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Developing a Spatial Sound Experience Framework for Immersive Heritage Exhibition: Exploring Emotional-Cultural Engagement in Indonesian Cultural Soundscape

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Abstract

In the era of immersive technology, cultural heritage exhibitions have become more interactive and multimodal. However, even in contemporary immersive heritage studies, the visual remains prominent and the contribution of spatial sound to cultural immersion and experiential engagement has been under-explored. This research seeks to build the framework of the spatial sound experience for the immersive heritage exhibition in Indonesia, by putting the spatial sound as the centre of the experiential medium in the immersive culture environment. The study adopted a qualitative Design-Based Research (DBR) approach and was conducted in an immersive living lab with 15-25 primary and 4-8 expert participants, including sound designers, immersive media designers, exhibition curators, cultural experts, and creative media academics. Data were acquired through in-depth interviews, participatory observation, immersive prototyping, reflective experience notes and expert validation and were analyzed using thematic analysis. The results show that spatial sound is relevant for the establishment of spatial presence, environmental immersion, emotional-cultural engagement and experiential heritage interaction. The utilization of Indonesian cultural soundscape components as traditional ambience, ritual sound, environmental audio and localized auditory narratives were proven to augment emotional resonance, cultural familiarity and immersive engagement. The study presented Spatial Sound Experience Framework comprising five interrelated dimensions including spatial sound stimulation, environmental immersion, emotional-cultural engagement, cultural presence formation, and experiential heritage interaction through thematic synthesis and iterative evaluation of the prototype. Theoretically, the study adds the concept of auditory-led immersion in immersive historical contexts and practically, a conceptual reference for

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immersive exhibition design and experience cultural preservation. The results support the relevance of incorporating spatial sound as a key experience

Keywords: spatial sound, immersive heritage exhibition, cultural soundscape, auditory immersion, experiential cultural preservation

INTRODUCTION

In the last ten years, advances in immersive technology have transformed museums and cultural heritage performances, making them more interactive, multisensory, and experience-centric. Technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), 3D reconstruction, interactive storytelling, and digital technologies for historical relics allow visitors to engage more deeply with cultural materials through a combination of physical and digital interactions[1]. Immersive technology also fosters the development of virtual museums, metaverse heritage environments, and XR-based cultural communication, expanding accessibility, realism, and visitor engagement in the context of cultural preservation[2]. In this context, immersive heritage exhibitions are no longer seen solely as a medium for conveying historical information but have evolved into an experiential cultural environment that emphasizes sensory immersion, interpretive interaction, and emotional engagement.

In line with these developments, various studies have explored the use of immersive technologies to increase spatial presence, environmental realism, and cultural interaction in heritage spaces. Previous research has found that VR, AR, and XR technologies have improved immersive storytelling, narrative interpretation, and participatory engagement through virtual

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environments, digital reconstruction, and interactive visualization[3]. In addition, integrating creative technologies and multisensory interaction in museums strengthens visitor co-creation and experiential participation, making cultural experiences more dynamic and contextual[4]. This development shows that immersive heritage research has shifted toward a more experience-oriented approach than conventional, object-centered exhibitions. On the other hand, advances in spatial sound, soundscape, and auditory perception research show that the auditory environment significantly influences emotional response, environmental awareness, spatial cognition, and immersive perception in virtual and interactive environments[5].

Spatial audio technologies, such as binaural audio, ambisonics, and environmental soundscapes, have been shown to improve spatial navigation, sensory depth, and sense of place in immersive environments[6]. Other research also shows that immersive auditory experience contributes to emotional immersion and environmental embodiment through the integration of auditory cues and realistic spatial interaction[7]. Thus, soundscape not only functions as a complementary audio element but also as an essential part of building immersive experiences and emotional-cultural interactions. However, most previous immersive heritage research has

[3] Stefan Mudicka and Roman Kapica, "Digital Heritage, the Possibilities of Information Visualisation through Extended Reality Tools," *Heritage* 6, no. 1 (2022): 112–31, https://doi.org/10.3390/heritage6010006; Zacharias Pervolarakis et al., "Visiting Heritage Sites in AR and VR," *Heritage* 6, no. 3 (2023): 2489–2502, https://doi.org/10.3390/heritage6030131; Gehan Selim et al., "The Virtual Living Museum: Integrating the Multi-Layered Histories and Cultural Practices of Gadara's Archaeology in Umm Qais, Jordan," *Sustainability* 14, no. 11 (2022): 6721, https://doi.org/10.3390/su14116721.

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still been oriented toward technological implementation, visual immersion, usability evaluation, and psychoacoustic optimization rather than the development of cultural experiences based on auditory immersion in a holistic manner. Spatial sound in many studies is still positioned as a supporting multimedia component, not as a core experiential medium that shapes cultural atmosphere, emotional immersion, and experiential heritage interaction[8]. Some studies have begun to explore the potential of soundscapes and sonic interaction in virtual museums and immersive environments, but research remains predominantly focused on audio technology, rendering systems, and engineering performance rather than on cultural immersion and experiential preservation (Al-Taie et al., 2022; Yang et al., 2022). Additionally, the dimension of the cultural soundscape rooted in local identity remains underexplored, especially in developing countries like Indonesia. These limitations indicate both a theoretical and a methodological gap in immersive heritage research. Theoretically, no specific conceptual framework integrates spatial sound, emotional-cultural engagement, cultural presence, and immersive heritage interaction into a single, unified cultural experience model. Most studies remain fragmented, focusing on XR visualization, spatial audio rendering, virtual reconstruction, or digital preservation without explaining how spatial sound can shape an immersive cultural experience in an experience-centered manner[9]. Methodologically, previous immersive heritage research has been dominated by systematic reviews, technological assessments, engineering evaluations, and usability testing, whereas the qualitative Design-Based Research (DBR) approach, based on iterative immersive prototyping, remains very limited in developing immersive cultural frameworks. The research gap is increasingly relevant in the context of Indonesia's local culture, which possesses a rich auditory-cultural identity expressed through cultural rituals, gamelan, traditional ambience, oral narratives, and community-based environmental soundscapes. Some studies have begun to explore the potential of local soundscapes for cultural preservation and the formation of spatial cultural identity[10]. However, there has not yet been comprehensive

[8] Hong et al., "Spatial Audio for Soundscape Design: Recording and Reproduction"; Wanti, Somantri, and Karyati, "Utilization of AR Technology for The Development of Speech Therapy Applications by Optimizing Marked-Based Tracking Method"; Alessandro Giuseppe Privitera, Federico Fontana, and Michele Geronazzo, "The Role of Audio in Immersive Storytelling: A Systematic Review in Cultural Heritage," *Multimedia Tools and Applications* 84, no. 16 (2025): 16105–43, https://doi.org/10.1007/s11042-024-19288-4.

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research that integrates spatial sound experience, emotional-cultural immersion, and experiential heritage interaction in immersive heritage exhibitions in Indonesia. Therefore, the integration of the Indonesian cultural soundscape into immersive auditory experiences remains an area of research that has not been extensively explored.

Based on these conditions, this research offers novelty by developing the Spatial Sound Experience Framework, which positions spatial sound as a core experiential medium for building emotional-cultural immersion in Indonesia's immersive heritage exhibition. In contrast to previous research that tends to be visual-centric and technology-oriented, this study integrates spatial sound stimulation, environmental immersion, emotional-cultural engagement, cultural presence formation, and experiential heritage interaction into a single cultural experience framework. This research also contributes by exploring the Indonesian cultural soundscape as an auditory-cultural identity within an immersive exhibition environment**.** In addition to theoretical contributions, this research offers methodological contributions by applying qualitative Design-Based Research (DBR) grounded in iterative immersive prototyping and participant-centered exploration. This approach enables more in-depth exploration of auditory-spatial experiences through iterative design refinement, experiential evaluation, and expert validation. Therefore, this research not only contributes to the development of immersive heritage theory but also provides a conceptual reference for future work on immersive exhibition design and experiential cultural preservation based on spatial sound.

METODS

Qualitative methods are used, with two main techniques: literature study and observation. The literature study was carried out by collecting and analyzing data from various written sources related to the research topic, namely government policies in advancing the Indonesian film industry. The research uses a qualitative Design-Based Research (DBR) approach to design, develop, and evaluate the Spatial Sound Experience Framework for Indonesia's immersive heritage exhibition. The DBR approach was chosen because it allows for the development of a design practice-based framework through an iterative process that integrates user experience exploration, prototype development, design evaluation, and conceptual reflection on an ongoing basis. In addition to producing practical contributions in the form of spatial sound-based immersive exhibition prototypes, this approach also allows the development of theoretical contributions related to the relationship between spatial audio, cultural immersion, emotional engagement, and immersive heritage interaction. The research is oriented toward experience-centered immersive design, with a focus on how spatial sound can

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shape spatial perception, cultural presence, emotional resonance, and immersive heritage engagement in the context of local Indonesian culture. The qualitative approach was chosen because immersive experience and auditory-spatial perception are subjective, contextual, and experiential phenomena that require an in-depth exploration of participants' experiences while interacting with the immersive exhibition environment.

The research was conducted in a living lab, an experimental immersive exhibition space that enables the development and evaluation of spatial sound-based immersive heritage exhibition prototypes in a controlled, iterative manner. The research context was selected to create an experimental environment that supports manipulation of spatial audio design, the development of immersive interactions, and in-depth exploration of the user experience. Compared with conventional museums, the immersive living lab approach offers greater flexibility for iterative prototyping, experiential testing, and design refinement, consistent with DBR characteristics. Research rooms can take the form of university creative media laboratories, immersive rooms, multimedia studios, interactive galleries, or experimental exhibition halls that support the implementation of spatial audio and immersive media technology. The heritage context used in the study focuses on the Indonesian cultural soundscape, including traditional market ambience, cultural rituals, gamelan spatialization, heritage environmental sounds, local cultural narratives, and traditional village soundscapes. This selection aims to strengthen cultural immersion while presenting Indonesia's local identity as the main medium of the immersive auditory experience.

The research participants consisted of two main groups, namely primary participants and expert participants. Primary participants are visitors or users of immersive exhibitions who are selected using purposive sampling techniques based on characteristics relevant to the research focus. Participant criteria include ages 18–35, familiarity with digital and interactive media, prior visits to exhibitions or museums, and an interest in local Indonesian culture. This group was chosen because it is considered able to evaluate immersive experiences and provide experiential reflection on spatial sound interaction in an immersive heritage environment. The number of participants ranged from 15–25 people, which was considered adequate for qualitative-based immersive experience research. In addition to the main participants, the research also involved expert participants consisting of sound designers, immersive media designers, exhibition curators, cultural experts, and creative media academics. The expert group plays a role in framework validation, prototype evaluation, and design refinement to ensure that the developed framework has conceptual validity, practical relevance, and suitability for the context

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of the immersive heritage exhibition. The number of experts involved ranges from 4-8 people, according to the needs of validation and the iterative design process.

Table 1. Research and Participant Characteristics

Components	Description
Research Approach	Qualitative Research
Types of Research	Design-Based Research (DBR)
Research Focus	Spatial sound experience pada immersive heritage exhibition
Main Output	Spatial Sound Experience Framework
Research Orientation	Experience design dan cultural immersion
Validation Strategy	Expert review, participant experience analysis, dan triangulation
Primary Participants	Age 18–35 years, familiar with digital/interactive media, have visited exhibitions or museums, have an interest in local Indonesian culture
Jumlah Primary Participants	15–25 participants
Expert Participants	Sound designer, immersive media designer, exhibition curator, cultural expert, dan akademisi creative media
Jumlah Expert Participants	4–8 expert

The research is carried out through several iterative stages in line with Design-Based Research. The first stage is a preliminary investigation that aims to identify the development of immersive exhibitions, the limitations of conventional audio, and the potential of spatial sound to build cultural immersion. At this stage, the researcher conducts a literature review, observations, and initial interviews with experts to gain a conceptual understanding of immersive sound experiences in the context of heritage exhibitions. The second stage is experience requirement exploration, which focuses on the elements of spatial sound experience that affect immersion and cultural engagement. This exploration is carried out through semi-structured interviews, participatory observation, and audio experience mapping to identify dimensions such as emotional resonance, spatial presence, auditory realism, cultural atmosphere, and narrative immersion. This stage produces experiential insights that form the basis for initial framework development. The third stage is the framework design phase, which produces the initial design of the Spatial Sound Experience Framework. The framework is

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developed based on the synthesis of results from user experience exploration and expert reviews. Some of the initial components of the framework include spatial audio layering, directional sound interaction, environmental heritage soundscape, emotional acoustic trigger, narrative spatialization, cultural presence formation, and immersive heritage engagement. The fourth stage is prototype development, which involves developing an immersive heritage exhibition prototype based on spatial sound. The prototype is designed using a combination of ambient audio, directional sound, and environmental soundscape to create an immersive auditory-spatial experience. The technology used can include binaural audio, Dolby Atmos, Ambisonics, Unity, Unreal Engine, Max/MSP, or TouchDesigner, according to the needs of developing immersive environments. Furthermore, the prototype is evaluated iteratively through participant experience evaluation and expert validation to refine the developed framework.

Table 2 Research Stages

Stages	Key Focus	Technical
Preliminary Investigation	Identify immersive exhibition gaps and spatial sound potential	Literature review, observation, expert interview
Experience Requirement Exploration	Exploration of immersive experiences based on spatial sound	Semi-structured interview, observation, audio experience mapping
Framework Design	Spatial Sound Experience Development Framework	Thematic synthesis dan expert consultation
Prototype Development	Pengembangan dan evaluasi prototype immersive exhibition	Iterative prototyping, participant evaluation, expert validation

The research data was collected through several techniques to gain a comprehensive understanding of immersive auditory experience and cultural immersion. The main technique used was in-depth interviews with primary and expert participants. The interviews were conducted in a semi-structured manner to explore the immersion experience, perception of the audio space, emotional engagement, cultural connection, and sensory-spatial experience while interacting with the immersive exhibition prototype. In addition to interviews, the study used participatory observation to observe movement patterns, interaction behavior, spatial engagement, and participants' responses to the immersive sound environment. Observations

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were carried out while participants interacted with the immersive exhibition prototype to understand the relationship between spatial sound and embodied interaction in the exhibition space. The research also used experience documentation in the form of audio recordings, visual documentation, field notes, and interaction mapping to record the dynamics of immersive experiences in greater depth. As a complement, participants were asked to keep reflective experience notes containing reflections on emotional experiences, spatial perception, and cultural experiences while interacting with the immersive exhibition environment. This technique was used to deepen experiential data and enrich qualitative findings.

The research data were analyzed using Braun and Clarke's thematic analysis to identify themes of experience related to immersive auditory perception, emotional-cultural engagement, spatial presence, and heritage interaction. The analysis process begins with the familiarization stage, involving reading and reviewing interview transcripts, observational notes, documentation, and reflective notes. Next, the researcher conducted initial coding to identify experiential patterns that arise from participants' interactions with immersive sound environments. The next stage includes theme generation and refinement to group codes with conceptual relevance into the main research theme. In the final stage, interpretation is carried out to compile a conceptual synthesis and formulate the final Spatial Sound Experience Framework as the main contribution of the research. To improve the validity and trustworthiness of the research, a triangulation strategy was used, which included data triangulation, method triangulation, and theory triangulation. Data triangulation is carried out by comparing data from primary participants and expert participants, while method triangulation is carried out through the integration of interviews, observations, documentation, and reflective notes. In addition, theory triangulation is carried out by integrating the perspectives of immersion theory, soundscape theory, spatial presence theory, cultural presence, and interactive exhibition theory in the process of interpreting research results. The study also applied member checking to ensure the suitability of the researcher's interpretation with the participant's experience. In addition, expert validation was carried out iteratively to evaluate the conceptual relevance, experiential framework quality, and suitability of prototype implementation to the context of Indonesia's immersive heritage exhibition. This validation strategy aims to ensure that the framework developed has credibility, dependability, and practical relevance in the development of immersive cultural exhibitions based on spatial sound.

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RESULTS OF RESEARCH AND DISCUSSION

1. Spatial Sound Perception in Immersive Heritage Space

The results of the study show that spatial sound plays an important role in shaping the perception of immersive space in the heritage exhibition environment. Participants stated that directional audio, environmental soundscapes, and layered spatial sound strengthened the perception of spatial realism and increased the sensation of "being inside" the cultural environment rather than simply observing the exhibition content visually. Spatial sound is perceived not only as an audio stimulus but also as a mechanism that directs attention, motion orientation, and environmental interpretation during immersive interactions. Several participants reported that the ambience of traditional markets, the sounds of cultural rituals, the ambience of the village environment, and the resonance of gamelan resulted in a stronger perception of spatial depth and cultural atmosphere. The integration of ambient and directional sound also increased participants' awareness of the boundaries of virtual space and helped the navigation process during the immersive experience.

Table 3 Dominant Themes of Spatial Sound Perception

Theme	Participant Experience Findings
Spatial Awareness	Participants felt a clearer spatial orientation and direction of the environment
Environmental Realism	Soundscape enhances the realism of the heritage atmosphere
Auditory Navigation	Directional sound helps with navigation and focus
Sensory Depth	Layered audio amplifies the perception of depth of space
Cultural Atmosphere	Traditional soundscape reinforces cultural ambience

The results of the observation also showed that participants tended to spend more time interacting in the exhibition area with a dynamic environmental soundscape than in the visually dominant area that lacked audio stimulation. This pattern indicates that spatial sound contributes to the sustainability of attention and environmental engagement during immersive interaction.

2. Emotional Engagement through Cultural Soundscape

Research found that the cultural soundscape strongly influences emotional engagement during immersive heritage interactions. Participants exhibited nostalgia, curiosity, calmness, emotional resonance, and cultural familiarity when engaging with the Indonesian cultural

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soundscape. These responses were most prominent in immersive scenes that incorporated local auditory elements, such as traditional musical instruments, cultural ritual ambience, village environmental sounds, and audio-based cultural narratives. Participants also often linked sound experiences to personal memories or imagined cultural situations, suggesting that spatial sound can build emotional-cultural connections beyond visual experience alone. In some immersive sessions, participants reported increased emotional attachment when audio elements responded dynamically to the user's movements and spatial interactions.

Table 4 Emotional Response to Cultural Soundscape

Emotional Dimension	Description of Participant Responses
Nostalgic Engagement	Participants recall familiar cultural experiences and atmospheres
Emotional Resonance	Spatial sound results in deeper emotional engagement
Cultural Familiarity	Local soundscape enhances cultural proximity
Curiosity and Exploration	Interactive audio encourages exploratory behavior
Psychological Comfort	Ambient environment creates a calming immersive experience

The results also showed that emotional engagement increased when soundscape transitions aligned with spatial movement and changes in the immersive environment. Such synchronization strengthens experiential continuity and reduces fragmented perception during interactions.

3. Spatial Presence and Environmental Immersion

The study's findings show that spatial sound makes a significant contribution to the formation of spatial presence and environmental immersion. Participants consistently reported a stronger sense of environmental embodiment when spatial audio was dynamically dispersed within the immersive space. Compared to conventional stereo audio, binaural audio and directional sound produce a stronger perception of proximity, environmental realism, and auditory depth. Observational data showed that participants exhibited more natural embodied interaction behavior in environments with a responsive soundscape. Some participants spontaneously turned their heads toward the sound source, approached a specific area of audio, and adjusted their movement patterns based on the auditory cues received.

These findings indicate that spatial sound functions as an active environmental interaction component, not just a passive background medium.

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Gambar 1. Hubungan Spatial Sound dan Pembentukan *Immersive Experience*



The study's findings also show that immersive presence is formed through the integration of spatial audio layering, environmental ambience, and synchronization of participant movements. This integration results in a more coherent sensory experience that strengthens immersion in the heritage exhibition space.

4. Cultural Attachment and Experiential Heritage Interaction

Research has found that immersive auditory interaction contributes to the formation of cultural attachment and experiential engagement with heritage. Participants view cultural heritage not only as the content of exhibition information but also as an experiential environment that can be felt emotionally and sensorily. Spatial sound allows participants to experience cultural narratives through embodied auditory interaction, thereby increasing cultural connectedness and experiential participation. Some participants emphasized that auditory immersion makes the cultural environment feel more "lively" and emotional than the conventional exhibition approach. The interactive soundscape also encourages participants to

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actively explore the showroom and build deeper interpretive engagement with the cultural narratives presented.

Table 5. Dimension of Experience in Immersive Heritage Interaction

Experience Dimension	Observed Interaction Patterns
Embodied Interaction	Participants respond to directional sounds physically
Cultural Presence	Participants feel a stronger closeness to the cultural atmosphere
Experiential Engagement	Interaction becomes more exploratory and participatory
Narrative Immersion	Audio reinforces interpretive understanding of cultural narratives
Environmental Participation	Participants experience active engagement with the immersive environment

This finding shows that spatial sound not only contributes to sensory immersion but also to experiential cultural preservation through strengthening participants' interaction with local cultural identity based on auditory-spatial experience.

5. Development of Spatial Sound Experience Framework

Based on thematic synthesis, participant experience analysis, observation results, and expert validation, this study successfully developed the Spatial Sound Experience Framework for immersive heritage exhibition environments. The framework integrates several interconnected experience dimensions that shape an immersive auditory-cultural experience. It consists of five main dimensions: spatial sound stimulation, environmental immersion, emotional-cultural engagement, cultural presence formation, and experiential heritage interaction. These dimensions consistently appeared in participant experiences and during the iterative prototype evaluations conducted throughout the research.

Table 6 Key Components of the Spatial Sound Experience Framework

Components Framework	Functional Roles
Spatial Sound Stimulation	Produces auditory-spatial perception and sensory immersion
Environmental Immersion	Building environmental realism dan immersive atmosphere

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Emotional-Cultural Engagement	Facilitating emotional resonance and cultural familiarity
Cultural Presence Formation	Strengthening the connection with the cultural environment
Experiential Heritage Interaction	Encourage participatory and embodied cultural interaction

The research results show that immersive cultural experience is not only formed through visual immersion but also through the integration of spatial auditory interaction, environmental soundscape, and emotional-cultural engagement. Therefore, spatial sound functions as the core experiential medium in immersive heritage exhibition environments.

6. Final Spatial Sound Experience Framework

The final framework demonstrates a sequential relationship between auditory-spatial stimulation, immersive environmental perception, emotional-cultural engagement, and experiential heritage interaction. This framework positions spatial sound as the primary medium that initiates immersive sensory interaction and facilitates the formation of cultural presence within the immersive heritage environment.

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Gambar 2. Final *Spatial Sound Experience Framework*



The framework also shows that the Indonesian cultural soundscape has great potential as an auditory-cultural identity that can support cultural preservation through immersive experiences. These findings underscore the importance of integrating spatial sound as a key experiential component in the development of immersive heritage exhibitions in the future.

DISCUSSION

1. Spatial Sound as an Immersive Cultural Experience Medium

The results show that the sound of the space not only serves as a supporting medium but also as the main medium that enables a sensational cultural experience in the heritage performance space. Despite the use of Virtual Reality (VR), Augmented Reality (AR), 3D reconstruction, and interactive visualization technologies, previous studies on immersive heritage still place visual immersion as the main focus (Boboc et al., 2022; Komianos, 2022; Theodoropoulos & Antoniou, 2022). In contrast, the results show that auditory-spatial interactions play a significant role in creating environmental realism, depth of sensation, and

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experiential engagement. Compared to simply seeing heritage content, participants considered directional sounds, environmental ambience, and layered sound spaces as components that enhance the sensation of "being inside" a cultural space. These findings reinforce the view that immersive perception is inherently multisensory and cannot be optimally constructed through visual stimulation alone. Hong explained that spatial audio contributes to immersive realism by providing environmental cues that support auditory navigation and perceptual continuity[11]. In line with this, Privitera emphasized that soundscape and sonic interaction can strengthen immersive storytelling through emotional and environmental engagement[12]. This research expands this perspective by showing that spatial sound functions as an experiential architecture that can foster immersive cultural interaction and environmental interpretation in heritage spaces. In addition, this study shows that when spatial sound is treated as an active component of the environment, rather than as a passive audio background, the experience inspired by the environment and sound becomes more significant. This conclusion suggests a conceptual shift from visual-centered experiences to voice-guided experiences, where sound serves as the primary medium to shape cultural moods, spatial orientation, and experiential engagement.

2. Spatial Sound and Emotional-Cultural Engagement

The results of the study show that Indonesia's cultural sound environment can increase emotional engagement and cultural bonding during deep interactions. When participants interacted with local sound elements such as gamelan resonance, cultural ritual atmosphere, village environmental sounds, and audio-based cultural narratives, they reported nostalgia, familiarity, emotional resonance, and psychological comfort. The results show that auditory engagement has significant emotional and cultural effects that improve the experience of interactions with heritage. These findings are in line with previous research on soundscapes and sound perception, which shows that environmental sounds influence emotional responses, memory activation, and environmental interpretation[13]. Mariette et al. (2021) report that soundscape perception affects emotional conditioning and familiarity with the environment[14].

[11] Hong et al., "Spatial Audio for Soundscape Design: Recording and Reproduction."
[12] Privitera, Fontana, and Geronazzo, "The Role of Audio in Immersive Storytelling: A Systematic Review in Cultural Heritage."
[13] Andringa, "Appraising the Sonic Environment: A Conceptual Framework for Perceptual, Computational, and Cognitive Requirements"; Searchfield, "Tinnitus What and Where: An Ecological Framework."
[14] Mylene M. Mariette, David F. Clayton, and Katherine L. Buchanan, "Acoustic Developmental Programming: A Mechanistic and Evolutionary Framework," *Trends in Ecology and Evolution* 36, no. 8 (2021): 722–36, https://doi.org/10.1016/j.tree.2021.04.007.

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In the context of immersive exhibitions, this study shows that the cultural soundscape does not only function as environmental decoration but also as an emotional trigger that fosters deeper participant involvement in cultural identity. The results of this study also strengthen immersive storytelling research by emphasizing the importance of sensory-emotional interaction in increasing narrative engagement[15]. However, unlike previous research that generally positioned audio as a narrative supporter, this study shows that spatial sound functions as a mechanism of cultural immersion that actively shapes emotional-cultural participation. The integration of a responsive soundscape and spatial auditory interaction allows participants to build stronger emotional attachment and experiential continuity during immersive exploration. These findings indicate that cultural soundscapes have great potential as an auditory-cultural identity that can support experiential cultural preservation. Through emotional resonance and cultural familiarity, spatial sound can transform immersive heritage exhibitions into an emotionally meaningful cultural environment, not just a space for conveying cultural information.

3. Formation of Spatial Presence through Auditory-Spatial Interaction

The results of the study show that auditory-spatial interaction has a significant contribution to the formation of spatial presence and embodied environmental immersion. Participants consistently showed stronger environmental awareness and spatial orientation when interacting with immersive environments using directional audio and binaural sound systems. The observation results also showed embodied behavioral responses such as spontaneously turning their heads towards the sound source, moving to follow auditory cues, and conducting audio-based environmental exploration. These findings support the concept of spatial presence theory which explains that immersive presence is formed when users feel themselves physically present in a mediated environment.

In immersive audio environments, spatial cues enhance environmental realism through perceptual coherence and embodied interaction[16]. This study expands this perspective by showing that auditory-spatial interaction not only increases perceptual realism but also stimulates bodily engagement and participatory interaction with the environment. The observed interaction patterns are also consistent with ecological approaches to auditory perception,

[15] Privitera, Fontana, and Geronazzo, "The Role of Audio in Immersive Storytelling: A Systematic Review in Cultural Heritage."
[16] Neidhardt, Schneiderwind, and Klein, "Perceptual Matching of Room Acoustics for Auditory Augmented Reality in Small Rooms - Literature Review and Theoretical Framework."

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which emphasize the role of environmental sound in shaping human interaction with the surrounding space[17].

1. In an immersive heritage environment, auditory cues serve as an active navigational and interpretive component that directs participants' attention and movement. This shows that spatial sound contributes to the formation of immersive environmental embodiment through synchronization of auditory-spatial perception. In addition, the results show that immersive presence becomes stronger when spatial audio, environmental ambience, and participant movement work as an integrated sensory system. This multisensory coherence seems important in building an immersive cultural experience that feels more realistic and emotional.
2. **Experiential Heritage Interaction and Cultural Preservation**
   This study shows that immersive auditory interaction can transform cultural heritage from static informational content into an experiential cultural environment that fosters participatory engagement and emotional involvement. Participants view heritage narratives more dynamically when auditory-spatial interaction is integrated into the exhibition environment. In these conditions, participants are no longer merely passive observers but experiential agents actively involved in the immersive cultural space. These findings align with recent developments in immersive heritage research that emphasize the shift from object-centered preservation to experience-centered cultural preservation[18]. Previous research has largely focused on technological preservation through digital reconstruction, XR visualization, and virtual museum systems[19].
3. However, this study shows that experiential engagement plays an important role in strengthening cultural attachment and heritage interpretation. The results also show that spatial sound contributes to experiential heritage interaction through embodied participation in the cultural environment. An interactive soundscape encourages exploratory behavior, environmental participation, and deeper narrative interpretation. These interaction patterns indicate that auditory immersion can strengthen participants' connection with local cultural identity through sensory-spatial experiences. This perspective

[17] Searchfield, "Tinnitus What and Where: An Ecological Framework."
[18] Mendoza, Franco, and Gómez, "Technologies for the Preservation of Cultural Heritage—A Systematic Review of the Literature"; Anastasios Theodoropoulos and Angeliki Antoniou, "VR Games in Cultural Heritage: A Systematic Review of the Emerging Fields of Virtual Reality and Culture Games," *Applied Sciences (Switzerland)* 12, no. 17 (2022), https://doi.org/10.3390/app12178476.
[19] Boboc et al., "Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications"; Wanti, Somantri, and Karyati, "Utilization of AR Technology for The Development of Speech Therapy Applications by Optimizing Marked-Based Tracking Method."

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reinforces the argument that immersive heritage preservation should not be limited to visual representation or technological reconstruction alone. Conversely, cultural preservation will be more effective when audiences engage emotionally and experientially through multisensory interaction. In this context, spatial sound emerges as an important medium that can increase cultural accessibility, emotional immersion, and experiential participation in the heritage environment.

4. **Theoretical Contributions of the Spatial Sound Experience Framework**

   The Spatial Sound Experience Framework developed in this study makes a theoretical contribution to immersive heritage and auditory-cultural immersion research. Previous research has extensively explored XR implementation, virtual reconstruction, spatial audio rendering, and immersive storytelling[20]. However, there is still very little research that develops an integrated conceptual framework for understanding how spatial sound shapes emotional-cultural immersion and experiential heritage interaction. The framework developed in this study builds on the previous immersive heritage model by positioning spatial sound as a core experiential architecture rather than merely a supplementary multimedia component. This framework integrates spatial sound stimulation, environmental immersion, emotional-cultural engagement, cultural presence formation, and experiential heritage interaction into a unified experience structure. This integration shows that immersive cultural experiences are formed through interconnected sensory, emotional, and spatial processes.

5. This framework also contributes to immersive media theory by introducing the concept of auditory-led immersion in an immersive heritage environment. While previous immersive research has predominantly emphasized visual immersion, this study shows that auditory-spatial interaction has a strong capacity to shape cultural atmosphere, environmental embodiment, and experiential participation. This conceptual contribution expands the understanding of immersive cultural interaction beyond the visual-technological paradigm that has dominated immersive heritage research. In addition, this framework presents the Indonesian cultural soundscape as an auditory-cultural immersion medium in immersive exhibition design. This contribution is important because immersive heritage research remains heavily dominated by Eurocentric and visually oriented perspectives. By integrating

[20] Hong et al., "Spatial Audio for Soundscape Design: Recording and Reproduction"; Wanti, Somantri, and Karyati, "Utilization of AR Technology for The Development of Speech Therapy Applications by Optimizing Marked-Based Tracking Method"; Privitera, Fontana, and Geronazzo, "The Role of Audio in Immersive Storytelling: A Systematic Review in Cultural Heritage."

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local auditory identity into immersive interactions, the framework offers a more contextual and experiential approach to cultural preservation.

6. **Practical Implications for Immersive Heritage Exhibition Design**

   The findings of this study have practical implications for developing immersive heritage exhibitions, digital museums, and cultural experience environments. This research shows that spatial sound should be positioned as the primary experiential component in immersive exhibition design, not merely a supporting audio element. Therefore, exhibition designers can integrate directional audio, an environmental soundscape, and responsive auditory interaction to enhance spatial immersion and visitors' emotional engagement.

   The integration of Indonesian cultural soundscape also creates opportunities for developing localized immersive storytelling and more contextual cultural communication. Heritage exhibitions can use the ambience of cultural rituals, traditional musical instruments, village environmental sounds, and oral narratives to create a more meaningful immersive cultural experience. This approach not only increases visitor engagement but also supports cultural preservation and public cultural awareness.

   The findings of this study are also relevant for creative media practitioners, immersive media designers, sound designers, and digital heritage developers. The framework developed can be used as a conceptual reference in designing immersive auditory-cultural interaction in museums, interactive exhibitions, virtual tourism environments, and digital heritage experiences. In addition, the use of iterative immersive prototyping in this study shows the importance of a participant-centered design process in the development of an experientially meaningful immersive environment.

7. **Methodological Contributions and Research Limitations**

   Methodologically, this research contributes to immersive heritage research by applying qualitative Design-Based Research (DBR) to explore immersive auditory-cultural experiences. Previous immersive heritage research was generally dominated by systematic reviews, technological assessments, engineering evaluations, and usability testing[21]. Instead, this study uses iterative immersive prototyping and participant-centered exploration to examine the experiential dimensions of spatial sound interaction.

   The use of DBR allows the framework to be developed through a continuous refinement process based on participant experience analysis, expert evaluation, and immersive

[21] Boboc et al., "Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications"; Mendoza, Franco, and Gómez, "Technologies for the Preservation of Cultural Heritage—A Systematic Review of the Literature."

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experimentation. This approach has proven to be effective in exploring complex experiential phenomena such as emotional immersion, cultural attachment, and environmental embodiment that are difficult to understand only through quantitative approaches. However, this study still has some limitations. First, the research was conducted in an immersive laboratory environment that is local so that ecological generalizations to large-scale public exhibitions are still limited. Second, the number of participants is relatively limited due to the exploratory and qualitative nature of the research. Third, the research framework still focuses on auditory-spatial interaction and has not integrated other multisensory dimensions such as haptic feedback or olfactory stimulation in depth. Despite these limitations, this research still provides a strong exploratory foundation for the development of immersive heritage research based on multisensory interaction and auditory-cultural immersion in future research.

8. Future Research Directions

Further research should explore integrating spatial sound with other multisensory immersive technologies, including haptic interaction, adaptive lighting systems, olfactory stimulation, and AI-generated soundscapes. This integration has the potential to enhance experiential immersion and environmental embodiment in immersive heritage spaces. Subsequent research can also conduct cross-cultural validation of the Spatial Sound Experience Framework across diverse cultural contexts to understand how localized auditory identity shapes immersive perception and emotional engagement. Comparative studies across various heritage environments will help develop an immersive framework that is more adaptive and culturally responsive. In addition, quantitative validation studies with larger samples are needed to strengthen the proposed empirical robustness framework. Longitudinal immersive experience studies can also provide a deeper understanding of the long-term effects of auditory-cultural immersion on cultural attachment, memory retention, and experiential heritage preservation.

CONCLUSION

The focus of this research is to improve the conceptual approach used to construct cultural experiences that span cultural heritage exhibitions across Indonesia. The results show that spatial sound not only serves as a supporting component of multimedia but is also a core experiential medium that shapes the presence of space, emotional engagement, cultural atmosphere, and legacy experiential interactions. The results prove that incorporating directional voices, environmental sound spaces, and voice-space interactions can enhance

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environmental realities and increase participants' participation in more engaging cultural experiences. In addition, the results of the study show that the Indonesian cultural voice space has great potential to function as an auditory-cultural identity in the formation of an attractive heritage environment. Emotional resonance, cultural familiarity, and deeper cultural ties can be built through local sound elements such as the atmosphere of cultural rituals, gamelan resonance, oral stories, and environmental soundscapes. As a result, immersive audience interaction can transform cultural heritage from a mere object of information into a cultural environment that allows audiences to experience culture emotionally, sensorially, and spatially.

Theoretically, this research contributes by developing the Spatial Sound Experience Framework. This framework integrates spatial sound stimulation, environmental influences, emotional-cultural engagement, the formation of cultural presence, and experiential interactions with cultural heritage into a unified experiential structure. This approach expands research on living heritage, which has been dominated by visual-centric approaches and heritage preservation technologies.

Practically, the results of this study provide implications for the development of immersive exhibitions, digital museums, and cultural experience environments based on spatial sound and cultural soundscapes. The resulting framework can serve as a conceptual reference for immersive media designers, sound designers, exhibition curators, and digital heritage practitioners in designing cultural experiences that are more interactive, emotional, and multisensory.

Although this research still has limitations in the context of the immersive laboratory environment and the relatively small number of participants, it provides a strong initial foundation for the future development of immersive auditory-cultural experience research. Further research can explore the integration of multisensory interaction, cross-cultural validation, and the implementation of large-scale immersive heritage exhibitions to advance the development of spatial sound-based experiential cultural preservation.

A. Artificial Intelligence (AI) Usage Statement

The author states that all research ideas, problem formulation, research design, framework development, data analysis, interpretation of results, discussion, and conclusion drawing in this article are the result of the author's original thoughts and work. Artificial Intelligence (AI) is used only as a tool for language editing, grammar checking, improving the readability of manuscripts, and improving the structure of academic writing. AI is not used to generate research data, analyze data, compile research results, make scientific interpretations,

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or make academic decisions related to the substance of the research. The entire content of the article has been reviewed, verified, and fully accounted for by the author.

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