead	1	
Storyteller		2
UX Researcher		1

The problem with museum exhibitions is that they're very static. We want to make sure that the information is up to date all the time. (Bella)

One reason for the infrequent updating of museum exhibitions is the limited space available (e.g., on a tombstone label) for presenting information about the artefacts. This insufficiently conveys the multifaceted histories that accompany the items. Aaron, the co-founder and creative leader of an AR company, argues the following:

I learned from my research that the label is called a tombstone because it contains so little information—55 words is generally a label's word limit. This is a function of museums being brick-and-mortar institutions, real places with real buildings where there is a limit to what they can display. (Aaron).

This epitomises the constraints of conventional museums, which traditionally encompass a singular interpretative narrative. Yet, the artefacts housed within these institutions are saturated with rich and multifaceted cultural histories, and their interpretation can vary widely amongst individuals. Aaron also argued that including multiple interpretations for complex and consequential topics, such as slavery or empire, may expand exploration and comprehension avenues. Moreover, offering diverse perspectives can enhance the visitor experience and encourage a more in-depth engagement with their collections.

Besides, insufficient information on museum artefacts and item inaccessibility are issues that museum professionals identify as challenging. They stated that:

In a lot of museums, of course, you can't touch stuff. So, I think by having these 3D models, you can make annotations on them and animate them in a really and truly engaging way. (Shawn).

The big problem for us is it's not accessible. Creative technologies offer us a way to activate it. (Mia).

In this instance, Shawn, a digital media director at a museum, and Mia, a VR artist, are exploring the potential of using technology

to address artefact inaccessibility issue in museums. For example, Shawn proposed creating 3D models that would enable visitors to interact with exhibits in a tactile manner and bring them to life through animation. The primary concern regarding inaccessibility is the failure to completely engage the senses of the visitors, who are often restricted to observing the artefacts without tactile interactions. From a user experience (UX) standpoint, individuals prefer to completely utilising the senses to assimilate diverse information, enhancing their appreciation of the exhibits. As a result, XR technologies may enable a multi-sensory experience for visitors, thereby broadening the scope of visitor engagement within museums (Marto et al., 2022).

Moreover, research shows that museums have shifted from an object-focused approach to a visitor-oriented model (Hein, 2014; Ch'ng, 2019), emphasizing the use of cutting-edge technologies to enhance the visitor experience and improve accessibility. Contemporary museums also function as customer service organisations, emphasising personalised experiences for their varied audience demographics (Kiourt et al., 2018). This study demonstrated that regular event and exhibition attendees are often from older age groups; hence, museums are keen to appeal to individuals from the younger generations through more interactive activities. Laura, a museum UX researcher, stated the following:

We lack interested young people, so this initiative aims to engage them in history and culture through new and exciting ways that may attract a diverse audience. (Laura).

Additionally, individuals from the younger generations are currently the museums' target audience and principal consumers within the XR industry. The conventional static museum exhibition mode, which caters to older demographics through research and visitation, must evolve to provide entertainment and active visitor engagement experiences. This evolution is necessary to strike a balance between the preferences of younger audiences and the expectations of professionals (Marques, Pedro and Araújo, 2023; Chernbumroong et al., 2024).

4.2 Enhancing museum exhibitions: the advantages of extended reality artefacts

This study revealed that professionals in the field believe that XR technologies may create new opportunities for museums regarding multiple storytelling, interactive experience and visitor attraction. First, many narratives remain that museum sectors do not present to the public.

Museums can be a centre for multiple perspectives and interpretations instead of one. It's about curating multiple perspectives and being the centre of effectively presenting that debate while encountering the artwork. (Aaron)

Aaron stated that museums are centres for presenting and discussing diverse cultures worldwide, and they assume the responsibility of conveying robust and multifaceted ideas to the public. Traditionally, this is achieved through tangible artefacts

accompanied by small tombstone labels providing background information. However, the constraints of physical space within museums often exclude the exhibition of extensive information. To address this challenge, participants highlighted the prospective capacity of XR technologies for multi-channel curation, which can enhance the presentation of information for museum objects. Ethan, a digital programme manager for a museum, articulated the following:

We wanted to use this immersive technology to update the narratives and bring in another layer, and the really great benefits of this is that we can tell different stories at different times. (Ethan).

Ethan explains that multi-channel curation involves presenting collected information in a layered manner with the aid of XR technologies. Within the digital network, significantly more space exists for storing and exhibiting digital artefacts and narratives. This approach assists museums in narrating the stories behind the artefacts. Aaron and Penny also indicated:

AR is an interesting place to develop the idea that you could have multiple narratives and perspectives presented in parallel without necessarily having to compete for attention. (Aaron).

The AR app, which has at least half a dozen voices on the same painting automatically proved that people come to a painting with different interests, knowledge and experiences, which are ways of opening up that painting to different people. (Penny).

Aaron, an AR developer, and Penny, a museum curator, both express their approval for the use of AR in multi-channel curation. AR technology fundamentally involves superimposing digital content onto the real world, allowing stories to be enriched and editorial interpretations to be effectively conveyed. Ideally, curators and XR designers must collaborate to create a digital narrative journey for museum visitors. This would enable them to explore multiple stories associated with a single painting or artefact without becoming overwhelmed or overlooking any valuable information.

The multi-sensory experience concept was a significant aspect highlighted during the interviews with the museum curators and UX researchers. As Laura suggests, engaging multiple senses can lead to a more immersive experience for museum visitors. Thus, XR technologies have the potential to augment this multi-sensory engagement, fostering a deeper connection between the exhibits and the audience.

As you enter an exhibit, you may encounter various forms of presentation: something in video form, objects with which you can interact physically or items you can read or touch. It's about engaging all the senses. In my view, the integration of AR, VR, or other technologies serves as an expansion of this multi-sensory engagement. (Laura).

In this case, engaging multiple senses induces a sense of immersion that can be created within the XR experience at museums. Evans (2019, p. 50) argued that "immersion is reframed here as a tightly crafted emergent property of the visual, sounds, narratives and haptics (or touch) of the VR

experience and the mood or orientation of the user towards the VR experience itself". Evans suggested that sensory stimulations like visuals, sounds and narratives help to evoke the mental activities and emotions of the user, mimicking a state of immersion.

Moreover, "being in a different world" is a notion that is often mentioned by interviewees. This theoretically relates to the concept of "presence." For instance, Brown and Cairns (2004) proposed an experience hierarchy, ranging from engagement to total immersion or presence. Evans (2019, p. 50) explained that "presence is the sense of "being there" in a particular space, and in the VR context, that sense is of being in a space or world that is in a different location from the one that we are physically in at that time". In a state of full immersion, presence represents the internal psychological state of the user (Evans, 2019, p. 50), which can be created by VR technologies. A museum curator, Noah, argued as follows:

I think VR takes you somewhere. It immerses you in a way that you can engage with your whole body. You know, it's like a literal portal to another place where you can engage with things in all sorts of new ways. (Noah).

Consequently, by creating an immersive experience that engages multiple senses and even the entire visitor's body, XR technologies can foster a deeper connection between the artefacts and those who observe them. Therefore, visitors can better appreciate the exhibits' narratives.

Finally, as mentioned previously, museums find it challenging to attract more visitors, especially from younger demographics. According to the interviews conducted, XR technologies may substantially benefit the cultural sector in audience engagement.

I think XR technologies could bring in a new type of audience to the museum. It could also be a really great way to engage with the museum's current audience. (Owen, storyteller).

I think the AR screens were mainly for families. I think, especially in the science galleries, it was families that enjoyed using them. (Bella).

A lot of young people were immediately attracted to the VR experience because they're more used to this sort of thing. So, they understand it. (Penny).

Bella expressed that AR is ideal for family experiences, as individuals can share and interact with the screens together. It fosters a social experience that can introduce social values into museum settings. Regarding VR, Penny, a museum curator, suggested that young people may quickly become comfortable with VR since they are already accustomed to using smartphones and playing video games. This implies that VR museum experiences may align with this generation's interests, potentially integrating them into the museum-going audience if they find the XR experience engaging.

In summary, addressing the research questions, our results indicate that museums face significant challenges, including limited physical space and static displays. Participants highlighted the integration of XR technologies as a solution to these issues, enabling more dynamic and engaging visitor experiences through digital overlays and interactive features. Multi-sensory and multi-channel curating is made possible by XR technology, which enables

museums to showcase a variety of stories and viewpoints. By increasing their accessibility and interactivity, this improves the intrinsic features of the objects and offers visitors a more interesting and fulfilling experience.

5 Discussion

This study's main observation is that XR technologies enable museums to overcome various limitations and transform objects, fully revealing their rich cultural backgrounds. The participants indicated that XR technologies augment artefacts from three perspectives: multi-channel curation, multi-sensory experience and the attraction of diverse audiences. This finding is significant because it suggests that museum artefacts have unrealised potentials (Spadoni et al., 2023), and the museum experience can be enhanced by showcasing these possibilities with the support of XR technologies. As noted in Section 1, museums have a longstanding history of curation and are currently experiencing a transformation in cultural representation and user engagement. XR technologies, with their unique advantages, could enable museums to achieve their goals in the modern era.

5.1 The thing and the fourfold in museum contexts

From a phenomenological perspective, this paper asserts that artefacts and artworks in museums gather mortals (i.e., the museumgoers), Earth (i.e., the activities performed by the visitors), skies (i.e., the possibilities and ideas evoked by the artefacts) and gods (i.e., the visitors' feelings as they interact with the exhibits). This conceptual framework is illustrated in Figure 2.

Specifically, the Earth element (i.e., the activities in which the visitors participate) can include activities, such as observing and studying the artefacts, reading information labels, attending guided tours and interacting with fellow visitors or museum staff. The skies element represents visitors who, while interacting with the exhibits, can ask questions like "How will I experience this?" "How will this artefact enrich my life?" and "How does this historical narrative influence my understanding of the world." These questions help visitors connect with the artefact. Moreover, the gods' fourfold aspect encapsulates the emotional responses of visitors towards the experience. This is extremely important for supporting the audience's understanding of the collections and exhibitions. Therefore, utilizing Heidegger's fourfold as a lens (Heidegger, 2019), this chapter interprets the assembly of artefacts within the museum context through the dynamic interplay of the human (i.e., the mortals), physical (i.e., the Earth), potential (i.e., the skies) and spiritual (i.e., the gods) realms.

According to the participant interviews, the museum's tangible and material components reflect Heidegger's idea of the Earth element in his fourfold theory. Meanwhile, human activities including observing the specimens and reading wooden labels embody the skies aspect. Thus, the minimal interactivity of the Earth element may create a potential issue, resulting in reduced engagement with the skies component.

Significantly, Aaron provided a compelling perspective in the expert interview. The below statement can be examined and interpreted within the context of the fourfold framework:

A museum is a centre for art or a place where people go, expecting to find art or a pedestal. It's an incredibly interesting space that is full of rich material. Like a gallery, a museum just gives you more stuff to work with in terms of being able to create a story that the user can walk through. (Aaron).

First, Aaron's mention of "people go, expecting to find art" is classified under the mortals component. It signifies the visitors who frequent the museum with the anticipation of encountering art. This aligns with the mortals element that represents the museum visitors. In addition, Aaron's description of the museum as "a centre for art," "a pedestal" and "a place. . . full of rich material" is consistent with the Earth component. These references indicate the tangible, physical elements and activities that take place within the museum, such as viewing and interacting with diverse materials and artworks. Next, the statement "a museum just gives you more stuff to work with in terms of being able to create a story that the user can walk through" resonates with the skies element. This notion reflects the potential for imaginative and cognitive exploration that a museum visit can provoke, as visitors construct narratives and derive meaning from the exhibitions. While Aaron does not explicitly address the gods aspect, it was implied through his portrayal of a museum as a place where one might expect to find art, which can evoke profound emotional responses or a sense of connection with the history or creators of the artefacts.

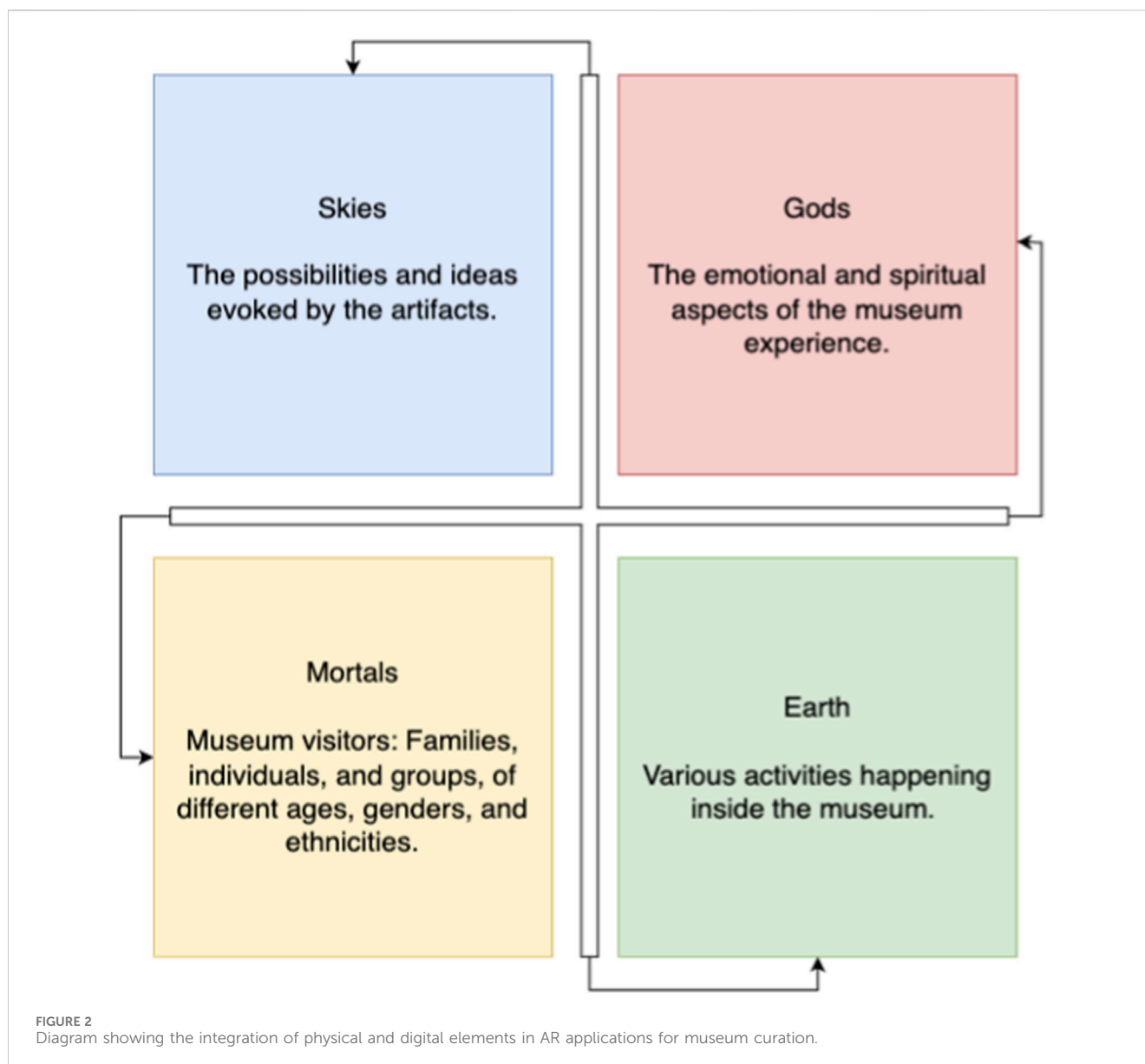
Furthermore, Ethan's statement below highlights that the museum is an intersection of the past, present and future.

Museums are great at showing you what happened in the past, what they did in the past and how they worked. The conversations that the people have are trying to bring more human elements. (Ethan).

Here, Ethan showed the temporal dimension of the museum, highlighting its role in uniting the past with the present and enriching the visitors' comprehension and appreciation of human history. Heidegger (2019) argued that time is fundamental to the understanding of "being." Dasein's existential unity is intrinsically attached to time, which is Dasein's way of perceiving the world. Heidegger asserted that the past, present and future are all jumbled up in the human experience. Thus, Dasein is a temporal space where past, present and future are interwoven. As a result, the fourfold components also have temporal aspects. When an object things, it integrates its history (i.e., the past) and potentiality (i.e., the future) into the present. This is achieved by establishing a connection with the surrounding material world, thereby incorporating it into the occurring event. In the context of the museum, as Ethan stated, individuals immerse themselves in the historical narrative, grounding it in the present to anticipate forthcoming actions.

5.2 The transformative role of extended reality objects

Immersive technologies like VR and AR offer solutions to the physical constraints of museums, thereby gathering the four



elements for curated objects. Concurrently, these technologies have facilitated the creation of virtual spaces, altering the visitors' relationship with their environment.

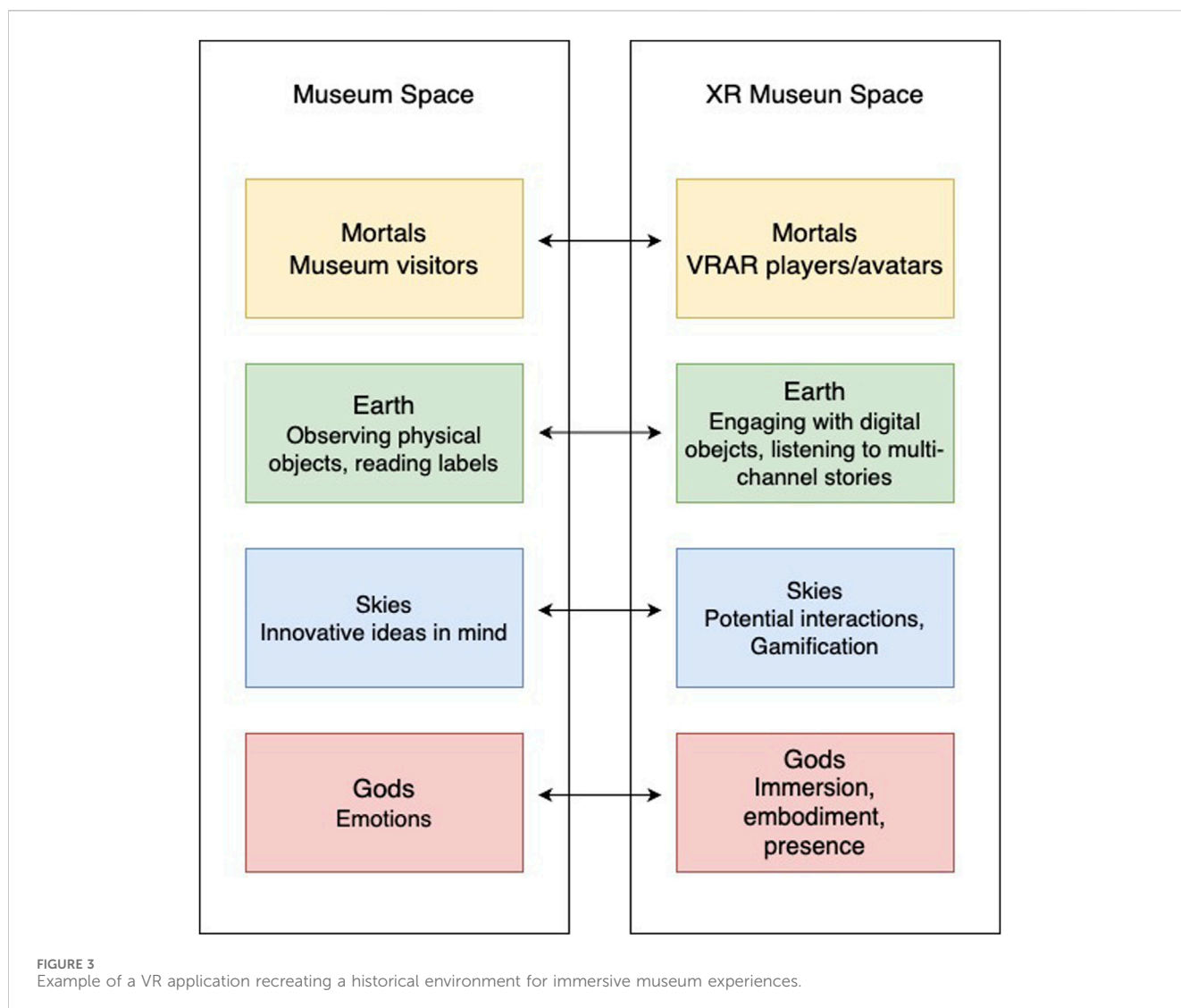
Hence, this research proposes that immersive technologies like AR and VR can elevate the fourfold element of a thing in museum contexts. On the one hand, by overlaying digital information on physical objects, AR can reveal the concealed aspects of an artefact, unearthing its inherent essence and hidden attributes (i.e., the Earth). It can enable the detection of the invisible by showing the cultural, historical and artistic context (i.e., the skies) of an object that may have otherwise been lost or misunderstood.

On the other hand, VR can create fully immersive environments that transport users to different times and spaces, providing a contextual backdrop (i.e., the skies element) that enriches their understanding. It enables a profound interaction with the Earth component, offering a tactile sense of the object, its weight, texture and other characteristics that are otherwise inaccessible in a traditional museum setup. These technologies can create

additional exhibition areas, offer new spatial narratives in museums, and enhance the overall experience of visitors (Jang et al., 2023).

Therefore, the fourfold theory undergoes a transformation in the context of XR museums, as illustrated in Figure 3. Each element adapts to fit the specific functions of XR utilised in museums. This adaptation allows the Earth, skies, mortals and gods components to be interwoven in innovative, interactive ways. When these elements are effectively integrated, they culminate in an enhanced museum experience facilitated by XR technologies.

Furthermore, Figure 4 elucidates a conceptual framework that clarifies the interplay between the fourfold aspects within the context of an XR-enhanced museum experience. In this context, visitors, referred to as mortals, transform into avatars in virtual museums. This represents a significant shift from passive spectators to active participants, as they engage interactively with digital objects, embodying the elements of Earth and skies. The profound interaction between visitors and artefacts evokes a sense of



immersion that highlights the gods aspects. This, in turn, strengthens the connection between visitors and artefacts, ultimately creating a comprehensive and enriching XR museum experience. By aligning these interactions with the four fundamental aspects, visitors' understanding and engagement with the artefacts are greatly enhanced. This interactive involvement fosters a deeper connection and appreciation of cultural heritage, thereby enriching the educational and experiential value of museum visits.

Finally, the participants proposed a transformative vision for future museums and galleries, emphasizing their potential as interactive, intellectual spaces that encourage diverse dialogues regarding art and history. In this model, museums will house artefacts and artworks, and also act as repositories for multiple perspectives curated in real time. This innovative approach exposes visitors to a broader range of interpretations, fostering critical thinking and enriching their overall experience, which is similar to Heidegger's idea of the Earth and skies in the fourfold theory. In this instance, the material and physical realms where entities are revealed and concealed generate a constant tension that triggers further exploration and interpretation. Furthermore, the real-time curation of different perspectives illustrates the realm of openness

and illumination that provides meaning and context to the artefacts. This aligns with how the skies provide the conditions for life on Earth. Last, the envisioned museum or gallery also mirrors Heidegger's "gathering" or "thinging" concept (Heidegger, 2019), where the fourfold components assemble, creating a sense of place that is more than just a physical location. It is a place of encounter, a space for dialogue and debate, and a centre for continuous learning and revelation, mirroring the essence of being.

Hence, by gathering the four elements—the Earth, skies, mortals and gods—immersive technologies can craft a comprehensive, multi-sensory experience that transcends conventional forms of viewing and interaction, enabling the potential to dwell with technology. As a result, this holistic experience facilitates a deeper understanding of and connection with the curated objects, enhancing the visitor's overall museum experience.

In practice, this means that traditional methods of curation and preservation can be complemented with digital methods in several ways. Digital archives can enhance access to collections (Parker and Saker, 2020), while AR and VR can provide interactive and immersive experiences that traditional displays cannot. For example, AR can overlay additional information and narratives on

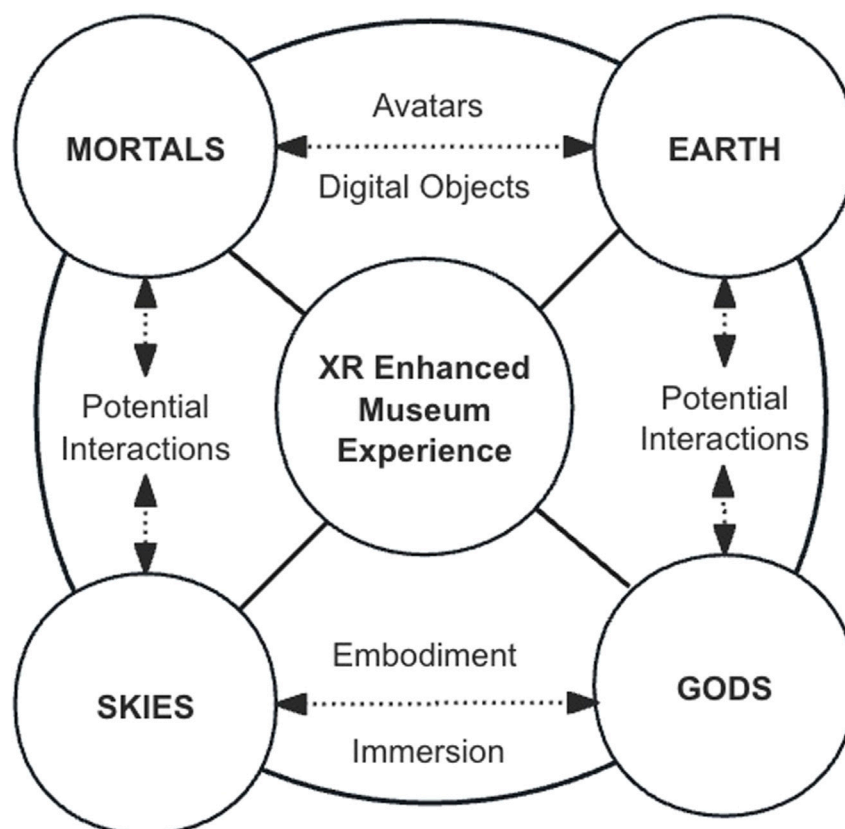


FIGURE 4
Conceptual framework illustrating the synergy of fourfold elements in XR-Enhanced museums.

physical objects, enriching the visitor's understanding. VR can recreate historical environments, providing context that enhances the preservation and interpretation of artefacts. The extent to which these methods complement traditional approaches depends on the specific goals of the exhibition and the resources available. As shown in this research, this can be in the context of improving accessibility, attracting new visitors and allowing for the co-construction of narratives. In the context of the "thing," these affordances of XR can allow for a new relationship with objects in museums. This could address issues that currently exist in accessibility, such as improving accessibility for people with disabilities by providing alternative ways to interact with and experience museum collections (Stendal et al., 2011). These technologies can enable the participation of audiences who would not otherwise be able to interact with the collections, but this needs to be considered in light of how people with disabilities may be able to interact with a virtual environment and the barriers to using XR technology.

6 Implications

Remarkably, while existing research on museum curation and user experience has largely concentrated on practical aspects and technical skills, it has overlooked the exploration of underlying curation theory. This research bridges that gap, recognising the vital hermeneutic relationship between theory and practice where

both enhance and inform each other. By introducing a novel theoretical framework that intertwines with the practical, the study uses Heidegger's concept of the fourfold to offer deep insights into museum interaction with artefacts. Artefacts are transformed from mere objects into "things" that engage with Earth, Skies, Mortals, and Gods. This phenomenological approach is essential for recognising each museum item through an ontological lens, thereby enabling the development of a detailed ontology for each item within a collection or museum exhibition. This ontology not only deepens the understanding of the artefacts but also facilitates more efficient and meaningful inquiries by museum visitors, thereby enhancing their overall engagement. By fostering connections on multiple levels—including tangible interactions, human engagements, and emotional connections—this perspective significantly enriches the museum experience. Meanwhile, by recognizing the central role of immersive technologies, museums can strategically align themselves with the evolving expectations of the public. This involves not only investing in new technologies but also understanding how they can be integrated into existing practices. The shift from static exhibitions to dynamic, interactive, and immersive experiences signifies a major change in the museum landscape. Traditional methods of curating and preserving cultural heritage can be supplemented or replaced with digital counterparts, allowing for richer engagement with audiences.

7 Conclusion

In conclusion, this study advances an ontological understanding of museum curation and UX, forming a design framework tailored for crafting multi-channel museum curations and multi-sensory visitor experiences. The findings suggest that XR can enhance museum curation and exhibition practices by providing new interaction dimensions for the museum's objects. It significantly contributes to the development of VR systems in museums, enhancing visitor experiences by deepening immersion and interaction and promoting an experience economy perspective. These insights are also valuable for evaluating the potential of redevelopment initiatives in museums and galleries.

This study encountered three distinct limitations. First, during qualitative data collection, our perceptions, which are shaped by personal values and assumptions may introduce subjective biases to the research. Second, due to the limited number of interviews, the study may not provide sufficient and exhaustive results; therefore, generalization is limited. Third, the study did not directly compare the processes curators used to select and preserve artefacts with and without XR technologies. Future research could explore this comparison in detail, potentially revealing differences in decision-making processes, engagement strategies, and preservation outcomes between traditional and XR-augmented curation. Based on these challenges, further research is required. Further research could conduct a systematic analysis of museum XR projects to assess the narrative efficacy during the design process and assess the audience's response using a range of qualitative and quantitative measures. The design analysis could involve sampling other XR content and developing a coding scheme that categorizes units by elements of immersion, narrative and interactivity. This coding scheme can be applied to the designed experience. Furthermore, the research could also use questionnaires and interviews to assess the participants' impressions and behaviours regarding VR experiences. Therefore, by combining design analysis and participant research, future studies can develop a clear model of the most salient interaction strategies and propose more effective experience designs and narrative strategies for museum-based exhibitions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the College Research Ethics Committee, Swansea University. The studies were conducted in accordance with the local legislation and institutional

requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ZS: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Writing–original draft, Writing–review and editing. LE: Conceptualization, Methodology, Supervision, Writing–review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

The authors wish to express their profound appreciation to all interviewees whose invaluable support and shared experiences were essential to the completion of this research. Heartfelt thanks are also due to Professor Sian Rees, whose passion and unwavering guidance have significantly shaped this work. We are particularly grateful to Rob from Playlines for his mentorship and friendship in media practice, which has been of immeasurable value. We extend our gratitude to the professionals at the National Museum Wales and the National Gallery London for their collaborative spirit and knowledge sharing, and to all the participants who contributed their perspectives, greatly enriching this study. Finally, the authors are grateful for the constructive critiques and comments provided by the anonymous reviewers and editors.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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