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Conceptual Design of Interactive Virtual Museum Using Artificial Intelligence and Virtual Reality

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ABSTRACT

Traditional museums face challenges in preserving fragile artifacts and providing immersive experiences due to physical limitations and accessibility issues. This study aims to develop a conceptual design of an interactive virtual museum that integrates virtual reality and artificial intelligence to enhance cultural preservation and public engagement. The research adopts a descriptive qualitative design with a literature-based methodology, focusing on the analysis and synthesis of previous studies related to virtual museums and immersive technologies. The conceptual design emphasizes four main components: a virtual reality module that provides an interactive 3D museum environment, an artificial intelligence module that offers adaptive guidance and recommendations, a database module that stores digital artifacts and interaction records, and a user interface that connects visitors with the system. The results present a comprehensive conceptual framework that illustrates how virtual reality and artificial intelligence can be combined to create a more engaging and accessible museum experience. The study concludes that integrating these technologies offers an innovative solution for digital cultural preservation, enabling people to explore museum collections without physical constraints while maintaining educational and historical values. This conceptual design serves as a foundation for future research and practical implementation of virtual museum systems that promote both cultural sustainability and technological advancement.

1. Introduction

Museums serve as an important place for preserving cultural heritage and providing educational experiences for the public, regardless of age. However, in the twenty-first century, rapid technological developments have reshaped how people access information, interact with historical artifacts, and engage with cultural institutions, as such museum must adapt to stay relevant [1]. As highlighted in the abstract, traditional museums face persistent challenges, including limited accessibility due to geographical constraints, fragile artifacts that restrict physical interaction, and the inability to provide immersive experiences that modern audiences expect [2][3]. Many cultural objects are sensitive to light, humidity, and excessive handling, which complicates preservation efforts and limits the depth of learning that can occur during on-site visits.

Virtual museums have emerged as a promising solution to these challenges. A virtual museum constitutes a digital repository of images, useful information, and virtual exhibition of an artifacts, which can be accessed via electronic platforms [4]. Through virtual reality environments, user can remotely explore collections using computers, mobile devices, or VR headsets, thereby expanding accessibility while reducing risks to fragile physical artifacts. This aligns with the broader need for more sustainable and widely accessible methods of cultural preservation raised in the abstract.

Furthermore, recent studies indicate that virtual museum platforms are beginning to incorporate narrative-driven personalization to enhance user engagement. Findings show that spatially generated narratives can guide visitors through coherent exploratory paths, allowing for more meaningful and immersive cultural experiences within virtual environments as the user seems to engage more with the exhibits [5]. This reflects increasing academic interest in virtual museum systems that do not merely display digital artifacts but actively shape user experience through adaptive storytelling.

Building upon this movement toward personalization, research on AI-enabled museum systems suggests that, although learning outcomes do not differ significantly between AI-enhanced and non-AI systems, artificial intelligence still offers considerable potential to improve user experience. A studies highlights that AI could support digital accessing and manage collections, positioning it as a complementary technology that enhance visitor engagement in virtual museum environments [6].

In light of these identified gaps, this study endeavors to conceptualize an interactive virtual museum system that integrates VR and AI as an innovative strategy for cultural preservation. This research employs a literature-based conceptual development methodology, synthesizing theories and findings from preceding studies to generate an architectural model, interaction flow, and conceptual user interface design. The aim is not to create a functional

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prototype but rather to lay the groundwork for future system development and offer insights for cultural institutions aspiring to implement digital preservation technologies.

The expected contribution of this study includes: (1) offering a conceptual model for an AI-supported VR museum, (2) identifying opportunities and challenges in applying immersive and intelligent technologies for cultural preservation, and (3) supporting digital transformation efforts within museums, especially in Indonesia, through accessible, adaptive, and engaging virtual environments.

2. Background of the Study / Related Work

Technological innovation in the cultural sector has transformed how museums operate, with Virtual Reality (VR) and Artificial Intelligence (AI) becoming key enablers for digital preservation and interactive education. Virtual museums offer an alternative means for visitors to explore historical artifacts without the constraints of location, time, or physical limitations of traditional exhibits. Incorporating digital tools into the way people visit and explore museums is sure to elevate their overall experiences [7], as they are designed not only to replicate real museum spaces but also to create new, immersive experiences that enhance user engagement and cultural learning [4][8].

Research on virtual museums has expanded significantly over the past decade, with many studies highlighting the potential of immersive technologies to enhance cultural learning. Several studies emphasize that virtual reality environments improve user engagement by enabling realistic 3D exploration and embodied interaction with cultural artifacts, allowing visitors to experience historical content in ways that are not possible in physical museum spaces [9][10][11]. Other reviews also indicate that VR-based museum systems can increase motivation, support experiential learning, and provide accessible alternatives for audiences who cannot visit museums physically [3][12].

In addition to general immersion, some virtual museum projects focus on interactive 3D design and visitor-centered navigation. Studies demonstrate that well-designed VR interfaces and spatial layouts contribute to higher satisfaction, especially when combined with intuitive interaction models and culturally authentic visual representations [13][14]. These findings indicate that VR is not only a tool for visualization but also a medium for meaningful cultural engagement [15].

While VR innovation continues to grow, the integration of artificial intelligence into virtual museum systems remains relatively limited. Existing studies on AI-assisted museum environments reveals that AI can support context-aware explanations, guide visitors through exhibitions, and adapt content based on user behavior [16][17][18]. Studies in related domains also confirm that generative AI can enhance interactive storytelling and improve the accessibility of cultural information within immersive environments [19]. However, despite these promising capabilities, real-world applications in museums often fall short.

Studies on digital transformation within museum ecosystems also show that institutional adoption of virtual exhibitions increased significantly after the pandemic, yet many implementations remain limited to basic virtual tours or digitized collections [20]. These systems often lack user personalization, intelligent recommendations, and dynamic interaction models, leaving opportunities for more advanced VR and AI integrations that can provide deeper educational impact and cultural preservation value.

Overall, previous research provides valuable insights into VR immersion, interactive design, and AI-assisted guidance. However, no existing work offers a comprehensive conceptual model that unifies VR environments with AI-driven personalization specifically for digital cultural preservation. This gap highlights the need for a structured conceptual design that combines immersive visualization with intelligent adaptation to support a more engaging virtual museum experience.

3. Research Method

This study adopts a qualitative descriptive design supported by a structured literature review. The method is used to analyze theoretical foundations, previous studies, and technological trends related to Virtual Reality and Artificial Intelligence in the context of digital museum development. Descriptive qualitative research aims to systematically interpret phenomena and derive conceptual insights based on secondary data rather than empirical experimentation, making it suitable for conceptual system development [12][21].

Data Sources

The study relies entirely on secondary data obtained from peer-reviewed journals, conference proceedings, and academic books related to VR, AI, digital heritage, and virtual museums. The primary data sources include digital academic databases such as Scopus, Frontiers, ScienceDirect, Artnodes, SCIRES-IT, and other Scopus-indexed journal. Priority was given to publications from the past five years to ensure relevance and technological accuracy, except for seminal works needed for definitions.

Data Collection Technique

The data collection process was conducted in the following steps:

a) Identification of Keywords
   Keywords such as virtual museum, virtual reality museum, artificial intelligence in museums, virtual reality in museums were used in databases including Scopus, Frontiers, ScienceDirect, Artnodes, SCIRES-IT, and other Scopus-indexed journal.

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b) Screening and Eligibility Filtering
Literature was filtered based on relevance, publication year (2020–2025), and Scopus indexation. Studies about VR immersion quality, virtual interaction design, AI-based museum systems, and adaptive cultural displays were prioritized.
c) Data Extraction
Extracted data included VR visualization techniques, AI-driven interaction models, user experience evaluation patterns, and existing limitations in digital museum implementations [3][22][23].
d) Synthesis and Interpretation
The synthesis was then used as the basis for constructing the conceptual model presented in this paper. Similar findings were grouped to form thematic patterns, including immersive environment design, adaptive mechanisms, user interaction problems, and digital heritage challenges. Comparative synthesis was then used to identify the research gap in current VR–AI museum integration.

Data Analysis Procedure

The study employs content analysis, enabling the researcher to interpret and classify information from literature sources into thematic categories such as:

a) immersive museum environments.
b) AI-driven personalization and guidance.
c) user experience factors.
d) digital preservation strategies.
e) limitations of existing virtual museum systems.

Content analysis is commonly employed in virtual museum research to interpret patterns in user interaction studies and evaluate the conceptual design of AI and VR-integrated interactive systems [24].

Expected Output

The expected output is a conceptual model for an interactive virtual museum integrating VR and AI. This includes architectural representation, interaction workflow diagrams, and conceptual user interface structures. The method enables systematic evaluation of potential system benefits, identification of design limitations, and formulation of recommendations for future implementation studies.

4. Results and Discussion

This section presents the results of the literature analysis and the conceptual design derived from it. The discussion focuses on how Virtual Reality (VR) and Artificial Intelligence (AI) can be integrated to enhance the museum experience while supporting the preservation of cultural heritage.

Key Findings from Literature

The review revealed three main trends in current research on virtual museums:

a) Virtual Reality as an Immersive Learning Medium
Recent studies highlight that VR technologies significantly increase visitor engagement and emotional connection with historical artifacts. Immersive 3D environments allow user to explore collections interactively while minimizing physical contact, thus preserving fragile cultural assets [5][8][10][13]. These findings are consistent with evidence showing that VR-based museums foster deeper memory retention and contextual understanding through experiential interaction [9][25].
b) Artificial Intelligence for Personalization and Guidance
The integration of AI has introduced adaptive storytelling and personalized recommendations within digital museum environments. AI-driven virtual assistant enhance accessibility and learning by tailoring information to user interests [6][18]. Moreover, recent implementations demonstrate that combining AI with VR provides dynamic narrative generation and responsive visitor support through intelligent dialogue systems [16].
c) Integration Challenges and Accessibility
While VR delivers immersion, accessibility and cost barriers remain. Studies emphasize that hybrid or web-based museum systems could bridge this gap by allowing broader access to collections through standard devices [11][21]. These findings indicate that a well-designed conceptual framework combining VR and AI can improve learning quality, inclusivity, and sustainability in digital museum environments [8].

Conceptual Architecture Design

Based on the synthesis of the reviewed studies, a conceptual architecture for the interactive virtual museum is proposed. The architecture consists of four primary modules that work collaboratively:

a) Virtual Reality Module: provides a 3D navigable museum environment where users can explore artifacts virtually.
b) Artificial Intelligence Module: handles the virtual guide system, personalized suggestions, and adaptive interactions.
c) Database Module: stores artifact metadata, descriptive texts, 3D models, and user interaction logs.
d) User Interface Module: serves as the visual and interactive bridge between users and the system.

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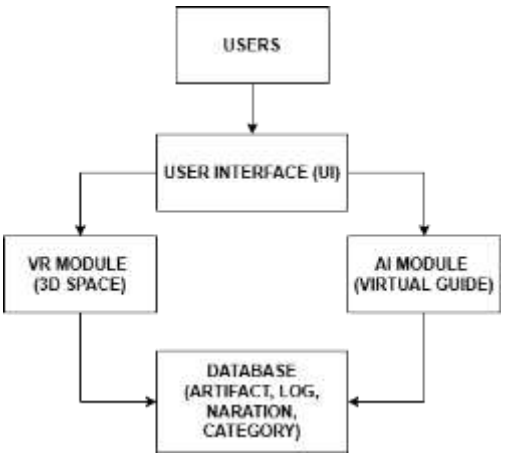

Figure 4. 2. Application Architecture Diagram

The interaction begins with the user interface connecting to VR devices via an adaptive storytelling platform. The platform retrieves contextual user data through meta-models to generate adaptive narration and feedback, ensuring seamless integration between immersion and information management. [23].

Conceptual ERD & Database Design

The conceptual database is structured to support cultural preservation and personalized experiences. Stored entities include:

a) Artifact: 3D model, description, origin, historical era.
b) Category: classification by culture, era, or type.
c) AI Narratives: dialogue and contextual explanations for the virtual guide.
d) User Interaction Logs: behavior, visit duration, and preferences for personalization.

This flexible model aligns with digital archiving practices used in virtual heritage systems [8].

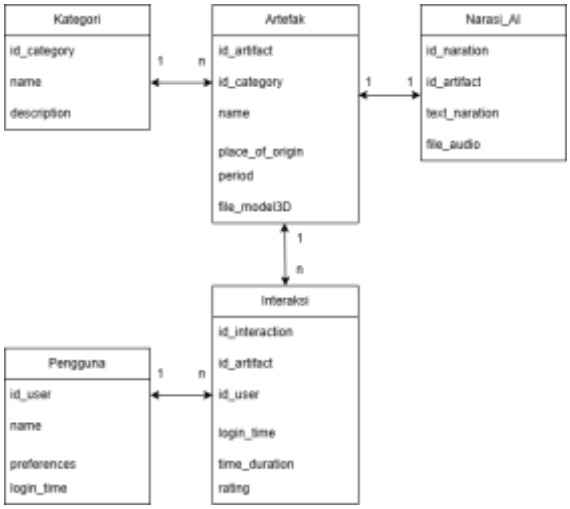

Figure 4. 3.ERD Conceptual

User Interface Design (Mock-up Based)

The User Interface (UI) is designed conceptually to support intuitive navigation and allow efficient access to museum features. A mock-up created using Figma represents the following key UI components:

a) Home Page: contains menus to start the virtual tour, a list of collections, and information about the museum.
b) Virtual Museum Map: displays a 3D floor plan of the exhibition space and assists user navigation.
c) 3D Exhibition Room: an area where users can explore the collection and interact with artifacts through virtual controls.
d) AI Virtual Guide: a digital character that provides explanations, answers questions, and recommends other relevant artifacts.

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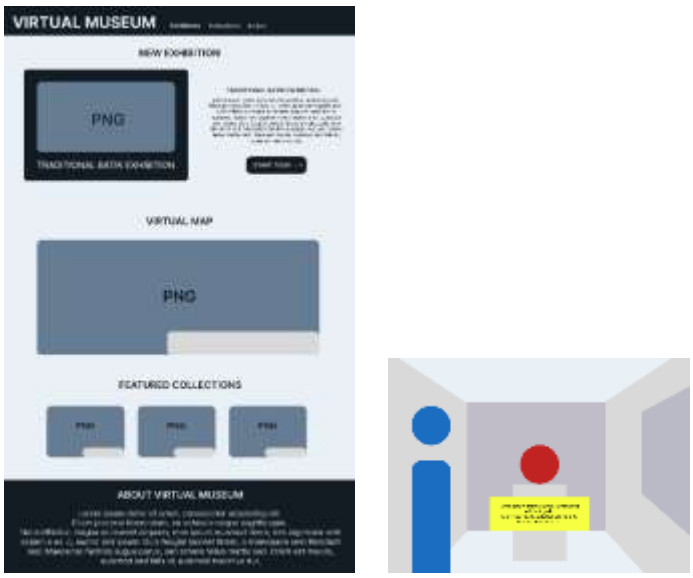

(a) (b)

Figure 4. 4. (a) Main Display Wireframe, (b) View User in the Virtual Exhibit, with AI Guide (Blue), Artifacts (Red), and Artifact Info (Yellow)

Interaction Flow

Interaction flow describes how users navigate and interact with the VR-AI museum. Here's the general flow:

a) Entering the System (Login/Guest Mode)
b) Exploring Exhibition Spaces with VR navigation tools.
c) Interacting with Artifact, triggering descriptive and narrative content.
d) AI Virtual Guide Activation, offering adaptive explanations.
e) Personalized Recommendations, adjusting exploration paths based on user preferences.

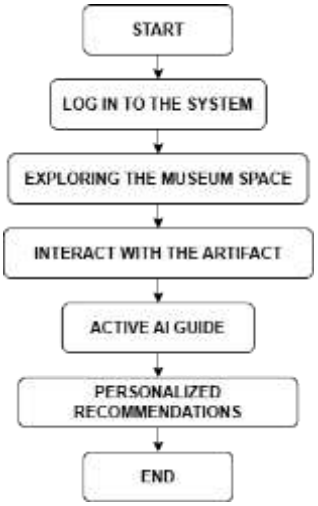

Figure 4. 5. Interaction Flow

This flow aligns with patterns found in AI-enhanced museum agents and VR narrative systems [16][18].

Conceptual Analysis and Discussion

The conceptual model demonstrates that combining VR and AI offers significant potential for cultural preservation and immersive learning. VR provides spatial immersion and reduced artifact handling risks, while AI enhances personalization and responsive storytelling [5]. Furthermore, the database model supports scalable digital archiving and the architecture enables hybrid access, supporting both VR headsets and standard devices, addressing digital divide challenges highlighted in online museum research [21]. This conceptual basis may guide cultural institutions and educational organizations in developing scalable, adaptive, and accessible virtual museum systems.

The conceptual model also aligns with recent insights on immersive museum practices, which emphasize that virtual environments must not only replicate physical spaces but also construct meaningful experiential conditions for visitors. Studies discussing immersive speculative environments highlight that VR can evoke embodied engagement and multisensory presence, enabling cultural spaces to function as exploratory and

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reflective domains rather than static displays [26]. Similarly, research on estrangement and immersion demonstrates that well-crafted virtual experiences can reshape visitor perception by combining spatial immersion with contextual narrative cues, producing deeper cognitive and emotional engagement within virtual museum settings [27]. These perspectives reinforce the relevance of the proposed model, suggesting that the integration of VR and AI must prioritize experiential coherence, narrative clarity, and visitor agency to support meaningful cultural interpretation.

5. Conclusions

This study conducted a comprehensive literature review to develop a conceptual model for an interactive virtual museum integrating Virtual Reality and Artificial Intelligence. The analysis shows that VR contributes significantly to immersive cultural learning experiences, while AI enhances user interaction through adaptive guidance and personalized content delivery. However, most existing studies focus on VR-only systems, with limited integration of AI-driven features. Based on these findings, the study proposes a conceptual system architecture consisting of four key modules: User Interface, Virtual Reality, Artificial Intelligence, and Database. This model aims to address current limitations by combining immersion, accessibility, and personalization in a unified framework.

The main contribution of this research is the formulation of a structured and scalable conceptual model that may serve as a foundation for future development of virtual museum systems. This model supports both cultural preservation and inclusive digital access, offering alternative solutions to challenges faced by physical museums, such as distance barriers and artifact fragility. The implications of this study highlight the potential of integrating immersive and intelligent technologies to enhance cultural education, support digital archiving, and increase public engagement with cultural heritage. The conceptual model can be adopted by researchers, cultural institutions, or system developers seeking to modernize museum experiences through digital technologies.

6. Limitations and future works

Despite its contributions, the study has several limitations. The research is conceptual and relies solely on secondary data from literature, without practical implementation or user evaluation. The model has not yet been tested in real-world conditions, and its effectiveness remains theoretical. Future studies may expand this work by developing a functional prototype, conducting user experience testing, evaluating the performance of AI-driven recommendations, and exploring multi-user interaction within virtual museum environments. Additional research can also examine accessibility strategies and cross-platform optimization to support wider user participation.

7. References

[1] J. Q. H. Yap, Z. Kamble, A. T. H. Kuah, and D. Tolkach, "The impact of digitalisation and digitisation in museums on memory-making," *Current Issues in Tourism*, vol. 27, no. 16, pp. 2538–2560, 2024, doi: 10.1080/13683500.2024.2317912.

[2] Z. Gao and T. Braud, "VR-driven museum opportunities: digitized archives in the age of the metaverse," *Artnodes*, vol. 2023, no. 32, pp. 1–14, 2023, doi: 10.7238/artnodes.v0i32.402462.

[3] C. C. de Araújo, F. de L. dos S. Nunes, and J. M. X. N. Teixeira, "User Experience Evaluation in Virtual Museum Tours: A Scoping Review (2014-2024)," *Journal of the Brazilian Computer Society*, vol. 31, no. 1, pp. 717–729, Jan. 2025, doi: 10.5753/jbcs.2025.5715.

[4] T. P. Kersten, F. Tschirschwitz, and S. Deggim, "Development of a virtual museum including a 4D presentation of building history in virtual reality," in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, International Society for Photogrammetry and Remote Sensing, Feb. 2017, pp. 361–367. doi: 10.5194/isprs-archives-XLII-2-W3-361-2017.

[5] Y. Chen, T. Tang, X. Chen, Y. Li, Q. Liu, and X. Wang, "VirtuNarrator: Crafting museum narratives via spatial layout in creating customized virtual museums," *Visual Informatics*, p. 100257, Sep. 2025, doi: 10.1016/j.visinf.2025.100257.

[6] M. Kiourexidou and S. Stamou, "Interactive Heritage: The Role of Artificial Intelligence in Digital Museums," *Electronics (Switzerland)*, vol. 14, no. 9, May 2025, doi: 10.3390/electronics14091884.

[7] A. N. Hijazi and H. Baharin, "The Effectiveness of Digital Technologies Used for the Visitor's Experience in Digital Museums. A Systematic Literature Review from the Last Two Decades," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 16, pp. 142–159, 2022, doi: 10.3991/ijim.v16i16.31811.

[8] B. D. Oladokun, Y. A. Ajani, B. C. N. Ukaegbu, and E. A. Oloniruha, "Cultural Preservation Through Immersive Technology: The Metaverse as a Pathway to the Past," *Preservation, Digital Technology and Culture*, vol. 53, no. 3, pp. 157–164, Oct. 2024, doi: 10.1515/pdtc-2024-0015.

[9] M. K. Bekele and E. Champion, "A Comparison of Immersive Realities and Interaction Methods: Cultural Learning in Virtual Heritage," *Front Robot AI*, vol. 6, Sep. 2019, doi: 10.3389/frobt.2019.00091.

DOI: https://doi.org/10.65126/jocosir.v2i3

ISSN 2502-3357 (Online)
[10] W. Zhao, L. Su, and F. Dou, "Designing virtual reality based 3D modeling and interaction technologies for museums," *Heliyon*, vol. 9, no. 6, Jun. 2023, doi: 10.1016/j.heliyon.2023.e16486.
[11] P. Gutowski and Z. Klos-Adamkiewicz, "Development of e-service virtual museum tours in Poland during the SARS-CoV-2 pandemic," in *Procedia Computer Science*, Elsevier B.V., 2020, pp. 2375–2383. doi: 10.1016/j.procs.2020.09.303.
[12] A. Soraya and Y. Sigit Martyastiadi, "Aesthetics of Virtual: The Development Opportunities of Virtual Museums in Indonesia," *International Journal of Creative and Arts Studies*, vol. 6, 2021.
[13] A. S. Hackenbroich, G. Taylor, and R. Williams, "Digging up Memories – Empowering collections at Vindolanda Museum through virtual exhibits," *Digital Applications in Archaeology and Cultural Heritage*, vol. 29, Jun. 2023, doi: 10.1016/j.daach.2023.e00267.
[14] G. Resta, F. Dicuonzo, E. Karacan, and D. Pastore, "THE IMPACT OF VIRTUAL TOURS ON MUSEUM EXHIBITIONS AFTER THE ONSET OF Covid-19 restrictions: visitor engagement and long term PERSPECTIVES," *SCIRES-IT*, vol. 11, no. 1, pp. 151–166, 2021, doi: 10.2423/i22394303v11n1p151.
[15] S. Aufenanger *et al.*, "Immersive virtual reality learning environments for higher education: A student acceptance study," *Computers and Education: X Reality*, vol. 7, Dec. 2025, doi: 10.1016/j.cexr.2025.100105.
[16] O. Shlyakhetko, S. Fedushko, M. Gregus, and L. Brych, "Smart Exhibits: AI Integration in Modern Museums," in *Procedia Computer Science*, Elsevier B.V., 2025, pp. 754–761. doi: 10.1016/j.procs.2025.03.097.
[17] Y. Wang and Y. Li, "Application of Artificial Intelligence Algorithm in Indoor Virtual Display System," in *Procedia Computer Science*, Elsevier B.V., 2023, pp. 1294–1301. doi: 10.1016/j.procs.2023.11.069.
[18] P. Ariya, S. Khanchai, K. Intawong, and K. Puritat, "Enhancing textile heritage engagement through generative AI-based virtual assistants in virtual reality museums," *Computers and Education: X Reality*, vol. 7, Dec. 2025, doi: 10.1016/j.cexr.2025.100112.
[19] C. Ciurea and F. G. Filip, "Collaboration in the AI Era - Creative AI and Virtual Exhibitions," in *Procedia Computer Science*, Elsevier B.V., 2025, pp. 198–204. doi: 10.1016/j.procs.2025.08.025.
[20] N. Mustika, S. Suhaeb, Mirfan, A. Aman, A. M. A. K. Parewe, and N. Lachlan, "Virtual Tour Web System as a Guide and Entrepreneurial Tool for Tourism in Selayar," *APTISI Transactions on Technopreneurship*, vol. 7, no. 2, pp. 663–675, Jul. 2025, doi: 10.34306/att.v7i2.574.
[21] F. Zhang, "Virtual space created by a digital platform in the post epidemic context: The case of Greek museums," *Heliyon*, vol. 9, no. 7, Jul. 2023, doi: 10.1016/j.heliyon.2023.e18257.
[22] S. Sylaiou and C. Fidas, "Virtual Humans in Museums and Cultural Heritage Sites," *Applied Sciences (Switzerland)*, vol. 12, no. 19, pp. 1–21, Oct. 2022, doi: 10.3390/app12199913.
[23] C. Khundam and F. Nöel, "Evaluation of adaptive interaction systems for virtual museum development," *Trends in Sciences*, vol. 18, no. 24, Dec. 2021, doi: 10.48048/tis.2021.1405.
[24] C. Ciurea, P. Pocatilu, and S. V. Oprea, "Attractiveness of Virtual Exhibitions in Cultural Institutions in the Post-pandemic Context: A Case Study," in *Procedia Computer Science*, Elsevier B.V., 2023, pp. 308–315. doi: 10.1016/j.procs.2023.07.042.
[25] Z. J. Long and A. Fuad, "Perancangan Dan Implementasi Museum Virtual Untuk Edukasi Dan Sosialisasi Kebudayaan Tionghoa Benteng Dari Kota Tangerang," *Scientica Jurnal Ilmiah Sain dan Teknologi*, p. 956, Aug. 2024.
[26] J. Pykett, K. Facer, C. Valladares-Celis, and B. Williamson, "Virtual flying carpets and digital disaster rooms: Towards a critical analysis of immersive speculative environments in Museums of the Future," *Futures*, vol. 172, Sep. 2025, doi: 10.1016/j.futures.2025.103643.
[27] E. Spiers *et al.*, "Estrangement, immersion, and the future: Designing the speculative environments of the virtual reality 'Museum of the Future,'" *Futures*, vol. 138, Apr. 2022, doi: 10.1016/j.futures.2022.102922.