Architecture
Image Studies

Vol.6, Issue 3, pp.1332-1346, 2025
DOI: https://doi.org/10.62754/ais.v6i3.454

https://journals.ap2.pt/index.php/ais/index

Co-Designing Immersive Experiences for Cultural Heritage: A User-Centric VR Approach for Intelligent Cultural Tourism

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Abstract

This project introduces a computational, user-centered co-design methodology for creating immersive Virtual Reality (VR) media aimed at augmenting cultural tourism and education at a Khmer heritage site in Surin, Thailand. The study specifically focused on two objectives: (1) to connect digital media with authentic cultural interpretation by incorporating local requirements, and (2) to provide an accessible VR intelligent platform for community empowerment and cultural dissemination. The design thinking paradigm highlighted stakeholder preferences for mobile accessibility, modern aesthetics, and culturally concise narratives in development. The VR prototype for the Si Khor Phum Temple includes 360° tours and interactive 3D models, affirming its function as an accessible Human-Computer Interaction (HCI) instrument. Validation affirmed the system's quality and effectiveness. Expert assessments resulted in an exceptional overall quality rating, achieving flawless marks in linguistic clarity and system reliability. User testing validated elevated satisfaction levels, particularly with engagement. The research presents a proven participatory system design model that illustrates VR's potential as an adaptive tool for immersive education, historical preservation, and a significant driver of community empowerment via locally grounded digital innovation.

Keywords: *Virtual Reality (VR), Intelligent Cultural Heritage Systems, Human-Computer Interaction (HCI), User-Centered Design (UCD).*

Introduction

The Rise of Immersive Technology in Intelligent Cultural Systems

The integration of immersive technologies, especially Virtual Reality (VR), with cultural heritage signifies a transformative transition towards Intelligent Cultural Tourism and enhanced teaching practices. Recently, immersive technologies have attracted considerable attention in the educational and tourism sectors because of their ability to generate highly dynamic and engaging learning environments [1], [2], [3], [4]. As an advanced iteration of Human-Computer Interaction (HCI), virtual reality (VR) is distinctly capable of conveying intricate cultural and historical tales, providing sensory immersion and experiential learning levels that traditional media typically cannot achieve.

VR as a Tool for Interpretation and Preservation

The utility of virtual reality transcends simple display. Research validates its efficacy in improving heritage interpretation and promoting perspective-taking [5], [6], while concurrently enabling immersive storytelling and augmenting user interaction with historical material [7], [8], [9]. From a technological perspective, virtual reality excels in the three-dimensional depiction and rendering of historical contexts and artifacts, facilitating a more profound spatial comprehension of cultural assets [10], [11], [12]. This technology provides an innovative method for sustainable historical tourism by drawing virtual tourists through digital platforms, thus reducing the physical burden on sensitive locations while augmenting the appreciation of urban cultural assets [13], [14], [15].

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The Challenge of Authentic and User-Centric Design

Notwithstanding the demonstrated technological potential, the creation of resilient, efficient, and culturally genuine VR-based instructional instruments in heritage tourism continues to pose difficulties. A significant concern highlighted in the literature is that numerous VR apps, while technically advanced, lack cultural relevance, favoring visual fidelity over genuine representation and contextual subtleties necessary for profound cultural interaction [35]. Although VR can enhance visitor pleasure, its actual efficacy relies on its deliberate incorporation into service models that prioritize authentic cultural interpretation and emotional connection—components frequently lacking in existing system implementations [36], [37].

This issue underscores a notable methodological deficiency: an absence of literature on user-centered design (UCD) and participatory design of VR media that effectively involves local stakeholders, particularly in youth-led heritage contexts [38], [39]. The absence of active participation from end-users—local youth tour guides and community members—may result in VR systems neglecting community-specific insights and expertise, thus compromising the prospects for sustainable and inclusive heritage preservation.

Study Objectives

This research presents a computational, user-focused co-design technique for the creation of immersive virtual reality media. This method intentionally engages local youth tour guides, tourists, and cultural stakeholders at a Khmer heritage site in Surin Province, Thailand. This research seeks to:

1. Address the needs and cultural understanding of the local community by bridging the divide between nascent AI-driven digital media practices and genuine cultural interpretation.
2. Create a VR system that is pertinent and accessible to both the local community and tourists, functioning as an intelligent platform for community empowerment and intergenerational cultural transmission.
   The subsequent parts include a comprehensive analysis of the literature concerning the utilization of immersive technology, the framework of cultural heritage tourism, and the imperative for participatory design in intelligent systems.

Literature Review

Immersive Technologies and Cultural Heritage Presentation

The use of immersive technologies in cultural heritage has witnessed a significant increase, motivated by the need to enrich tourist experiences and enhance educational outcomes. Literature reviews, such as [16], offer comprehensive analyses of Augmented Reality (AR) applications, whereas [17] explores the overarching potential of immersive technology to profoundly alter conventional heritage presentations.

Experiential Models: Research has advanced toward conceptualizing the complete immersive experience. A conceptual paradigm for managing immersive heritage tourism demonstrates the vital role of interactive storytelling in captivating tourists [18]. Subsequent investigation validates the increasing importance of immersive technology in historic tourism, highlighting its ability to generate memorable, informative experiences [19].

Digital Storytelling and Preservation: Virtual reality provides a twin advantage by facilitating impactful digital storytelling that enriches educational engagement [30], [31] and concurrently advancing the sustainable preservation of physical locations. Technology enables users to engage with both tangible and intangible cultural heritage content without physical interference, thereby protecting delicate items and environments [32], [33], [34].

The Evolving Context of Cultural Heritage Tourism

Cultural heritage tourism has transitioned from mere preservation to a multifaceted enterprise that significantly enhances local economic growth and strengthens cultural identity.

Economic studies demonstrate that deliberately improving some site characteristics and matching services with tourist preferences—such as transportation and variety-seeking behaviors—can substantially increase visitors and bolster local economies [20], [21]. This underscores the idea that a thoughtfully crafted, user-centric digital product may serve as an economic catalyst.

Sustainability and Community Welfare: The worldwide expansion of tourism requires a meticulous equilibrium between economic advantages and environmental practices. Policy and management viewpoints underscore the incorporation of cultural sustainability concepts into the management of World Heritage Sites, integrating heritage protection with overarching sustainability frameworks such as the UN Sustainable Development Goals. Recreational demand and community well-being significantly link cultural heritage places, highlighting their importance in maintaining cultural ecosystem services [22], [23], [28]. This underscores the need for digital interventions to promote balanced development and reduce risks like overtourism [26], [27], [29].

The Call for Participatory System Design

The primary shortcoming in the present implementation of immersive legacy technology is the absence of a user-centered methodology, which is essential for the creation of effective intelligent systems.

Deficiencies in Existing Implementations: Current literature indicates that although VR systems possess technological capabilities, they frequently do not meet the cognitive and emotional requirements of users [38]. This imbalance results in challenges including restricted user engagement and accessibility problems [39]. Failing to include local knowledge and user preferences, VR apps may provide technically stunning experiences that lack cultural depth, ultimately undermining the contextual richness essential for genuine heritage interpretation [35].

The Imperative of Co-Design: For a VR system to effectively serve as an intelligent, adaptable instrument that fosters community empowerment and cultural transmission, it must be built within a participatory framework. Engaging local stakeholders, particularly youth tour guides, is crucial. This co-design methodology guarantees that the resultant digital media is not an external imposition but rather an inclusive, locally rooted invention that authentically represents and enhances the community's cultural voice and interpretative proficiency. This study tackles this significant deficiency by employing a stringent user-centered design and co-design methodology.

Materials and Methods

This section outlines the methodology and resources utilized in the study to accomplish the goal of co-designing a culturally genuine and technologically pertinent Virtual Reality (VR) system for intelligent cultural tourism.

Research Design and Participants

This research employed a mixed-methods approach, integrating qualitative and quantitative data to achieve a comprehensive understanding of stakeholder requirements, prototype quality, and user approval. The study encompassed three unique participant groups, with sampling methodologies customized to their functions in the co-design process:

Group 1: Principal Stakeholders (N=7). This group, chosen through deliberate sampling, ensured underlying cultural and historical correctness for the VR content. It comprised specialized professionals, including a heritage site officer, an archaeologist, two tourist specialists, a local sage, and two community leaders. Their qualitative contributions were essential for achieving the study objective of assuring authentic cultural interpretation.

Group 2: Expert Evaluators (N=5). These specialists, chosen by purposive sampling from archeological site management, tourism, and media design, evaluated the prototype's technical and design qualities. Their assessment yielded both quantitative and qualitative insights regarding the prototype's usability, interactivity, and design quality, facilitating the advancement of a resilient intelligent platform.

Group 3: Target Users (N=60). This group, comprising local kids and tour guides, engaged in the final user testing and effect evaluation. This empirical data collection emphasized usability, educational efficacy, cultural relevance, and user pleasure, directly targeting the goal of developing a VR system that is pertinent and accessible to the local population.

Data Collection and Design Thinking Stages

The study employed a sequential, three-phase methodology grounded in design thinking principles to convert cultural content into an engaging and sophisticated digital experience.

Phase One: Evaluation of Heritage Sites and Assessment of Stakeholder Requirements

This discovery process was crucial for anchoring the VR information in local knowledge and cultural comprehension.

Methodology: Data was gathered through document analysis of Khmer heritage sites, interviews, and structured questionnaires.

Focus: Assessing site conditions, user expectations, and preliminary requirements for cultural media. The major objective was to create a basis for integrating traditional interpretation with digital media methodologies.

Phase Two: Prototype Development and Expert Assessment

This phase concentrated on the computational design and technical evaluation of the prototype.

Development of Systems: The interactive VR media prototype was created according to the specifications obtained in Stage One, emphasizing elements like 360° visuals, mobile accessibility, and interactive narrative.

Assessment Instrument: Experts (Group 2) employed a formal assessment form consisting of Likert-scale items and open-ended questions to meticulously evaluate the prototype's content quality, interface usability, and cultural relevance.

Phase Three: User Testing and Impact Assessment

The concluding phase confirmed the system's efficacy as an intelligent platform for community users.

Participants: Sixty local youths and tour guides (Group 3) participated in the evaluation of the VR media prototype.

Evaluation Instrument: A user satisfaction survey was conducted, employing Likert-scale items and open-ended questions to assess usability, educational value, user involvement, and overall satisfaction. This immediately evaluated the system's cultural relevance and accessibility.

Data Analysis

Reliability and Validity Checks

The research instruments were rigorously evaluated for quality:

Reliability: Cronbach's alpha was computed for the Likert scale surveys, resulting in a number that signifies an adequate degree of internal consistency.

Content Validity: This was verified via a rigorous evaluation conducted by subject-matter experts in archaeology, tourism, and associated disciplines. The instruments were evaluated for relevance, clarity, and connection with the study's aims, ensuring they appropriately represented the research constructs.

Results

Addressing Local Needs and Cultural Interpretation

The findings from Stage One: Heritage Site Analysis and Stakeholder Needs Assessment directly fulfill the initial study objective: to meet the needs and enhance the cultural comprehension of the local community by reconciling emerging AI-driven digital media practices with authentic cultural interpretation.

The results delineate explicit, actionable criteria for the VR media's content, aesthetics, and technological attributes, guaranteeing that the co-designed system is culturally anchored and pertinent to users.

Design Requirements for Culturally Authentic VR Media

Stakeholder feedback delineated explicit preferences for the cultural context and aesthetic presentation of the VR media, guaranteeing that the final system will serve as a significant cultural representation rather than merely a technical endeavor.

Site Suitability and Content Scope

Optimal Site Selection: Stakeholder consensus designated Prasat Sikhoraphum as the premier Khmer heritage site for virtual reality development. This selection was predicated on its meticulously preserved architectural attributes (e.g., apsara carvings and Shiva dance reliefs), visual allure, and accessibility, which offer a profound, captivating, and practical subject for a virtual experience.

Concise and Organized Content: Stakeholders advocated for a succinct and systematically organized content format for the VR media, delivered in an electronic medium (e.g., e-books). Essential subjects were required to encompass historical context, architectural characteristics, artistic importance, and regional customs, beliefs, and celebrations associated with the location.

Language and Media: Content should employ simple, accessible language with limited academic jargon, accompanied by pertinent pictures. Video content must be concise, ideally not exceeding 5 to 6 minutes, to sustain viewer involvement.

Aesthetic and Format Preferences

The examination of stakeholder preferences indicated a pronounced inclination towards a contemporary, refined, and professional aesthetic that appropriately reflects the site's cultural significance.

- Style and Tone: A significant majority (86.7%) preferred a semi-formal style for the media format rather than a completely formal one. Likewise, 86.7% favored opulent and sophisticated hues (e.g., gold, deep colors) that signify value and affluence over cool, nature-inspired tones.
- Visuals: Participants exhibited a substantial preference for pictures (90.0%) over illustrated representations, underscoring a demand for visual authenticity
- Typography: 86.7% opted for a modern, styled sans-serif typeface, indicating a desire for contemporary clarity and legibility.

Technical Requirements for Bridging Digital Media and Interpretation

The examination of preferred attributes determined the requisite technological specifications to guarantee that the VR media operates as a highly accessible, cross-platform, and social media-integrated intelligent tool.

Table 1. Summary of desired VR system features, prioritization, and interpretation for cultural relevance.

Feature (Mean Score)	**Interpretation**
Share images via social networks (5.00)	Highest priority; indicates strong demand for **social media integration** to facilitate intergenerational cultural transmission.
Access via QR Code (4.87)	High priority for **ease of access** in the physical heritage setting.
Compatibility with Smartphones/ Tablets (4.87)	Critical for ensuring **cross-platform accessibility** and reducing barriers to entry for local youth and tourists.
Ability to display videos (4.83)	Supports the content requirement for **brief, engaging video content** for storytelling.
Ability to display 3D images (4.40)	Supports the expert recommendation for **modern tools** like 3D models to explore the site from various perspectives.
Use without Internet Connection (4.13)	Moderately important for **accessibility and system reliability** in areas with varying internet connectivity.
360° Image Display (4.13)	Required feature to provide the core **immersive experience** and varied perspectives recommended by experts.

The results collectively indicate that the local community and stakeholders necessitate a system that integrates cultural richness (semi-formal, luxurious tone, historical emphasis) with contemporary digital interactivity (QR codes, smartphone compatibility, social sharing), thereby offering a comprehensive framework to reconcile digital media with authentic cultural interpretation.

The essential criteria determined by the local needs assessment in Section 4.1—specifically the inclination for a semi-formal, visually appealing style, mobile adaptability, and succinct, culturally precise content—directly informed the system's architecture. These co-design criteria were essential

for connecting developing digital media practices with authentic cultural representation. The next phase concentrated on converting these user-centric requirements into a concrete and assessed Virtual Reality (VR) Intelligent Platform, ensuring that the generated technology was relevant and culturally anchored for local stakeholders and the target audience.

Development and Validation of the VR Intelligent Platform

This part outlines the implementation of the co-design technique, demonstrating how the local community's needs and cultural requirements (identified in part 4.1) were converted into a functioning and assessable VR system. The process followed a stringent design thinking framework, advancing through pre-production, production (development), and post-production phases to guarantee that the final product—an intelligent platform—was culturally relevant, technically accessible, and effective for intergenerational cultural transmission.

Development of the VR System Based on Local Needs and Cultural Interpretation

The development phase methodically integrated stakeholder preferences for aesthetics, content, and accessibility, guaranteeing that the VR media served as a genuine digital interpretation tool.

Pre-Production: Defining the Cultural and Technical Scope

This phase established the essential factors derived from the Stage 1 findings, specifically focusing on the preservation of cultural authenticity and local significance:

Goal Setting: Established desirable objectives aimed at enhancing historical knowledge and site understanding, aligned with the educational objective, while delineating explicit quantitative (test scores) and qualitative (satisfaction) success metrics.

Target Audience Analysis (Co-Design Input): Data regarding local young tour guides, including age, education, and technological proficiency, alongside their learning practices, were utilized to align the VR's interactivity and content complexity with user needs, thereby emphasizing job readiness.

Content Structuring: Essential content themes (historical context, architectural features, symbols, and regional customs) were systematically arranged in a progressive sequence, directly addressing the experts' request for succinct, well-organized cultural narratives.

Storyboarding and Wireframing: The storyboards maintained visual narrative coherence, while wireframes established the interface configuration, emphasizing navigational simplicity and a lucid display of cultural information (aligning with the purpose of an accessible platform).

Production: Translating Co-Design into Digital Architecture

The design and development phase concentrated on executing the desired aesthetic and functional attributes specified by the stakeholders (luxurious tones, contemporary typefaces, and mobile compatibility):

Table 2. Translation of stakeholder requirements into VR system design architecture

Design Element Implemented	Stakeholder Preference	Architectural/Aesthetic Rationale
UI/UX Design & Layout	Semi-formal style, modern typeface, high usability.	Established an intuitive flow (main menu, back buttons, help buttons) to ensure effortless cross-platform functionality on mobile devices.
Aesthetic Theme	Luxurious and elegant tones (86.7%), photographs (90%).	Utilized warm color tones (brown, sand) to reflect the ancient stone architecture, aligning the digital aesthetic with the physical site's atmosphere. Typography balanced readability (modern sans-serif) with a subtle Thai traditional style.
Development of Content Modalities	Videos (high demand), 360° images, 3D models.	Created distinct media types (e-Posters, e-Books, 3D Models, 360° Tours, Digital Videos) to cater to diverse learning styles and maximize interactive storytelling.
Media Development Tools	Mobile-compatible, interactive.	Employed industry-standard tools (Unity/Unreal Engine for VR, Figma/Adobe XD for mockups, professional graphic/video software) to ensure system reliability and high media quality, essential for an intelligent platform.

Developed digital components include:

Interactive E-Poster (Figure 1): Intended to serve as the entry point for QR code access and preliminary information.

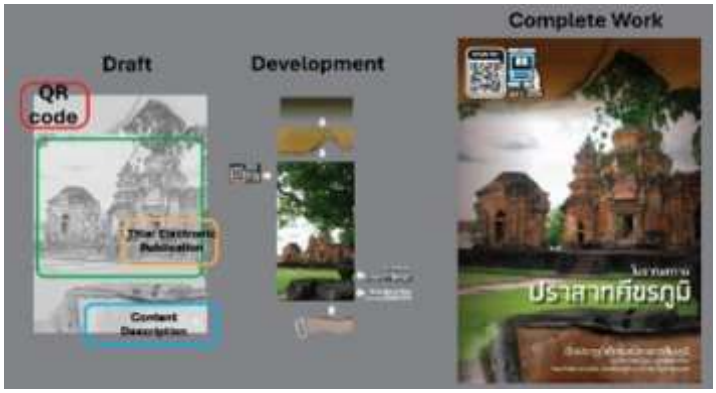

Figure 1. Interactive e-poster.

Interactive E-Book (Figure 2): Incorporates multimedia elements (brief movies, interactive maps) and hyperlinks to fulfill the criteria for succinct, multi-faceted electronic information.

Figure 2. Interactive e-book

3D Model Creation (Figure 3): Models were generated or modified (from actual scans) with authentic texture and illumination, satisfying the requirement for comprehensive architectural examination.

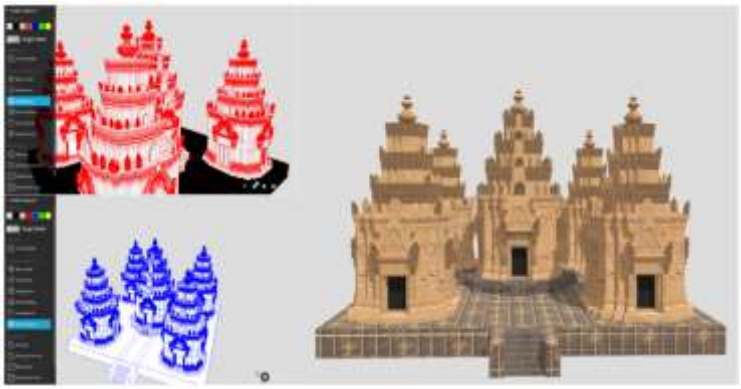

Figure 3. 3D model creation

360° Virtual Tour (Figure 4): Created utilizing specialist camera footage and gaming engines to facilitate virtual site exploration and perspective-taking.

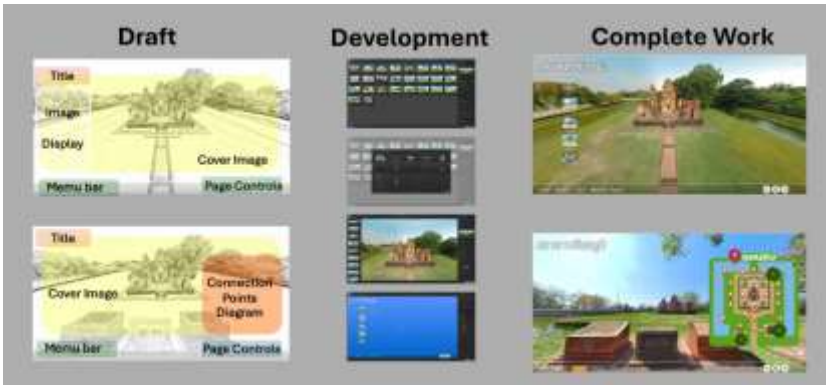

Figure 4: 360° virtual tour.

Digital Video Production (Figure 5): Created concise, narrative-focused videos featuring voice-overs and effects, according to the optimal 5–6-minute length for enhanced viewer engagement.

Figure 5. Digital video production.

Post-Production: Finalizing Interactivity and Accessibility

This phase confirmed the platform's readiness for user validation by incorporating the necessary interactive and social components:

Interactive Components: Incorporated professional voice-overs, music, and sound effects. Essential interactive components such as social sharing buttons (the most highly rated feature at $\bar{x} = 5.00$), interactive maps, and control buttons were incorporated to enhance the system's functionality as a socially connected tool.

Compatibility Assessment: Comprehensive testing was conducted on many platforms (PC, mobile, tablet) and operating systems to verify the elevated rating for cross-platform compatibility ($\bar{x} = 4.87$) and to ascertain operation in the absence of an internet connection ($\bar{x} = 4.13$).

The VR Prototype: Design and Features

The ultimate VR prototype, created via the co-design process, is a mobile-compatible intelligent platform centered on the Si Khor Phum Temple. The design incorporates many interactive media formats available through a single-entry point, guaranteeing excellent accessibility, engagement, and

the delivery of rich cultural material. The prototype explicitly integrates stakeholder requirements for cross-platform capability, succinct content, and social engagement.

Key Features and Interactivity

The prototype operates as an integrated digital environment, providing users with five separate content modules, all interconnected through a central entry point:

Centralized Access via QR Code (Figure 6)

Figure 6. User QR code

Access is enabled by scanning a QR code located on a physical interactive poster at the heritage site. This singular action promptly initiates the application on the user's mobile device (smartphone or tablet), granting immediate access to all essential functions—including 3D models, 360° virtual tours, and video clips—thereby satisfying the imperative for accessibility and cross-platform compatibility (x^{-} = 4.87).

Immersive 360° Virtual Tour (Figure 7)

Figure 7. 360° virtual tour

The 360° tour offers a fundamentally immersive experience, enabling users to explore the Si Khor Phum Temple from both terrestrial and aerial viewpoints, recorded with advanced camera techniques. This module incorporates social media capability, enabling users to shoot and distribute still photos straight to their chosen platforms, fulfilling the paramount user need for social integration (x^{-} = 5.00).

Interactive 3D Modelling (Figure 8)

Figure 8. 3D Modelling.

Users can interact with the site's 3D models, facilitating comprehensive, tactile architectural analysis. The interactivity includes the ability to rotate, zoom in, and change the model's surface and surroundings, providing views that can't be seen in real life and helping to improve understanding of history.

Digital Video Clips (Figure 9)

Figure 9. Digital video clips.

The video module addresses stakeholder requirements for succinct and captivating information by encompassing four primary cultural and historical themes: history, architecture, artistic beauty, and local traditions. Videos are recorded from several perspectives (low, normal, and high) to emphasize delicate features and are enhanced by professional narration and calming background music, maximizing the system for efficient knowledge transfer.

Electronic Publications (Figure 10)

Figure 10:. Electronic publications

The electronic publications (e-books) include comprehensive textual and graphic information regarding the temple. These publications are directly accessible via the QR code link, providing essential historical background and specific information that enhance the visual and interactive media formats.

Prototype Evaluation and Validation

The prototype underwent a dual validation process: a formal Expert Evaluation (Group 2, N=5) to assess technical and educational quality, followed by user testing (Group 3, N=60) with the target population to verify accessibility, relevance, and satisfaction. These findings unequivocally affirm the VR system's efficacy as an intelligent platform.

Expert Evaluation of VR Media Quality

The assessment conducted by five specialists resulted in an extraordinarily high overall quality rating, with a mean score across all areas, indicating that the system adheres to elevated criteria for an educational tool.

Optimal Quality Indicators ($\bar{x} = 5.00$): Experts unanimously validated the prototype's fundamental functionality and dependability. The highest ratings were given to the Appropriate Language Level, System Reliability, Navigation Accuracy and Appropriateness in 360-degree Images, Audio and Narration Accuracy and Appropriateness, Database Interaction Speed, and Information Presentation Speed. This verifies that the platform is technically robust, efficient, and employs a linguistic level appropriate for cultural dissemination.

Robust Performance and Design: Performance-related factors (e.g., overall system speed, ($\bar{x} = 4.80$)) and design elements (e.g., color scheme and font style) garnered high ratings, affirming the effective translation of stakeholders' aesthetic preferences (luxurious tones) into a superior visual experience.

Content and Interactivity: The quality of content received great ratings ($\bar{x} = 4.60$), especially for its accuracy and appropriateness ($\bar{x} = 4.60$), as well as its clear and logical organization ($\bar{x} = 4.60$). The interactivity received a high rating ($\bar{x} = 4.40$), validating the efficacy of the employed interactive elements.

The professional agreement affirms that the VR prototype is a high-quality, dependable, and well-constructed instructional instrument capable of assisting local youth tour guides.

The thorough findings from the expert assessment and user testing phases validate that the built VR system satisfies the defined standards for a culturally relevant and accessible intelligent platform. The quantitative data indicates the prototype's exceptional quality ($\bar{x} =4.68$) and elevated user satisfaction ($\bar{x} =4.48$). The discussion now critically analyzes how the co-design methodology facilitated the successful amalgamation of local cultural authenticity and advanced digital media, investigating the implications of these findings for community empowerment and future heritage system research.

Discussion

The successful development and validation of the VR intelligent platform affirm the effectiveness of the proposed computational, user-centered co-design methodology in solving significant deficiencies in cultural heritage research. This analysis contextualizes the elevated quality ratings and high user satisfaction scores by referencing the current research on immersive technology, cultural tourism, and participatory design.

Anchoring Immersive Design in Cultural Authenticity

The study's achievement in attaining an exceptional overall quality score and near-perfect scores in language clarity and dependability substantiates the choice to implement a user-centric strategy, directly contesting the "deficiency in existing implementations" referenced in the literature [38-39]. Previous studies demonstrate that VR systems frequently do not satisfy users' cognitive and emotional requirements, resulting in diminished engagement. Our methodology directly alleviated this risk:

Countering Technical Arrogance: The primary stakeholder inclination for a semi-formal style and opulent tones (86.7% preference) indicates that cultural profundity and aesthetic congruence are vital for authentic historical representation. This finding substantiates the argument of [35] that neglecting local knowledge yields technically impressive yet culturally superficial experiences. By aligning the design with the local style of the Khmer location, the platform attained genuine contextual depth.

Verifying Experiential Models: The elevated user satisfaction with interactivity and the authenticity of the 360° tour substantiates the system's capacity to produce memorable and instructive encounters deemed essential in experiential models of immersive tourism [18-19]. This illustrates the effective conversion of interactive components into compelling digital narratives, aligning with the benefits of VR identified by [30-31].

The study's achievement of an exceptional overall quality score and nearly flawless scores in language clarity and dependability substantiates the choice to apply a user-centric strategy, directly contesting the "deficiencies in existing implementations" referenced in the literature [38-39]. Previous studies demonstrate that VR systems frequently do not satisfy users' cognitive and emotional requirements, resulting in diminished engagement. Our methodology directly alleviated this risk:

VR as a Catalyst for Sustainable Community Welfare

The success of the built platform transcends technology, positively impacting cultural heritage tourism and community welfare objectives.

Economic Pertinence: The study establishes the VR media as a viable, user-centric digital product with high quality and mobile accessibility, positioning it as an economic accelerator, as indicated by [20-21]. The software offers young guides an innovative way to align tourist preferences with site attributes, thereby strengthening the local economy.

Cultural Sustainability and Conservation: The advanced functionality of 360° tours and 3D models provides the "twin advantage" identified in the literature, enhancing digital storytelling while simultaneously promoting sustainable preservation [32-34]. The platform facilitates profound engagement with both tangible and intangible heritage without physical disruption, hence promoting the integration of cultural sustainability principles into heritage management, in accordance with global frameworks such as the UN Sustainable Development Goals [22], [28].

Upholding the Imperative of Co-Design

The study's findings affirm the necessity of co-design in system deployment [35]. The project remedied the "primary shortcoming" of modern legacy technology, characterized by a lack of user-centered methodology, by involving local youth tour guides as the definitive interpreters of history.

Empowerment through Inclusion: The exemplary score attained by users for Consistency Between Content and Display, together with the elevated rating for Appropriate Language Level, are direct outcomes of the participative process. The co-design approach guaranteed that the digital medium was not an external imposition but a locally rooted invention that genuinely enhanced the community's cultural expression and interpretative capability. This result confirms that a participatory framework is crucial for a VR system to function as a flexible tool that promotes community empowerment and cultural transmission.

This research transcends the conceptualization of immersive experiences by empirically validating the effective development of a culturally genuine and technologically advanced VR platform. The findings offer an essential framework for the advancement of legacy systems, emphasizing that genuine innovation is rooted not solely in technology but in the rigorous incorporation of local cultural intelligence via a committed co-design methodology.

Conclusion

This research effectively developed and validated a computational, user-centered co-design methodology for producing immersive Virtual Reality (VR) media, fulfilling both study objectives by involving local stakeholders and youth tour guides at the Khmer heritage site, Prasat Sikhoraphum, in Surin Province, Thailand.

Key Findings and Objective Achievement

The accomplishment of the study's two main objectives inextricably links to its conclusions:

Addressing Local Needs and Cultural Interpretation

The research successfully connected digital media with authentic cultural interpretation by methodically converting local knowledge into technical specifications.

Cultural Grounding: The preliminary requirements assessment revealed a robust agreement among stakeholders (archaeologists and local leaders) that the media should conform to a semi-formal,

visually engaging, and historically succinct content framework. Crucial decisions, including the selection of Prasat Sikhoraphum and the stipulation of opulent tones and contemporary fonts (86.7% preference), guaranteed that the digital platform communicated the site's significance with dignity and refinement.

Accessibility Requirements: User feedback emphasized essential aspects for an intelligent platform, particularly social media sharing ($x^- = 5.00$) and cross-platform mobile compatibility ($x^- = 4.87$). This affirmed the imperative of developing the system not alone for observation, but for dynamic intergenerational sharing and utilization within a practical tourism setting.

Creating a Pertinent and Accessible VR Intelligent Platform

The final VR prototype was confirmed as a relevant, accessible, and high-quality intelligent platform that can facilitate local community empowerment.

The prototype effectively incorporated many interactive modules (3D models, 360° virtual tours, video clips, and e-publications) accessible by a single QR code scan. The system was designed for effortless utilization on smartphones and tablets, ensuring its superior accessibility for both local youth tour guides and tourists.

Quality and Reliability: Both expert evaluation ($x^- = 4.68\$$) and user testing ($x^- = 4.48\$$) validated the prototype's efficacy. Experts commended the system's reliability and rapid information presentation ($x^- = 5.00\$$), affirming its quality as a digital instrument.

Community Empowerment: User satisfaction reached its peak for interactivity ($x^- = 4.63$) and consistency between content and display ($x^- = 5.00$). The elevated satisfaction with the content's appropriate language level ($x^- = 4.78\$$) indicates the platform's efficacy in offering youth an effective, engaging, and reliable resource for cultural education and interpretation, thereby fostering community empowerment through enhanced professional competencies.

Significance and Future Implications

The findings illustrate the effectiveness of the computational, user-centered co-design method as a feasible framework for creating genuine digital heritage media. By prioritizing the cultural and technical requirements of local stakeholders in the development process, the research produced a highly acclaimed VR system and established a framework for future AI-driven media practices that are authentically informed by and conducive to local cultural interpretation and intergenerational cultural transmission within the tourism sector.

Limitations and Future Research

Limitations

This study presents a robust approach for co-design; nonetheless, two primary limitations must be acknowledged. The user testing for Group 3 did not utilize probabilistic sampling, thereby constraining the generalizability of the satisfaction results outside the examined cohort of young guides. The study concentrated on prototype creation and preliminary impact assessment; it did not monitor the system's enduring effects on tourist happiness or the economic empowerment of the local population.

Future Research

Subsequent research ought to concentrate on integrating the VR platform inside the tourism cycle to assess its influence on tourist engagement, knowledge retention among young guides, and the measurable consequences on local firm revenue. Subsequent research could investigate the application of this co-design methodology to other minority heritage sites with analogous issues in the digital age.

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