



Digital Preservation of artifacts and symbols: the role of technology driven education in West Africa (Meta-Synthesis Study)

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Abstract: Preserving cultural artifacts and symbols are essential for maintaining historical and cultural heritage, yet many of them face deterioration due to inadequate conservation knowledge and resources. This study explored how technology driven education can contribute to digital artifacts and symbols preservation by equipping conservators, curators, professionals, students, and the public with the necessary knowledge and skills to safeguard cultural heritage. The actor-network theory underpinned the discussion, providing insights into how technological interventions shape conservation practices across different cultural contexts. Using PRISMA-based methodologies, an exploratory systematic review was employed to analyse findings from multiple academic sources. The review ensured a thorough synthesis of 14 relevant studies on technology-driven preservation education. Findings revealed how digital preservation methods (such as 3D modelling, artificial intelligence-based restoration, and digital archiving) ensured that cultural heritage remained accessible and relevant. Also, using digital training programs, virtual workshops, and community engagement initiatives, institutions can create accessible learning opportunities that enhances expertise in artifact conservation. However, infrastructural limitations, ethical dilemmas related to ownership and representation, and cultural sensitivities in digitizing artifacts calls for global collaboration, sustainable implementation strategies, and culturally relevant approaches to ensure the longevity and accessibility of historical artifacts and symbols for future generations

Keywords: artifacts, conservation practices, digital preservation, symbols, technology driven education

Introduction

The preservation of cultural artifacts is essential for safeguarding the historical and symbolic narratives of diverse communities. However, many artifacts face deterioration due to environmental factors, limited conservation expertise, and inadequate infrastructure (Fierascu et al., 2021; Smith, 2016). Traditional preservation methods, while valuable, often lack the technological support needed for sustainable conservation in the modern era (Uche, 2024). Recent studies emphasize the potential of digital tools in enhancing conservation outcomes. For instance, Paul (2023) discusses how digitization and intellectual property frameworks can protect traditional knowledge, while Boden (2022) highlights the role of digital archives in fostering community engagement in preservation efforts. These insights underscore the importance of exploring how educational technology can be leveraged to train professionals and communities in artifact and symbol preservation.



Technology-enhanced education offers promising solutions to preservation challenges. Digital training programs, virtual reality (VR) simulations, and online collaborative platforms provide accessible learning experiences that equip individuals with essential conservation skills. Ngom, Rodima-Taylor, and Robinson (2023) demonstrate how digital literacy initiatives in African Ajami traditions support knowledge preservation and accessibility. Similarly, Schmidt (2014) argues that community-centered archaeological approaches benefit from digital engagement, which enhances local participation and documentation of intangible heritage. These findings suggest that technology-driven education can play a transformative role in making conservation knowledge more widely available and actionable.

Despite these advancements, a critical gap persists in the sustainable preservation of West African artifacts and symbols due to inadequate conservation infrastructure, limited access to technological tools, and insufficient education and training in heritage conservation. Traditional preservation methods, while valuable, often lack the technological support necessary for long-term sustainability. Although global initiatives and studies have demonstrated the potential of digital tools and education in enhancing artifact preservation, these approaches are largely centered on Western or non-African contexts, leaving a significant gap in region-specific strategies for West Africa (Boden, 2022; Obi, 2024; Onibere & Edewor, 2024). This gap is further exacerbated by challenges such as digital illiteracy, limited funding, and the marginalization of indigenous knowledge systems (Mungwini, 2011). Consequently, there is an urgent need to investigate how technology-driven education can be localized and leveraged to empower West African communities in preserving their cultural heritage effectively and sustainably.

The need to study the preservation of West African artifacts is both urgent and justified, as these artifacts embody the region's unique cultural narratives, historical transitions, and social identities. Ayiku (1997) emphasizes that Ghanaian cultural arts, for example, play a crucial role in everyday life and education, yet they have suffered from neglect due to colonial influences and insufficient conservation knowledge. Without focused preservation efforts, the loss of these artifacts represents not only the erosion of physical objects but also the gradual disappearance of cultural heritage that defines West African societies. Research into artifact preservation would bridge the existing knowledge gap, empower local communities to safeguard their heritage, and challenge the lingering effects of colonial narratives that devalue indigenous arts (Mungwini, 2011). Investing in preservation studies will not only protect the material heritage of West Africa but also promote a more inclusive and culturally sensitive approach to global heritage conservation through technology.

Thus, the purpose of this study is to investigate the role of technology in preserving artifacts and symbols through education. The specific objectives are to explore how traditional artifacts and symbols are preserved using technology, to examine the role of technology-driven education in training conservators, curators, students, and the public in artifact and symbol preservation, to identify the challenges of using technology in conservation efforts and to analyze sustainable measures for addressing these challenges.

This study will address the following research questions:



How are traditional artifacts and symbols preserved using technology? What role does technology-driven education play in training conservators, curators, students, and the public in artifact preservation? What challenges are faced when using technology to conserve artifacts? What sustainable measures are in place to address these challenges?

Literature Review

The preservation of cultural heritage, particularly artifacts, has been a subject of scholarly discourse, with a significant focus on the role of education and technology. Various studies have examined how technological advancements can be leveraged to document, digitize, and promote cultural artifacts and symbols while simultaneously educating and training curators, conservators, students, and the public. This review explores existing digital preservation strategies, including digital archiving, 3D modelling, and artificial intelligence (AI) applications.

Preservation of Cultural Artifacts and Symbols

Artifacts, ranging from tools and pottery to artistic and written texts, have long served as repositories of cultural memory in West Africa. Archaeological findings, such as those examined by Breunig and Neumann (2002), illustrate how the transition from hunting and gathering to food production varied across regions, challenging notions of a uniform Neolithic transition. These artifacts provide tangible evidence of West Africa's cultural and technological evolution. Beyond their functional use, artifacts carry deep symbolic meanings. Ayiku (1997) discusses how Ghanaian artistic expressions such as the “*akuaba*” doll, wood carvings and textiles, serve as vehicles for transmitting cultural knowledge and aesthetic principles across generations. Ngom et al. (2023) highlight the importance of Ajami script in preserving West African identity, noting that texts written in local languages using Arabic script document histories, religious teachings, and communal knowledge. Schmidt (2014) then stresses the role of community archaeology in preserving artifacts. The works of Schmidt (2014) revealed the need for local participation in heritage management to ensure cultural authenticity and continuity.

Aside artifacts, symbols have long been fundamental to the expression and preservation of West African identity, serving as both visual and conceptual mediums for conveying cultural values and historical experiences. Ayiku (1997) points out the role of symbolic meanings in Ghanaian arts, emphasizing the contributions of visual, performing, and verbal art forms to cultural literacy. Similarly, Wilkens and Goshadze (2023) explore how masks, rituals, and other symbolic practices in West African religions help sustain communal identities. These symbols serve not only as aesthetic elements but also as integral components of cultural transmission, reinforcing traditions and collective memory across generations.

In Ghana, the preservation of traditional artifacts and symbols is increasingly facilitated by technology. Ofori et al. (2023) document efforts to revive indigenous symbols from the Akan, Ewe, Ga-Adangbe, and Mole-Dagbani ethnic groups by incorporating them into contemporary interior decoration. Using Cora Marshall's aesthetico research model, they developed a “*Quali-Aesthetico*” framework to integrate these symbols into wall hangings for public spaces. Notable Adinkra symbols, such as *Gye Nyame* (symbolizing divine omnipotence), Sankofa (emphasizing the value of learning from the past), *Duafe* (representing beauty and cleanliness),



Adinkrahene (denoting leadership and excellence), and *Fawohodie* (symbolizing independence and freedom) (Mawuli, 2019), are increasingly preserved and promoted through ornamentals, interior decorations and digital means. The application of technology ensures that these cultural markers remain relevant in modern society while enhancing public appreciation of Ghanaian heritage.

Educational initiatives also contribute to the preservation and interpretation of these symbols. Project-Based Learning (PBL) has been adopted in Ghanaian sculpture programs, allowing students to engage deeply with Adinkra symbols through creative expression (Boakye-Yiadom et al., 2024). This could be witnessed in crafting artworks that incorporate these motifs. Thus, students connect their work to indigenous knowledge systems and historical narratives. Also, contemporary artistic projects have sought to integrate near-extinct symbols into modern interior design, furthering public awareness of Ghana's rich cultural heritage (Ankyiah, et al., 2020; Ofori et al., 2023). However, the global spread of these symbols, particularly within the African diaspora, raises questions about their evolving significance. Ansong (2022) examines how Adinkra symbols influence African Diaspora literature and identity formation in the United States, demonstrating their continued relevance beyond Ghanaian borders.

The impact of globalization on symbolic identity is profound, as cultural symbols are increasingly mobilized to reaffirm connections among African-descended communities. Ullan de la Rosa (2011) discusses the emergence of a "trans-African identity," in which cultural symbols serve as a bridge across the Atlantic, fostering unity among black populations. Meanwhile, William (2003) explores the integration of Islamic influences into West African artistic traditions, showing how architecture, textiles, and textual symbols reflect the fusion of Islamic and indigenous heritage. Moreover, Asmah et al. (2015) investigate the preservation of Ga proverbial symbols through extensive interactions with custodians of Ga royal culture. Their research documents and interprets over ninety Ga proverbs, providing visual representations to facilitate educational use. While technology has significantly contributed to the preservation and dissemination of Ghanaian symbols, debates persist regarding the balance between innovation and cultural authenticity. Ensuring that digital methods do not dilute traditional meanings remains a critical challenge for future preservation efforts.

Preservation of traditional artifacts and symbols using technology

The preservation of traditional artifacts and symbols using technology is essential for safeguarding cultural heritage against the threats of time, globalization, and external influences. Various digital preservation methods, including 3D modelling, AI applications, virtual museums and digital archiving, have proven to be effective in maintaining the integrity of cultural artifacts. Ayiku (1997) highlights the role of digital documentation in preserving Ghanaian arts, emphasizing that symbolic expressions found in visual, performing, and verbal art forms can be systematically recorded and incorporated into educational curricula. This aligns with a study that stresses on collaborative digital databases designed to reflect the authentic knowledge systems of communities rather than imposing external categorizations (Boden, 2022).

The use of 3D modelling and AI plays a critical role in ensuring accessibility to artifacts that are either fragile or geographically distant. A study advocates for community archaeology



initiatives that apply digital tools to enhance cultural heritage education. These efforts empower local populations to participate in the preservation and interpretation of their own history (Schmidt, 2014).

Additionally, a study stresses the role of Ajami literacies in documenting historical narratives, underscoring the significance of integrating indigenous writing systems and symbols into digital preservation efforts (Ngom et al., 2023). Digital storytelling and online repositories provide new avenues for maintaining cultural narratives, artefacts and symbols while ensuring their continued relevance to contemporary audiences. The use of digital media to document ensures their transmission to future generations while fostering a sense of cultural continuity. Through leveraging digital tools, communities can preserve and revitalize their cultural heritage in a manner that aligns with both traditional knowledge systems and contemporary technological advancements. The integration of digital archives, AI-driven preservation techniques, and community-driven digital initiatives ensures that West African artifacts and symbols remain relevant and accessible for future generations.

Technology driven education in artifacts and symbols preservation

Technology offers innovative solutions for educating and training curators, conservators, professionals, students, and the public about cultural heritage preservation. The type of technology used here is Virtual reality (VR) and augmented reality (AR) applications which enable immersive learning experiences, allowing users to explore historical sites and artifacts in digital environments. Another technology is Learning Management Systems (LMS) and E-Learning tools which provide digital training programs. It delivers structured training programs on digital preservation techniques for building the capacity among conservators, curators, and students, especially in regions with limited access to traditional education. These programs can include interactive courses and on-demand videos that cover various aspects of preservation, such as environmental management, material deterioration, and emergency preparedness (National Preservation Institute, 2025; Northeast Document Conservation Center, 2025).

In addition, hosting virtual workshops and webinars allows experts to share knowledge and best practices in artifact preservation with a global audience. These events can include lectures, hands-on interactive sessions, and question and answer segments, making it easier for participants to learn and apply new techniques (Conservation Center for Art & Historic Artifacts, 2025).

Moreover, community-based digital projects can empower local populations to take an active role in preserving their heritage. Engaging the public in artifact preservation through crowdsourcing initiatives can significantly enhance preservation efforts. Projects can involve activities like transcription, tagging, and documenting artifacts, which not only help in preserving cultural heritage but also foster a sense of community and shared responsibility (Oomen & Aroyo, 2011). Schmidt (2014) advocates for participatory archaeology, where digital tools are used to engage communities in documenting and interpreting their own histories. This approach aligns with constructivist learning theories, which emphasize hands-on, experiential learning as a means of knowledge acquisition.

Opportunities and Challenges faced in Digital Preservation of Artifacts



Technological advancements have had profound effects on the preservation of artifacts. While these influences have facilitated the documentation and dissemination of cultural heritage, they have also introduced challenges related to cultural homogenization, ownership, and ethical concerns. The interaction between global and local cultural practices has shaped the ways in which West African heritage is preserved, transmitted, and transformed in the contemporary era. The preservation of West African identity and heritage has faced numerous challenges, particularly in the context of colonialism, globalization, and modernization. However, these challenges have also created opportunities for innovation and renewal, particularly through digital technologies and community-driven efforts.

The colonial era significantly disrupted indigenous systems of cultural preservation, imposing foreign norms and marginalizing local practices. As Ayiku (1997) notes, Western religious and educational institutions have historically denigrated Ghanaian indigenous arts, portraying them as primitive and superstitious. Christianity and Islam have discouraged traditional artistic expressions, leading to a decline in the appreciation and transmission of local cultural knowledge. Similarly, there are critiques on the racial theories of the colonial period, emphasizing the need for Africans to reclaim their cultural heritage through education and self-governance (Horton, 2011). Despite these disruptions, the postcolonial period has seen a resurgence of efforts to document and preserve indigenous heritage, often through interdisciplinary and community-driven approaches (Boden, 2022).

Globalization has introduced both opportunities and threats to the preservation of West African heritage. On the one hand, it has facilitated the global dissemination of West African cultural symbols, allowing for greater recognition and appreciation. For instance, in relation to Ullan de la Rosa (2011) the concept of “*glocalization*”, which tends to describe the interplay between local traditions and global influences, provides a framework for understanding how West African communities navigate cultural change while maintaining distinctiveness. However, globalization also leads to cultural homogenization, where indigenous identities are overshadowed by dominant global narratives. De Jorio (2006) highlights how memory and identity are often shaped by political forces, influencing what aspects of heritage are preserved and how they are represented in national and global contexts.

Community-driven efforts have played a crucial role in heritage preservation. Heritage tourism, particularly in Ghana’s Cape Coast and Elmina, has provided economic incentives for preserving historical sites (Schmidt, 2014; Teye et al., 2011). However, the commercialization of heritage raises ethical concerns about the commodification of culture and the potential for historical distortion. Boden (2022) underscores the importance of integrating local narratives into museum collections, advocating for a more inclusive and participatory approach to heritage documentation. While tourism can provide financial support for cultural preservation, it must be carefully managed to ensure that it benefits local communities rather than external stakeholders.

Advancements in digital technologies have opened new possibilities for preserving and sharing West African heritage. The digitization of Ajami texts, for example, has enabled scholars to access and study historical manuscripts that might otherwise have been lost (Ngom et al., 2023). Digital archives, virtual museums, and 3D modelling have also facilitated the preservation of



artifacts, allowing for broader accessibility and engagement. However, challenges remain regarding access, ownership, and the potential for cultural misrepresentation. Paul (2023) examines how intellectual property rights complicate the digitization of traditional knowledge, emphasizing the need for policies that protect indigenous communities from exploitation.

Exploring the history of various artifacts, and symbols in West Africa reflects the region's rich cultural diversity and resilience in the face of external influences. These elements have long served as markers of identity, encoding historical, spiritual, and cultural meanings that remain relevant today. While globalization and modernization present challenges to cultural preservation, they also offer opportunities for innovation with community-driven initiatives through digital technologies.

Potential Risks and Limitations of Technology-Driven Cultural Preservation

Though technology offers innovative solutions for preserving cultural artifacts and symbols, it also introduces a range of risks and limitations that must be carefully addressed. One of the most pressing concerns is digital inequality. Many communities, particularly in under-resourced regions, lack the infrastructure, internet access, and digital literacy needed to engage with or benefit from digital heritage initiatives. This exclusion can deepen existing disparities in cultural representation and access (Pandey & Kumar, 2020).

Another significant limitation is the risk of cultural misrepresentation. Technologies such as artificial intelligence and 3D modeling often rely on standardized frameworks that may not align with indigenous knowledge systems. Without culturally sensitive approaches, these tools can distort or oversimplify the meanings embedded in artifacts and symbols (Siliutina et al., 2024). Ethical and legal challenges also arise, particularly in the context of digital restitution. While virtual replicas can increase visibility, they do not resolve ownership disputes or replace the cultural and spiritual value of original artifacts. Additionally, concerns about intellectual property and unauthorized use of cultural materials persist (Azamede, 2024; Ter-Zakaryan, 2021).

There is also the danger of losing cultural context. Digitized artifacts may lack the environmental, spiritual, or communal settings that give them meaning (Wagner & Clippele, 2023). Furthermore, the dominance of Western institutions in digital preservation raises the issue of digital colonization, where local voices are marginalized (Kusimba & Pikirayi, 2020). Sustainability is also a critical concern. Digital tools and archives require ongoing maintenance, funding, and technological updates. Without long-term planning, these initiatives risk becoming obsolete, undermining their preservation goals (Diaz Mendoza et al., 2023).

Theoretical Framework

The preservation of West African artifacts through education and technology requires a theoretical framework that can adequately capture various interactions between technological tools, institutions, communities, and cultural heritage itself. This study was underpinned by the Actor-Network Theory (ANT) developed by scholars in the field of science and technology studies, notably Bruno Latour, Michel Callon, and John Law. The ANT provides a framework for understanding how various actors such as people, institutions, digital technologies, and artifacts interact (Latour, 1987; Callon, 1986; Law, 1986 as cited in Dankert (2012)) to shape



cultural heritage preservation. ANT challenges the notion of cultural heritage as a static entity; instead, it conceptualizes it as a dynamic assemblage shaped by the interactions of diverse actors within a network (Dolwick, 2009). A crucial aspect of ANT is the recognition of technology as an active participant in the preservation and dissemination of cultural heritage. Digital technologies such as 3D scanning, virtual reality, and online archives are not merely passive tools; they shape and influence how cultural heritage is recorded, stored, and accessed. For example, the Aluka Project (Rüther & Rajan, 2007) demonstrates how digital documentation transforms the ways in which African heritage sites are preserved and shared globally. Through the creation of detailed 3D models of historical landmarks and artifacts, digital technologies enable immersive educational experiences, making heritage more accessible to scholars, students, and the public.

ANT also highlights the necessity of forming alliances between museums, local communities, educational institutions, and digital platforms in cultural heritage preservation. Gwyneira (2015) discusses the concept of “*perclusive alliances*,” where digital preservation initiatives foster collaborations that transcend institutional and cultural boundaries. Such alliances are particularly significant in ensuring that the digitization of West African artifacts is inclusive and representative of indigenous perspectives. Without the active involvement of local communities, digital heritage projects risk reproducing colonial dynamics that marginalize indigenous voices and knowledge systems.

A critical component of ANT is the agency of local communities in shaping heritage preservation efforts. Digital tools should not impose an external framework but rather facilitate the active participation of indigenous groups in the documentation process. Alex and Ichumbaki (2024) emphasize that communities in East Africa assign value to heritage sites based not only on their physical structures but also on their cultural and spiritual significance. Technology can then serve as a medium for both safeguarding tangible artifacts and preserving the intangible heritage embedded in oral histories, rituals, and communal practices, through integrating local perspectives into digital preservation initiatives.

However, ANT also draws attention to the challenges associated with negotiating responsibilities in cross-cultural digital heritage initiatives. The assignment of ownership, intellectual property rights, and access control becomes particularly complex when multiple stakeholders are involved. Gwyneira (2015) critiques the notion of secrecy in cross-cultural knowledge-sharing, arguing that digital heritage initiatives must prioritize ethical considerations in assigning responsibility and negotiating power dynamics. In the case of West African artifacts, issues of cultural appropriation and digital colonization must be carefully addressed to ensure that technological advancements do not reinforce historical patterns of exploitation.

ANT emphasizes the networked nature of heritage preservation, recognizing the agency of both human and non-human actors. Digital technologies should not only facilitate access to cultural heritage but also empower local communities to shape how their history is preserved and communicated. Ethical considerations must remain at the forefront of digital heritage initiatives, ensuring that technology serves as a tool for cultural continuity rather than displacement.



Methodology

The exploratory qualitative systematic review was used in the study. It uses an interpretative case study approach to investigate technology driven education in digital artifact and symbol preservation. The study adopts a PRISMA-based systematic review process, excluding meta-analyses, to collate and synthesize findings addressing the research questions above. This approach ensures a structured synthesis of existing literature while maintaining flexibility in interpreting findings within the broader context.

Sampling Technique and Search Strategy

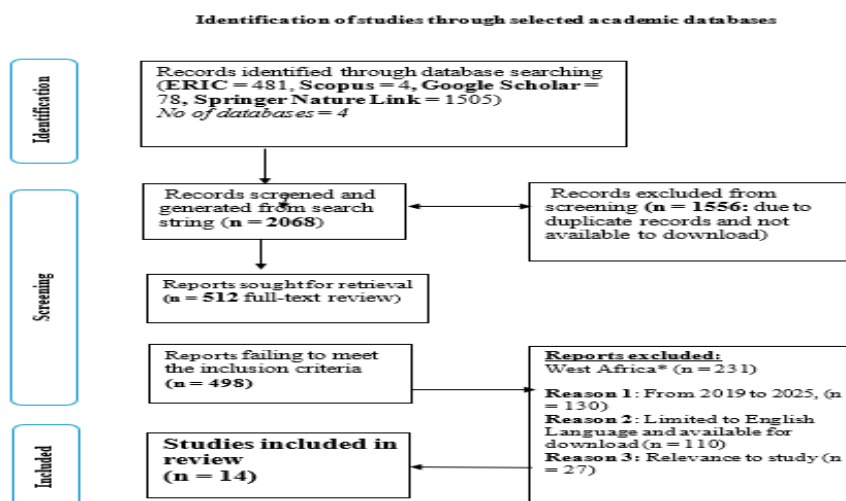
Relevant articles were drawn from four academic databases. They were Education Resource Information Centre (ERIC), Springer Nature Link, Google Scholar and Scopus.

Table 1. Search Equation

Connector	Keywords
	("traditional artefacts" OR artifacts OR symbols)
AND	("archival studies" OR "digital museums" OR "digital conservation" OR "technology-based preservation")
AND	("cultural heritage" OR "preservation education" OR "conservation training")
AND	"West Africa*"

A replicable search query, as displayed in Table 1., employed a combination of Boolean operators and field-specific codes to maximize precision and coverage. Using purposive sampling, this systematic review followed the 2020 PRISMA guidelines, as outlined in Figure 1, progressing through three key stages. In the identification stage, 2,068 records were retrieved from 4 academic database searches. During screening, duplicate and inaccessible records (1,556) were removed. The eligibility and inclusion stage involved reviewing 512 full-text articles, with 498 failing to meet predefined inclusion criteria (with 130 empirical studies from 2019–2025).

Figure 1. PRISMA 2020 flow diagram for new systematic reviews with meta-analyses but excluded





Further, 231 articles focused on West Africa were excluded, while other reasons were based on limited language availability and relevance. Excluding articles beyond language and relevance is necessary to maintain scientific rigor, consistency, and validity of the findings. Articles were omitted due to poor quality, incompatible study designs, missing data, differing populations, non-peer-reviewed sources, or duplicate datasets. These exclusions help maintain consistency, reduce bias, and enhance the validity of the overall findings.

Fourteen (14) studies were then selected for this review (see Table 2.), ensuring a targeted analysis of technology driven education for digital artifact and symbol preservation. The selection of 14 studies for this meta-analysis is justified through a rigorous and transparent screening process as seen above. The final 14 studies offer in-depth insights into digital preservation methods, educational strategies for training conservators and communities, and the challenges and sustainable solutions in technology-based conservation. This focused, high-quality selection provides a strong foundation for thematic analysis and supports the study's aim of exploring technology-driven education in artifact preservation, particularly in a field where research on West African contexts remains limited.

Ethical Consideration

Confidentiality and accuracy in data handling and interpretation were prioritized. Triangulation of sources was used to validate findings.

Data Analysis

Thematic analysis was applied to identify trends, gaps, opportunities and challenges in technology driven education for digital artifacts and symbols preservation. The analysis began with coding, where labels are assigned to meaningful segments of text from included studies. These codes emerged inductively from the data or were guided by existing theories. Next, similar codes are grouped into broader themes based on shared meanings or conceptual similarities. Within these themes, more specific patterns, subthemes were identified to capture nuanced insights. The themes and subthemes were then reviewed and refined to ensure they were coherent, distinct, and well-supported by the data. (Wæraas, 2022).

Table 2. List of all studies included in review

Reference No.	Author(s)	Academic Database	Paper Source	Study Area(s)
[1]	Azamede (2024)	Scopus	<i>Pluto Press</i>	Togo
[2]	Lor (2019)	Scopus	<i>De Gruyter Saur</i>	Africa
[3]	Owoo (2024)	Scopus	<i>Pluto Press</i>	Ghana
[4]	Lamprey and Dumavor (2021)	ERIC	<i>Composition Studies</i>	Ghana
[5]	Adewumi (2019)	Google Scholar	<i>Art Antiquity and Law</i>	Nigeria



[6]	Anyim (2020)	Google Scholar	<i>Central European University, Budapest</i>	Ghana
[7]	Biveridge (2021)	Google Scholar	<i>Legon Journal of the Humanities</i>	Ghana
[8]	Hediger et al. (2021)	Google Scholar	<i>The Moving Image</i>	Nigeria
[9]	King (2020)	Google Scholar	<i>Institute of Archaeology, University College London</i>	Africa
[10]	Kpedekpo (2024)	Google Scholar	<i>The University of British Columbia</i>	Ghana
[11]	Ter-Zakaryan (2021)	Google Scholar	<i>University of Oxford</i>	Benin
[12]	Appeaning Addo et al. (2025)	Springer Nature Link	<i>Built Heritage</i>	Ghana
[13]	Daraojimba et al. (2022)	Springer Nature Link	<i>African Archaeological Review</i>	Nigeria
[14]	Kusimba and Pikirayi (2020)	Springer Nature Link	<i>African Archaeological Review</i>	Ghana, Nigeria

Results

Findings from this review reveal significant gaps in the use of technology-driven education for digitally preserving cultural artifacts and symbols across West Africa. It is important to clarify that the findings presented from this point forward are exclusively derived from the 14 studies included in the systematic review, and not from the background literature. An overview of the systematic review of 14 studies shows some critical roles of digital education in conservation efforts, disclosing four major themes with ten interconnected sub-themes (Table 3.). Key findings emphasize the importance of digital training programs and virtual workshops in enhancing conservators' skills and public engagement, while crowdsourcing initiatives creates awareness and participation. However, challenges such as limited digital infrastructure and inadequate policy support hinder progress.

The study also explores emerging technological advancements, including AI and VR, as potential tools for artifact preservation. Framed within the ANT, the findings provide a structured understanding of the role of digital technologies in artifact preservation, means of technology-driven preservation challenges, and sustainability measure necessary to strengthen technology-driven education in digital cultural conservation across diverse West African contexts (Table 3.).

Table 3. Overview of the systematic review

Themes	Sub-themes	Author(s) References	Citations per category	Main Gap(s)
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Role of Digital Technologies in Artifact Preservation	Digital Documentation and Archiving	5, 10, 2	3	Gaps exist in accessing digitally preserved content or artifacts, policy implementation, and infrastructural challenges.
	Virtual Reality and 3D Reconstruction	3, 13, 8	3	
Means of Technology-Driven Preservation	Community Involvement and Education	6	1	Lack of holistic preservation frameworks that can bridge the gap between grassroots cultural expressions, digital innovation, and policy implementation.
	Policy Interventions	12	1	
	Institutional Support	14	1	
Challenges in Technology-Driven Preservation	Infrastructure and Resource Constraints	12, 4, 9	3	Limited perceptual discussions on how digital tools, policy innovations, and community engagement can collectively address the challenges of technology-driven preservation.
	Ethical Concerns	1, 11	2	
	Cultural Sensitivity	7, 10	2	
Sustainability Measures	AI and Machine Learning in Artifact Conservation	8, 13	2	Interdisciplinary collaborations aimed at merging technological innovation with decolonized frameworks of heritage preservation do not exist.
	International Collaborations	14, 1, 3	3	

Role of technology in the preservation of artifacts and symbols

The role of technology in artifacts and symbols preservation has become a significant area of study, especially in African contexts where historical and cultural heritage faces threats from natural decay, political instability, and lack of infrastructure. This review synthesizes and extensively discusses some contributions, research methods, findings, and main gaps in the works of Adewumi (2019), Kpedekpo (2024), Lor (2019), Owoo (2024), Daraojimba et al. (2022), and Hediger et al. (2021). The analysis highlights the intersections of digital documentation and archiving, virtual reality and 3D reconstruction while comparing their approaches.

Digital Documentation and Archiving

Several studies emphasize the importance of digital documentation in preserving historical artifacts and symbols. Adewumi (2019) emphasizes the critical role of digitization in preventing the loss of Nigeria's historical records, framing digital documentation as a necessary response to the deteriorating state of national archives. Kpedekpo (2024) extends this discourse by focusing on digital storytelling and smartphone technology in Ghana, demonstrating how digital platforms can foster engagement among the youth. Lor (2019), taking a more global perspective, discusses



international trends in archival sciences and the increasing accessibility enabled by digital repositories.

With regards to methods, Adewumi (2019) employs qualitative analysis, drawing from archival policies and case studies to illustrate the deteriorating condition of Nigerian archives. While Kpedekpo's (2024) interdisciplinary approach combines digital humanities, participatory research, and digital storytelling, using ArcGIS Story Maps as an interactive tool. Lor, in contrast, provides a comparative analysis of international librarianship, leveraging secondary sources and policy studies. Outcomes of these studies indicate that the urgency of government intervention to digitize and preserve historical records, noting challenges such as poor electricity infrastructure (Adewumi, 2019). However, Kpedekpo (2024) debunks the notion that digital technology alienates youth from cultural heritage, showing that smartphone-based storytelling can enhance engagement. While Lor (2019) points out the role of international cooperation in improving digital access to cultural artifacts, advocating for standardized methodologies in global archival practices.

Although Adewumi (2019) underscores the need for digitization, the study does not offer specific technological frameworks for implementation. Kpedekpo's (2024) research, though innovative, is limited to the Ghanaian context and does not fully explore scalability to other African nations. Lor's (2019) work, though very relatable, does not address the specific challenges of digitization in regions with infrastructural deficiencies.

Virtual Reality and 3D Reconstruction

Virtual reality (VR) and 3D scanning are emerging as essential tools for conservation. Owoo (2024) examines the restitution of Asante regalia and the use of VR for digital repatriation. Daraojimba et al. (2022) explore how archaeological discoveries at Igbo-Ukwu can be digitally reconstructed to enhance public education. Hediger et al. (2021) highlight AI-assisted restoration of Nigerian film archives, demonstrating how machine learning can be adapted for broader artifact preservation efforts.

Further, Owoo (2024) employs historical analysis, tracing the journey of looted Asante artifacts and their eventual digital restitution. Daraojimba et al. (2022) adopt a multi-scalar archaeological approach, combining stratigraphic analysis, radiocarbon dating, and digital modelling. Hediger et al. (2021) employ a technological approach, analysing AI's role in film restoration through machine learning techniques. Owoo (2024) finds that while digital repatriation is a step forward, the continued ownership disputes surrounding African artifacts remain unresolved. Daraojimba et al. (2022) demonstrate that digital reconstructions can provide new insights into historical settlements, revealing evidence of ancient trade and subsistence practices. Hediger et al. (2021) highlight the potential of AI in restoring degraded film archives, ensuring the longevity of audiovisual heritage.

Moreso, Owoo's (2024) study does not address the technical limitations of VR in effectively recreating tangible heritage experiences. Daraojimba et al. (2022) focus heavily on excavation findings but provide limited discussion on the accessibility of their digital reconstructions to the public. Hediger et al. (2021) mainly address Nigerian film restoration, leaving room for broader application to other African film industries. While all six authors engage with the theme of digital preservation, they differ in their methodological approaches and focal areas. Adewumi (2019) and



Kpedekpo (2024) emphasize textual and storytelling-based documentation, whereas Owoo, Daraojimba et al., and Hediger et al. explore technological reconstructions. Lor provides a broad international context but lacks specificity in African case studies. Thematically, Owoo (2024) and Hediger et al. (2022) address restitution and repatriation, while Adewumi (2019) and Kpedekpo (2024) focus on digital archiving and engagement. Daraojimba et al. (2022) bridge both spheres by incorporating archaeology into digital conservation.

Means of Technology-Driven Preservation

The scholarly discourse surrounding technology-driven preservation highlights the intersection of digital innovation, community engagement, and policy development in sustaining cultural heritage. Findings from the review reveal that technology-driven heritage preservation requires an integrated approach that combines digital innovation, community involvement, and institutional support. Appeaning Addo et al. (2025) advocate for policy-driven interventions that support heritage sustainability.

Community Involvement and Education

According to Li, Krishnamurthy, Roders, & van Wesemael (2020), engaging local communities in heritage preservation through participatory planning and volunteer programs fosters a sense of ownership and responsibility. Most importantly Langton & Ma Rhea (2003) emphasize that education plays a crucial role in preserving traditional knowledge and promoting cultural diversity by raising awareness and advocating for the preservation of cultural heritage.

Community involvement can be spear headed by engaging local communities in the decision-making process regarding the management and conservation of cultural heritage sites ensuring that preservation efforts align with the community's needs and values (Li, Krishnamurthy, Roders, & van Wesemael, 2020). Sometimes, communities may establish volunteer programs to maintain and promote cultural heritage sites, which fosters a sense of ownership and responsibility among residents too. In some cases, there is collaboration between local communities and heritage organizations which can lead to successful preservation efforts.

Education also has its role to play in the preservation of traditional knowledge such as artifact and symbol preservation. It helps preserve traditional knowledge and practices by teaching them to new generations, ensuring that cultural traditions are not lost over time (Langton & Ma Rhea, 2003). It also promotes cultural diversity by exposing individuals to different cultures and traditions, fostering an appreciation for cultural heritage. It raises awareness about the importance of preserving cultural artifacts and sites, inspiring individuals to take action to protect them (Langton & Ma Rhea (2003). With the advent of modern technology, various innovative methods have been developed to ensure the longevity, enhanced documentation, improved accessibility, preservation of fragile artifacts, real-time monitoring and enhanced security of these artifacts. Educational opportunities are also created through digital replicas and virtual experiences providing valuable educational resources. Students and researchers can interact with digital models of artifacts, gaining insights into their history and significance without needing to handle the physical objects. This promotes a more engaging and interactive learning experience. Other technological means of preservation are through digital storytelling, webinars and virtual workshops in communities to have more knowledge and skills on the digital preservation of artifacts and symbols.



Policy Interventions

Government and private institutional policies play a crucial role in fostering technology-driven preservation. They establish comprehensive standards and procedures for the lifecycle management of digital artifacts ensuring their long-term preservation and accessibility. They also promote the use of open standards-based formats and widely accepted community-based standards facilitating the preservation and supporting the future access to digital content (National Archives and Records Administration, 2022).

Implementing risk planning and mitigation strategies to address potential threats to digital artifacts is also essential for their preservation (National Archives and Records Administration, 2022). There is also a need to encourage collaboration between cultural heritage organizations, libraries, and archives to share best practices and resources for digital preservation. For example, the review of Ghana's culture policy. The Ministry of Tourism, Arts, and Culture, with support from UNESCO, is reviewing Ghana's 2004 Culture policy to accommodate modern development trends. This policy review aims to preserve and promote the nation's rich cultural heritage, including historical sites, artifacts, oral traditions, and indigenous practices (Ministry of Tourism, Arts and Culture, 2023).

Notable policy interventions aimed at preserving artifacts in Africa include advocating for the return of cultural artifacts taken during colonial times. This includes efforts by governments and international organizations to negotiate the repatriation of items such as the Benin Bronzes and Nok terracotta figures (African Leadership Magazine, 2024). In addition, developing and enforcing robust global frameworks to prevent the unauthorized trade of cultural property such as traditional artifacts is a key policy intervention. The need for collaboration among museums, governments, and cultural organizations to streamline the repatriation process is crucial (African Leadership Magazine, 2024). There is also a need for community engagement and technological innovation initiatives to preserve cultural heritage. For example, Mali collaborates with UNESCO to protect historic sites such as Timbuktu which has traditional artifacts (particularly its ancient manuscripts) of historic significance (Pan African News Media, 2024).

Institutional Support

Kusimba and Pikirayi (2020) advocate for the decolonization of archaeological research, urging African institutions to take ownership of digital conservation initiatives. The necessity of institutional support in digital heritage preservation is articulated in the work of Kusimba and Pikirayi (2020). They advocate for the decolonization of African archaeological research, arguing that local institutions must take ownership of digital conservation initiatives. Their conversation with Peter Schmidt underscores the historical marginalization of African voices in archaeological discourse and the ongoing efforts to reclaim indigenous narratives. Their research aligns with Anyim's (2020) emphasis on the role of digital platforms in historical representation but extends the argument by stressing the importance of institutional backing in sustaining these initiatives. Kusimba and Pikirayi (2020) highlight the systemic and structural challenges that must be addressed to achieve sustainable digital conservation.

Challenges in technology driven preservation



The discourse on technology driven artifacts and symbols preservation reveals both its transformative potential and its inherent challenges, as various scholars highlight the infrastructural, ethical, and cultural constraints that complicate digital conservation efforts.

Infrastructure and Resource Constraints

Despite the potential of digital solutions, infrastructural challenges hinder implementation. Lamptey and Dumavor (2021) argue that colonial-era curricula continue to restrict digital literacy, affecting students' ability to engage with modern preservation techniques. Similarly, King (2020) examines archaeological challenges in Africa, noting that resource limitations prevent the full utilization of digital methodologies in conservation. Lamptey and Dumavor (2021) assert that colonial-era curricula continue to shape educational practices, restricting digital literacy and, by extension, engagement with modern preservation techniques. King (2020) similarly addresses resource limitations but within the broader context of African archaeology, arguing that while digital methodologies promise to revolutionize conservation, they remain inaccessible to many due to financial and infrastructural deficiencies.

While these works effectively illustrate structural impediments, they differ in their research approaches. Lamptey and Dumavor (2021) take a more theoretical stance, critiquing the historical continuity of colonial influences on education in West Africa. While King (2020) integrates archaeological perspectives, considering both methodological and theoretical adjustments necessary to adapt digital tools for Africa. Despite these diverse angles, a common limitation in their works is a lack of engagement with policy frameworks that could potentially bridge these technological gaps.

Ethical Concerns

Beyond infrastructure, ethical concerns emerge as another key issue in digital preservation. Azamede (2024) interrogates the restitution of looted Togolese artifacts, raising questions about the ethical implications of digitizing objects with contested ownership. This author's analysis is complemented by Ter-Zakaryan (2021), who examines British museums' handling of the Benin Bronzes, revealing how colonial-era mindsets persist in debates on restitution. While both scholars focus on issues of provenance and ownership, their methodologies diverge: Azamede (2024) adopts a historical and discursive analysis to trace colonial violence through looted artifacts, whereas Ter-Zakaryan (2021) incorporates legal and institutional analysis to explore the evolving attitudes of British museums. Despite their contributions, these works fall short of offering concrete resolutions to the restitution dilemma, leaving the question of how digital technology might mediate these tensions unanswered.

Cultural Sensitivity

Culturally sensitive, technology-driven educational initiatives are crucial when digital repatriation efforts, entail customarily appropriate actions. Sharing or digitizing artifacts can conflict with the cultural or spiritual values of source communities creating dilemmas. Many artifacts hold significant cultural or spiritual value for the communities they originate from. Sharing or digitizing these artifacts without proper consideration can be seen as disrespectful or harmful to those communities (Marsh, 2022). In addition, returning cultural heritage items in digital format to their originating communities, have been recognized to empower communities and promote cultural preservation. Such initiatives enable broader participation in cultural



heritage projects, allowing communities to curate and define access to their cultural materials, thereby enhancing cultural sensitivity and preservation efforts.

In his 2021 study, Biveridge examines the socio-cultural consequences of small-scale artisanal gold mining, known locally as “galamsey,” on the archaeological record and heritage resources at Awudua Dada in Ghana’s Western Region. Employing archaeological, historical, and ethnohistorical research methods, Biveridge (2021) reveals that unregulated mining activities have led to significant environmental degradation and the destruction of cultural heritage sites, notably the remnants of Fort Ruychaver. He advocates for immediate educational programs targeting miners to raise awareness about the harmful effects of their practices and the introduction of technological innovations to mitigate environmental and cultural damage. Biveridge’s (2021) work draw attention to the necessity of integrating cultural sensitivity into educational initiatives, emphasizing that preserving archaeological records requires not only regulatory enforcement but also community engagement and education (Biveridge, 2021).

Kpedekpo (2024) further explores the potential of digital technology, particularly smartphones, to promote the transmission and engagement of cultural heritage among Ghanaian youth. Challenging the notion that digital technology alienates youth from their culture, Kpedekpo (2024) applies principles of minimal computing to create accessible digital solutions tailored to users’ technological constraints in Ghana. She introduces Digital Storytelling (DST) as an arts-based method, employing ArcGIS Story Maps to develop an interactive platform centred on Ghana’s bead-making arts. This platform integrates various media forms, providing an immersive learning experience that fosters a meaningful connection with cultural identity among the youth. Kpedekpo’s work highlights the potential of digital technology to empower cultural heritage engagement, ensuring that Ghana’s cultural identity remains vibrant and accessible to future generations Kpedekpo (2024).

These studies contribute to the theme of cultural sensitivity in preserving artifacts and symbols through technology-driven education. Biveridge (2021) emphasizes the importance of educating local communities about the adverse effects of harmful practices on cultural heritage, advocating for the use of technology to promote sustainable mining practices. Kpedekpo (2024) focuses on leveraging digital tools familiar to the youth to enhance their engagement with cultural heritage, demonstrating how technology can serve as a bridge between tradition and modernity. However, gaps remain in their research. Biveridge’s (2021) study could benefit from exploring specific technological tools and educational strategies to effectively communicate the importance of cultural preservation to miners. Kpedekpo (2024) work, while innovative, could further examine the long-term impact of digital storytelling on cultural engagement and identity formation among the youth.

Synthesizing these scholarly contributions, it is evident that technological advancement alone cannot resolve the complexities of heritage preservation. The convergence of infrastructural inadequacies (Lampsey & Dumavor, 2021; King, 2020), ethical concerns (Azamede, 2024; Ter-Zakaryan, 2021), and cultural sensitivities (Biveridge, 2021; Kpedekpo, 2024) suggests that a multidisciplinary approach is necessary. Digital solutions must be coupled with policy interventions, ethical considerations, and culturally sensitive methodologies to ensure that preservation efforts are both effective and respectful. While these scholars provide critical insights into different facets of the issue, future research should aim to integrate these



perspectives, exploring how digital tools, policy innovations, and community engagement can collectively address the challenges of technology-driven preservation.

Other challenges associated with digital preservation of artifacts and symbols include high cost of technological devices, lack of technical expertise and the digital divide. The development and maintenance of advanced technologies like VR and 3D printing are expensive, often limiting their use in underfunded educational institutions. Also, teachers and students may lack the necessary skills to effectively use these technologies, leading to a steep learning curve. Unequal access to technology, particularly in developing regions, creates disparities in learning opportunities (Wiggins, 2020).

Sustainability Measures

The discourse surrounding sustainability measures in digital artifacts and symbols conservation have been significantly shaped by recent scholarly contributions. The integration of AI, international collaborations, and equitable restitution frameworks has emerged as key components in ensuring the longevity of cultural heritage. While AI-driven approaches enhance precision in artifact analysis, they must be balanced with ethical considerations and the socio-political dimensions of heritage conservation. Similarly, global partnerships and legal frameworks play a critical role in addressing challenges related to repatriation and the control of cultural heritage.

AI and Machine Learning in Artifact and symbol Conservation

AI and machine learning are emerging as key technologies in conservation. Hediger et al. (2021) highlight how Nigerian film heritage has been preserved through AI-based restoration, suggesting similar applications for historical artifacts. Daraojimba et al. (2022) discuss how AI-driven analysis of archaeological findings at Igbo-Ukwu can refine interpretations and enhance historical accuracy. Hediger et al. (2021) delve into the intersection of AI and machine learning with audiovisual heritage, particularly within the Nigerian context. Through analysing the restoration of Shehu Umar, they illuminate the technological possibilities for preserving historical films, positioning AI as a crucial tool in maintaining fragile cultural artifacts. This perspective aligns with the work of Daraojimba et al. (2022), who apply AI-driven methodologies to archaeological research at Igbo-Ukwu. Their use of multi-method analysis, including radiocarbon dating, soil analysis, and elemental measurements, reflect the increasing reliance on technology in enhancing the accuracy of historical interpretations. Both studies highlight AI's transformative potential; however, while Hediger et al. (2021) emphasize audiovisual heritage, Daraojimba et al. (2022) focus on physical artifacts, demonstrating a broader scope for AI in artifact conservation.

Despite their valuable contributions, these studies reveal significant gaps. Hediger et al. (2021) and Daraojimba et al. (2022) explore the benefits of AI but do not fully engage with its ethical implications, such as data sovereignty and the potential biases embedded in machine learning models. Moreover, the infrastructural challenges facing many African institutions remain underexplored, posing a barrier to implementing the technological advancements discussed. Future research should address these concerns while integrating AI-driven conservation with ethical considerations and localized knowledge systems.

International Collaborations

International partnerships are essential for sustainable preservation efforts. Kusimba and Pikirayi (2020) examine the role of Western institutions in African archaeology, advocating for equitable



collaborations. Azamede (2024) highlights the transnational restitution debate, emphasizing the need for African nations to assert greater control over their heritage. Owoo (2024) discusses the ongoing negotiations for the return of Asante artifacts, stressing the importance of international legal frameworks in ensuring rightful repatriation.

The sustainability of artifact conservation also relies on international collaborations and equitable partnerships. Kusimba and Pikirayi (2020) critically assess the role of Western institutions in African archaeology, arguing for decolonized frameworks that prioritize local agency and knowledge systems. This argument finds resonance in the work of Azamede (2024), who situates the issue of restitution within a transnational context, highlighting the continued struggles of African nations to reclaim their cultural heritage. Owoo (2024) extends this discussion by examining the repatriation of Asante artifacts, illustrating the legal and diplomatic negotiations that shape contemporary restitution efforts.

Together, these works reveal the importance of global cooperation. While Kusimba and Pikirayi (2020) advocate for ethical collaborations, Azamede (2024) and Owoo (2024) illuminate the structural challenges that impede the full realization of these ideals. Similarly, while they effectively critique Western dominance in artifact conservation, they provide limited insights into how digital tools could facilitate more equitable collaborations. Synthesizing these perspectives, it becomes evident that a holistic approach is necessary.

There should be integration of AI and scientific methodologies with ethical, legal, and socio-political considerations. The convergence of these approaches can ensure that artifact conservation is not only technologically advanced but also culturally sensitive and equitable. Most findings reveal that technology-driven education offers a transformative approach to artifact preservation. However, challenges such as infrastructural limitations, ethical dilemmas, and policy constraints must be addressed through community engagement, policy interventions, and international collaborations. The infrastructural limitations include limited internet connectivity, inadequate hardware and equipment, unreliable power supply, lack of technical support, insufficient storage and server infrastructure and cybersecurity and data protection issues. Through the leveraging of digital tools, AI, and VR, institutions can bridge the gap between historical conservation and contemporary technological advancements, ensuring the sustainable preservation of cultural artifacts and symbols for future generations.

In all, the ANT offers a valuable framework for understanding how technology mediates relationships within cultural preservation networks. Rather than viewing technology as a passive tool, ANT conceptualizes it as an active agent that interacts with human actors, such as conservators, curators, educators, and communities to shape the processes and outcomes of preservation. In the context of digital heritage, technologies like artificial intelligence, 3D modeling, and digital archiving systems play a central role in how artifacts are restored, interpreted, and shared. These tools influence not only the technical aspects of conservation but also the cultural narratives that emerge from them. ANT helps to reveal how these non-human actors co-construct meaning alongside human participants.

Moreover, ANT emphasizes the interdependence of all actors in the network. Preservation is not a linear process but a collaborative one, involving dynamic interactions between people and technologies. This perspective also highlights how technology mediates access, representation,



and control, raising questions about power dynamics, especially when digital tools are developed or controlled by institutions outside the communities they aim to serve.

By mapping these relationships, ANT provides insights into the sustainability of preservation efforts. A stable network, where human and technological actors are well-integrated, can support long-term cultural conservation. However, if the network is imbalanced or excludes key voices, it risks undermining the authenticity and inclusivity of heritage preservation.

Discussion

The interplay between infrastructure challenges and global collaboration is critical. While global frameworks provide technical expertise, local efforts ensure cultural relevance. Investing in digital access and partnerships with international organizations can strengthen educational resilience in artifact preservation. The findings of this study emphasize the crucial role of digital technologies in artifact and symbol preservation while highlighting the interplay between technological advancements, global collaboration, and local efforts. The systematic review results have so far shown how digital education, and technological interventions provide a transformative approach to safeguarding cultural heritage, yet they also expose several infrastructural and ethical challenges that must be addressed to ensure sustainable artifact and symbol conservation.

Role of technology in the preservation of artifacts and symbols

Artifacts have long served as repositories of cultural memory, encoding historical, spiritual, and technological knowledge. The literature highlights how artifacts, from tools and pottery to written texts, document historical transitions, such as those examined by Breunig and Neumann (2002) regarding how the Neolithic transformation in West Africa are preserved. These artifacts do not merely reflect past subsistence patterns but also illustrate the region's technological evolution. Beyond their functional roles, cultural artifacts carry profound symbolic meanings. As Ayiku (1997) describes Ghanaian artifacts such as the “*akuaba*” doll, wood carvings, and textiles serve as intergenerational vessels of aesthetic and philosophical knowledge. Likewise, Ngom et al. (2023) stress the role of Ajami script in documenting communal histories and religious teachings, reinforcing the literature review's emphasis on the importance of script-based heritage preservation.

The systematic review results align with these perspectives, demonstrating that digital tools such as 3D modelling, AI, and virtual reality (VR) enhance artifact conservation and accessibility. Studies from the review, such as Adewumi (2019) and Kpedekpo (2024), highlight the importance of digital storytelling and archives in maintaining cultural artifacts, echoing the works of Lor (2019) on international digital repositories. Similarly, the use of VR in the restitution of Asante regalia (Owoo, 2024) aligns with the theoretical perspective of ANT, which highlights the interdependence between human actors (local communities, curators, and educators) and technological actors (digital archives, AI systems, and VR simulations) in shaping preservation efforts.

This implies that digital storytelling platforms empower communities to narrate their own histories, countering dominant narratives and fostering cultural pride. This aligns with the symbolic role of artifacts reinforcing their relevance in contemporary identity formation.



addition, the findings suggest a need for policies that support digital heritage initiatives and integrate them into educational curricula. This ensures that future generations not only learn about their heritage but also participate in its preservation using modern tools.

Means of Technology-Driven Preservation

One of the most significant findings of the systematic review is the role of technology in preserving both artifacts and symbols, echoing the literature's insights into how Ghanaian artistic traditions integrate digital preservation techniques (Ofori et al., 2023). The review confirms that digitization allows for the promotion of cultural symbols such as Adinkra motifs through digital ornamentation and interior design, ensuring their continued relevance. This aligns with Boakye-Yiadom et al. (2024), who advocate for Project-Based Learning (PBL) to engage students with traditional symbols, fostering cultural literacy through digital education. Literature supports the role of community-driven preservation, as discussed by Schmidt (2014), which aligns with Anyim (2020) and Kusimba and Pikirayi (2020) in the systematic review, advocating for local agency in heritage conservation efforts.

The implications on technology-driven preservation are important for cultural sustainability, education, and community empowerment. Digitizing cultural motifs like Adinkra symbols ensures their continued visibility and relevance in modern contexts such as digital art, fashion, and interior design. This not only preserves the symbols but also recontextualizes them for contemporary audiences, bridging tradition and innovation. The integration of PBL into digital education implies that students are not just passive recipients of cultural knowledge but active participants in its preservation. This fosters cultural literacy and creativity, ensuring that traditional knowledge systems are embedded in future generations. The alignment between literature and systematic review findings underscores the importance of local agency. When communities lead preservation efforts, supported by technology, they are more likely to maintain authenticity, cultural ownership, and sustainability.

Challenges in Technology-Driven Preservation

While digital technologies provide new avenues for artifact conservation, the systematic review identifies significant challenges that align with concerns raised in the literature. Infrastructure limitations, as noted by Lamptey and Dumavor (2021), and King (2020), hinder access to digital archives and virtual museums, particularly in regions with inadequate technological infrastructure. This is particularly concerning given that artifacts, as described by Greene (2002) and Asmah et al. (2015), are deeply embedded in the socio-political and historical contexts of West African communities. Without proper digital access, marginalized groups may be excluded from engaging with their own cultural heritage.

Ethical concerns regarding digital restitution and ownership disputes are another key challenge. The literature review discusses the contested repatriation of looted artifacts (Azamede, 2024; Ter-Zakaryan, 2021), which remains unresolved in many cases. The systematic review findings support this, indicating that while digital repatriation via VR can partially bridge restitution gaps, unresolved legal and ethical dilemmas persist. This echoes the concerns raised by Boden (2022), who warns against digital preservation methods that impose external categorizations on indigenous knowledge systems rather than reflecting their authentic structures. Studies in the review, such as Owoo (2024) on Asante regalia and Ter-Zakaryan (2021) on the Benin Bronzes,



further confirm these challenges, demonstrating the contested nature of ownership and representation in digital heritage projects.

Cultural sensitivity remains a pressing concern in the digitization of heritage, as evidenced by the contributions of Marsh (2022) and Kpedekpo (2024). Marsh's (2022) study explained how many artifacts are deeply significant to communities both culturally and spiritually and a need to carefully consider sharing or digitizing these items which can be perceived as disrespectful or even harmful to the communities involved. Kpedekpo's (2024) work highlights this challenge by advocating for digital storytelling as an interactive and participatory medium, ensuring that digital heritage remains engaging and reflective of lived cultural experiences rather than mere archival data. This aligns with King (2020) and Azamede (2024), whose research underscores the tension between preservation and cultural authenticity, warning that digitization must be done in ways that respect and accurately represent indigenous narratives. The findings from these scholars reinforce Actor-Network Theory (ANT), which argues that non-human actors, such as digital tools, must be carefully integrated with human knowledge systems to maintain cultural integrity. Without thoughtful implementation, technological interventions may inadvertently dilute the cultural significance of artifacts and symbols rather than preserving them in their full historical and contextual richness.

The implications on the challenges in technology-driven preservation are critical for understanding the limitations and ethical complexities of digital heritage work. Despite the promise of digital tools in preserving cultural heritage, several challenges hinder their effectiveness. One major issue is digital inequality. Many communities, especially in under-resourced regions, face limited internet access, low digital literacy, and insufficient funding. These barriers prevent them from accessing or contributing to digital heritage platforms, reinforcing existing disparities in cultural representation. Another challenge lies in the ethical and legal complexities of digital restitution. While technologies like virtual reality can simulate the return of looted artifacts, they do not resolve the deeper issues of ownership and cultural significance. Digital replicas may offer visibility but cannot replace the emotional, spiritual, and historical value of original items. There is also a risk of cultural misrepresentation. When digital systems categorize artifacts without understanding their cultural context, they may distort or oversimplify their meaning. This highlights the need for culturally sensitive frameworks. Furthermore, not all heritage should be digitized. Some artifacts hold sacred or private meanings and digitizing them without community consent can be harmful. Respectful engagement with communities is essential. These challenges point to the need for inclusive policies that ensure equitable access, protect indigenous knowledge, and promote community-led digitization. Thoughtful integration of technology is crucial to preserving cultural integrity.

Sustainability Measures

Ensuring the sustainability of digital preservation efforts requires strategic investments in AI, international collaborations, and policy frameworks. The systematic review highlights how AI-driven artifact analysis, as demonstrated by Hediger et al. (2021) and Daraojimba et al. (2022), enhances conservation accuracy. However, the literature warns against over-reliance on AI without ethical oversight. The works of Paul (2023) and Boden (2022) stress the importance of balancing technological innovation with indigenous knowledge systems to prevent cultural misrepresentation. International collaborations also emerge as a key factor in ensuring long-



term preservation. The literature review discusses the role of partnerships in securing artifact repatriation (Owoo, 2024; Azamede, 2024), which the systematic review findings support. However, while such collaborations facilitate resource mobilization, they also present challenges related to control and ownership, as some returned artifacts remain on loan rather than being permanently repatriated. The literature further warns against the risk of “digital colonization,” where technological advancements in preservation remain primarily controlled by Western institutions rather than being driven by local actors (Kusimba & Pikirayi, 2020). This concern is also reflected in the systematic review findings from Kusimba and Pikirayi (2020) who highlight the importance of policy interventions in regulating digital heritage projects.

Sustainable digital preservation requires a careful balance between innovation, inclusivity, and ethical responsibility to protect cultural heritage for future generations. The integration of advanced technologies such as artificial intelligence (AI) and international collaborations into cultural preservation efforts presents both opportunities and challenges. One key implication is the potential for enhanced conservation accuracy. AI-driven tools can analyze and restore artifacts with remarkable precision, improving long-term preservation outcomes. However, this benefit must be balanced with ethical oversight to avoid cultural misrepresentation, especially when indigenous knowledge systems are sidelined in favour of algorithmic interpretations. Another significant implication is the importance of equitable international partnerships. Collaborations between institutions across borders can mobilize resources and expertise, facilitating the repatriation and digitization of cultural artifacts. Yet, these partnerships often raise concerns about control and ownership, particularly when artifacts are returned on loan rather than permanently. These dynamic risks perpetuating unequal power structures in heritage management. Furthermore, the discussion highlights the threat of digital colonization, where technological advancements are dominated by institutions in the Global North. This underscores the need for policy frameworks that prioritize local agency, regulate digital heritage projects, and ensure that preservation efforts are community-led and culturally respectful.

Conclusion

The study reveals that a variety of traditional artifacts and symbols are being preserved using digital technologies, ranging from pottery, wood carvings, and textiles to historically significant scripts such as Ajami and Adinkra symbols. These digital preservation methods include 3D modelling, artificial intelligence-based restoration, and digital archiving, all of which ensure that cultural heritage remains accessible and relevant. The integration of technology in artifact conservation enables communities to safeguard their historical narratives while promoting the transmission of indigenous knowledge across generations. Likewise, digital repatriation efforts, such as VR simulations of looted artifacts, exemplify how technology bridges the gap between cultural heritage and global accessibility. The ANT offered a lens through which the complex, interconnected relationships between human and non-human actors in cultural heritage preservation can be understood. ANT does not treat technology as a neutral tool but as an active participant in shaping how cultural artifacts are preserved, accessed, and interpreted. This theoretical framework allowed for the analysis of how digital tools, such as 3D modeling, AI restoration, and virtual reality, interact with institutions, communities, and cultural materials to co-construct new forms of heritage preservation.



Technology driven education plays a crucial role in equipping conservators, curators, and the public with the necessary skills to engage in artifact preservation. Through online courses, virtual workshops, and interactive learning platforms, stakeholders gain expertise in heritage management, conservation techniques, and ethical considerations surrounding digital documentation. This has broadened access to conservation training and empowered communities to take ownership of their cultural heritage.

The benefits of technology in preservation are extensive, from improving artifact longevity and accessibility to fostering cross-cultural exchange and promoting economic opportunities through heritage tourism. Nonetheless, significant challenges persist, including infrastructural limitations, ethical dilemmas related to ownership and representation, and cultural sensitivities in digitizing performance-based heritage. These challenges necessitate continued collaboration between policymakers, researchers, and local communities to develop sustainable and inclusive technological preservation frameworks that uphold cultural authenticity while embracing innovation. By emphasizing the agency of both human actors (e.g., conservators, local communities, educators) and non-human actors (e.g., digital platforms, software, artifacts), ANT supports the conclusion that preservation is a dynamic, collaborative process. It also highlights the importance of inclusive networks, that is, bridging institutional and cultural boundaries. This perspective justifies the study's emphasis on interdisciplinary collaboration, ethical digitization, and the integration of indigenous knowledge systems. Ultimately, ANT provides the conceptual foundation for understanding why digital preservation must be both technologically innovative and culturally sensitive. It validates the study's call for sustainable, community-driven approaches that empower local actors while leveraging global technological advancements.

Recommendations

To ensure sustainable and effective artifact preservation, policymakers should prioritize investment in digital infrastructure, expanding technological access to support online education and digitization efforts. Adequate funding from international organisations and institutions such as the Heritage Management Organization (HERITAGE), the Ambassadors Fund for Cultural Preservation (AFCP) in the US and in Ghana the Institute Museum of Ghana, Ghana Museums and Monuments Board (GMMB) and the Ghana Heritage Committee should be allocated to heritage education programs, equipping institutions with the necessary tools to train conservators and curators in digital preservation techniques.

Strengthening international collaborations by bodies such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), International Council of Museums (ICOM), in Ghana, the Ministry of Tourism, Arts and Culture, along with the GMMB, will further enhance knowledge exchange, allowing local professionals to benefit from advanced technological training and research partnerships.

Encouraging interdisciplinary cooperation by the National Endowment for the Humanities (NEH), UNESCO and ICOM between technologists, historians, and local communities will ensure that preservation efforts remain culturally sensitive and technologically efficient.



To ensure ethical and responsible digital preservation of cultural artifacts, it is recommended that policymakers develop robust ethical and legal frameworks. These should include clear guidelines on the digitization, ownership, and representation of cultural materials, particularly those belonging to indigenous and marginalized communities. Transparent repatriation policies must be established to respect the cultural origins and significance of artifacts, promoting justice and reconciliation. Furthermore, national policies should be harmonized with international standards set by organizations such as FADGI, UNESCO, and ICOM. This alignment will foster consistency, accountability, and cultural sensitivity in preservation practices. By embedding these principles into legislation and institutional protocols, countries can safeguard cultural heritage while ensuring that the rights and voices of source communities are respected and upheld.

Policy Implications

The findings of this study highlight the need for robust policy frameworks that support the integration of digital technology in artifacts and symbols preservation. Governments must prioritize investments in digital infrastructure to enhance access to preservation education and technological tools across West Africa. Educational funding should mostly be directed towards heritage institutions and training programs that equip conservators, curators, and local communities with digital skills necessary for sustainable conservation efforts. Strengthening global partnerships, particularly through collaboration with international organizations, will further facilitate knowledge exchange and capacity-building initiatives.

The Economic Community of West African States (ECOWAS) will need to promote regional cooperation in heritage preservation by facilitating joint initiatives among member states. Through coordinated policy efforts, ECOWAS can advocate for the development of standardized digital preservation strategies, ensuring that cultural heritage across West Africa is documented and shared responsibly. Regional partnerships can also provide funding mechanisms and technical support for digital conservation projects, reinforcing the importance of cross-border collaborations in safeguarding shared cultural identities. When digital heritage policies are incorporated into its broader cultural development agenda, ECOWAS can help member states bridge technological gaps and promote inclusive access to preserved historical artifacts and symbols.

Limitations of the Study

This study primarily relies on secondary data, which limits direct observations and empirical engagement with conservation practices. The absence of field studies, interviews, and firsthand documentation presents a gap in understanding the practical challenges faced by conservators in implementing digital preservation techniques. While the systematic review provides a comprehensive synthesis of existing research, future studies should incorporate qualitative and ethnographic approaches, including interviews with preservation experts, policymakers, and local community members. Future research should explore interdisciplinary methodologies that integrate perspectives that ensures technology-driven preservation is both inclusive and sustainable. Besides, assessing the long-term impacts of digital preservation efforts on cultural identity and historical continuity would provide deeper insights into the evolving role of technology in heritage conservation.



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