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Implementing Virtual Reality and the Metaverse to Preserve the Culture of the Baileo Negeri Rutong House, Maluku

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Abstract

This research was conducted to introduce the Baileo Traditional House of Negeri Rutong, located in Ambon City, Maluku Province, which holds significant philosophical, religious, historical, and cultural values. Maluku, one of the provinces in Indonesia, is rich in diverse cultural heritage, including the philosophy of the Baileo Traditional House in Negeri Rutong. Baileo is a traditional communal house in Maluku, playing a central role in the local community's life. This traditional house needs to be preserved so that it can become a world attraction and a valuable cultural heritage for future generations. The purpose of this research is to develop Virtual Reality (VR) and the Metaverseas suitable media to introduce the Baileo traditional house to the world and to study the effectiveness of these media in preserving and conserving the traditional house. A design-based approach is used in this research to ensure that the development of VR and the Metaverse is conducted properly and effectively. The research stages include problem identification and needs assessment, planning and design, system development, evaluation and implementation, as well as maintenance and further development..

Keywords: *Virtual Reality; Metaverse; Baileo Traditional House; Rutong Country; Philosophy*

1. Introduction

In the contemporary digital era, cultural heritage institutions are increasingly adopting advanced technology frameworks to redefine visitor accessibility, engagement and experience.(Mestiri et al., 2025)In particular, the integration of virtual reality and the metaverse represents a new paradigm in the preservation and promotion of cultural heritage, offering an immersive platform for digital reconstruction, educational outreach, and global accessibility.(Buragohain et al., 2024)This approach not only allows for the digital preservation of vulnerable artifacts and sites, but also expands the audience beyond geographic boundaries, promoting cultural understanding and appreciation globally.(Buragohain et al., 2024) (Aziz et al., 2024)The purpose of this study is to investigate the application of VR and Metaverse technologies in preserving the cultural heritage of Rumah Baileo Negeri Rutong in Maluku, known for its traditional architecture and historical significance. This study aims to address the physical preservation challenges faced by heritage sites, while simultaneously harnessing the potential of immersive technologies to create interactive, educational experiences for users worldwide. Digital preservation efforts through metaverse emerge as an innovative approach to protect, experience, and educate about architectural wonders such as Rumah Baileo.(Buragohain et al., 2025). Traditional approaches to cultural preservation often rely on physical methods such as museum displays and historical records, but immersive technology has brought about a significant transformation in engagement with digital content.(Oladokun et al., 2024). Virtual reality and metaverse technologies provide immersive and interactive experiences that transcend the boundaries of physical space and time, allowing users to explore and interact with digitally reconstructed cultural environments.(Oladokun et al., 2024)This technological application allows users to interact with a simulation of the Baileo House, understand its architectural structure, and delve deeply into its cultural context, without having to be physically present at the site. Through this approach, metaverse technology offers revolutionary potential for cultural preservation, enabling virtual representations of historical sites, monuments, artworks, and rituals with unparalleled accuracy and interactivity.(Oladokun et al., 2024)This approach is particularly relevant given the ongoing physical conservation challenges faced by heritage sites, which are often vulnerable to environmental degradation, natural disasters, and the impacts of globalization.(Buragohain et al., 2024). Therefore, the implementation of VR and metaverse technologies not only protects cultural heritage from physical damage, but also expands accessibility and allows for the preservation of its original form for future generations.(Kawato et al., 2021)The use of data science and artificial intelligence, such as deep learning, can be integrated to analyze cadastral data and automate the process of delineating agricultural land parcels, which is relevant for the protection and spatial planning of cultural heritage.(Utilization of Data Science and Artificial Intelligence in Cadastral Data Analysis for Various Purposes, nd)The evolution of cadastral data utilization from paper-based to digital systems, particularly with the integration of Geographic Information Systems, demonstrates the potential for digital transformation that underlies the implementation of AI and data science in the context of cultural preservation.(Utilization of Data Science and Artificial Intelligence in Cadastral Data Analysis for Various Purposes, nd)Artificial intelligence technology has been proven to transform educational curriculum and will change the face of the world of education as a whole, providing an immersive and interactive learning experience for students.(Raup et al., 2022)Specifically, immersive technologies including virtual reality, augmented reality, mixed reality, expanded reality, and the metaverse are transforming the field of

cultural heritage education by enabling new forms of interaction and experiences that are far more immersive than traditional learning methods.(Anwar et al., 2025). Thus, this technology not only supports contemporary student-centered and immersive learning models, but also enriches traditional models through adaptive elements of interactivity and personalization.(Larasati, nd). By leveraging the metaverse platform, it is possible to create an accurate virtual representation of the Baileo House, allowing users to interactively explore its architecture, history, and cultural context, similar to visiting the original site.(Buragohain et al., 2025)This approach has great potential to preserve endangered cultural heritage sites and expand their accessibility globally, making them an invaluable educational resource for future generations.(Buragohain et al., 2024) (Anwar et al., 2025)Utilizing machine learning can analyze user interactions in the metaverse, identify interest patterns, and dynamically adapt the cultural content presented, thereby optimizing the learning experience and engagement.(Raup et al., 2022) (Larasati, nd). Thus, the implementation of VR and Metaverse in the context of Rumah Baileo is expected to create an innovative model for cultural preservation, one that not only maintains the authenticity of the heritage but also enriches educational experiences and public interaction with it.

2. Basic Theory

Relevant theoretical foundations include concepts from virtual reality technology, the metaverse, digital cultural heritage preservation, and human-computer interaction theory that underpin immersive experience design. Furthermore, pedagogical theories relevant to immersive learning and user experience are also fundamental in designing the VR and Metaverse implementation for Rumah Baileo, ensuring that the experiences presented are not only immersive but also effective in conveying cultural values.(Anwar et al., 2025). Thus, a deep understanding of these principles is crucial to ensure that the digital representation of Rumah Baileo is not only technically accurate but also rich in cultural context and meaning, so that the virtual experience can approximate the physical experience.(Chamola et al., 2025).

2.1. Virtual Reality (VR)

Virtual Reality provides a simulated environment that can be experienced immersively by users through specialized devices, such as VR headsets (Abukarki, 2025) . This technology allows individuals to interact with virtual objects and simulated environments as if they were physically present, providing an immersive and multidimensional experience (Serghides et al., 2024) . The application of VR in the context of the Baileo House allows for the digital reconstruction of architecture and cultural artifacts, providing users with a richly detailed exploration experience. This immersive experience can include interactive virtual tours, narrative-based storytelling, and simulations of cultural activities that once took place at the Baileo House, thereby enriching visitors' understanding of the cultural heritage. Through high interactivity, users can manipulate objects, move freely within the virtual space, and even participate in replicated scenarios, intensifying emotional and cognitive connections with the cultural heritage (Larasati, n.d.) .

2.2. Metaverse

The metaverse, as an evolution of the internet, offers a persistent and interconnected 3D virtual space, where users can interact with each other and with digital objects in a collectively shared environment. Unlike the traditional internet, the metaverse promises more immersive, authentic, and diverse digital experiences, merging physical and virtual reality through advanced technologies such as VR, AR, AI, and blockchain (Yang et al., 2024) . In the context of cultural preservation, the metaverse provides a unique platform for creating a globally accessible digital replica of the Baileo House, allowing visitors from various locations to explore, learn, and interact with Maluku's cultural heritage (Shamim et al., 2024). (Oladokun et al., 2024) . This platform goes beyond conventional digital museums by facilitating social interaction and collaboration between users, for example through participation in virtual cultural events or the creation of creative content related to Rumah Baileo (Buragohain et al. , 2024). (Aziz et al., 2024) . The potential of the Metaverse in cultural preservation is particularly prominent due to its ability to integrate various immersive technologies, such as Virtual Reality and Augmented Reality, to create a more immersive and interactive experience compared to traditional digital conservation methods (Oladokun et al., 2024). (Ebrahimzadeh & Safa, 2024) . Thus, the metaverse enables the preservation of endangered cultural assets and provides unprecedented accessibility to a global audience, transforming the way individuals interact with history and traditions (Buragohain et al., 2025) .

2.3. Baileo Culture House

The Baileo Cultural House is a form of traditional Maluku architecture rich in historical and sociocultural values, serving as a center for customary deliberation and communal activities among indigenous communities. The physical structure and decorative elements of the Baileo House often harbor profound symbolism reflecting the beliefs, customs, and social hierarchies of the local community, making it an important object of study in cultural heritage preservation. Therefore, the implementation of VR and Metaverse technology offers an innovative approach to documenting, reconstructing, and presenting the Baileo House and its cultural narratives immersively to a wider audience, both for educational and preservation purposes. The use of this technology not only allows for detailed visualization of the architecture but also the reconstruction of cultural practices that once took place within it, such as traditional ceremonies or important meetings. Thus, this digitalization has the potential to revitalize the Baileo House's function as a center of cultural activity in a virtual dimension, enabling rich and in-depth interactions with ancestral heritage (Buragohain et al., 2024) . This is crucial considering that cultural preservation encompasses not only physical artifacts but also traditions, customs, and practices that define a community's identity (Oladokun et al., 2024) . This digital approach is also a strategic solution for preserving cultural objects that are difficult to access or have been damaged, as well as mitigating the risk of cultural loss due to natural and social factors (Elfizar et al., 2020) . The use of VR and the Metaverse in this context opens up opportunities to create dynamic digital archives, not only as static repositories but also as interactive platforms that enable contextual reconstruction and re-experience.

3. Research Methodology

This research uses a qualitative approach with a descriptive case study, focusing on an in-depth analysis of the potential and challenges of implementing immersive technology (Buragohain et al., 2024). (Pérez et al., 2024) . This methodology will involve data collection through participant observation, in-depth interviews with cultural stakeholders, and document analysis related to the architecture and function of

the Baileo House. The next steps will be to design an ethical framework to ensure accurate and sensitive cultural representation, as well as to develop an initial prototype of a VR application for the Baileo House (Utilization of Data Science and Artificial Intelligence in Cadastral Data Analysis for Various Purposes, n.d.) (Wathon, 2024) (Talani et al., 2023) . Prototype evaluation will involve user trials to gather feedback on the immersive experience, ease of navigation, and accuracy of cultural representation. Qualitative data analysis will then be used to refine the prototype and formulate comprehensive recommendations for the full implementation of VR and Metaverse in the preservation of the Baileo Cultural House. An ethnographic approach will also be applied to holistically understand the cultural elements that bind individuals within the socio-cultural group surrounding the Baileo House, including behavioral patterns, belief systems, language, and relevant cultural values (Abdussamad, Zuchri, 2021) . This approach allows researchers to comprehensively interpret and describe what is observed from the perspective of community members, including group history, social structure, politics, religious beliefs, symbols, customs, rituals, and the environment (Rasyid et al., 2022) . This ethnographic research will attempt to capture a holistic view of the culture associated with Rumah Baileo, looking beyond the immediate events to understand the larger context in which traditions and practices occur (Rasyid et al., 2022) . Thus, the ethnography in this research will provide a strong theoretical foundation for the design of authentic VR and Metaverse experiences, ensuring that digital representations of Rumah Baileo are not only visually accurate but also rich in cultural meaning (Abdussamad, Zuchri, 2021) .

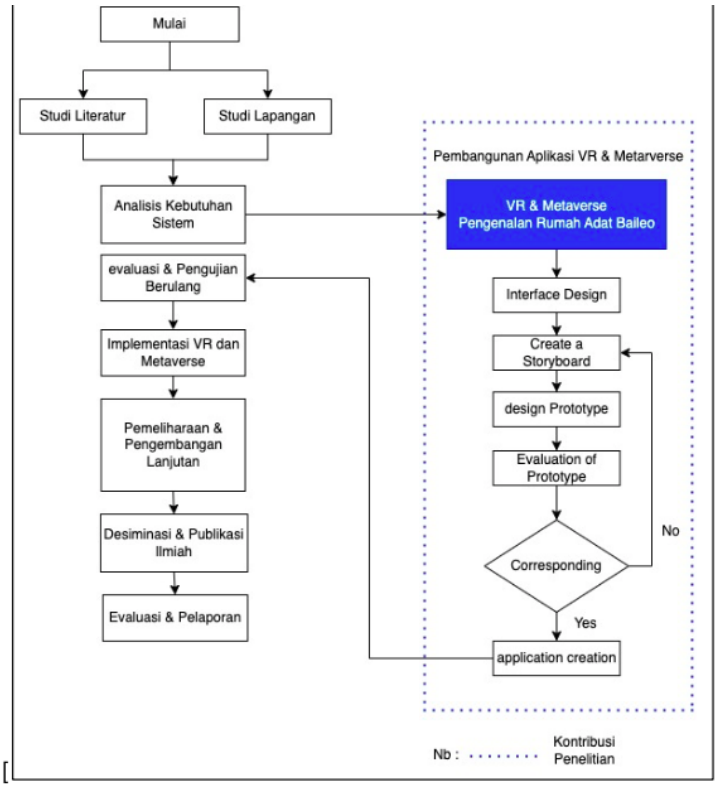


Fig. 1: Research Flowchart

3.1. Research Design

A qualitative research design was chosen because it allows researchers to delve deeply into the cultural values and social interactions surrounding the Baileo House, in line with the goal of understanding complex social and cultural phenomena (Sulistyawati, 2023) . This approach also allows for the exploration of hidden stories and local wisdom woven into this architectural masterpiece through immersive site visits and in-depth data collection (Suprapto et al., 2024) . Ethnographic research, in particular, will be crucial in this endeavor, as it allows researchers to describe, analyze, and interpret patterns of behavior, beliefs, and language shared by cultural groups associated with the Baileo House (Rukminingsih et al., 2020). (Abdussamad, Zuchri, 2021) . This field research allows for naturalistic and in-depth observation of behavior, as well as intensive interviews with community members to capture their emic perspectives (Rukminingsih et al, 2020). (Sulistyawati, 2023) . This aligns with the definition of ethnography as an attempt to describe culture resulting from ethnographic records of events in society over a period of time, including informants' responses to researchers, guides, tests, and research apparatus (Abdussamad, Zuchri, 2021) . Through this approach, the research will attempt to capture the complex nuances of cultural practices and oral traditions that shape the identity of Rumah Baileo, ensuring that its digital representation reflects its spiritual and social essence (Allo et al., 2024). (Abdussamad, Zuchri, 2021) . This holistic approach in ethnography will also ensure that the study does not only focus on the architectural aspects, but also on non-physical elements such as belief systems, rituals, and social structures that surround the Baileo House (Rasyid et al., 2022).

3.2. Data Collection

Data collection will be carried out through a series of qualitative methods, including participant observation, in-depth interviews, and document analysis, all of which aim to comprehensively understand the cultural and social context of Rumah Baileo (Rukminingsih et al, 2020). (Rasyid et al. , 2022) . Informal interviews will be a key instrument, allowing researchers to place field observations and experiences within a broader context, in accordance with ethnographic principles that rely on interviews as an essential tool for in-depth understanding (Rasyid et al., 2022) . Through interviews with key informants, researchers can gain an emic perspective, understand participants'

perspectives, and explore culturally sensitive interpretations (Rasyid et al., 2022) . This approach will also be enriched with participant observation, where researchers will be directly involved in cultural activities and social interactions around the Baileo House to gain a deep contextual understanding (Rukminingsih et al, 2020). (Rasyid et al., 2022) . This ethnographic method focuses not only on external observation, but also on insightful and sensitive cultural interpretation, combined with rigorous collection and analysis of what is seen and heard (Rasyid et al., 2022) . Participatory observation allows researchers to identify and describe the activities of social groups and their members as a textual reconstruction of reality, which is essential in understanding maritime cultural practices in the region (Zabulis et al., 2025) . (Nur et al., 2023) . Furthermore, in-depth interviews will be conducted with traditional elders, community leaders, and individuals who have extensive knowledge of the history, function, and symbolic meaning of the Baileo House (Sulistyawati, 2023). (Pratiwi et al., 2023) . The main questions asked during the observations will include identifying individuals present in the research setting, their activities, and the physical setting of the social situation (Rukminingsih et al., 2020) . Analysis of documents, such as historical records, folklore, and cultural artifacts, will also complement the collected data to provide a richer historical and symbolic context to the digital representations. This method also allows researchers to identify important sites, artifacts, and relevant maritime cultural practices, particularly in the context of the maritime cultural heritage of fishing communities in the region (Nur et al., 2023) . The entire data collection process is designed to create a comprehensive multidisciplinary and interdisciplinary understanding, integrating historical, social, and cultural perspectives (Nur et al., 2023) . The data collected through this triangulation approach will be processed to identify key themes relevant to the implementation of VR and the Metaverse, ensuring that the digital narratives constructed align with the authenticity of Baileo culture (Rukminingsih et al., 2020) . Qualitative data analysis will be conducted continuously alongside the data collection process, using a thematic approach to identify patterns, categories, and themes emerging from interviews, observations, and documents. This approach will allow for cross-validation of information and a deeper understanding of cultural practices, as well as the essential elements that should be integrated into VR and the Metaverse environment.

Fig. 2: Data Collection.

3.3. Data analysis

A data triangulation approach will be used to validate findings from multiple sources, ensuring the accuracy and depth of cultural interpretations. Qualitative data collected from participant observation and interviews will be analyzed thematically, identifying recurring patterns, categories, and key themes emerging from informant narratives and field observations (Wu & Xu, 2023) . This analysis will involve thick description to present in detail what has been seen and heard in the field, often using extensive quotes from participants (Rasyid et al., 2022) . This approach aligns with Spradley's ethnographic method, which emphasizes the importance of in-depth description to uncover the meaning of local wisdom (Ericha & Rahardi, 2023) . The analysis will also integrate an emic perspective to understand informants' perspectives, as well as an etic perspective to place the findings within a broader theoretical framework, in accordance with ethnographic principles (Rasyid et al., 2022) . Validation of the researcher as an instrument will also be conducted, including validation of the qualitative research method, mastery of insights in the research field, and the researcher's readiness to enter the research object, both academically and logistically (Rukminingsih et al., 2020) . In addition, thematic analysis will be assisted by NVivo 12 software to systematically organize and categorize qualitative data, enabling the identification of recurring themes, patterns, and insights from in-depth interviews (Pratiwi et al., 2023) . The Miles and Huberman approach, which includes data reduction, data presentation, and conclusion

drawing, will be applied to ensure a comprehensive and valid analysis (Maghfiroh & Mustofa, 2023) . The credibility of the resulting descriptions and interpretations will be enhanced through investigator triangulation, where more than one researcher will be involved in data collection, analysis, and interpretation to reduce bias (Rasyid et al., 2022) . This triangulation approach can also be strengthened by method triangulation and theory triangulation, to ensure the consistency of findings from various perspectives (Wathon, 2024) (Sulistyawati, 2023) (Ericha & Rahardi, 2023) . This qualitative data analysis process will also involve repeated reading and review of the data to identify emerging themes and patterns, followed by interpretation and dissemination of the results in narrative form (Abdussamad, Zuchri, 2021) . In the interpretive phase, the researcher will summarize the overall findings, compare them with relevant literature, and discuss personal insights from the findings, while also stating limitations and directions for future research (Rasyid et al., 2022) . Data validity will be strengthened through extended observation periods and continuous observation, which allows for more careful and in-depth data collection to enrich the research results (Saadah et al., 2022) . Data validity will also be checked through method triangulation, peer review, and member checking, to ensure the reliability of the findings (Santoso & Sugiri, 2022) . These steps are important to increase the credibility of the findings, ensuring that the interpretation of the data reflects the reality of the participants and their social context (Ezatifard et al., 2024) .

3.4. System Development Stages

The development of this virtual reality and metaverse system will follow an iterative design methodology, beginning with a planning phase and in-depth requirements analysis to identify core functionality and desired user experiences. This phase includes designing the system architecture, selecting appropriate technology, and identifying the 3D assets necessary for an accurate representation of Rumah Baileo. Next, prototype design and development will occur, including 3D modeling, texturing, and interactivity implementation, followed by user testing to identify areas for improvement and refine the immersive experience. This entire process will be repeated in iterative cycles to ensure that the developed system meets high quality standards and effectively replicates the cultural and architectural aspects of Rumah Baileo (MY et al., 2024). (MacDowell et al. , 2024) . System testing will include evaluation of functionality, usability, and immersive experience by target users to validate the effectiveness of the digital representation (Reddy et al., 2023) . The implementation phase involves the development of a virtual reality and metaverse platform, including user interfaces, database structures, and program specifications (Wannapiroon et al., 2023) . Development will include the creation of a detailed 3D model of the Baileo House, the integration of audio-visual assets, and the development of interactive functionality that allows users to explore and interact with the virtual environment (Aziz et al., 2024) . Next, user evaluations will be conducted to identify areas of improvement and refine the immersive experience, as well as test the reliability of the system in various usage scenarios.

4. System Design

The design of this system will be based on an iterative design cycle that supports the connection between design activities and the environment and the scientific knowledge base (Johansson & Roupé, 2023) . This process will integrate a user-centered design approach to ensure that VR systems and metaverses can meet the needs and expectations of the target audience, particularly in the context of cultural preservation (Kurozy et al., 2025) . The development will also consider agile methodologies for rapid adaptation to changing needs and user feedback throughout the development cycle (Yolthasart et al., 2024) . This design approach will involve the creation of low-fidelity prototypes to test core mechanisms and user experience flows, which will then be iteratively refined based on user feedback (Wannapiroon et al., 2023). (Karabin et al., 2021) . The prototype will then be extensively tested to validate the functionality and accuracy of the architectural and cultural representation of Rumah Baileo, identifying potential improvements before full implementation (Walsh et al., 2023) . The development process will also integrate field testing with participants to assess the immersive experience and the accuracy of the cultural content, ensuring that the virtual environment provides an authentic and meaningful experience (Yolthasart et al., 2024). (Rasyid et al., 2022) . This aligns with the development phase involving coding, testing, and documentation to ensure service quality and reliability (Costa et al. , 2024) . In this context, the use of low-poly models for visual assets will be considered to reduce the system's computational load and ensure a smooth user experience, especially in VR and metaverse environments that require high graphics performance (Kong & Zhang, 2021) . Furthermore, optimization of visual assets and interactions will be carried out to ensure a smooth and immersive user experience, in line with interactive design principles (Holdnack & Brennan, 2021) .

4.1. System Architecture

The system architecture will be designed to support the integration of Building Information Modeling and Virtual Reality, utilizing a game engine platform to create an immersive experience (Rostamiasl & Jrade, 2024) . The system will include the integration of a 3D model of the Baileo House extracted from architectural data, where each element of the 3D object will be identified and managed through a connected database, allowing dynamic modification and automatic reflection of changes in the design model (Albourae et al., 2017). (Rostamiasl & Jrade, 2024) . This approach facilitates real-time visualization and immersive user interaction with the virtual environment (Hao et al., 2021) . The user interface will be developed to enable intuitive navigation through the virtual environment, with support for VR HMD devices to maximize user immersion and presence (Jiang, 2025) . The implementation of agile methodologies, such as those used in the development of the bWell platform, will ensure flexibility and adaptation to changing needs throughout the development process, with a focus on continuous user testing for validation (Shaigetz et al., 2021) .

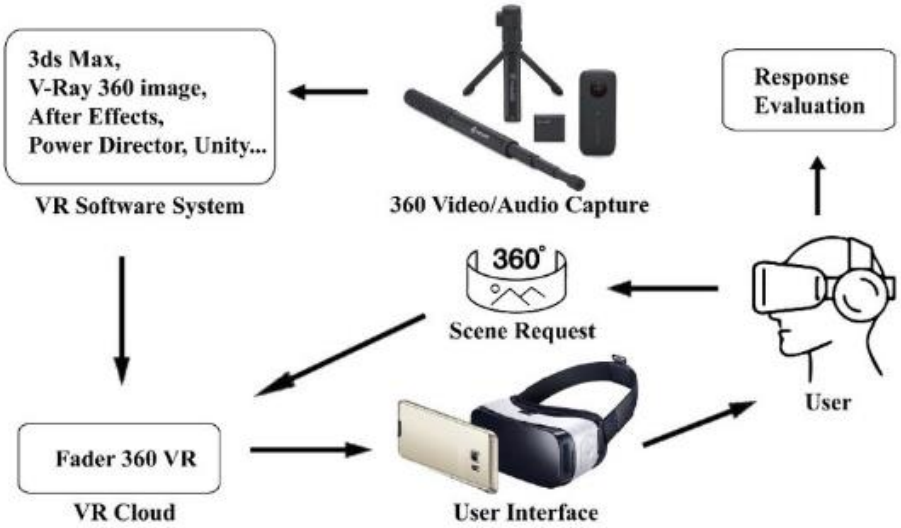


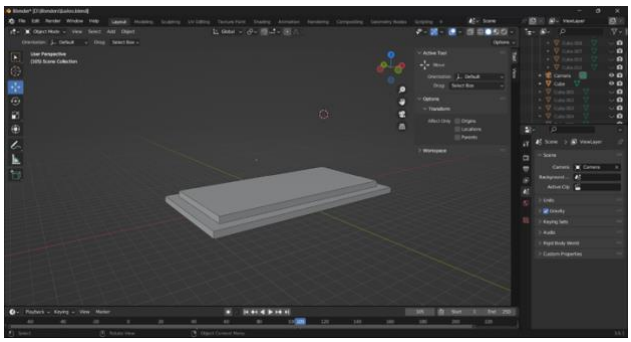
Fig. 3: VR Working Mechanism

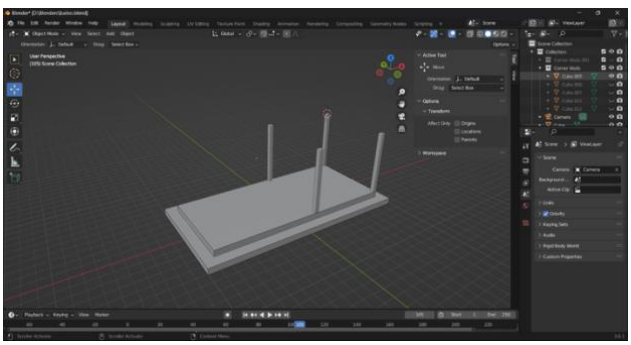
4.2. User Interface Design

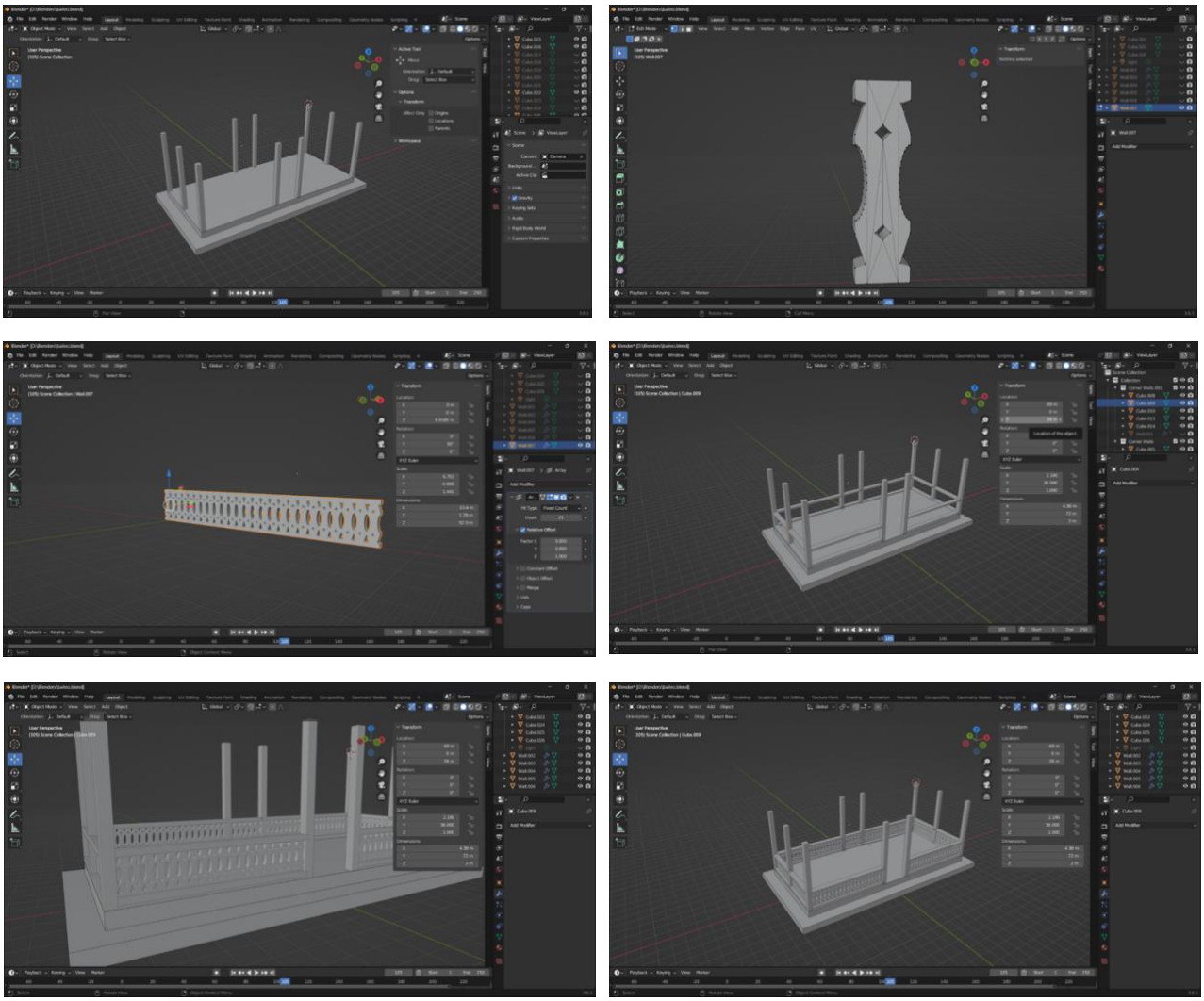
The user interface design will focus on intuitive navigation and interaction within the virtual environment, ensuring users can explore Baileo House and interact with its cultural elements without technical barriers. This will be achieved through the use of consistent design elements, clear iconography, and simple interaction flows, similar to the approaches used in other VR platforms to effectively present information (Kong & Zhang, 2021). (Rasyid et al., 2022) . The interface will integrate rich visual elements and haptic feedback to enhance the immersive experience, while providing customization options for users to adjust their display and control preferences (Yolthasart et al., 2024) . Furthermore, the interface will be designed to support various types of interactions, including hand gestures and voice control, to accommodate diverse user preferences and improve accessibility. The system will utilize VR technologies such as Vizard or Unity to build an immersive environment, allowing users to move and look around freely with dedicated devices (Wang et al., 2018) . The interface design will also consider ergonomic and cognitive aspects of the user, ensuring a non-burdensome and easy-to-understand interaction (Jin et al., 2020) . The implementation of free-motion control and bimanual input will be a focus to enhance the naturalness of user interactions, as they have been shown to facilitate faster learning compared to virtual controls based on input devices (Koebel et al., 2020) . In addition, clear feedback mechanisms will be integrated to guide users and confirm their actions (Jalilova et al., 2023) .

4.3. 3D Object Modeling of Baileo House

The 3D object modeling of the Baileo House will involve parametric modeling techniques and the use of CAD or BIM software to produce spatially accurate representations and architectural details (A lbourae et al., 2017) . This process will require extensive data acquisition, including 3D laser scanning and photogrammetry, to capture complex geometry and surface textures with high precision. This data will then be processed using software such as SketchUp or Unity3D to create realistic 3D models, ensuring every architectural detail of the Baileo House can be digitally replicated (Parulian & Mardiyati, 2021) . These models will then be optimized for real-time performance in VR and metaverse environments, considering the balance between visual detail and computational efficiency. Furthermore, the integration of these 3D models into the metaverse platform will utilize a layered architecture to ensure a seamless and interactive user experience (Aziz et al., 2024) . The use of game engines such as Unity or Unreal Engine will facilitate this integration, allowing the addition of avatars and cameras for effective navigation, communication, and visualization within the virtual model (Rostamiasl & Jrade, 2024) . The texture and material aspects of the 3D model will also be carefully developed using PBR techniques to achieve maximum visual realism, replicating the authentic appearance of the traditional building materials of the Baileo House such as wood, roofing, and carved ornaments. The 3D model will also be equipped with rich contextual information, such as the history, function, and cultural significance of each architectural element, to enrich the user's educational experience (Albourae et al., 2017). (Song et al., 2003) . This will be achieved through the integration of semantic data and metadata into 3D models, allowing users to access detailed information about construction, materials, and symbolic meaning through interaction in a virtual environment (Banfi & Mandelli, 2021) .







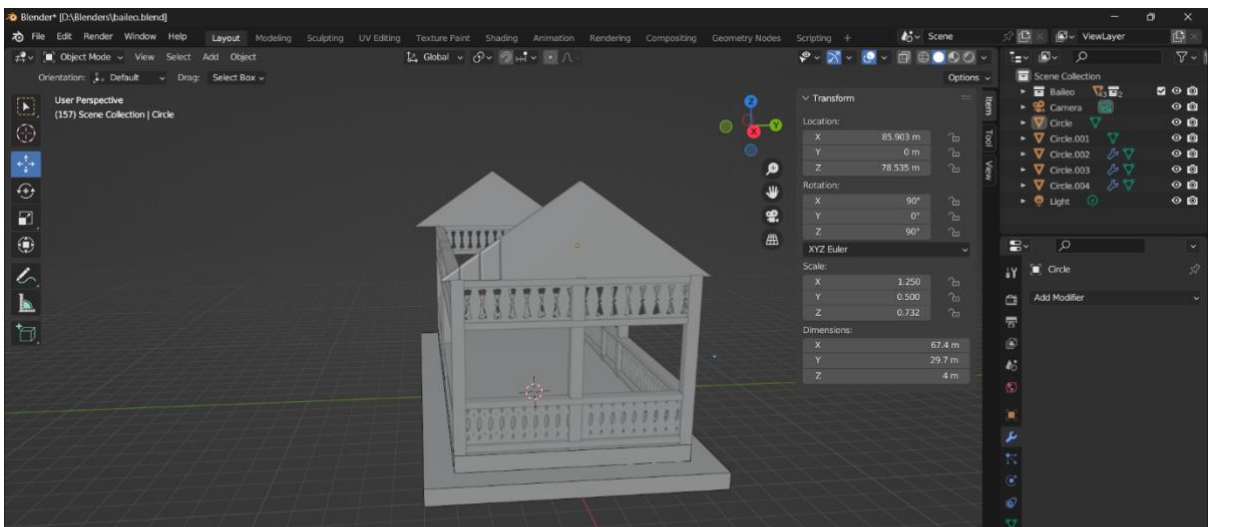


Fig. 4: 3D Model Design

4.4. System Implementation

The system implementation will involve the development of interactive interfaces that enhance the user experience in the protection of intangible cultural heritage, such as navigation in the virtual environment, object selection, and adjustment of element transparency (Song & Ghani, 2023) (Jin et al., 2020) . A key aspect of this implementation is the use of an integrated database to manage geospatial and attributive information, ensuring data consistency and accuracy across platforms (Eko, 2025) . This will include the use of Geographic Information Systems for spatial visualization, as well as data integration through web applications to display information in the form of tables and interactive maps (Eko, 2025) . This development will specifically focus on the integration of 3D models and rich contextual data, allowing users not only to view cultural objects but also to understand their history and cultural significance (Albourae et al., 2017) . This process will be supported by technologies such as Unity 2023.1.5 and C# 12.0 to ensure a rich and interactive augmented reality experience, with the ability to import 3D models, videos, and images (Rupa et al., 2023) . Optimizing models for various VR hardware, such as Meta Quest 2, will be a key concern to ensure smooth performance and fast loading times, by minimizing file size and texture count (Morrow & Wernke, 2023) . The use of the WebGL API and Mapbox Unity SDK will enable the creation of an online version of the interactive 3D viewer, facilitating widespread accessibility without physical location restrictions (Andaru et al., 2019) . The application of modern technologies such as Unmanned Aerial Vehicles can also be used to obtain high-resolution orthophotomaps as a basis for mapping and verifying cadastral data, which are then integrated into the VR system (Utilization of Data Science and Artificial Intelligence in Cadastre Data Analysis for Various Purposes, n.d.) . This careful utilization of spatial data will not only enrich VR models but can also support information transparency and accountability in cross-agency data management (Eko, 2025) . This database, encompassing both spatial and non-spatial data, will be designed to facilitate the matching and integration of different types of cultural heritage data (Eko, 2025) . This approach will allow users to intuitively explore the 3D representation of the Baileo House while simultaneously accessing in-depth contextual information about the associated intangible cultural heritage. The flexibility of the back-end infrastructure will be crucial for storing, managing, and accessing collaboratively interoperable data, aligning with the needs of a 4D cultural heritage information platform (Ioannidis et al., 2020) . This data integration will utilize a data dictionary to organize relationships between columns and associated values, as well as data mapping to ensure the 3D representation accurately displays the selected data (Masud et al., 2023) . The next step will be to thoroughly test and validate this data integration to ensure the accuracy and performance of the overall system. Furthermore, the use of the Unity 3D game engine will facilitate the visualization of large-scale topographic data from various sources, including terrestrial laser scanner modeling and topographic map data, allowing users to explore 3D models at a detailed level (Andaru et al., 2019) . The system will also support the exploration of complex geospatial data, such as land use analysis and cadastral data, through interactive visualization in a 3D environment (Utilization of Data Science and Artificial Intelligence in Cadastral Data Analysis for Various Purposes, n.d.) (Eko, 2025) .

4.5. Virtual Reality Module Development

The development of the virtual reality module will focus on creating an immersive and interactive experience, allowing users to explore a digital replica of the Baileo House and related cultural artifacts (Guardia et al., 2022) . This will include designing an intuitive user interface, enabling seamless navigation and direct interaction with virtual objects to trigger contextual information or historical narratives. This technique will involve integrating data from a centralized database, ensuring that the information presented is always accurate and up-to-date, and will prioritize data interoperability to ensure compatibility with various platforms and devices (Eko, 2025). (Rostamiasl & Jrade, 2024) (Bruzelius et al., 2020) . Developers also need to consider the different types of media to be used, including audio, video, and graphics, as well as any third-party resources that may be needed to enhance the immersive experience (Rasyid et al., 2022) . Furthermore, development should consider the level and type of activities to be generated, whether collaborative, interactive, or participant-based, as well as how the teaching style approach will be implemented (Rasyid et al., 2022) . VR modules will also include mechanisms for digital preservation and visualization of cultural heritage, allowing users to interact with detailed 3D models and access textual and visual information regarding their historical and cultural significance (Quattrini et al., 2018) .

Fig. 5: VR Model Interface

4.6. Integration with Metaverse Platform

Integration with the metaverse platform will leverage Unity 3D's flexible architecture and rendering capabilities, enabling the export of 3D objects modeled from software such as Blender to create dynamic virtual environments (Selman et al., 2024) . This approach will allow users to interact with Rumah Baileo in a shared virtual space, facilitating collaborative learning and cultural exchange (Mu'ti et al., 2025) . The platform will be designed to support various forms of social interaction and educational activities, such as virtual guided tours, interactive workshops, and digital exhibitions, all accessible from any geographic location. Optimizing this metaverse experience will also consider how users can build strong relationships with the content, similar to how developers foster trust among students in face-to-face sessions (Rasyid et al., 2022) . Therefore, the development of this metaverse platform will integrate immersive learning environments, physical spaces, and virtual spaces to facilitate collaboration and reflection (Mu'ti et al., 2025) . This will broaden the reach and impact of cultural preservation, enabling global access to the heritage of Baileo Negeri Rutong (Pybus, 2019) (Willmes et al., 2024) .

Fig. 7: Exploring VR

4.7. System Testing

The system testing phase will focus on validating the platform's overall functionality and performance, including interoperability testing to ensure compatibility across devices and platforms (Zierau, 2019) . This testing will also involve evaluating the user experience to identify areas for improvement, ensuring that navigation and interaction in the virtual environment are intuitive and engaging (Rasyid et al., 2022) . Another important aspect is testing VR functionality, including controls, feedback mechanisms, and VR hardware integration such as headset compatibility and controller support (Jalilova et al., 2023) . Furthermore, performance testing will be conducted to assess latency, frame rate, and system stability across various usage scenarios, particularly when visualizing complex 3D models (Radanović et al., 2021) This testing will ensure that the system can perform optimally across various hardware and network configurations, minimizing disruption and maximizing user immersion. Security testing will also be crucial to protect user data and digital assets from potential cyberthreats, ensuring the integrity and confidentiality of information stored on the platform. Quality testing will also assess the accuracy of the digital representation of the Baileo House and other cultural artifacts, ensuring that historical and architectural details are faithfully replicated.

5. Conclusion

This study has comprehensively examined the potential of implementing Virtual Reality and Metaverse for the preservation and promotion of the Baileo Negeri Rutong Traditional House culture in Maluku, identifying innovative opportunities as well as underlying challenges. The study emphasizes the importance of a multidisciplinary approach that combines technological, social, and cultural aspects to create platforms that are not only immersive but also relevant and sustainable for local communities (Buragohain et al., 2024) . Furthermore, it is recommended that future research focus on developing sustainable business models and effective educational strategies to ensure widespread adoption and long-term benefits of these immersive technologies (Ivanov & Velkova, 2025) . Future research can further explore the development of VR and Metaverse content that is adaptive to varying levels of digital literacy and network infrastructure conditions, particularly in remote areas (Wathon, 2024) . (Utilization of Data Science and Artificial Intelligence in Cadastral Data Analysis for Various Purposes, n.d.) . Furthermore, it is important to thoroughly consider the legal and ethical aspects of cultural heritage representation in virtual environments, ensuring respect for cultural significance and appropriate consent from relevant communities (Sicklinger et al., 2023) . Aspects such as age, gender, socioeconomic status, and cultural background also need to be considered to understand user perceptions and hedonic and utilitarian values in the design of a more inclusive and equitable metaverse (Shamim et al., 2024) . Cross-disciplinary collaboration between historians, anthropologists, technology developers, and local communities is also essential to ensure authentic and accurate cultural representation in virtual environments. A multicultural approach in content development and training of Islamic religious educators can also be applied to ensure inclusive cultural narratives and respect for diverse perspectives in the metaverse (MUSLIM & YUSUF, 2024) . Future studies should also consider longitudinal research and international collaborations to develop a framework that links cultural preservation with sustainable education practices globally (Zhou & Saearani, 2025) . Further research could include exploring the impact of immersive technologies on user psychology and cognition in cultural learning contexts , as well as developing more sophisticated evaluation metrics to measure the effectiveness and long-term sustainability of metaverse platforms (Li et al., 2023). (Lian & Jia-feng, 2024) .

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References

[1] Abdussamad, Zuchri, CV. syakir MP (2021). QUALITATIVE RESEARCH METHODS. CV. syakir Media Press.
[2] Abukarki, HJ (2025). Beyond Preservation: A Survey of the Role of Virtual Reality in Experiencing and Understanding Historical Architectural Spaces. Buildings, 15(9), 1531. https://doi.org/10.3390/buildings15091531
[3] Albourae, A. T., Armenakis, C., & Kyan, M. (2017). ARCHITECTURAL HERITAGE VISUALIZATION USING INTERACTIVE TECHNOLOGIES. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 7. https://doi.org/10.5194/isprs-archives-xlii-2-w5-7-2017
[4] Allo, MDG, Nyhof, M., La'biran, R., Sudarsi, E.T., Taula'bi', N., & Basongan, W. (2024). The Intricate Tapestry of Toraja Spirituality: An Exploration of Animism, Ancestor Veneration, and Symbolic Rituals. International Journal of Religion, 5(9), 37. https://doi.org/10.61707/q4115w74
[5] Alnuaimi, M., & Awad, M. (2024). VR Environment of Digital Design Laboratory: A Usability Study. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-5344948/v1
[6] Andaru, R., Cahyono, BK, Riyadi, G., Ramadhan, G., & Tuntas, S. (2019). THE COMBINATION OF TERRESTRIAL LIDAR AND UAV PHOTOGRAMMETRY FOR INTERACTIVE ARCHITECTURAL HERITAGE VISUALIZATION USING UNITY 3D GAME ENGINE. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 39. https://doi.org/10.5194/isprs-archives-xlii-2-w17-39-2019
[7] Anwar, MS, Yang, JC, Frnda, J., Choi, A., Baghaei, N., & Ali, M. (2025). Metaverse and XR for cultural heritage education: applications, standards, architecture, and technological insights for enhanced immersive experiences. Virtual Reality, 29(2). https://doi.org/10.1007/s10055-025-01126-z
[8] Aziz, O., Farooq, M.S., Khelifi, A., & Shoaib, M. (2024). Archaeometa: leveraging blockchain for secure and scalable virtual museums in the metaverse. Heritage Science, 12(1). https://doi.org/10.1186/s40494-024-01416-w
[9] Banfi, F., & Mandelli, A. (2021). INTERACTIVE VIRTUAL OBJECTS (IVOs) FOR NEXT GENERATION OF VIRTUAL MUSEUMS: FROM STATIC TEXTURED PHOTOGRAMMETRIC AND HBIM MODELS TO XR OBJECTS FOR VR-AR ENABLED GAMING EXPERIENCES. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 47. https://doi.org/10.5194/isprs-archives-xlvi-m-1-2021-47-2021
[10] Borba, E. Z., Corrêa, A. G. D., Lopes, R. de D., & Zuffo, M. K. (2019). Usability in virtual reality: evaluating user experience with interactive archaeometry tools in digital simulations. Multimedia Tools and Applications, 79, 3425. https://doi.org/10.1007/s11042-019-07924-3
[11] Bruzelius, C., Leidwanger, J., & Greene, E. S. (2020). DIGITAL MODELS FOR THE ANALYSIS AND ENHANCEMENT OF HYBRID SPACES: ARCHITECTURE OF THE MATTANZA. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 443. https://doi.org/10.5194/isprs-archives-xliv-m-1-2020-443-2020
[12] Buragohain, D., Buragohain, D., Meng, Y., Deng, C., & Chaudhary, S. (2025). A metaverse based digital preservation of temple architecture and heritage. Scientific Reports, 15(1). https://doi.org/10.1038/s41598-025-00039-w
[13] Buragohain, D., Meng, Y., Deng, C., Li, Q., & Chaudhary, S. (2024). Digitalizing cultural heritage through metaverse applications: challenges, opportunities, and strategies. Heritage Science, 12(1). https://doi.org/10.1186/s40494-024-01403-1
[14] Chamola, V., Peelam, M.S., Mittal, U., Hassija, V., Singh, A., Pareek, R., Mangal, P., Sangwan, D., Albuquerque, VHC de, Mahmud, M., & Brown, DJ (2025). Metaverse for Education: Developments, Challenges, and Future Directions. Computer Applications in Engineering Education, 33(3). https://doi.org/10.1002/cae.70018
[15] Chen, G., Jin, Y., & Chen, P. (2024). Development of a platform for state online education services: Design concept based on meta-universe. Education and Information Technologies, 29(17), 23605. https://doi.org/10.1007/s10639-024-12792-y
[16] Costa, RRM de S., Oliveira, VBJ de, Melo, KDN de, Costa, CCS, & Filho, S.E.A. (2024). Integrated Data Processing Architecture Applied to Learning Objects Repository for Educational Robotics: Proposing Approach. Journal of Intelligent & Robotic Systems, 110(2). https://doi.org/10.1007/s10846-024-02109-z
[17] Costello, E., Brunton, J., Otrel-Cass, K., Lyngdorf, N.E.R., & Brown, M. (2024). Hacking Happier Futures : An AI-augmented student hackathon to address affective and ethical digital learning challenges. Danish Research Portal, 9. https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=aau&id=aau-40fe5df2-680d-4e0a-8285-69066ff15b33&ti=Hacking%20Happier% 20Futures%20%3A%20An%20AI-augmented%20student%20hackathon%20to%20address%20affective%20and%20ethical%20digital%20learning%20challenges
[18] Ebrahimzadeh, F. M., & Safa, R. (2024). Unlocking the Potential of the Metaverse for Innovative and Immersive Digital Care. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2406.07114
[19] Eko, T. (2025). REPORT ON THE ACTION OF CHANGES IN THE INTEGRATION OF LAND-BASED TAX DATA (CADASTER) AS A REALIZATION OF “BEYOND COMPLETE CADASTRE” IN KULON PROGO REGENCY.
[20] Elfizar, Sukamto, S., Fitriansyah, A., Sastria, G., & Erna, M. (2020). Preserving Riau's Malay Culture Through Virtual Environment Application. IOP Conference Series Earth and Environmental Science, 519(1), 12019. https://doi.org/10.1088/1755-1315/519/1/012019
[21] Ericha, F., & Rahardi, RK (2023). The Preservation of Local Values in the Ritual Spell of Barape Sawa Dayak Bakati`: An Anthropolinguistic Study. Indonesian Language Education and Literature, 9(1), 194. https://doi.org/10.24235/ileal.v9i1.13444
[22] Ezatifard, A., Rezaei, F., Dargahi, H., Yarmohammadian, M. H., & Atighechian, G. (2024). Development of an Integrated Model for Providing Public Health Services to Refugees in Iran: Study Protocol. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-5297231/v1
[23] Guardia, M.L., Koeva, M., D'Ippolito, F., & Karam, S. (2022). 3D DATA INTEGRATION FOR WEB BASED OPEN SOURCE WebGL INTERACTIVE VISUALIZATION. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 89. https://doi.org/10.5194/isprs-archives-xlviii-4-w4-2022-89-2022
[24] Hao, Z., Zhang, W., & Zhao, Y. (2021). Integrated BIM and VR to implement IPD mode in transportation infrastructure projects: System design and case application. PLOS ONE, 16(11). https://doi.org/10.1371/journal.pone.0259046
[25] Holdnack, J. A., & Brennan, P. F. (2021). Usability and Effectiveness of Immersive Virtual Grocery Shopping for Assessing Cognitive Fatigue in Healthy Controls: Protocol for a Randomized Controlled Trial. JMIR Research Protocols, 10(8). https://doi.org/10.2196/28073
[26] Ioannidis, C., Verykokou, S., Soile, S., & Boutsi, A.-M. (2020). A MULTI-PURPOSE CULTURAL HERITAGE DATA PLATFORM FOR 4D

VISUALIZATION AND INTERACTIVE INFORMATION SERVICES. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 583. https://doi.org/10.5194/isprs-archives-xliiii-b4-2020-583-2020

[27] Ivanov, R., & Velkova, V. (2025). Analyzing Visitor Behavior to Enhance Personalized Experiences in Smart Museums: A Systematic Literature Review. Computers, 14(5), 191. https://doi.org/10.3390/computers14050191

[28] Jalilova, D., Kurbonova, R., Erejepov, M., & Nematov, L. A. (2023). Development and analysis of logical scenario design in virtual reality laboratories for higher education institutions. E3S Web of Conferences, 461, 1097. https://doi.org/10.1051/e3sconf/202346101097

[29] Jiang, C., Phoong, S. W., & Moghavvemi, S. (2025). Cultural odyssey in the metaverse: investigating the impact of virtual technologies on tourist reuse behavior and social sustainability. Humanities and Social Sciences Communications, 12(1). https://doi.org/10.1057/s41599-025-05132-z

[30] Jiang, X. (2025). The analysis of interactive furniture design system based on artificial intelligence. Scientific Reports, 15(1). https://doi.org/10.1038/s41598-025-14886-0

[31] Jin, Y., Joblot, L., Lou, R., & Merienne, F. (2020). Utilization du BIM dans une application RV à des fins de maintenance d'un bâtiment. HAL (Le Center Pour La Communication Scientifique Directe). https://hal.archives-ouvertes.fr/hal-02988563

[32] Johansson, M., & Roupé, M. (2023). Real-world applications of BIM and immersive VR in construction. Automation in Construction, 158, 105233. https://doi.org/10.1016/j.autcon.2023.105233

[33] Karabin, M., Kitsakis, D., Koeva, M., Navratil, G., Paasch, J.M., Paulsson, J., Vučić, N., Janečka, K., & Lisec, A. (2021). 3D Cadastre in the Case of Engineering Objects, such as Bridges and Road Viaducts. Danish Research Portal, 19. https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=aau&id=aau-7b5419f3-6ca0-4755-b4b3-078e897421ad&ti=3D%20Cadastre%20in%20the%20Case%20of%20Engineering%20Objects%2C%20such%20as%20Bridges%20and%20Road%20Viaducts

[34] Kawato, M., Li, L., Hasegawa, K., Adachi, M., Yamaguchi, H., Thufail, FI, Riyanto, S., Brahmantara, & Tanaka, S. (2021). A DIGITAL ARCHIVE OF BOROBUDUR BASED ON 3D POINT CLOUDS. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 577. https://doi.org/10.5194/isprs-archives-xliii-b2-2021-577-2021

[35] Kersten, T. P., Trau, D., & Tschirschwitz, F. (2020). THE FOUR-MASTED BARQUE PEKING IN VIRTUAL REALITY AS A NEW FORM OF KNOWLEDGE TRANSFER. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 155. https://doi.org/10.5194/isprs-annals-v-4-2020-155-2020

[36] Kim, S.H. (2025). Agile Heritage: Revolutionizing Digital Content Development in Cultural Preservation and Beyond. In Lecture notes in networks and systems (p. 91). Springer International Publishing. https://doi.org/10.1007/978-3-031-80946-0_9

[37] Koebel, K., Agotai, D., & Çöltekin, A. (2020). EXPLORING CULTURAL HERITAGE COLLECTIONS IN IMMERSIVE ANALYTICS: CHALLENGES, BENEFITS, AND A CASE STUDY USING VIRTUAL REALITY. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 599. https://doi.org/10.5194/isprs-archives-xliiii-b4-2020-599-2020

[38] Kong, C., & Zhang, L. (2021). DEVELOPING A CO-DESIGN PROCESS MODEL FOR THE DIGITAL PRESENTATION OF INTANGIBLE CULTURAL HERITAGE: A CASE STUDY OF “WARM INHERITORS DIGITAL DIABOLO.” ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 89. https://doi.org/10.5194/isprs-annals-viii-m-1-2021-89-2021

[39] Kurozy, DN, Pratama, RG, & Muhammad, AE (2025). Application of the Prototype Method in the Design of a New Student Registration System. JPNM Jurnal Pustaka Nusantara Multidisciplinary, 3(1). https://doi.org/10.59945/jpnm.v3i1.300

[40] Larasati, C. (nd). IMPLEMENTATION OF DEEP LEARNING WITH AI TO REDUCE TEACHER WORKLOAD AND IMPROVE STUDENT UNDERSTANDING.

[41] Lataifeh, M., & Ahmed, N. (2024). Metamorphosis of EduX: a comparative study for education in the metaverse. Frontiers in Computer Science, 6. https://doi.org/10.3389/fcomp.2024.1423768

[42] Li, J., Wider, W., Ochiai, Y., & Fauzi, M.A. (2023). A bibliometric analysis of immersive technology in museum exhibitions: exploring user experience. Frontiers in Virtual Reality, 4. https://doi.org/10.3389/frvir.2023.1240562

[43] Lian, Y., & Jia-feng, X. (2024). The Evolution of Digital Cultural Heritage Research: Identifying Key Trends, Hotspots, and Challenges through Bibliometric Analysis. Sustainability, 16(16), 7125. https://doi.org/10.3390/su16167125

[44] MacDowell, P., Jaunzems-Fernuk, J., Clifford, J., Ghani, A. M., & Hoy, B. (2024). Virtual Reality in History Education: Instructional Design Considerations for Designing Authentic, Deep, and Meaningful Learning. Journal of Applied Instructional Design, 13(4). https://doi.org/10.59668/2033.19032

[45] Maghfiroh, DL, & Mustofa, A. (2023). Social Reflection and Contemplation of Character Education in the Novel "Garbage in the Sea," Meira, by Mawan Belgia. Diglossia Journal of Scientific Studies of Language and Literature, 14(2), 86. https://doi.org/10.26594/diglossia.v14i2.2077

[46] Masud, SMRA, Adiba, H., Hossain, T., Saha, A.K., & Rahman, R. (2023). Development of Interactive Data Visualization System in Three-Dimensional Immersive Space. International Journal of Advanced Computer Science and Applications, 14(10). https://doi.org/10.14569/ijacsa.2023.01410108

[47] Mestiri, M., Khadhar, M., Huftier, A., & Fergombé, A. (2025). Fostering Social Interaction Variability in the Metaverse: A Case Study of the Museum of L'Avesnois in Fourmies. Heritage, 8(5), 171. https://doi.org/10.3390/heritage8050171

[48] Morrow, G.S., & Wernke, S.A. (2023). Thinking through the tool: collaborative archaeological bodywork in immersive virtual reality. Virtual Archeology Review, 15(30), 21. https://doi.org/10.4995/var.2024.19806

[49] MUSLIM, M., & YUSUF, M. (2024). MANAGEMENT OF MULTICULTURAL ISLAMIC RELIGIOUS EDUCATION CURRICULUM IN AR-RAHMAH INTEGRATED ISLAMIC HIGH SCHOOL IN DEVELOPING STUDENTS' AWARENESS TOWARDS THE DIVERSITY OF MUSLIM SOCIETY.

[50] Mu'ti, A., Ir, S., Toharudin, T., Suhardi, D., Jamali, A., Yusro, M., Dewi, L., Prof, S., Mubarak, A., Suryadi, B., Darmawan, C., Wahyudin, D., Qodir, D., Iskandar, H., Wiyono, H., Dr, I., Prof, K., Yuliati, K., Dr, M., … Kamdi, W. (2025). ACADEMIC MANUSCRIPT OF DEEP LEARNING Towards Quality Education for All.

[51] MY, N., Hajar, S., & Arsyad, NF (2024). Utilizing Quizizz for Game-Based Learning in Elementary Science Education. Journal of Education and Computer Applications, 1(1), 12. https://doi.org/10.69693/jeca.v1i1.2

[52] Nur, M., Nurbayani, KS, Jumadi, J., Supriadi, A., Hasni, H., & Sultan, H. (2023). Maritime Cultural Heritage of Fishermen Communities in the Sangkarrang Islands Subdistrict, Makassar City, Indonesia. BIO Web of Conferences, 70, 5007. https://doi.org/10.1051/bioconf/20237005007

[53] Nur, M., Nurbayani, S., Mulyana, A., Dermawan, W., Sapriya, S., Supriyadi, A., & Jumadi, J. (2023). Histoire et culture maritimes en Indonesia : mise en œuvre dans l'apprentissage des études sociales. Encounters in Theory and History of Education, 24, 230. https://doi.org/10.24908/encounters.v24i0.16705

[54] Oladokun, BD, Ajani, YA, Ukaegbu, BCN, & Oloniruha, EA (2024). Cultural Preservation Through Immersive Technology: The Metaverse as a Pathway to the Past. Preservation Digital Technology & Culture, 53(3), 157. https://doi.org/10.1515/pdtc-2024-0015

[55] Onu, P., Pradhan, A., & Mbohwa, C. (2023). Potential to use metaverse for future teaching and learning. Education and Information Technologies, 29(7), 8893. https://doi.org/10.1007/s10639-023-12167-9

[56] Paolis, LTD, Gatto, C., Corchia, L., & Luca, V.D. (2022). Usability, user experience and mental workload in a mobile Augmented Reality application for digital storytelling in cultural heritage. Virtual Reality, 27(2), 1117. https://doi.org/10.1007/s10055-022-00712-9

[57] Parulian, D., & Mardiyati, S. (2021). Virtual Reality Modeling: A Case Study of the Introduction to the Computer Laboratory at Indraprasta University. Journal of Informatics, Pamulang University, 6(1), 152. https://doi.org/10.32493/informatika.v6i1.9673

[58] Utilizing Data Science and Artificial Intelligence in Cadastral Data Analysis for Various Purposes. (nd).

[59] Pérez, GAJ, Gamboa, AJP, & Cano, CAG (2024). Virtual reality and virtual worlds: a favorable setting for the preservation of cultural heritage. Metaverse Basic and Applied Research, 3. https://doi.org/10.56294/mr2024.110

[60] Prandi, C., Nisi, V., Ceccarini, C., & Nunes, N. (2021). Augmenting Emerging Hospitality Services: A Playful Immersive Experience to Foster Interactions among Locals and Visitors. International Journal of Human-Computer Interaction, 39(2), 363. https://doi.org/10.1080/10447318.2021.2012382

[61] Pratiwi, MA, Wahyu, HR, & Normande, BE (2023). Understanding Knowledge Acquisition, Adaptive Strategies, Challenges, and Preservation Methods Among Traditional Fishermen in a Digital Age. BIO Web of Conferences, 70, 5008. https://doi.org/10.1051/bioconf/20237005008

[62] Pyae, A., Ravyse, W., Luimula, M., Pizarro-Lucas, E., Sánchez, P.L., Dorado-Diaz, I.P., & Thaw, A.K. (2023). Exploring User Experience and Usability in a Metaverse Learning Environment for Students: A Usability Study of the Artificial Intelligence, Innovation, and Society (AIIS). Electronics, 12(20), 4283. https://doi.org/10.3390/electronics12204283

[63] Pybus, C. (2019). NEW TOOLS FOR CULTURAL HERITAGE TOURISM: ACCESSIBLE VIRTUAL REALITY FOR MILAN'S BASILICA SANT'AMBROGIO. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 1003. https://doi.org/10.5194/isprs-archives-xlii-2-w11-1003-2019

[64] Quattrini, R., Battini, C., & Mammoli, R. (2018). HBIM TO VR. SEMANTIC AWARENESS AND DATA ENRICHMENT INTEROPERABILITY FOR PARAMETRIC LIBRARIES OF HISTORICAL ARCHITECTURE. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 937. https://doi.org/10.5194/isprs-archives-xlii-2-937-2018

[65] Quattrini, R., Pierdicca, R., Paolanti, M., Clini, P., Nespeca, R., & Frontoni, E. (2020). Digital interaction with 3D archaeological artefacts: evaluating user's behavior at different representation scales. Digital Applications in Archeology and Cultural Heritage, 18. https://doi.org/10.1016/j.daach.2020.e00148

[66] Radanović, M., Khoshelham, K., & Fraser, C.S. (2021). A PLATFORM FOR MULTILAYERED DOCUMENTATION OF CULTURAL HERITAGE. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 9. https://doi.org/10.5194/isprs-annals-v-4-2021-9-2021

[67] Rasyid, F., String, E., & Latifa, A. (2022). QUALITATIVE AND QUANTITATIVE RESEARCH METHODOLOGY Theory, Methods, and Practice.

[68] Raup, A., Ridwan, W., Khoeriyah, Y., Supiana, S., & Zaqiah, QY (2022). Deep Learning and Its Application in Learning. JIIP - Scientific Journal of Educational Sciences, 5(9), 3258. https://doi.org/10.54371/jiip.v5i9.805

[69] Reddy, VS, Yadav, S.A., Rao, A.L.N., Kanday, R., Tyagi, L.K., Reddy, U.M., & Ftaiet, A.A. (2023). Designing Beyond Borders: A Study of E-Design and Virtual Collaboration in Modern Innovation. E3S Web of Conferences, 453, 1033. https://doi.org/10.1051/e3sconf/202345301033

[70] Rostamiasl, V., & Jrade, A. (2024). A cloud-based integration of Building Information Modeling and Virtual Reality through game engine to facilitate the design of Age-in-Place homes at the conceptual stage. Journal of Information Technology in Construction, 29, 377. https://doi.org/10.36680/j.itcon.2024.018

[71] Rukminingsih et al. (2020). Educational Research Methods: Quantitative Research, Qualitative Research, Classroom Action Research.

[72] Rupa, Ch., Harshitha, MM, Vineetha, MS, & Shah, MA (2023). Weaving Legacies: AR-Enhanced Exploration of GI Heritage Mangalagiri Saree Tradition. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-3677662/v1

[73] Saadah, M., Prasetiyo, YC, & Rahmayati, GT (2022). STRATEGIES IN MAINTAINING DATA VALIDITY IN QUALITATIVE RESEARCH. Al-'Adad, 1(2), 54. https://doi.org/10.24260/add.v1i2.1113

[74] Santoso, ST, & Sugiri, WA (2022). The Process of Adapting Personal Hygiene Behavior in Early Childhood. PAUDIA JOURNAL OF EARLY CHILDHOOD EDUCATION RESEARCH, 11(2), 562. https://doi.org/10.26877/paudia.v11i2.11519

[75] Selman, A.D., Klitgaard, A., Jørsfeldt, L.M., & Heiselberg, H.L.D. (2024). Shaping the Future : The Role of Educators in Construction Programs Towards Climate Legislation in a Danish Context. Research Portal Denmark, 2024, 551. https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=ucn&id=ucn-ddffbd37-d260-480d-a65b-fbd28f48fb1c&ti=Shaping%20the%20Future%20%3A%20The%20Role%20of%20Educators%20in%20Construction%20Programs%20Towards%20Climate%20Legislation%20in%20a%20Danish%20Context

[76] Serghides, C.-G., Christoforides, G., Iakovides, N., & Aristidou, A. (2024). Design and implementation of an interactive virtual library based on its physical counterpart. Virtual Reality, 28(3). https://doi.org/10.1007/s10055-024-01023-x

[77] Shaigetz, V.G., Proulx, C., Cabral, A., Choudhury, N., Hewko, M., Kohlenberg, E., Segado, M., Smith, M.S., & Debergue, P. (2021). An Immersive and Interactive Platform for Cognitive Assessment and Rehabilitation (bWell): Design and Iterative Development Process. JMIR Rehabilitation and Assistive Technologies, 8(4). https://doi.org/10.2196/26629

[78] Shamim, N., Gupta, S., & Shin, M. M. (2024). Evaluating user engagement via Metaverse environment through immersive experience for travel and tourism websites. International Journal of Contemporary Hospitality Management. https://doi.org/10.1108/ijchm-10-2023-1590

[79] Sicklinger, A., Mehmeti, L., Bregasi, L., & Krasniqi, F. (2023). Community heritage: an immersive approach to disaster resilience. In Academia Press eBooks. Academic Press. https://doi.org/10.26530/9789401496476-128

[80] Song, M., Elias, T., Müller-Wittig, W., & Chan, TKY (2003). Interacting with the virtually recreated Peranakans. https://doi.org/10.1145/604471.604515

[81] Song, S., & Ghani, D. A. (2023). Design a Virtual Reality Interface to Enhance the User Experience of Intangible Cultural Heritage Protection. Deleted Journal, 1(1), 37. https://doi.org/10.56225/gjeset.v1i1.19

[82] Subroto, DE, Supriandi, Wirawan, R., & Rukmana, AY (2023). Implementation of Technology in Learning in the Digital Era: Challenges and Opportunities for the World of Education in Indonesia. Journal of Education West Science, 1(7), 473. https://doi.org/10.58812/jpdws.v1i07.542

[83] Sulistyawati, K.-M. (2023). Qualitative Research Methods. K-Media.

[84] Suprapto, N., Rizki, IA, & Kholiq, Abd. (2024). Exploring the Cultural Fabric: A Study on Indonesia's Unique Architectural Marvels for Ethno-STEAM Education System. TEM Journal, 2249. https://doi.org/10.18421/tem133-52

[85] Talani, NS, Kamuli, S., & Juniarti, G. (2023). The Problems of semiotic interpretation in communication and media studies: A critical review.

[86] Wallgrün, J.O., Huang, J., Zhao, J., Masrur, A., Oprean, D., & Klippel, A. (2017). A FRAMEWORK FOR LOW-COST MULTI-PLATFORM VR AND AR SITE EXPERIENCES. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 263. https://doi.org/10.5194/isprs-archives-xlii-2-w8-263-2017

[87] Walsh, G., Andersen, N.S., Stoianov, N., & Jänicke, S. (2023). Towards a New Symbology and Visual Interaction Design for Sub-Sea Military Operations. Danish Research Portal, 24. https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=sdu&id=sdu-145ca22b-f48d-48cd-8ffd-bb523392d67 7&ti=Towards%20a%20New%20Symbology%20and%20Visual%20Interaction%20Design%20for%20Sub-Sea%20Military%20Operations

[88] Wang, B., Dane, G., & Vries, B. de. (2018). INCREASING AWARENESS FOR URBAN CULTURAL HERITAGE BASED ON 3D NARRATIVE SYSTEM. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 215. https://doi.org/10.5194/isprs-archives-xlii-4-w10-215-2018

[89] Wannapiroon, N., Shawarangkoon, S., Chawarangkoon, C., Kucharoenthavorn, A., & Wannapiroon, P. (2023). Metaverse Learning Experience Platform (MLXP) for Immersive Design Thinking to Enhance Digital Intelligence Quotient and Virtual Game Developer Skills. International Journal of Information and Education Technology, 13(12), 1879. https://doi.org/10.18178/ijiet.2023.13.12.2001

[90] Wartelle, A., Abiven, M.-M., Laroche, F., & Querrec, R. (2023). Preserving and Reviving Industrial Heritage with Virtual and Augmented Realities.

HAL (Le Center Pour La Communication Scientifique Directe). https://hal.science/hal-04210227
[91] Wathon, A. (2024). The Compatibility of the Independent Curriculum with the Deep Learning Curriculum. ARZUSIN, 4(6), 1280. https://doi.org/10.58578/arzusin.v4i6.4442
[92] Willmes, C., Canals, L., Ganser, C., Mennecke, D., Phillipps, F.L., Pietsch, A.-K., Reichenau, T.G., Reuhl, E., Schildkamp, P., Stempel, M., Wickeroth, D., Wieners, J.G., & Eide, Ø. (2024). The Technology Stack and System Architecture of the University of Cologne Virtual Campus. ˜The œinternational Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 153. https://doi.org/10.5194/isprs-archives-xlviii-4-w11-2024-153-2024
[93] Wu, Y., & Xu, Z. (2023). Reinventing the gastronomic experience: using interactive digital environments to raise awareness of food-related cultural heritage. In Academia Press eBooks. Academic Press. https://doi.org/10.26530/9789401496476-181
[94] Xu, Y., Feng, D., Zhao, M., Sun, Y., & Xia, X. (2023). Edge Intelligence Empowered Metaverse: Architecture, Technologies, and Open Issues. IEEE Network, 37(6), 92. https://doi.org/10.1109/mnet.2023.3317477
[95] Yang, L., Yan, X., & Pan, H. (2024). Metaverse Identity: Core Principles and Critical Challenges. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2406.08029
[96] Yolthasart, S., Intawong, K., Thongthip, P., & Puritat, K. (2024). The Game of Heritage: Enhancing Virtual Museum Visits Through Gamification for Tourists. TEM Journal, 3359. https://doi.org/10.18421/tem134-70
[97] Zabulis, A Digitally Enhanced Ethnography for Craft Action and Process Understanding. Applied Sciences, 15(10), 5408. https://doi.org/10.3390/app15105408
[98] Zhou, L., & Saearani, M. F.T. (2025). Bridging Traditions and Knowledge: A Bibliometric Review on Cultural Sustainability in Education [Review of Bridging Traditions and Knowledge: A Bibliometric Review on Cultural Sustainability in Education]. International Journal of Academic Research in Progressive Education and Development, 14(1). https://doi.org/10.6007/ijarped/v14-i1/24579
[99] Zierau, E. (2019). Preservation of Metadata : A case study of a strategy to ensure technology agnostic metadata preservation. Danish Research Portal. https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=kum&id=kum-de6422a7-05dd-4e44-a324-e4e8163713a9&ti=Preservation%20of%20Metadata%20%3A%20A%20case%20study%20of%20a%20strategy%20to%20ensure%20technology%20agnostic%20metadata%20preservation
[100] Žilak, M., Monzó, J.M., Bachiller, C., & Solaz, B.R. (2025). Towards an Accessible Metaverse Experience: Evaluation of a Multiplatform Technological Heritage Museum Prototype. Electronics, 14(8), 1635. https://doi.org/10.3390/electronics14081635