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ENHANCING CULTURAL LEARNING THROUGH VIRTUAL REALITY: A CASE STUDY OF THE ‘AIN GHAZAL STATUES

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ABSTRACT

Aim/Purpose	This study aims to determine whether a task-based virtual reality (VR) experience can significantly enhance users’ factual understanding and cultural appreciation of a lesser-known archaeological site. The purpose is to evaluate how an interactive reconstruction task impacts perceived educational value and emotional engagement in a cultural heritage context.
Background	Many virtual reality experiences in cultural heritage are limited to passive tours, failing to leverage the technology’s full potential for interactive learning. Grounded in embodied cognition theory, this study posits that active, hands-on participation is crucial for deeper learning. We explore this using the Neolithic statues of ‘Ain Ghazal as a case study, addressing the need for more engaging educational models for lesser-known heritage.
Methodology	A task-based VR application simulating the statue-building process was developed. A mixed-methods approach was used, with 272 participants completing pre-tests and post-tests and a survey, and a subset of 41 participants being interviewed. Quantitative analysis included Wilcoxon tests and correlations, while qualitative analysis identified key user experience themes.
Contribution	This study’s key contribution is a novel, task-based approach to immersive learning in cultural heritage. It highlights the educational effectiveness of VR in both cognitive (factual learning) and affective (cultural appreciation) domains, offering evidence-based design considerations for future heritage-focused VR applications.

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Findings	The task-based VR experience led to a significant improvement in factual knowledge ($Z = -12.498$, $p < .001$). A strong, positive correlation was found between cultural appreciation and learning outcomes ($r = 0.582$, $p < .001$). Perceived authenticity was also a strong predictor of the experience’s educational effectiveness ($r = 0.549$, $p < .001$). Key interview themes included “Learning by Doing” and “Cultural Appreciation.”
Recommendations for Practitioners	Museum professionals and educators should design interactive, task-based VR experiences that allow users to “learn by doing.” To maximize educational impact, practitioners must carefully balance archaeological authenticity with user-centered design, as this balance directly fosters both factual understanding and cultural appreciation.
Recommendations for Researchers	Further research should investigate how specific VR affordances, such as interactivity, embodiment, and sensory fidelity, impact presence, knowledge retention, and cultural empathy across different heritage contexts.
Impact on Society	By making underexplored heritage accessible and engaging, task-based VR can strengthen cultural identity, support preservation efforts, and create new, meaningful opportunities for museums and tourism.
Future Research	Future studies should examine long-term knowledge retention from task-based VR, explore the role of creative freedom within these experiences, and assess their impact on diverse global audiences.

Keywords	virtual reality, cultural heritage education, immersive learning, Ain Ghazal statues

INTRODUCTION

It is becoming evident that rapid technological advancements are shaping the way we interact with the world around us. Innovative technologies, such as Artificial Intelligence (AI), virtual reality (VR), and augmented reality (AR), are transforming and enhancing user experiences across sectors, including education, healthcare, and entertainment (Fazil et al., 2024). VR is revolutionizing people’s interactions with digital environments, offering new, enhanced experiences that allow users to engage with different simulated environments (Vlahovic et al., 2022). This technology has become a powerful tool, providing an interactive, three-dimensional experience of ancient and historical sites that enhances visitor engagement (Ribeiro et al., 2024).

To guide this study, we adopted a conceptual framework integrating embodied cognition theory, which posits that physical interaction with learning materials enhances understanding and memory by engaging sensorimotor systems alongside conceptual reasoning (Barsalou, 2007). In VR, manipulating objects such as placing reed bundles and applying plaster embodies this principle, creating richer cognitive representations. This aligns with Kolb’s (1984) experiential learning model, which emphasizes learning as an active cycle of experience, reflection, abstraction, and experimentation. Additionally, VR research highlights how immersive environments can enhance emotional engagement and perceived educational value (Petersen et al., 2022). Together, these frameworks support our hypothesis that an embodied, immersive task-based VR experience can strengthen factual understanding and deepen cultural appreciation of underrepresented cultural heritage sites.

While VR has been widely used in science, technology, engineering, and mathematics (STEM) education and training simulations (Radianti et al., 2019), its role in cultural heritage learning, especially for lesser-known archaeological sites, remains underexplored. Traditional approaches to cultural heritage education, such as museum exhibits and classroom instruction, often face limitations. These methods can foster a passive learning environment where students are merely recipients of information, potentially hindering deep engagement and critical thinking (Awang et al., 2016; Levstik & Barton, 2018). Static displays, for instance, may struggle to convey the dynamic processes underlying the creation of historical artifacts, and a one-size-fits-all approach may not accommodate diverse learning styles (Hooper-Greenhill, 2007; Styliani et al., 2009). Most existing VR heritage projects focus on well-known museums or iconic archaeological sites (Bekele et al., 2018; Dieck & Jung, 2017), leaving less-known but culturally significant sites underrepresented (Landeschi, 2020). Furthermore, although VR has been used for visualization and narrative experiences, far fewer studies investigate how task-based VR experiences influence factual learning, perceptions of authenticity, and cultural appreciation (Mortara et al., 2013; Sylaiou et al., 2009).

Many people are unfamiliar with the rich history and cultural significance of early Neolithic sculptures, despite their importance as among the earliest. To address this knowledge gap, our research explores how immersive VR can create a more meaningful educational experience. A VR application was developed to enable users to actively participate in the virtual reconstruction of these ancient artifacts, using the ‘Ain Ghazal statues as a representative case study, simulating the techniques used by their ancient creators. This study aims to investigate how this hands-on process fosters a deeper appreciation for cultural heritage and how that appreciation enhances factual learning. To test the effectiveness of task-based VR, this study focuses on the Neolithic site of ‘Ain Ghazal in Jordan as a research setting. Jordan has some of the world’s most ancient archaeological sites. ‘Ain Ghazal, a remarkable historical discovery that is in the eastern part of Amman, is one of the most important Neolithic sites that existed in the 8th and 7th millennia BCE (Grissom, 2000). ‘Ain Ghazal is famous for its advanced social and economic organization, as well as its achievements in early architecture and material culture. The site provides valuable insights into the development of early human societies, particularly during the Pre-Pottery Neolithic B (PPNB) and Pottery Neolithic (PN) periods (Rollefson & Kafafi, 2013). ‘Ain Ghazal city and the limestone statues, which are among the oldest known large-scale human figures, were found by the archaeological team under the supervision of Gary Rollefson and Alan Simmons during the 1982 excavations in Jordan. These statues were made approximately 6500 BCE. Both single-headed and two-headed figures may be seen in these statues, which were constructed using innovative and revolutionary techniques for their era. Clay-based lime plaster was applied after reeds were bound with cordage to create human-shaped figures (Rollefson, 1992). One of the limestone figures found at the ‘Ain Ghazal site (c. 6500 BCE) is shown in Figure 1, demonstrating early Neolithic craftsmanship using lime plaster and reed frameworks (Amin, 2019).

Figure 1. A two-headed statue was discovered at the ‘Ain Ghazal site and displayed at the Jordan Museum in Amman, and made of lime plaster over reed framework, dating to approximately 6500 BCE
(Source: Photograph by Osama Shukir Muhammed Amin, 2019. From Wikimedia Commons, CC BY-SA 4.0.)

Museums play a vital role in this effort by safeguarding artifacts and making them accessible to future generations. Similarly, the Jordan Museum fulfills this role by preserving the Neolithic statues from ‘Ain Ghazal, some of the oldest known large-scale human figures (Grissom, 2000; Rollefson, 1992). By exhibiting these invaluable pieces, the museum helps educate the public and sustain Jordan’s cultural legacy.

Drawing on embodied cognition and experiential learning theories, this study investigates a task-based VR reconstruction of the heritage artifacts to address these gaps. The primary contribution of this paper is therefore methodological and empirical. Methodologically, we present a novel, task-based VR framework that applies the principles of embodied cognition to cultural heritage learning, which is a significant departure from the everyday use of VR for passive tours. Empirically, we provide new insights into how active participation in a virtual reconstruction process at a lesser-known archaeological site can simultaneously enhance factual understanding and deepen cultural appreciation. By focusing on this specific Neolithic site, our work provides a replicable model for leveraging immersive technology to bring underrepresented histories to a broader audience.

In addition to assessing factual learning outcomes, this study examines perceptual and experiential dimensions that are central to learning in immersive cultural heritage environments. Specifically, we focus on perceived learning outcomes, cultural appreciation, and perceived authenticity of the VR experience. These constructs were selected because embodied and experiential learning theories emphasize that meaningful learning emerges not only from cognitive understanding but also from active engagement, emotional involvement, and the perceived credibility of the learning environment. Prior research in VR-based heritage education suggests that such perceptions play an important role in shaping how learners interpret, value, and internalize cultural knowledge. The following research questions, therefore, guide the study:

- **RQ1:** How does participating in a task-based VR experience influence users’ factual understanding of the statue-building process?
- **RQ2:** What is the relationship between cultural appreciation and perceived learning outcomes?
- **RQ3:** How do users perceive the authenticity and educational value of VR experience?

To explore these objectives, the study used a mixed-methods approach that combined pre- and post-tests to assess cognitive learning outcomes, along with Likert-scale surveys and qualitative interviews to explore participants’ emotional engagement and perceptions of cultural value.

This paper is organized as follows: the next section reviews related literature on VR, embodied learning, and cultural heritage education; the methodology section describes the research design, participants, instruments, and procedures; the results section presents the quantitative and qualitative findings; the discussion interprets these findings in relation to the research questions and prior work; and the final section concludes with implications and directions for future research.

LITERATURE REVIEW

Understanding how immersive technologies reshape learning and cultural interpretation requires placing VR within the broader context of experiential learning, digital pedagogy, and cultural heritage reconstruction. This review begins by outlining how VR has evolved as an educational tool, then shifts its focus to immersive applications in heritage contexts. It concludes by highlighting the conceptual and methodological gaps that motivate this study on the digital interpretation of underrepresented archaeological sites.

Conceptual Framework

Understanding the role of VR in education and heritage interpretation requires a grounding review in the theories that explain how people learn through immersive experiences. Experiential learning theory (Kolb, 1984) positions learning as a four-stage cycle in which individuals acquire knowledge through concrete experience, reflection, abstract conceptualization, and active experimentation. These processes align closely with VR's interactive features. Similarly, research on grounded cognition (Barsalou, 2007) proposes that conceptual understanding emerges from the reactivation of perceptual, motor, and sensory experiences. Physical action, spatial manipulation, and embodied engagement, therefore, play a central role in how individuals form and use concepts. VR environments, particularly those designed around task-based interaction, support these mechanisms by allowing users to engage directly with reconstructed settings, objects, and procedures.

Task-based reconstruction, such as simulating building techniques or interacting with material culture, embodies these principles by encouraging procedural reasoning, contextual understanding, and emotional engagement. This conceptual grounding provides a foundation for examining VR not merely as an engaging medium but as a pedagogical tool capable of supporting meaningful learning outcomes.

Building on this theoretical foundation, the present study focuses on three constructs that operationalize learning in immersive heritage contexts: perceived learning outcomes, cultural appreciation, and perceived authenticity. Perceived learning outcomes reflect learners' self-assessed understanding of the reconstruction process and its historical context, which aligns with experiential learning's emphasis on reflection and meaning making. Cultural appreciation captures affective and value-based engagement with heritage content, including emotional connection and reflection on preservation, which are central to embodied and situated learning experiences. Perceived authenticity refers to the extent to which the VR environment is experienced as credible, immersive, and faithful to the cultural context, a factor widely associated with engagement and interpretive learning in immersive environments.

From this perspective, experiential and embodied learning theories suggest that stronger cultural appreciation and higher perceived authenticity are likely to be associated with stronger perceived learning outcomes, as emotional engagement and credible context support deeper interpretation and understanding in immersive learning environments.

VR in Education

Unlike traditional media, VR has the unique ability to transport learners from their desks into dynamic, interactive environments, allowing them to visualize complex data, conduct experiments in safe, simulated settings, or walk through historical reconstructions (Radianti et al., 2019). Prior research consistently notes that the shift from passive observation to active participation contributes to greater cognitive engagement and improved retention of difficult material (Wu et al., 2020).

Evidence for the benefits of VR in STEM education was presented in a study by Rahmaniar et al. (2025), which found that undergraduate engineering students who participated in interactive VR tours of renewable energy systems performed better than their peers who relied on traditional textbooks. The advantages were twofold: the VR group scored higher on summative assessments and reported significantly greater motivation and a firmer grasp of complex system dynamics. The research supports the conclusion that, when professionally designed, immersive VR environments are practical tools for strengthening conceptual understanding and student engagement.

Stephan et al. (2025) explored how VR can serve as a teaching tool in online archaeology courses. Their university-level course, *Seven Wonders of Ancient Greece*, used immersive 360° VR video to simulate site visits to major archaeological landmarks for remote learners. Grounded in immersive learning theory and digital pedagogy, the course offers a model for integrating VR in heritage education.

The study also highlights the need for further evaluation of learning outcomes and cultural appreciation, both of which remain underexplored.

Birrenbach et al. (2021) evaluated the effectiveness of an immersive VR simulation compared to traditional video-based instruction for training medical students in essential COVID-19 procedures, including proper hand hygiene, donning and doffing personal protective equipment (PPE), and performing nasopharyngeal swab techniques. While both groups demonstrated significant improvement in post-training performance, the VR cohort achieved superior performance in nasopharyngeal swab acquisition immediately following the intervention. Furthermore, the VR group reported significantly higher user satisfaction. The authors concluded that VR simulation is at least as effective as conventional video instruction and offers distinct advantages in user engagement and satisfaction for complex procedural training.

A comprehensive meta-analysis by Yang et al. (2024) examined 37 empirical studies on VR’s impact on practical skill acquisition in science and engineering education. The authors identified a moderate, positive overall effect of VR interventions. Furthermore, the moderator analysis highlighted that VR was particularly beneficial for medical students and that its effectiveness was maximized when integrated into a blended learning model that combines VR with traditional instructional methods. This finding aligns with a broader pattern suggesting that VR is most effective when used to complement rather than replace conventional teaching approaches.

Digital technologies have long played a central role in archaeological documentation and interpretation. Early work by Landeschi (2020) focused on 3D digital documentation, photogrammetry, and virtual reconstruction as tools for recording excavation processes and supporting archaeological analysis. These approaches emphasize accuracy and visual communication, but they do not necessarily involve immersive or interactive VR experiences. Building on this foundation, subsequent studies explored virtual environments as platforms for presenting reconstructed sites to broader audiences. For example, Rua and Alvito (2011) demonstrate how VR environments can be used to visually reconstruct and explore historical architecture; however, user interaction remains primarily observational, with limited emphasis on task-based engagement or procedural learning.

Although many studies emphasize the benefits of VR for learning, several scholars caution that its adoption is not without obstacles. Research has identified challenges, including the high cost of VR hardware and the substantial resource investment required to deploy and sustain immersive systems in educational settings (Radianti et al., 2019). Broader disparities in digital infrastructure and institutional access to advanced educational technologies also affect the feasibility of adopting VR, particularly in settings with uneven technological capacity (Miao et al., 2020). Physiological comfort barriers also continue to surface, particularly cybersickness and discomfort experienced by some learners even in well-designed immersive environments (Mareta et al., 2022; Rebenitsch & Owen, 2020). Another study has raised concerns that although VR can increase motivation and presence, these factors do not necessarily lead to improved learning outcomes and, in some cases, may even hinder retention due to increased cognitive load (Makransky & Mayer, 2022). Taken together, these points remind us that VR is not a perfect solution and that its success depends on practical, realistic implementation, something that can be especially challenging in heritage education, where access to resources and technology often varies from one institution to another (Makransky & Lilleholt, 2018).

Immersive Experiences in Cultural Heritage and Virtual Tourism

Trunfio et al. (2021) describe how immersive storytelling and multisensory experiences at the Ara Pacis Museum in Rome have redefined visitor engagement, making historical artifacts more emotionally resonant. Similarly, VR reconstructions of fragile sites, such as the Lascaux Caves, allow users to explore sensitive locations without physical risk. These examples reveal how immersive environments can bridge the gap between historical abstraction and lived experience, providing users with a sense of spatial and emotional presence. This study follows a similar direction by applying VR to a lesser-known Neolithic context. One study demonstrated how VR could create immersive environments that not only preserve cultural heritage sites but also bring them to life through interactive storytelling. By integrating restoration with exploration, VR platforms can make cultural heritage more engaging and informative, offering users a sense of connection to history that static displays cannot provide (Smith, 2023).

Daniela (2020) evaluated virtual museum applications as an educational tool. In her study, the author examined thirty-six virtual museum applications from a phenomenological perspective. The study's findings suggest that although virtual museums perform well in information structure and technical quality, they often fall short in educational interactivity, particularly in interactive narration and accessibility.

Allal-Chérif (2022) explored how VR, AR, and AI enhance cultural and religious tourism experiences in cathedrals. The study highlights how these technologies not only aid in cultural heritage preservation but also offer new means of education, accessibility, and visitor engagement. These findings suggest that VR's value in heritage contexts extends beyond information delivery to include practical and spiritual dimensions of engagement.

AR applications enhance experiences in urban heritage sites, while VR offers fully immersive reconstructions accessible through wearable devices. Mobile-mediated virtual tourism provides flexible and accessible alternatives to physical travel, expanding opportunities for cultural exploration (Verma et al., 2022).

Lee and Kim (2021) investigated the dual-path model of utilitarian and hedonic experiences in virtual tourism and their effects on users' intention to visit real-world destinations. Their findings emphasize the importance of balancing functional and experiential components in immersive environments, reinforcing the idea that VR experiences should be both informative and enjoyable.

Although VR has been widely applied in heritage contexts, most existing applications emphasize passive viewing rather than task-based interaction or reconstructive problem solving. Users commonly explore finished reconstructions rather than participate in the interpretive process that shapes them. This distinction is crucial for Neolithic contexts, where understanding material culture often requires reconstructive or experiential engagement. Despite the growing body of work on immersive heritage experiences, little research has examined how VR can support task-based, hands-on reconstruction activities that mirror archaeological reasoning, especially in educational settings. The task-based VR experience developed for this study addresses this gap by engaging learners not only as observers but as active participants in reconstructing Neolithic life, offering a pedagogically grounded alternative to purely observational heritage simulations.

VR Application Design and Implementation

Overview

The VR application developed in this study provides an interactive simulation of a Neolithic heritage reconstruction process. The application is intended to support experiential learning by enabling users to engage in historically informed tasks, thereby enhancing their understanding of both ancient construction techniques and Jordan's cultural heritage. Although the system does not introduce new software frameworks or interaction techniques, its value lies in the pedagogical translation of archaeological findings into immersive educational content. The sequence of interactions was intentionally designed to align with principles of embodied cognition and experiential learning, translating theoretical constructs discussed earlier into concrete, task-based user actions.

System Architecture

The application was built using the Unity 3D engine (version 2023.1.10f1) and designed for standalone execution on the Oculus Quest 2 and Quest 3 headsets. The core system follows a modular design consisting of:

- *Scene Management Module:* Manages transitions between various stages of the experience (environment entry, task scenes, and a final feedback screen providing completion confirmation and brief instructional guidance).
- *Interaction Layer:* Manages hand tracking, grab-and-release mechanisms, and haptic/audio cues.
- *Task Progress Tracker:* Monitors completion of steps such as reed bundling, mud application, and sculpting to control progression.
- *Feedback System:* Provides users with real-time visual and auditory guidance.

All interactions were developed using Unity’s XR Interaction Toolkit and optimized for Quest’s hand tracking and controller input modes.

Content and Historical Grounding

The educational content and interactive sequence were informed primarily by archaeological documentation, with a focus on the detailed construction processes described by Grissom (2000). To ensure cultural and historical accuracy, the development team also collaborated closely with experts from the Jordan Museum in Amman.

Prior to modeling and interaction design, several consultation meetings were held with museum staff, including curators and archaeologists who have worked with the ‘Ain Ghazal statue collection. These discussions provided valuable insight into the physical characteristics, fabrication steps, and interpretative context of the statues. The museum visits also allowed the team to examine statue reconstructions and displays, which helped refine the shape, surface treatment, and material layering featured in the VR simulation. The final application sequence replicates three core stages of the historical construction method:

- Placing the reed bundles to form the internal armature of the statue mimics the original use of phragmites tied with cordage.
- Applying a virtual plaster layer on the form, simulating the lime-based mixture described in archaeological reports.
- Shaping the statues, including smoothing the surface and refining the overall form.

The application is designed to be both educational and true to archaeological findings, helping learners understand how material constraints and construction techniques shaped artistic expression in the Neolithic era.

Interaction and User Experience Design

To better illustrate the user flow, Figure 2 presents the sequential steps learners go through in the VR experience, from entering the simulated Neolithic environment to completing the reconstruction task.

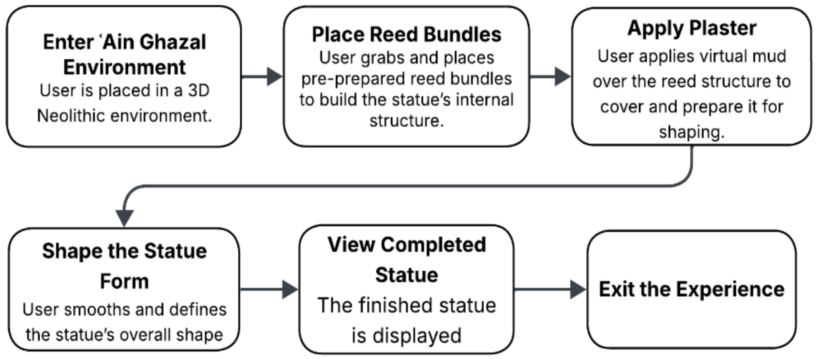

Figure 2. User interaction workflow in the heritage VR application, showing each stage of the statue-building process

VISUAL ENVIRONMENT AND MODELING

The visual environment in the application was designed to represent the original location of the settlement's original Neolithic context near the Azraq area. The design was informed by archaeological references and consultation with experts at the Jordan Museum.

The scene includes simple rectangular houses based on excavated structures with stone foundations and mud-built walls. In addition, a natural terrain was modeled to give users a sense of the site's original layout. The environment was intentionally kept minimal to keep the focus on the statue-building process, while providing an appropriate historical setting.

The experience was designed around four key interactive stages that mirror archaeological reconstructions of the Neolithic statue-building process: placing bundled reeds, applying lime-based plaster, shaping the form, and detailing facial features. These stages were supported by visual cues and audio narration to guide the user. Figure 3 presents selected screenshots from the VR experience, highlighting visual elements, materials, and interactions that contributed to the simulation's educational and immersive qualities.

All 3D models, including the statues, tools, environment, and buildings, were created in Autodesk Maya. Textures were designed in Substance Painter to reflect the raw and handcrafted appearance of Neolithic materials. Models were optimized for standalone headset performance by reducing polygon counts and using compressed texture maps.

DEPLOYMENT AND RUNTIME

The VR application was developed for Oculus Quest 2 and Quest 3 headsets. It runs as a standalone experience without a computer or external sensors. The entire experience lasts 60-80 seconds, allowing users to build a statue from start to finish. The application was tested to ensure smooth performance, and adjustments were made to reduce file size and improve loading times. The frame rate was kept stable to avoid discomfort and support clear interaction.

The short duration and simple interaction design make the application suitable for use in museums, classrooms, or short educational demonstrations.

Figure 3. Selected in-VR screenshots from immersive experience, illustrating key visual components and user interactions (the environment and assets were informed by archaeological data and designed to promote cultural engagement through immersive learning)

METHODOLOGY

RESEARCH DESIGN

This study adopted a mixed-methods approach to evaluate the educational and cultural impact of a VR experience simulating the Neolithic statue-building process, utilizing the site of ‘Ain Ghazal as a representative research setting. The aim was to explore both factual learning outcomes and the degree of heritage appreciation resulting from the interactive VR experience.

The research combined quantitative and qualitative methods. A pre- and post-test was used to assess knowledge gain, while a perception survey captured participants’ self-reported learning and connection to the heritage. Additionally, a set of interviews was conducted with a subset of participants to gain deeper insight into their experience and emotional engagement with the content.

A mixed-methods approach was appropriate because the study needed to capture both the measurable learning effects of the VR experience and the deeper cultural and emotional responses that cannot be understood through quantitative data alone. The pre-/post-tests and surveys provided statistical evidence of knowledge gain, while the interviews explained how participants interpreted the experience and why specific learning patterns emerged. The study followed a sequential explanatory mixed-methods design, in which quantitative data were collected and analyzed first, followed by qualitative interviews to clarify and enrich the quantitative findings.

The application and study were designed for a general audience, including students, educators, and the wider public. Participants came from diverse backgrounds and levels of familiarity with VR, allowing the research to explore the effectiveness of the experience across different user groups.

A control group was not included in this study due to logistical constraints associated with conducting the VR experience in a public, open participation setting. In this context, it was not feasible to design or administer a comparable non-VR activity that could isolate the specific effects of the immersive simulation. As a result, random assignment to experimental and control conditions was not possible.

The study, therefore, adopted a pre–post design to examine changes in participants' learning and cultural appreciation following the VR experience. While this approach provides meaningful insight into participants' responses, the absence of a control group means that the findings cannot be interpreted as causal. Instead, the results should be understood as indicative patterns that highlight potential relationships and motivate future research using controlled experimental designs.

PARTICIPANTS

A total of 272 individuals participated in this study. The sample consisted of university students, educators, and members of the public. Most participants were young adults, and the group included both male and female participants across different age categories. A full breakdown of demographic characteristics is presented in Table 1.

Table 1. Participant demographics

Variable	Category	N	Percentage
Gender	Female	113	42%
	Male	159	58%
Age group	18-24	232	85%
	25-35	13	5%
	35+	27	10%
VR experience	Yes	181	67%
	No	91	33%

Although the sample included a small number of participants aged 35 and older, the majority (85%) were aged 18-24, resulting in a strong youth concentration. The study also relied on convenience sampling, which reflects the practical context of delivering the VR experience but introduces demographic and recruitment bias. As a result, the findings may not fully generalize to older or more diverse populations, who may engage with VR and cultural content differently. This limitation should be considered when interpreting the results.

From the larger group of participants, 41 individuals volunteered for short follow-up interviews conducted after the VR session. These interviewees were drawn from the same group who completed the VR experience and the post-test. All participants were invited to take part, and those who agreed and were available at the time were included. No additional selection criteria were applied, but the volunteer group naturally reflected variation in age, gender, and familiarity with VR. This approach allowed the qualitative data to complement the quantitative findings without introducing a separate participant pool.

PROCEDURE

Participants first completed a short pre-test via Google Forms. Each participant then used a VR headset to experience the VR application individually. Each VR experience lasted approximately 2 to 4 minutes. Including the VR session, post-test, and brief perception survey, the entire procedure took approximately 3 to 5 minutes per participant. A subset of forty-one participants was later interviewed to explore their perceptions of learning and cultural connection.

Data Collection Instruments

Objective knowledge assessment (pre-test and post-test)

A pre-test was administered before the VR experience to measure participants’ prior knowledge about the historical statue-building process at ‘Ain Ghazal. The pre-test, which included multiple-choice questions, was completed by all 272 participants.

Example questions include:

- “Which materials were used to construct the Neolithic statues?”
- “Which historical period does the archaeological site belong to?”

The complete list of pre-test items is presented in Appendix A.

The post-test included the same set of questions as the pre-test and was administered immediately after the VR experience. It aimed to assess factual learning gains through direct comparison. All post-test items are also included in Appendix A.

Perceptual survey instruments

In addition to the objective knowledge assessment, participants completed a post-experience perception survey using a 5-point Likert scale. The perception survey was designed based on the study’s conceptual framework, grounded in experiential learning and embodied cognition. These theories emphasize that learning in immersive environments is reflected not only in objective knowledge gains but also in learners’ perceived understanding, emotional engagement with content, and the perceived credibility of the learning environment.

Accordingly, survey items were grouped into three theoretically derived constructs representing complementary dimensions of learning in VR-based cultural heritage experiences: perceived learning outcomes, cultural appreciation, and perceived authenticity.

Perceived learning outcomes were assessed using three items capturing participants’ self-reported understanding of the statue-building process and its historical context (e.g., “The VR experience helped me better understand how the statues were built”).

Cultural appreciation was measured using four items assessing participants’ emotional engagement with the heritage content and perceived cultural value of the ‘Ain Ghazal statues (e.g., “This experience increased my appreciation of the cultural significance of the ‘Ain Ghazal statues”).

Perceived authenticity was measured using eight items that captured perceptions of realism, immersion, and the credibility of the VR environment (e.g., “The VR environment felt authentic to the original archaeological site”).

All survey items are provided in Appendix B.

Qualitative interviews

A subset of forty-one participants volunteered for short individual interviews conducted after the VR experience. The interviews focused on participants’ experiences, emotional reactions, and how the VR simulation influenced their understanding of the cultural heritage site.

Scale reliability

All three multi-item survey scales demonstrated acceptable to high internal consistency. The Perceived Learning scale showed acceptable reliability (Cronbach’s $\alpha = .667$, 3 items); the Cultural Appreciation scale demonstrated good reliability ($\alpha = .782$, 4 items); and the Perceived Authenticity scale showed high internal consistency (α = .890, 8 items). These values indicate that the scales used in the study were dependable and appropriate for further analysis.

DATA ANALYSIS

Quantitative data

Quantitative data from the pre- and post-tests were analyzed using descriptive statistics (mean and standard deviation) and paired-sample t-tests to assess statistically significant learning gains. Survey responses were analyzed to assess trends in perceived learning and cultural appreciation across the whole sample.

Qualitative data

Qualitative data from the interviews were analyzed using thematic analysis. Most interviews were conducted in English, while a smaller number were conducted bilingually in Arabic and English, depending on participants' comfort. All recordings were transcribed verbatim. For the bilingual interviews, the researcher translated the Arabic segments into English. To ensure meaning accuracy, a bilingual reviewer checked a subset of these translated sections, and any discrepancies were resolved through discussion.

Thematic analysis was conducted following Braun and Clarke's (2006) framework. The researcher first familiarized herself with the data by reading the transcripts multiple times. Open coding was then used to identify initial concepts and meaningful units across the dataset. Codes were developed primarily inductively, allowing themes to emerge from participants' descriptions rather than being based on predefined categories.

During axial coding, related codes were grouped to explore relationships and develop broader categories. Code clusters related to emotional engagement, cultural appreciation, perceived authenticity, and learning experiences were gradually refined into higher-order themes representing the main patterns in participants' experiences.

One primary coder conducted the initial coding. To enhance credibility, a second reviewer independently examined 20% of the coded transcripts. Intercoder agreement reached 87%, and disagreements were resolved through discussion, strengthening the reliability of the qualitative findings.

Integration of quantitative and qualitative findings

The study employed a mixed-methods approach, integrating quantitative and qualitative findings to provide a more comprehensive understanding of participants' learning and cultural engagement. Integration occurred during the interpretation stage using a triangulation approach, in which results from pre-/post-tests and survey data were compared with themes derived from the interviews. Quantitative findings were first analyzed to identify patterns in learning outcomes, perceived learning, cultural appreciation, and authenticity. The qualitative themes were then examined to explain, support, or contextualize these patterns. Convergences and divergences between the two data sources were noted to strengthen the validity of the conclusions and to provide deeper insight into how participants experienced and interpreted the VR simulation.

RESULTS

RESULTS OVERVIEW

This study investigated the educational and cultural impact of the VR reconstruction of the 'Ain Ghazal statue-building process. Quantitative analyses included descriptive statistics, non-parametric tests, and correlation analyses to examine factual learning outcomes, perceived learning, cultural appreciation, and perceived authenticity. All statistical analyses were conducted using SPSS.

To complement the quantitative findings, semi-structured interviews were conducted with forty-one participants. Themes were derived through iterative coding. Five themes emerged: Learning by Doing, Cultural Appreciation and Awareness, Motivation and Preference for VR in Education, Technical and Usability Challenges, and Limited Creativity/Guided Experience. These themes provide deeper insight into participants' experiences, emotional responses, and engagement with the VR environment. The mixed-methods structure allowed quantitative results to identify patterns in learning and perception. At the same time, the qualitative findings explained the underlying reasons for these patterns, offering a coherent, integrated understanding of the VR experience.

RQ1: How Does Participating in a Task-Based VR Experience Influence Users' Factual Understanding of the Statue-Building Process?

To address RQ1, which examines whether participation in the VR experience is associated with changes in factual understanding of the statue-building process, a pre–post comparison of knowledge scores was conducted.

To evaluate factual knowledge gained regarding the 'Ain Ghazal statue-building process, participants completed a pre- and post-test. Different scores were first assessed for normality. Results from the Shapiro-Wilk test indicated a significant deviation from normal distribution, $W = .955$, $p < .001$, as shown in Table 2.

Table 2. Tests of normality for the difference scores between pre-test and post-test

Tests of normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	DF	Sig.	Statistic	DF	Sig.
diff_score	.146	272	.000	.955	272	.000

a. Lilliefors significance correction

Because the data violated the assumption of normality, a Wilcoxon signed-rank test was used to assess the significance of the score changes. The results showed a statistically significant increase in post-test scores: $Z = -12.498$, $p < .001$, as shown in Table 3, indicating that the VR experience had a positive impact on participants' factual understanding of the 'Ain Ghazal statue-building process.

Table 3. Wilcoxon signed-rank test results comparing post-test and pre-test scores

Test statistic[a]	
	Post-test – pre-test
Z	-12.498[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks

An effect size (r) was also calculated, giving r = 0.76. The effect size was computed using the formula:

$$r = \frac{Z}{\sqrt{N}} = \frac{-12.498}{\sqrt{272}} \approx 0.76 \quad (1)$$

Descriptive statistics for pre-test and post-test scores, including means and standard deviations, are presented in Table 4.

Table 4. Descriptive statistics for pre-test and post-test scores

Descriptive statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
Pre-Test	272	0	5	1.26	1.459
Post-Test	272	0	5	3.37	1.437
Valid N (listwise)	272				

Of the 272 participants, 218 demonstrated improved post-test scores compared to the pre-test, 33 showed no change, and 21 obtained lower post-test scores; these participant-level score changes are derived from participant-level pre–post comparisons underlying the analyses reported in Tables 3 and 4 and are summarized in Figure 4.

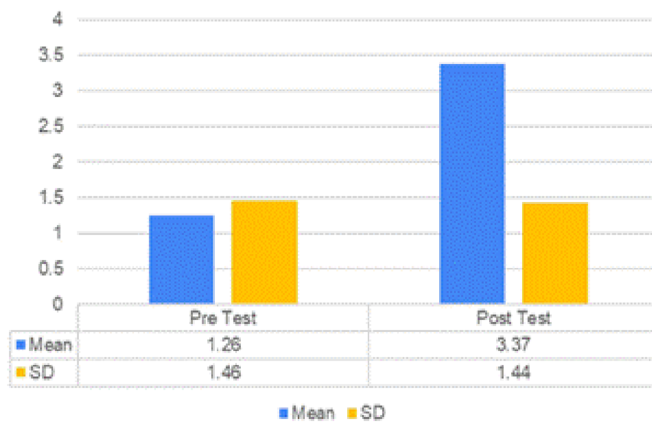

Figure 4. Comparison of pre-test and post-test scores showing the mean and standard deviation

To further contextualize the observed change in test scores, qualitative interview data were examined to explore how participants described their learning experience during the VR activity.

Learning by doing (embodied learning)

Participants consistently reported that physically performing the statue-building steps in VR, such as placing reed bundles and applying plaster, helped them understand the process more clearly than passive learning.

- "Because I actually did it with my own hands, I remember how the statue was made. It's different from just reading or watching." (I14)
- "Building the statue step by step helped me know the order and tools without needing to memorize them. I understood it because I lived it." (I03)
- "It wasn't like a game, it was like I had to build it carefully. That made me pay more attention and remember everything." (I29)

Overall, this theme indicates that embodied, experiential interaction in VR enhanced cognitive engagement and improved retention of factual information.

Taken together, the improvement in test scores and participants' descriptions of embodied learning indicate an association between engagement in the VR activity and improved factual understanding of the heritage reconstruction process.

Perceived Learning (Descriptive Results Supporting RQ2 and RQ3)

Perceived learning is reported here as a descriptive construct that supports the analyses for RQ2 and RQ3.

Participants' perceived learning was evaluated using three Likert-scale items: learning how the statues were built, understanding the Neolithic context, and the clarity of the presented information. Descriptive statistics show consistently high agreement across all items. Participants reported the highest mean for "learning how the statues were built" ($M = 4.61$, $SD = 0.67$), followed by "understanding the Neolithic period" ($M = 4.46$, $SD = 0.84$), and "information clarity" ($M = 4.44$, $SD = 0.85$).

To explore overall perceived learning, a composite variable was calculated by averaging the three items. The composite score had a mean of 4.50 ($SD = 0.61$), indicating strong perceived learning across participants. While internal consistency was slightly below the conventional threshold ($\alpha = 0.667$), it was considered acceptable for exploratory research involving a small number of items.

RQ2: What is the Relationship Between Cultural Appreciation and Perceived Learning Outcomes?

Consistent with the study's conceptual framework, grounded in experiential and embodied learning, this analysis examines the relationship between participants' cultural appreciation and their perceived learning outcomes. To address RQ2, correlation analyses were conducted using post-experience survey data. The findings for RQ2, which examine the relationship between cultural appreciation and perceived learning, are presented next.

To explore how cultural engagement influenced learning, four Likert-scale items were used to construct a cultural appreciation composite: perceived heritage value, emotional engagement, reflection on preservation, and the importance of protecting cultural sites. Similarly, the learning outcomes composite was calculated as the mean of three items assessing perceived understanding of the building process, the Neolithic context, and the clarity of the presented information.

Analysis showed high average scores across all cultural appreciation items (M range: 4.18–4.32), with the composite cultural appreciation score averaging $M = 4.23$, $SD = 0.92$. The learning outcomes composite had a mean of $M = 4.50$ and an SD of 0.61.

Pearson correlation analysis revealed a strong and statistically significant relationship between cultural appreciation and learning outcomes, $r = 0.582$, $p < 0.001$ (see Table 5). This suggests that participants who felt more emotionally and intellectually connected to the heritage experience also perceived greater learning benefits. However, although the relationship is significant, this correlation reflects association rather than causation. Participants who experienced stronger emotional and cultural engagement tended to report higher learning, but the design does not allow us to infer that cultural appreciation directly caused improved learning outcomes.

To further contextualize this relationship, qualitative interview data were examined to explore how participants described their cultural engagement and its perceived influence on learning.

Table 5. Pearson correlation between cultural appreciation and learning outcomes

Correlations			
		Learning outcomes	**Cultural appreciation**
Learning outcomes	Pearson correlation	1	0.582**
	Sig. (2-tailed)		0.000
	N	272	272
Cultural appreciation	Pearson correlation	0.582**	1
	Sig. (2-tailed)	0.000	
	N	272	272

** Correlation is significant at the 0.01 level (2-tailed)

Cultural appreciation and awareness

The VR experience strengthened participants' emotional and intellectual connection to Jordan's heritage, allowing them to appreciate the cultural significance of the archaeological site.

- "I didn't know anything about these statues before. Now I feel proud that they are part of our history." (I07)
- "They did all this without any modern tools, and it still looks amazing. I feel like people need to know more about it." (I36)
- "It makes you think - what if these things disappear and we don't even know they existed? The experience makes you care." (I22)

This theme highlights how immersive experiences can foster empathy, pride, and responsibility for cultural preservation, contributing to a more profound sense of identity and awareness.

Together, the statistical association between cultural appreciation and perceived learning, supported by interview reflections expressing pride, emotional engagement, and heritage awareness, indicates that cultural connection and perceived learning tended to co-occur within the VR experience.

RQ3: How Do Users Perceive the Authenticity and Educational Value of the VR Experience?

Drawing on the study's conceptual framework, this analysis examines how perceived authenticity of the VR environment relates to users' perceived learning outcomes. To address RQ3, analyses focused on post-experience authenticity ratings and their association with perceived learning. The results related to RQ3, focusing on perceived authenticity and learning, are summarized below.

To assess whether participants perceived the VR experience as an authentic and educational tool, a composite score was calculated from eight post-experience Likert-scale items measuring sense of presence, realism, immersion, authenticity, satisfaction, and educational usefulness. The internal consistency of this scale was excellent, with a Cronbach's α of .890. All items received high ratings, with mean scores ranging from 4.11 to 4.77, indicating strong agreement among participants.

The overall composite score for perceived authenticity was $M = 4.39$, $SD = 0.68$ ($N = 272$), demonstrating that participants viewed the VR experience as both realistic and valuable for learning. A Pearson correlation analysis revealed a statistically significant and moderately strong positive relationship between perceived authenticity and learning outcomes ($r = 0.549$, $p < 0.001$), as shown in Table 6. Table 6 reports the Pearson correlation between the perceived authenticity composite score and perceived learning outcomes, both calculated from post-experience survey responses. This finding suggests that participants who perceived the VR environment as more immersive, realistic, and credible tended to report stronger perceived learning.

Table 6. Pearson correlation between perceived authenticity and learning outcomes

Correlations			
		Learning outcomes	**Authenticity score**
Learning outcomes	Pearson correlation	1	0.549**
	Sig. (2-tailed)		0.000
	N	272	272
Authenticity score	Pearson correlation	0.549**	1
	Sig. (2-tailed)	0.000	
	N	272	272

** Correlation is significant at the 0.01 level (2-tailed)

To further contextualize participants' authenticity ratings, qualitative interview data were examined to explore how users described realism, immersion, and the educational value of the VR experience.

Comparison across constructs

To visually summarize participants' responses across the three key constructs, perceived learning outcomes, cultural appreciation, and authenticity, Figure 5 presents a comparison of the mean Likert-scale scores. As shown, all three constructs received high ratings, with learning outcomes receiving the highest mean score, followed by perceived authenticity and cultural appreciation. This pattern suggests that participants found the VR experience particularly effective for learning, while also perceiving it as authentic and culturally valuable.

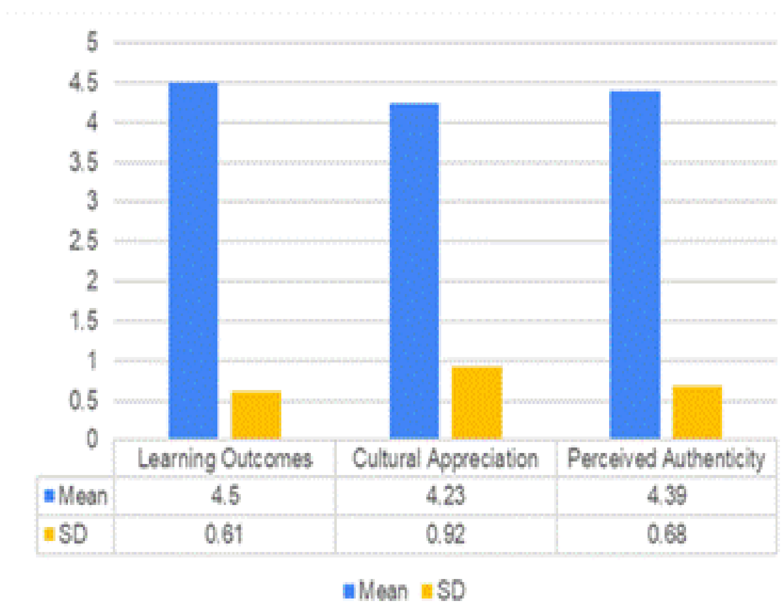

Figure 5. Comparison of mean scores for perceived learning outcomes, cultural appreciation and authenticity after the VR experience

Motivation and preference for VR in education

Participants expressed strong motivation and preference for learning through VR, describing the experience as more engaging and attention-sustaining than traditional instructional methods.

- "Usually I get bored quickly, but in VR I wanted to keep going. It made me focus more." (I08)
- "It felt like I was actually there. That made it more exciting and made me want to learn more." (I19)
- "I hope we can use VR in other courses too. It helps you learn things in a new way." (I11)

This theme suggests that VR not only supports knowledge acquisition but also fosters learner motivation, contributing to sustained interest and deeper engagement with educational content.

Technical and usability challenges

Some interviewees reported technical limitations or interaction issues that affected their experience. These included difficulties with the VR controls, performance lags, or discomfort during use.

- "It was a bit hard to grab the reeds. Sometimes it didn't respond, and I had to try again." (I10)
- "I couldn't reach the mud properly – it was floating too high." (I05)
- "I didn't understand how to start. Someone had to show me where to go first." (I27)

These comments highlight the importance of refining the usability and responsiveness of interactive VR applications, especially for first-time users.

Limited creativity / Guided experience

Several interviewees noted that while the VR experience was engaging, it felt too guided or lacked opportunities for individual creativity.

- "It was interesting, but I just followed steps. I couldn't really do things my own way." (P20)
- "I wanted to build a different shape or choose how the statue looks, not just follow instructions." (P31)

This feedback suggests that while the structure supports learning, future versions could offer greater freedom or more options to personalize the experience. These qualitative perspectives help explain the quantitative relationship between authenticity and learning: participants who experienced more substantial presence, realism, and usability challenges interpreted authenticity as a key contributor to engagement and understanding.

Taken together, the quantitative association between perceived authenticity and learning, along with interview accounts emphasizing realism, immersion, and usability, indicates that perceptions of authenticity were closely linked to how participants evaluated the educational value of the VR experience.

Summary Table of Main Outcomes

To consolidate the primary quantitative outcomes, Table 7 summarizes the key findings on knowledge gain, cultural appreciation, and perceived authenticity.

To present the qualitative findings concisely, Table 8 summarizes the five themes generated through thematic analysis. The table includes each theme's description, code frequency, and illustrative participant quotations, offering a clear view of how the themes supported the overall interpretation.

Table 7. Summary of key quantitative findings

Outcome	Finding	Statistical evidence
Knowledge gain (pre–post learning improvement)	Participants showed substantial improvement in factual understanding of the historical reconstruction task after the VR experience.	Wilcoxon test: $Z = -12.498$, $p < 0.001$; effect size $r = 0.76$; mean increased from 1.26 to 3.37
Relationship between cultural appreciation and learning	Higher cultural appreciation was associated with higher perceived learning outcomes.	Pearson correlation: $r = 0.582$, $p < 0.001$
Relationship between perceived authenticity and learning	Participants who rated the VR experience as more authentic also reported greater perceived learning.	Pearson correlation: $r = 0.549$, $p < 0.001$

Table 8. Summary of qualitative themes, code counts, and representative quotes

Theme	Short description	No. of codes	Example quotes
Learning by doing (embodied learning)	Participants understood the building process better through physical interaction and multisensory engagement in VR.	3	“It’s the best way to learn … to actually do the thing with your own hands.” (P7) “Because I’m doing the thing … the information sticks more.” (P36)
Cultural appreciation and awareness	VR strengthened emotional and intellectual connection to Jordan’s heritage.	3	“I gained more respect for them, honestly.” (P16) “Impressive how they built these things with zero capabilities.” (P3)
Technical and usability challenges	Users faced performance, interaction, and control issues that affected immersion.	3	“The shovel fell … I spent an hour looking for it.” (P11) “Needed better graphics.” (P2)
Limited creativity/ guided experience	The experience felt too structured; participants wanted more freedom and choice.	3	“It was just specific steps … more like instructions.” (P16) “No choices being made.” (P12)
Motivation and preference for VR in education	VR increased motivation, attention, and perceived learning compared to traditional study.	3	“It’s fun and helps me learn better because I see and do things.” (P1) “The information sticks more than studying on paper.” (P17)

DISCUSSION

This study investigated how an immersive VR experience simulating a Neolithic artifact-building process is associated with factual learning, cultural appreciation, and perceptions of authenticity and educational value. Using a mixed-methods approach, the findings suggest how participants perceived hands-on interaction and cultural immersion in relation to their learning outcomes and emotional engagement. The results also extend prior research by exploring a lesser-known archaeological site through task-based VR design.

The findings align with its emphasis on integrating cognitive and emotional engagement in immersive environments (Makransky & Petersen, 2021). Similarly, the results reflect the value of learning through physical activity, as emphasized in prior VR education research (Alhalabi, 2016). The statues themselves have been studied extensively for their construction techniques and historical significance (Grissom, 2000; Rollefson, 1992), but they have rarely been explored through interactive digital learning experiences.

Recent studies highlight that incorporating cultural authenticity into VR experiences can enhance emotional involvement and learning satisfaction (Daniela, 2020; Trunfio et al., 2021). Although the original artifacts can be viewed at the Jordan Museum, the VR experience gives users a new way to understand how they were built, something not possible through static exhibits alone. This shows how VR can add value by enabling people to interact with ancient practices in a hands-on, memorable way.

Interpretation of Findings

RQ1: How does participating in a task-based VR experience influence users' factual understanding of the statue-building process?

To answer RQ1, both quantitative and qualitative analyses were conducted. Participants demonstrated a significant improvement in factual knowledge following the VR session, supported by a large effect size. These results confirm that task-based VR interactions, in which users actively placed reeds and applied mud, contributed to more effective learning of the construction sequence and the materials used.

Qualitative findings supported these results. The theme Learning by Doing (Embodied Learning) reflected the interviewees' emphasis on remembering steps more effectively by physically performing them. These experiences align with theories of embodied cognition, which suggest that physically enacting concepts improve understanding and recall. Rather than passive observation, interviewees described developing knowledge through active simulation. This process also reflects Kolb's (1984) experiential learning model, where participants engaged in a concrete experience (the VR task), then reflected on it during interviews, forming abstract insights that could inform future understanding.

RQ2: What is the relationship between cultural appreciation and perceived learning outcomes?

To answer RQ2, both quantitative and qualitative analyses were conducted. A statistically significant correlation was found between participants' cultural appreciation and their perceived learning outcomes. Those who felt emotionally connected to the heritage site also reported more substantial educational benefits in the post-experience survey. The theme Cultural Appreciation and Awareness captured interviewees' pride in discovering a local Neolithic heritage and reflecting on its historical value.

This connection supports previous studies indicating that emotional engagement in cultural VR experiences can enhance self-reported learning (Wu et al., 2020). The findings suggest that VR applications can serve not only cognitive functions but also foster cultural empathy and heritage awareness.

RQ3: How do users perceive the authenticity and educational value of the VR experience?

To answer RQ3, both quantitative and qualitative analyses were conducted. Participants perceived the experience as both authentic and educationally effective. The high scores for perceived authenticity and their positive correlation with perceived learning outcomes indicate that realism and credibility played a key role in enhancing understanding. These impressions were likely shaped by specific design elements, such as the historically accurate statue-building process, the tactile task of placing reed bundles, and the use of Neolithic construction sequences based on archaeological research. By allowing users to perform culturally meaningful tasks rather than observe, the VR experience fostered a stronger sense of authenticity and educational immersion.

The theme *Motivation and Preference for VR in Education* highlighted learners' enthusiasm for using VR in other subjects. Many interviewees described the experience as "real," "convincing," and more engaging than traditional formats like lectures or videos. These reactions support the idea that perceived presence and realism directly influence users' perception of educational effectiveness in VR contexts.

However, two qualitative themes also highlighted areas for improvement. *Technical and Usability Challenges* and *Limited Creativity/Guided Experience* revealed that some interviewees desired smoother controls and greater freedom to personalize their interaction. These insights suggest that while structured learning is helpful, future VR designs should aim to balance instructional guidance with creative exploration.

CONTRIBUTION

This study contributes to virtual reality–based cultural heritage education in several key ways. First, it presents one of the few empirical investigations of underrepresented archaeological artifacts using task-based, interactive VR reconstruction rather than passive viewing or textual presentation. By focusing on the digital interpretation of a lesser-known archaeological site, the study extends existing VR heritage research beyond commonly studied iconic locations.

Second, the study integrates cognitive outcomes (factual learning) with affective outcomes (cultural appreciation, emotional engagement, and perceived authenticity), offering a more holistic understanding of how VR supports learning in heritage contexts. This responds to calls in the literature for research that examines learning and emotional engagement together rather than in isolation.

Third, the study contributes theoretically by applying embodied cognition and experiential learning principles through historically grounded, hands-on interaction. By physically performing reconstruction tasks based on archaeological evidence, users engage in learning through action rather than observation, providing empirical support for task-based VR as a practical educational approach.

Finally, the study offers a methodological contribution through a large mixed-methods dataset, combining quantitative results from 272 participants with qualitative insights from 41 interviews. This approach strengthens the reliability of the findings and provides a replicable framework for future VR-based cultural heritage research.

PRACTICAL IMPLICATIONS

The findings of this study have practical implications for educators, museum professionals, and cultural heritage institutions. For museums, task-based VR experiences offer a way to transform static exhibitions into interactive, visitor-centered learning environments. Allowing users to simulate ancient construction processes actively can deepen understanding and foster emotional connections to artifacts that may otherwise appear distant or abstract.

In educational settings, the observed learning gains and high learner motivation suggest that task-based VR applications can complement traditional instructional methods in history, archaeology, and cultural studies. VR may be particularly beneficial for learners who struggle with text-heavy materials, as experiential interaction supports understanding through action rather than memorization.

The results also highlight the importance of perceived authenticity in VR design. Accurate reconstruction, credible interaction sequences, and coherent visual environments were closely associated with stronger perceptions of learning. Designers and educators should therefore prioritize historical accuracy, meaningful interaction, and usability when developing VR applications intended for educational or cultural purposes.

Limitations

Several limitations should be considered when interpreting the findings of this study. While the findings are tied to a specific Neolithic case study, the results provide indicative patterns for task-based learning in similar heritage contexts. Although participants demonstrated significant learning gains after the VR experience, it cannot be determined whether these improvements were solely attributable to VR.

Second, learning outcomes were measured immediately after the experience, reflecting only short-term knowledge acquisition. The absence of delayed testing prevents conclusions about long-term retention.

Third, some outcomes relied on self-reported measures of learning, cultural appreciation, and authenticity. Such measures may be influenced by novelty effects, social desirability, or enthusiasm for immersive technology, potentially inflating responses.

Fourth, while most interviews were conducted in English, some involved bilingual Arabic–English responses. Although care was taken to translate quotations accurately, subtle meanings may have been altered in the process.

Finally, the use of convenience sampling resulted in a participant pool dominated by young adults, primarily university students. This limits generalizability to older populations or individuals with limited digital experience. In addition, technical and usability issues reported by some participants may have influenced engagement and learning outcomes.

Future Research

Future studies should incorporate a control group or a comparative learning condition to isolate the educational impact of VR better. Expanding the participant pool to include school learners, older adults, and international visitors would also improve understanding of how diverse audiences engage with VR-based heritage experiences.

Further research could explore less guided or more open-ended versions of the experience, allowing users to experiment with alternative construction approaches or personalize outcomes. Investigating long-term retention, emotional impact over time, and transfer of learning to real museum visits would provide valuable insight into the lasting effects of immersive heritage learning.

Finally, future work may examine how advances in interaction fidelity, hand tracking, and environmental realism influence perceived authenticity and educational engagement in task-based VR applications.

Conclusion

This study examined the educational impact of an immersive, task-based VR experience designed to simulate a historical reconstruction process using a Neolithic site as a case study. By engaging users in archaeologically informed reconstruction tasks, the experience supported learning through embodied interaction rather than passive observation. Applying this approach to a lesser-known archaeological site that has received limited digital interpretation represents a key novel contribution of this work.

The findings directly address the study's research questions. In relation to RQ1, hands-on participation in the VR experience was associated with significant improvements in participants' factual understanding of the statue-building process. Regarding RQ2, a strong relationship was observed between cultural appreciation and perceived learning, indicating that emotional and cultural engagement played an important role in participants' evaluation of their learning outcomes. For RQ3, high perceived authenticity ratings were positively associated with learning outcomes, highlighting the importance of realism and credibility in educational VR design.

Qualitative findings further supported these results. Participants consistently emphasized “learning by doing,” increased cultural pride, and a stronger emotional connection to the Neolithic environment. The integration of quantitative and qualitative evidence demonstrates how task-based VR can simultaneously support cognitive understanding and affective engagement, reinforcing the educational value of embodied learning in cultural heritage contexts.

From a practical perspective, the study offers clear guidance for museums, heritage institutions, and educators. For museums, task-based VR can complement traditional exhibits by allowing visitors to actively engage with reconstruction processes rather than viewing finished artifacts alone. For educators, integrating structured VR tasks, such as guided building sequences or comparative reconstruction activities, can support archaeological reasoning and deepen understanding of cultural context. Designers are encouraged to prioritize historical accuracy, meaningful interaction, and usability to enhance both authenticity and learning value.

Several limitations should be acknowledged. The absence of a control group limits causal interpretation, and learning outcomes were measured only in the short term. Broader challenges related to scalability, accessibility, and technological cost may also affect the feasibility of implementing similar VR experiences across institutions. Minor usability constraints and limited creative flexibility identified by participants suggest opportunities for future refinement.

Overall, the findings support immersive, task-based VR as a promising platform for cultural heritage education. As VR technologies become more accessible and affordable, they have the potential to transform how archaeological knowledge is preserved, interpreted, and shared. Future applications that combine embodied learning, emotional engagement, and authenticity may play a significant role in shaping cultural preservation and heritage education over the coming decade.

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DECLARATION

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Conflicts of interest/Competing interests

The author declares no competing interests.

Ethical approval

This study was conducted in accordance with the ethical guidelines of Princess Sumaya University for Technology (PSUT), Amman, Jordan. All procedures involving human participants were reviewed and approved under institutional academic research ethics. The study adhered to the principles of the Declaration of Helsinki. No sensitive or identifying personal information was collected.

Consent to participate

All participants were informed about the purpose of the study and voluntarily agreed to take part.

Consent to publish

Participants provided consent for the publication of anonymized data collected during the study. No identifiable personal data is included in this publication.

Data availability statement

The data supporting the findings of this study – including anonymized pre- and post-test results, survey responses, and interview codes – are available from the corresponding author upon reasonable request, in order to maintain participant confidentiality.

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APPENDIX

APPENDIX A

Pre-Test and Post-Test Knowledge Questionnaire

The following items were used to assess participants' factual knowledge of the 'Ain Ghazal statue-building process before and after the VR experience. The same set of questions was administered in both the pre-test and post-test.

The questionnaire was initially administered in Arabic. All items were translated into English for reporting purposes, and a bilingual reviewer verified a subset of translated items to ensure accuracy.

Q1. What was the primary purpose of collecting reeds at the beginning of the statue-building process?

- To light fire inside the site
- To manufacture ropes used for decoration
- To construct the internal framework of the statue
- To plant new vegetation around the site
- I do not know

Q2. Why was fresh reed preferred over dry reed?

- It is shorter and easier to carry
- It absorbs clay better
- It is more flexible and easier to shape into bundles
- It has a lighter color and is easier to distinguish
- I do not know

Q3. What was the step used to stabilize reed bundles in the statue frame?

- Directly covering the statue with mud
- Covering the frame with a layer of lime plaster
- Placing the statue under the sun
- Painting the statue with plant dyes
- I do not know

Q4. Why was lime plaster used to coat the statue?

- It repels insects
- It forms a solid layer that preserves the outer shape
- It gives the statue a darker color
- It helps fix the statue to the ground
- I do not know

Q5. What material was sometimes used to shape facial features such as the eyes?

- Pieces of reed
- Shells
- Plant dyes
- Black bitumen (asphalt)
- I do not know

APPENDIX B

Post-Experience Perception Questionnaire

All items were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Although the complete questionnaire contained multiple item groups, the present study quantitatively analyzed only the items related to Perceived Learning, Cultural Appreciation, and Perceived Authenticity, as these constructs directly align with the study’s research questions. The remaining items were collected for exploratory purposes and to support future analyses; they are included here for transparency but were not incorporated into composite scales or statistical testing.

Perceived Learning Scale (3 items)

- The VR experience helped me understand how the ‘Ain Ghazal statues were built.
- I learned new information about Neolithic Jordan through the VR experience.
- The information provided in the VR experience was clear and easy to understand.

Cultural Appreciation Scale (4 items)

- The VR experience increased my appreciation of Jordan’s ancient heritage.
- I felt emotionally connected to the culture represented in the VR experience.
- The VR experience made me reflect on the importance of preserving ancient heritage.
- I feel more responsible toward protecting archaeological sites after learning about ‘Ain Ghazal.

Perceived Authenticity and Presence Scale (8 items)

- I felt like I was physically present at the ‘Ain Ghazal site.
- The environment in the VR experience felt realistic and believable.
- I felt I was inside the ‘Ain Ghazal environment rather than just observing it.
- The virtual environment seemed to surround me completely.
- The VR experience felt like an authentic representation of the real ‘Ain Ghazal site.
- I believe VR is a useful tool for learning historical and cultural topics.

- Overall, I am satisfied with my VR experience.
- I would like to participate in similar VR educational experiences in the future.

AUTHORS

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