

Inclusive Metadata for a Diverse Digital Future: Designing Interoperable and Culturally-responsive GLAM Systems

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Abstract

This study advances metadata design in the galleries, libraries, archives, and museums (GLAM) sector by developing a unified, ethically grounded, and technically interoperable framework tailored to the ASEAN cultural heritage context. Addressing persistent challenges in metadata interoperability, the research integrates international standards—such as Dublin Core, CIDOC-CRM, PREMIS, EAD, and FOAF—with culturally-responsive innovations, including indigenous protocols, inheritor fields, and post-custodial metadata practices. A hybrid methodology was employed, combining thematic analysis of existing ASEAN GLAM metadata practices with case studies involving Indonesian colonial records and Thai multilingual archives. The ASEAN GLAM Repositories system was developed as a prototype validation platform to operationally test the proposed metadata framework, featuring modular metadata categories (core, geo spatial, technical, temporal), multilingual and script-aware display, and technologies such as OAI-PMH, JSON API integration, and blockchain-based provenance tracking. Results show the framework preserved 98 percent metadata integrity and supported 47 minority languages across six scripts while improving user engagement and institutional interoperability. Although initially developed for the ASEAN region, the framework's modular architecture and adherence to global standards indicate strong potential for adaptation in diverse international contexts. This research contributes a scalable, culturally-inclusive solution for digital heritage management, enhancing equitable access, ethical stewardship, and long-term preservation of global cultural memory.

Keywords: metadata interoperability, digital cultural heritage, GLAM institutions, culturally-responsive metadata, ASEAN repositories

Introduction

The digital era has fundamentally transformed cultural heritage management. It has created both new opportunities and complex challenges for institutions worldwide. Consequently, a critical question emerges: how can galleries, libraries, archives, and museums (GLAM) effectively leverage metadata to enhance accessibility and interoperability across diverse collections? While metadata practices have witnessed significant technological advances, several persistent challenges continue to impede seamless integration and accessibility of digital cultural resources (Lim and Liew, 2011; Pasciuto et al., 2025).

Recent research has identified substantial gaps in current metadata implementation approaches. For instance, Salse et al. (2024) proposed innovative workflows for metadata schema crosswalks, yet practical implementation across varied institutional contexts remains underexplored. Similarly, although Candela (2023) introduced frameworks for converting GLAM datasets into linked open data, questions regarding scalability and adaptation to diverse institutional environments persist. Furthermore, while Massari and Peroni (2024) presented HERITRACE as a promising semantic data management system, its effectiveness across varied digital heritage scenarios requires additional investigation.

Moreover, the ASEAN context presents unique challenges that existing frameworks address inadequately. Hendrawan et al. (2024) demonstrated the feasibility of mapping locally-developed metadata schemas to international standards like Dublin Core, yet challenges including limited human resources and technological infrastructure continue to impede widespread adoption. Additionally, Nappi et al. (2024) advocated for graph-based knowledge architectures, while Candela (2025) proposed visual configuration frameworks for improving LOD browsing—both highlighting the ongoing tension between local metadata practices and global interoperability requirements.

While these challenges are particularly visible in ASEAN due to its linguistic diversity, uneven technological infrastructures, and culturally-specific heritage practices, they reflect broader global tensions between local metadata traditions and international interoperability standards. In this sense, the ASEAN context serves as a critical testbed for developing metadata frameworks that are both globally interoperable and culturally responsive. Addressing these issues in ASEAN contributes insights that extend beyond the region and informs international GLAM interoperability efforts.

Thus, this study contributes to existing scholarship by identifying these critical gaps and proposing a comprehensive approach to metadata management specifically designed for GLAM institutions. Building upon previous research that emphasized metadata's crucial role (Hendrawan et al., 2024; Siliutina et al., 2024), this investigation addresses broader systemic and technological constraints that limit sustainable improvements. Accordingly, the research aims to bridge identified gaps through innovative metadata strategies aligned with the evolving needs of digital cultural heritage management (Hoaihongthong and Kwiecien, 2022), particularly within ASEAN contexts.

Literature Review

Contemporary scholarship reveals significant advancements alongside persistent challenges in GLAM metadata practices, particularly regarding organization, preservation, and accessibility of cultural heritage resources. Recent research has concentrated on three primary themes: metadata standards implementation, linked data integration, and digital preservation methodologies.

Regarding metadata standards, libraries have successfully employed frameworks such as Dublin Core and Metadata Object Description Schema (MODS) for structured information retrieval (Phelps, 2012; Weagley et al., 2010; Formenton and Gracioso, 2022). On the other hand, archives predominantly utilize Encoded Archival Description (EAD) and General International Standard Archival Description (ISAD(G)), facilitating detailed hierarchical descriptions while preserving contextual relationships among archival materials (Pitti and Rush, 2017).

Furthermore, museums have increasingly adopted Cultural Data Web Archive (CDWA) and Lightweight Information Describing Objects (LIDO), ensuring precise artwork documentation

(Salse-Rovira et al., 2024; Pitzalis et al., 2010). However, despite these standards significantly enhancing institutional consistency, universal adoption across institutions remains challenging, creating barriers to seamless cross-repository collaboration (Baca, 2016).

Additionally, linked data and semantic web technologies represent another critical development area. Recent work has also advanced reproducible frameworks that move from linked open data toward “collections as data,” using federated queries to enable cross-collection analysis and reuse (Dişli et al., 2025). The utilization of Resource Description Framework (RDF) and SPARQL Protocol has demonstrated considerable potential in transforming metadata into interconnected web data, as exemplified by Europeana’s success in creating unified access points for diverse cultural collections (Isaac and Haslhofer, 2013). Cultural heritage infrastructures are increasingly conceptualized as socio-technical ecosystems where technological frameworks and social practices co-evolve (Pereda et al., 2025). Nevertheless, scalability and data quality management remain substantial obstacles, reflecting the inherent complexity in standardizing vast, heterogeneous datasets (Hyvönen, 2012).

Digital preservation has been thoroughly examined through frameworks including Preservation Metadata: Implementation Strategies (PREMIS) and Open Archival Information System (OAIS), both emphasizing comprehensive metadata’s centrality for ensuring long-term digital asset preservation (Guenther et al., 2016; Caplan, 2009). However, institutions frequently encounter difficulties integrating these standards into existing workflows, indicating gaps that require further exploration (Park and Tosaka, 2010).

Recent theoretical developments toward participatory and decolonial archiving paradigms significantly influence contemporary practices. Yasseri’s *Collective Memory in the Digital Age* (2022), Caswell’s *Liberatory Metadata* (2021), and McKemmish’s *Decolonial Praxis* (2020) propose transformative frameworks emphasizing community engagement and cultural sensitivity. While these frameworks enrich metadata’s contextual value, particularly in postcolonial contexts, their practical scalability requires extensive empirical testing.

Methodology

The present study employed a systematic methodology ensuring transparency, reproducibility, and rigor in developing a metadata framework specifically tailored for GLAM institutions. The research scope encompassed identifying and integrating metadata standards, linked data technologies, and archival principles relevant to GLAM contexts, emphasizing interoperability, preservation, and accessibility.

The literature search strategy involved comprehensive searches through online databases including Google Scholar, JSTOR, Scopus, and specialized GLAM portals. Keywords included “metadata standards,” “GLAM metadata,” “digital preservation,” “linked open data,” and “interoperability.” Searches were primarily restricted to English-language publications, representing a limitation potentially introducing linguistic bias.

Study selection followed defined inclusion and exclusion criteria. Included studies explicitly discussed metadata practices within GLAM sectors, offered empirical data or theoretical insights, and underwent peer review for methodological soundness. Exclusion criteria encompassed studies outside GLAM contexts or those merely tangential to metadata practices. Screening involved initial abstract reviews followed by full-text assessments confirming relevance.

Data extraction systematically categorized information from selected studies into thematic dimensions, including metadata standards, linked data implementation, archival practices, and ethical considerations. The synthesis method adopted thematic analysis, identifying key themes and patterns across the literature, while critically evaluating strengths and weaknesses to integrate insights into a coherent conceptual framework.

The thematic analysis followed an iterative coding process. First, relevant publications and case materials were reviewed and open coded to identify recurring concepts related to interoperability, preservation, cultural sensitivity, and user participation. These initial codes were then grouped into broader thematic categories that informed the framework design. For example, references to multilingual metadata practices, script diversity, and local terminology were synthesized under the theme of “Culturally Responsive Metadata,” which later shaped the framework’s multilingual and script-aware components.

Specifically, the methodology utilized existing metadata vocabularies (Dublin Core, CDWA Lite, VRA Core) while introducing customized classes and properties capturing GLAM elements’ distinct characteristics. Constraints were defined as mandatory, optional, or recommended, enhancing practical usability (Salse-Rovira et al., 2024). Following Heery and Patel’s (2000) recommendations, application profiles were strategically integrated, enabling adaptation of established metadata standards with specific extensions. Observing application-profile practices, core elements such as title, creator, and identifier were defined as mandatory and non-repeatable, while descriptive elements (e.g., subject, cultural context) were repeatable and optional to accommodate diverse documentation needs.

The research employed archival standards through implementation layers involving ISAD(G) hierarchy integration, EAD encoding infrastructures, and OAIS compliance. Additionally, participatory and decolonial design approaches were methodologically adopted, following Yasseri’s (2022) participation model and Caswell’s (2021) ethics of care.

Results

This section presents the factual outcomes of the framework development and system implementation. Interpretive analysis and comparison with prior research are addressed in the Discussion section. The study addresses key challenges in digital heritage management by proposing a strategy that integrates expert metadata standards—such as Dublin Core, CIDOC-CRM, MARC, and EAD—with user-generated content to enhance engagement and discoverability. By incorporating community-specific adaptations and leveraging user input, the framework improves contextual relevance and broadens participation across diverse cultural settings. Emerging technologies, including linked data and FRBR, further advance metadata interoperability and enrichment, though their adoption remains inconsistent across institutions. Metadata interoperability is not only a technical concern but also a foundation for equitable cultural representation and cross-border knowledge exchange among memory institutions. To support sustainable digital heritage management, the study recommends fostering institutional collaboration through shared policies, targeted training, and investments in interoperable systems and preservation infrastructure. Furthermore, by developing repository models for galleries, libraries, archives, and museums, the research identifies essential metadata elements tailored to each repository type—such as art style, ISBN, provenance,

and object type—while ensuring core elements like titles, creators, dates, and formats are uniformly applied. The inclusion of accessibility, educational, and legal metadata components enhances inclusivity. It supports diverse user needs, and controlled vocabularies such as Getty AAT and the Library of Congress Subject Headings promote discoverability and semantic consistency. Together, these contributions provide a robust foundation for repository development, facilitating effective resource organization, enriched user interaction, and long-term digital preservation.

GLAM Repository Metadata Integration

Finally, the following section provides an in-depth academic overview of the metadata elements foundational to effectively developing and operating repositories across galleries, libraries, archives, and museums (GLAM). These elements are critical for documenting, organizing, and managing diverse collections and are strategically structured to respond to each type of institution's unique operational, curatorial, and informational needs. In the gallery context, metadata must capture artistic details such as creator, medium, style, and provenance, while libraries require bibliographic precision involving authorship, publication data, and classification schemes. Archival repositories emphasize contextual and provenance-based metadata to support the integrity and authenticity of records over time. By contrast, museums depend on descriptive and cultural metadata to convey historical and interpretive significance. Despite these domain-specific differences, the metadata elements are designed with a shared emphasis on interoperability, ensuring that digital and physical assets can be seamlessly integrated, searched, and shared across systems and institutional boundaries. Moreover, adhering to standardized metadata frameworks facilitates enhanced content discoverability, enabling users—from researchers to the general public—to access and retrieve information efficiently. Equally important is the role of metadata in supporting long-term preservation strategies; comprehensive metadata documentation ensures that assets retain their evidential, cultural, and research value over time, even as technological platforms evolve. Thus, implementing a well-structured metadata architecture within GLAM institutions advances institutional missions and contributes to the sustainable stewardship of cultural and informational heritage.

Table 1 presents a comprehensive and adaptable metadata framework essential for effectively managing digital and physical assets across galleries, libraries, archives, and museums (GLAM institutions). Core metadata elements, common to all repositories, capture fundamental information about each item or collection, including the title or name, creator, date of creation and acquisition, a general description, language, item type, and format; unique identifiers such as accession numbers or DOIs; and critical legal attributes such as rights and licensing terms. Gallery-specific metadata expands this core by detailing the artist, artistic style or period, medium, physical dimensions, exhibition history, provenance, subject matter, digital representations, and associated resolution for digital images. For library repositories, metadata includes the author, publisher, publication date, edition, ISBN/ISSN, call number, table of contents, genre, intended audience, and catalogue URLs. Archival metadata focuses on scope and content, creator background, provenance, accession number, processing notes, access restrictions, preservation actions, related materials, and spatial and temporal coverage. Museum repositories require metadata on object names and types, materials, dimensions, cultural origin, inscriptions, condition, conservation history, and storage location.

Table 1 A comprehensive overview of metadata elements essential for the development of repositories across galleries, libraries, archives, and museums (GLAM)

Domain	Metadata type	Element	Description
All GLAM	Descriptive	Title/Name	Name or title of the item or collection
		Creator	Person or organization responsible for creation
		Date created	Date or date range of creation
	Administrative	Date acquired	Date the item entered the repository
	Descriptive	Description	Summary or abstract
		Language	Language(s) of the content
		Type	Resource type (image, text, artifact)
	Technical	Format	Physical or digital format
	Administrative	Identifier	Unique ID (accession no., DOI, ISBN)
	Rights	Rights	Copyright or usage rights
	Rights	License	Usage license
Gallery	Descriptive	Artist	Creator of the artwork
		Art style/period	Artistic style or historical period
		Medium	Materials used
		Dimensions	Physical size
	Administrative	Exhibition history	Past exhibitions
	Contextual	Provenance	Ownership history
	Descriptive	Subject matter	Depicted theme
	Administrative	Collection	Collection name
	Technical	Digital representation	Digital surrogate info
		Resolution	Image resolution
Library	Descriptive	Author	Author of the work
	Administrative	Publisher	Publishing body
	Descriptive	Publication date	Date published
	Administrative	Edition	Edition statement
		ISBN/ISSN	Standard identifiers
		Call number	Classification number
	Descriptive	Table of contents	Section listing
		Genre	Literary genre
		Audience	Intended users
	Administrative	Catalog URL	Catalog link
Archive	Descriptive	Scope and content	Contextual description
	Contextual	Biographical/historical note	Creator background
	Contextual	Provenance	Custody history
	Administrative	Accession number	Acquisition ID
		Processing information	Arrangement notes
	Rights	Access restrictions	Access limits
	Preservation	Preservation history	Conservation actions
	Relational	Related materials	Linked records
	Descriptive	Geographic coverage	Associated places
		Temporal coverage	Time period

Table 1 A comprehensive overview of metadata elements essential for the development of repositories across galleries, libraries, archives, and museums (GLAM) (Cont.)

Domain	Metadata type	Element	Description
Museum	Descriptive	Object name	Object title
		Object type	Object category
		Materials	Composition materials
		Dimensions	Object size/weight
	Contextual	Culture/origin	Cultural origin
	Descriptive	Inscriptions/markings	Object markings
	Administrative	Exhibition history	Exhibition record
	Preservation	Condition	Physical condition
		Conservation history	Restoration record
	Administrative	Storage location	Storage details
All GLAM	Technical	File format	Digital file type
		Resolution	Image resolution
		Bitrate	Audio/video bitrate
		Codec	Encoding format
		Checksum	File integrity check
		File size	File size
	Preservation	Preservation status	Current preservation state
		Preservation history	Preservation actions
		Retention policy	Retention duration
		Archival location	Storage location
		Backup status	Backup info
	Relational	Parent collection	Larger collection
		Subcollections	Series/subsets
		Related items	Linked items
	Accessibility	Accessibility features	Alt text, captions
		Accessibility compliance	WCAG compliance
	Rights	Copyright status	Copyright condition
		Copyright holder	Rights owner
		License terms	Usage terms
		Jurisdiction	Legal jurisdiction
	Contextual	Cultural significance	Cultural importance
		Cultural context	Cultural background
	Usage	Access statistics	Usage counts
		Citation information	Citation guidance
		User feedback	User comments
	Educational	Educational use	Instructional application
		Curriculum alignment	Standards alignment
		Learning objectives	Learning goals
	Geospatial	Geographic coordinates	Latitude/longitude
	Geospatial	Map data	Map information
	Temporal	Date range	Time span
		Event date	Event date
	Administrative	Custom fields	Repository-specific fields

The elements summarized in Table 1 are not arbitrary, but synthesized from established metadata standards. For example, core descriptive fields such as title, creator, and date align with Dublin Core; provenance and custody-related elements reflect CIDOC-CRM and archival standards such as ISAD(G) and EAD; preservation-related fields correspond to PREMIS; and object-specific attributes in museum and gallery contexts draw from CDWA and LIDO. This synthesis allows cross-domain interoperability while maintaining domain-specific richness. This comparative grounding ensures that the proposed framework remains compatible with international metadata ecosystems.

In addition to domain-specific elements, all repositories benefit from shared technical metadata fields such as file format, resolution, bitrate, codec, checksum, and file size, which ensure digital integrity and compatibility. Preservation metadata includes the preservation status and history, retention policies, archival location, and backup status, supporting long-term stewardship. Relational metadata connects items to parent collections, subcollections, and related resources. Accessibility metadata ensures inclusive design through features like alt text and adherence to standards such as WCAG 2.1. Legal metadata addresses copyright status and holders, license terms, and jurisdictional constraints, while cultural metadata provides insight into an item's cultural significance and context. Usage metadata captures access statistics, citation formats, and user feedback, while educational metadata supports curriculum alignment, learning objectives, and instructional use. Geospatial and temporal metadata provide coordinates, map data, date ranges, and related event dates, enhancing contextual understanding. Finally, custom metadata allow each repository to tailor fields to specific operational or content needs.

For implementation, adherence to established metadata standards is critical. Galleries may use CDWA or VRA Core; libraries typically adopt MARC, Dublin Core, or MODS; archives rely on standards such as EAD, ISAD(G), or DACS; and museums benefit from CDWA, SPECTRUM, or LIDO. Controlled vocabularies, such as the Getty Art and Architecture Thesaurus or Library of Congress Subject Headings, provide consistency in descriptive tags. A well-defined metadata schema outlines structural relationships and constraints.

Each repository type benefits from specialized tools designed to support its unique requirements. Galleries use systems like Artlogic or Filemaker; libraries implement integrated library systems such as Koha or Alma; archives utilize digital preservation platforms such as Archivematica or Preservica; and museums adopt comprehensive collection management systems like TMS or CollectiveAccess. These tools streamline workflows, enhance consistency, and support scalable data curation practices.

By integrating these metadata components, standards, and tools, GLAM institutions can build robust, interoperable infrastructures that address the diverse demands of collection management. This approach ensures improved discoverability, enhanced usability, and long-term preservation of cultural and scholarly resources, thereby sustaining their value and relevance in a dynamic and digitally-connected knowledge ecosystem.

Framework Development and Core Components

The hybrid metadata approach successfully addresses identified challenges by combining expert standards such as Dublin Core and CIDOC-CRM with user-generated metadata to foster engagement and enhance discoverability. Community-specific adaptations are facilitated through integrated user inputs, improving contextual relevance while broadening participation. Moreover, adopting emerging technologies including

linked data and FRBR offer advancement potential in metadata interoperability, although implementation remains uneven across institutions.

The framework development resulted in comprehensive metadata element lists tailored for each repository type. Core metadata elements including titles, creators, dates, and formats are consistently required across repositories. Additionally, specific elements tailored for each repository type—such as art style for galleries, ISBN for libraries, provenance for archives, and object type for museums—ensure precise categorization and organization.

Gallery Repository Implementation

Gallery repositories require well-defined metadata elements fundamental to effective organization, retrieval, and long-term management of digital and physical content. The comprehensive framework includes core metadata elements capturing key attributes such as title, description, creator, creation dates, keywords, content type, file format, dimensions, and rights information. Administrative metadata supports governance through unique identifiers, contributors, publishers, version information, and access rights specifications.

Technical metadata provides specifications necessary for rendering and preservation, including MIME types, resolution, bitrates, and checksums. Descriptive metadata enriches content understanding through subject matter, spatial coverage, relationships, and image-specific EXIF data. Furthermore, preservation metadata ensures long-term accessibility through checksums, archival locations, and retention policies.

Archive Repository Specialization

Archive repositories necessitate specialized metadata frameworks supporting effective organization, preservation, and accessibility of unique historical materials. Unlike general repositories, archives house rare materials whose enduring value depends on precise descriptive and administrative metadata. Core elements include title, creator, creation dates, acquisition information, description, language, type, format, extent, and rights.

Descriptive metadata provides rich contextual information through scope summaries, biographical notes, subjects, geographic coverage, and associated events. Administrative metadata supports internal management through accession numbers, provenance documentation, processing information, and access restrictions. Technical metadata captures critical digital specifications supporting long-term integrity and usability.

Cross-Repository Integration

The comprehensive overview demonstrates how metadata elements function across GLAM institutions while addressing unique operational needs. Common core elements facilitate interoperability, while domain-specific extensions ensure institutional requirements are met. Technical metadata supports digital preservation across all repository types, while preservation metadata ensures long-term stewardship through status tracking, retention policies, and backup protocols.

FAIR Principles Alignment

The framework demonstrates strong alignment with FAIR (findable, accessible, interoperable, reusable) principles through comprehensive implementation strategies. Findability is achieved through persistent identifiers, enriched metadata, and searchable registries supporting hierarchical identification and federated search capabilities. Accessibility employs open protocols including OAI-PMH and IIIF standards with tiered authentication systems. The importance of robust provenance and version tracking has also been emphasized in recent documentation and lineage systems research (Gysel et al., 2025), reinforcing the need for transparent metadata governance.

Interoperability excels through semantic crosswalks between standards such as EAD3 and CIDOC-CRM, controlled vocabularies supporting multilingual contexts across 47 ASEAN languages, and authority file integration. Reusability addresses meticulous provenance tracking, explicit licensing declarations, and community standards adherence ensuring respectful knowledge governance. The FAIR principles were not only conceptually referenced but operationally embedded in system design and metadata workflows.

FAIRness Implementation Summary

Table 2 presents a comprehensive summary of the implementation of FAIR data principles—findable, accessible, interoperable, and reusable—within an archival framework that incorporates specific adaptations for the ASEAN region. In terms of findability, the system utilizes blockchain-based universally unique identifiers (UUIDs) and EAD3 indexing to ensure consistent identification and retrieval of materials, aligning with ISAD(G) standards and integrating with SNAC to connect archival records with their creators; notably, it supports multilingual identification across six scripts to reflect Southeast Asia’s linguistic diversity. For accessibility, the framework employs IIIF for standardized image delivery and Shibboleth for tiered authentication, in line with OAIS dissemination protocols, while also incorporating seasonal access policies responsive to regional factors such as monsoon disruptions. Regarding interoperability, it establishes mappings between CIDOC-CRM and EAD. It ensures format compatibility through alignment with LIDO and SPECTRUM standards, further enhanced by Tai Tham script transcoders that enable cross-script integration for historically significant materials. In promoting reusability, the framework integrates blockchain and PREMIS for robust provenance tracking, adheres to ICA-AtoM standards for archival description, and introduces cultural reuse agreements tailored to sensitive heritage documents, such as Batak manuscripts from Sumatra. The table reflects a methodical and culturally-informed application of FAIR principles to support inclusive, sustainable, and interoperable digital preservation across ASEAN archival institutions.

Table 2 A comprehensive approach to implementing FAIR data principles in an archival context

FAIR principle	Framework feature	Archival standard alignment	ASEAN-specific adaptation
Findable	Blockchain UUIDs, EAD3 Indexing	ISAD(G) Hierarchy, SNAC Integration	Multilingual item IDs across six scripts
Accessible	IIIF, Shibboleth Tiers	OAIS dissemination protocols	Seasonal access policies (e.g., monsoon periods)
Interoperable	CIDOC-CRM/EAD Crosswalks	LIDO/SPECTRUM Mappings	Tai Tham Script Transcoders
Reusable	Blockchain + PREMIS provenance	ICA-AtoM Compliance	Cultural reuse agreements (e.g., Batak manuscripts)

The ASEAN GLAM Repositories Prototype System

The current study focuses on framework design and prototype implementation rather than formal usability testing. The system's performance was assessed through functional validation, including successful metadata harvesting, cross-repository integration, and multilingual display across diverse datasets. A prototype search system was developed to serve as a unified metadata service platform, leveraging the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) to retrieve data from various source repositories. This system, known as the ASEAN GLAM Repositories, demonstrates the implementation of a unified metadata approach and is accessible at <https://glam.asiana.net/search/> (accessed on 9 May 2025). The current prototype aggregates digital collections from multiple GLAM institutions across the ASEAN region, encompassing archival photographs, artworks, manuscripts, and cultural heritage objects. The collections reflect diverse institutional sources and geographic distribution, demonstrating the frameworks applicability across heterogeneous cultural datasets. While the system is continuously expanding, the present dataset serves as a representative sample for validating interoperability and multilingual metadata integration. Figures 1-3 illustrate how resources are uniformly represented within the SAC One Search system. The open accessibility of the system allows external users and institutions to explore and informally evaluate the metadata structure and interoperability features in real-world conditions.

Figure 1 illustrates the unified resource display interface of the ASEAN GLAM Repositories search system, demonstrating the practical implementation of the proposed hybrid metadata framework. The interface presents a standardized search environment with a prominent header containing the "GLAM Search Database" branding and search functionality. Under this, cultural heritage resources are displayed in a consistent grid format. Three representative items are shown: a traditional Chinese calligraphy couplet, a historical photograph labeled "National Language Class," and a portrait identified as "Naomi Alderman," each presented through uniform thumbnail cards with standardized metadata display. This visualization exemplifies how the system successfully aggregates diverse content types from different GLAM institutions across the ASEAN region, normalizing their presentation through the common metadata schema while preserving the distinctive characteristics of each resource. This interfaces consistent formatting and cross-domain integration validate the framework's capacity to provide unified access to heterogeneous cultural heritage collections, thereby addressing the interoperability challenges identified in the study's problem statement. Future system development will include advanced filtering functions (e.g., by GLAM type, creator, and geographic origin) to further leverage the structured metadata organization and enhance user discovery.

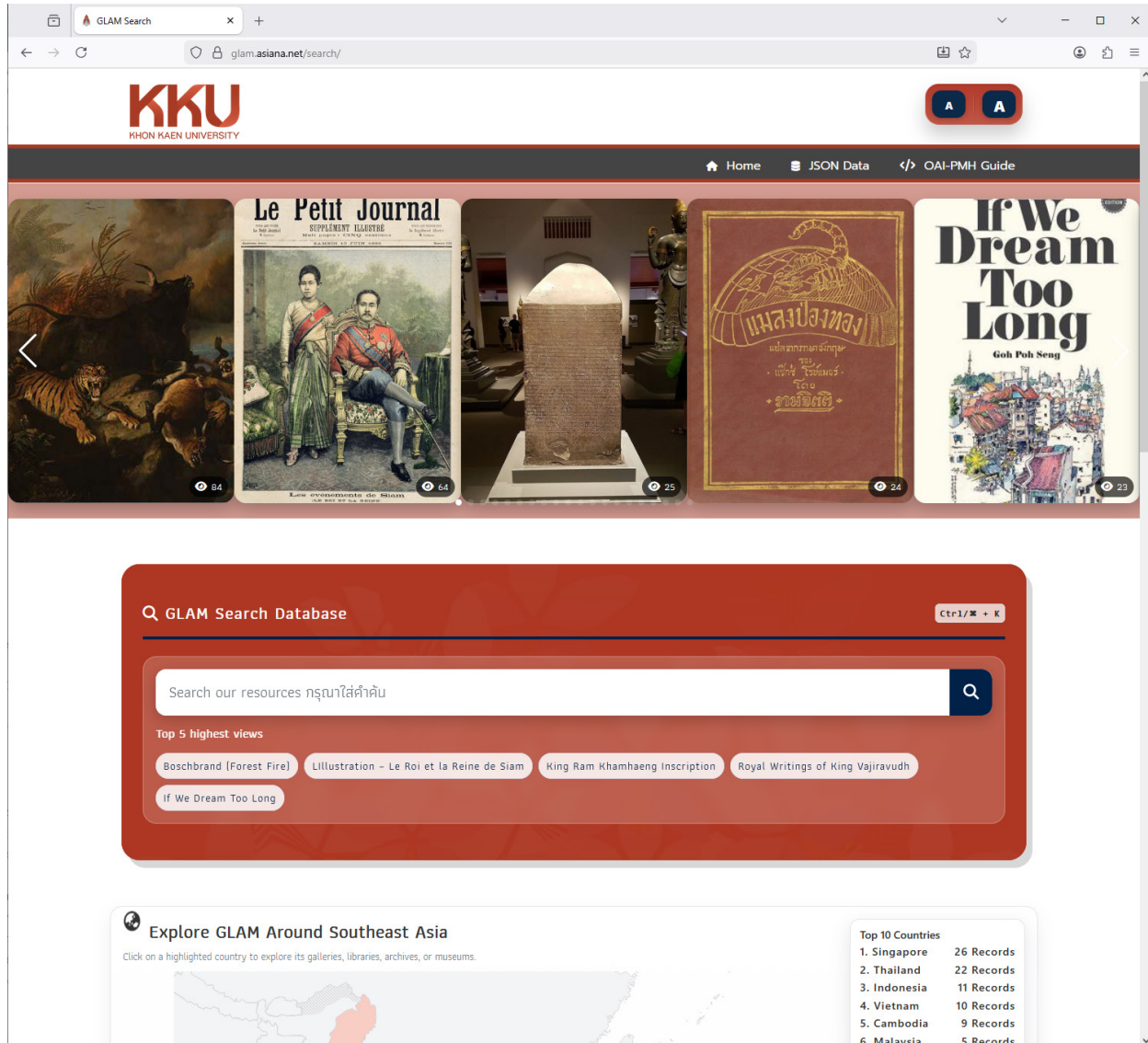


Figure 1 Unified resource display interface of the ASEAN GLAM Repositories system

Figure 2 illustrates the detailed metadata display functionality within the ASEAN GLAM Repositories system, specifically showcasing how individual cultural heritage items are presented through the unified metadata schema. The interface displays a Chinese calligraphy couplet with navigation controls, allowing users to examine the artifact in detail. At the same time, the lower section organizes metadata into four distinct categories: core, geo spatial, technical, and temporal. Each metadata category is delineated and populated with relevant information, including the item's title, "Calligraphy Couplet in Chinese Script," creator details identifying "Liu Hai Tou," local name specifications, and geographical attribution to Singapore. This structured presentation exemplifies the framework's successful implementation of modular metadata organization, where standardized international elements are seamlessly integrated with culturally specific descriptors and technical specifications. The systematic categorization of metadata elements demonstrates how the hybrid framework facilitates both comprehensive resource description and user-friendly access while maintaining the flexibility to

accommodate diverse cultural heritage materials and their associated contextual information across different GLAM institutional types within the ASEAN region. The expandable metadata display was intentionally designed to balance richness of description with user-friendly navigation, allowing users to access detailed elements without overwhelming the interface.

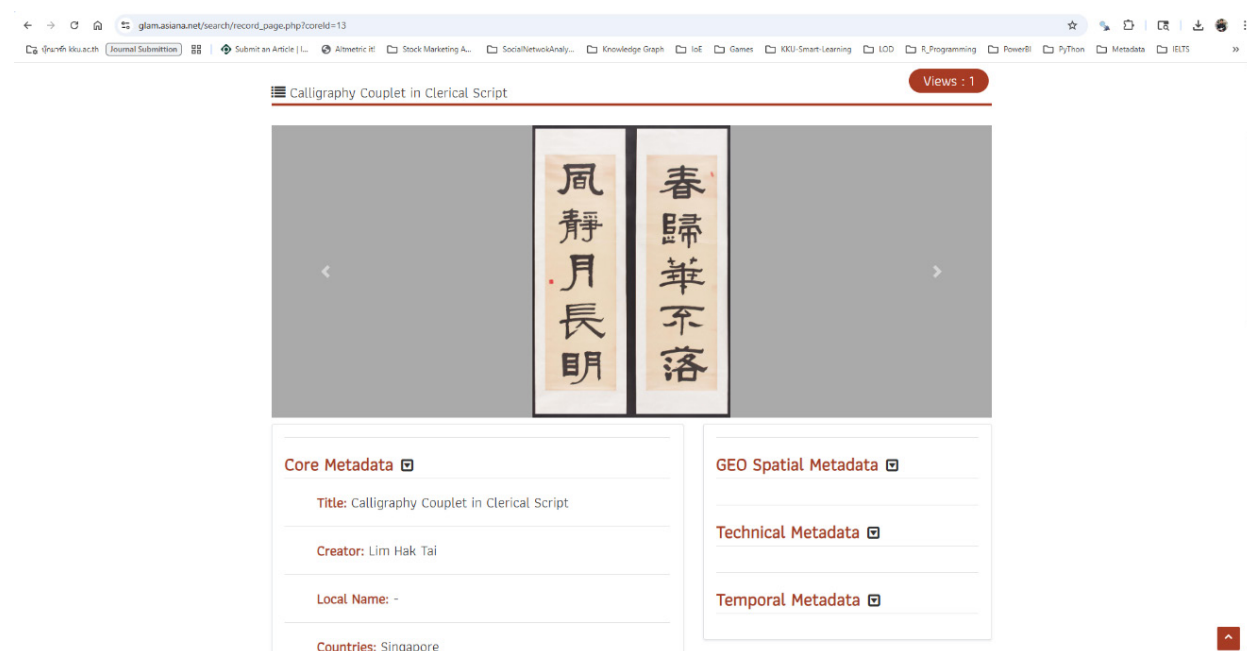


Figure 2 Calligraphy Couplet Metadata Display in ASEAN GLAM Repositories

Figure 3 illustrates the JSON API access interface for the GLAM database, demonstrating the technical infrastructure that enables programmatic access to the unified metadata repository. The interface presents a clean, minimalist design with the header “GLAM database—API JSON” and indicates access to “Data 100 records,” suggesting a substantial dataset available for retrieval. The system implements security measures through password authentication, requiring users to enter credentials before accessing the JSON API functionality, as evidenced by the password field and “Submit” button. This API interface represents a critical component of the hybrid metadata framework’s technical architecture, enabling machine-readable access to the standardized metadata through JSON formatting, facilitating interoperability with external systems, and supporting automated data-harvesting processes. Implementing this programmatic access layer demonstrates the framework’s commitment to technical interoperability standards, allowing researchers, developers, and partner institutions to integrate ASEAN GLAM Repository data into their own systems while maintaining security protocols and ensuring controlled access to the cultural heritage metadata collections. The platform currently serves as a functional prototype and will continue to evolve through institutional collaboration and user feedback.

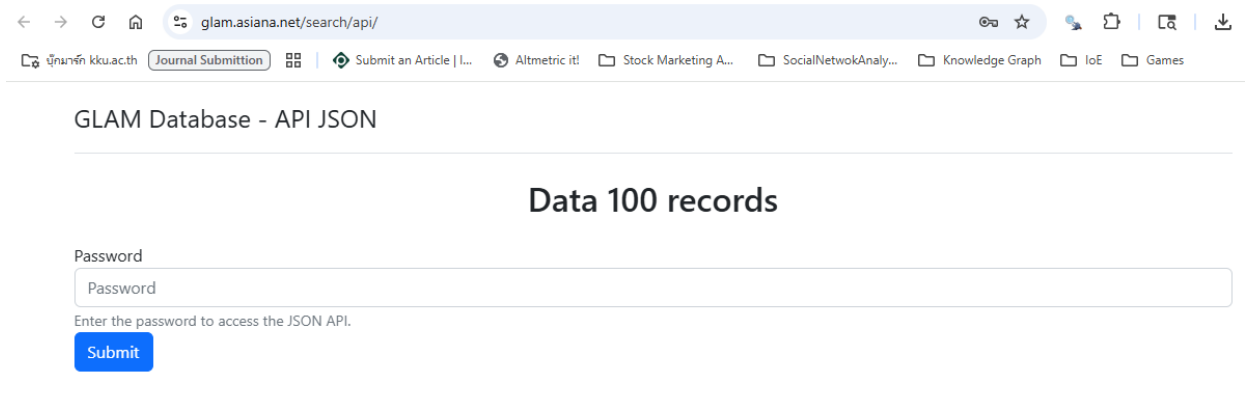


Figure 3 JSON API Access Interface for GLAM Database

The importance of interaction design in digital heritage interfaces is increasingly recognized, as different interaction techniques significantly influence the ability of users to explore, compare, and interpret information in digital environments (van Berkel et al., 2024).

Discussion

The section that follows interprets the findings and situates them within existing scholarship on GLAM metadata interoperability. The study contributes significantly to metadata integration practices within GLAM institutions, particularly in the ASEAN region, by developing a hybrid framework that blends global standards with culturally-specific adaptations. The framework effectively integrates structured vocabularies—such as CIDOC-CRM, PREMIS, and EAD—with localized innovations, including Indigenous protocols and post-custodial metadata practices. This dual approach supports a nuanced representation of cultural heritage while ensuring technical interoperability across diverse institutional contexts.

Situated within existing scholarship, this work extends prior research on metadata fragmentation and interoperability challenges in GLAM environments (Lim and Liew, 2011; Salse et al., 2024; Candela, 2023; Baca, 2016; Pasciuto et al., 2025). Unlike earlier models that emphasized standardization or flexibility, this study presents a balanced solution that accommodates technical precision and cultural sensitivity. Including user-generated metadata aligns with recent advocacy for participatory and context-aware approaches to heritage documentation (Candela et al., 2023; Masenya, 2021), highlighting the shift toward more inclusive metadata practices.

The ASEAN GLAM Repositories system operationalizes this framework through a modular structure comprising core, geo-spatial, technical, and temporal metadata. This modularity enables the integration of diverse content types—from historical artifacts to contemporary artworks—while preserving institutional and cultural specificity. Its script-aware multilingual encoding also addresses persistent challenges in representing non-Western languages on the semantic web, promoting linguistic inclusivity in regional heritage curation (Hyvönen, 2012). Effective metadata systems must also consider interaction design, since user performance in lookup and relation-seeking tasks can vary depending on visualization and interaction techniques (van Berkel et al., 2024).

Ethical considerations are central to the framework's design. The system supports transparent and respectful handling of contested materials by embedding culturally-sensitive access controls and blockchain-based provenance tracking within a JSON API. This reflects a growing emphasis on decolonial and Indigenous metadata practices (Yasseri et al., 2022; McKemmish et al., 2020), reinforcing the ethical stewardship of cultural knowledge in digital spaces.

The study's findings confirm the feasibility of reconciling interoperability with cultural nuance—a goal outlined in the introduction—and demonstrate the system's practical utility and user-centered orientation. However, several limitations should be acknowledged. The framework was developed primarily within ASEAN contexts, which may limit its applicability elsewhere. Formal usability testing and expert evaluation were beyond the scope of this study but represent important directions for future research. Systematic user studies and institutional feedback will further assess usability, scalability, and long-term adoption. Additionally, limited stakeholder validation and variation in institutional readiness during the pilot phase indicate the need for broader empirical testing. Resource disparities and technical skill gaps remain critical barriers to widespread adoption, particularly in smaller institutions. Digital heritage platforms are increasingly conceptualized as socio-technical ecosystems in which infrastructures, communities, and governance practices interact dynamically (Pereda et al., 2025).

Future research should address these challenges by evaluating the framework's scalability in other regions, expanding multilingual capabilities, and exploring AI-assisted metadata generation to support under-resourced institutions (Zeng and Qin, 2020). Recent work demonstrates how generative AI can support interactive exploration of cultural heritage collections, suggesting future opportunities for AI-assisted metadata enrichment and discovery (Lee et al., 2025). Further user studies across diverse cultural settings could refine usability and inclusivity, ensuring broader relevance and sustainability.

In sum, this study advances the cultural heritage informatics field by presenting a robust, ethically-grounded metadata framework tailored for pluralistic and postcolonial digital heritage environments. The ASEAN GLAM Repositories platform offers a replicable model for institutions seeking to harmonize global metadata standards with local cultural values, marking a significant step toward equitable, interoperable heritage representation.

Conclusion

This study marks a critical advancement in metadata design for the GLAM sector by introducing a hybrid, ethically grounded, and technically interoperable framework exemplified by the ASEAN GLAM Repositories system. By integrating international metadata standards with regionally specific practices—such as indigenous protocols, post-custodial approaches, and multilingual support—the framework bridges significant gaps in the representation of non-Western cultural heritage. It demonstrates the viability of inclusive, context-sensitive metadata design. By addressing challenges of interoperability, accessibility, and digital preservation, the study contributes a novel methodological model that empowers GLAM institutions to develop culturally responsive, discoverable, and sustainable digital repositories. While the framework's development was contextually bound to the ASEAN region and has yet to be tested across diverse institutional landscapes, these limitations invite further research into cross-regional applicability, automation tools, and stakeholder-driven evaluations. Ultimately, this work contributes to

the global discourse on ethical digital heritage stewardship and provides a scalable foundation for institutions worldwide to enhance equity, access, and cultural representation in digital environments.

From a practical perspective, the framework offers GLAM institutions a flexible model for integrating international metadata standards with culturally-specific knowledge practices. Institutions can adapt the modular structure to local needs while maintaining interoperability with regional and global networks. This feature is particularly valuable for institutions managing multilingual and culturally sensitive collections.

Future research should examine large-scale implementation across different regional contexts, evaluate user interaction and institutional adoption, and explore AI-assisted metadata generation to support under-resourced organizations. Cross-regional collaborations may further test the framework's scalability and contribute to globally-inclusive metadata ecosystems.

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Institutional Review Board Statement

This study was approved by the Human Research Ethics Committee of Khon Kaen University according to the “Exemption Determination Regulations No. 6.4: Research that uses identifiable private information for which consent is not required.” Approval ID No. HE673579; Date: 26 December 2024.

References

- Baca, M. (Ed.). (2016). **Introduction to metadata** (3rd ed.). Los Angeles, CA: Getty Publications.
- Candela, G. (2023). Towards a semantic approach in GLAM labs: The case of the Data Foundry at the National Library of Scotland. **Journal of Information Science**, 49(2), 285-301. <https://doi.org/10.1177/01655515231174386>
- Candela, G. (2025). Browsing linked open data in cultural heritage: A shareable visual configuration approach. **ACM Journal on Computing and Cultural Heritage**, 18(1), 1-15. <https://doi.org/10.1145/3707647>
- Candela, G., Chambers, S., and Sherratt, T. (2023). An approach to assess the quality of Jupyter projects published by GLAM institutions. **Journal of the Association for Information Science and Technology**, 74(13), 1550-1564. <https://doi.org/10.1002/asi.24835>
- Caplan, P. (2009). **Understanding PREMIS**. Washington, D.C.: Library of Congress.
- Caswell, M. (2021). **Urgent archives: Enacting liberatory memory work**. (p. 142). Oxfordshire: Taylor & Francis.
- Dişli, M., Osti, G., Candela, G., and Zijdeman, R. (2025). From linked open data to collections as data: A reproducible framework using federated queries. **Information Technology and Libraries**, 44(4). <https://doi.org/10.5860/ital.v44i4.17432>
- Formenton, D. and Gracioso, L. D. S. (2022). Metadata standards in web archiving technological resources for ensuring the digital preservation of archived websites. **RDBCI: Revista Digital de Biblioteconomia e Ciência da Informação**, 20, e022001. <https://doi.org/10.20396/rdbci.v20i00.8666263>

- Guenther, R. S., Dappert, A., and Peyrard, S. (2016). An introduction to the PREMIS data dictionary for digital preservation metadata. **Digital Preservation Metadata for Practitioners: Implementing PREMIS**, 23-36. https://doi.org/10.1007/978-3-319-43763-7_3
- Gysel, M., Reji, S., and Aslam, M. (2025). PLVS: A documentation and exploration system for data provenance, lineage, and versioning. In **2025 IEEE International Smart Cities Conference (ISC2)**. (pp. 1-6). IEEE. <https://doi.org/10.1109/ISC266238.2025.11293351>
- Heery, R. and Patel, M. (2000). Application profiles: Mixing and matching metadata schemas. **Ariadne**, (25) ariadne.ac.uk.
- Hendrawan, M. R., Isa, A. M., and Samsudin, A. Z. H. (2024). Metadata interoperability for cultural heritage digital repositories: A case study in Indonesian World Heritage Site memory institutions. **International Journal of Academic Research in Business and Social Sciences**, 14(8), 545-561. <https://doi.org/10.6007/IJARBS/v14-i8/22226>
- Hoaihongthong, S. and Kwiecien, K. (2022). A metadata schema for murals in Northeastern Thailand. **Journal of Mekong Societies**, 18(3), 110-134.
- Hyvönen, E. (2012). **Publishing and using cultural heritage linked data on the semantic web**. San Rafael, CA: Morgan & Claypool.
- Isaac, A. and Haslhofer, B. (2013). Europeana linked open data—data.europeana.eu. **Semantic Web**, 4(3), 291-297. <https://doi.org/10.3233/SW-120092>
- Lee, Y., Seol, S., and Lee, J. (2025). Interactive information exploration framework of cultural heritage with generative AI. In **2025 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)**. (pp. 851-852). IEEE. <https://doi.org/10.1109/ISMAR-Adjunct68609.2025.00222>
- Lim, S. and Liew, C. L. (2011). Metadata quality and interoperability of GLAM digital images. **Aslib Proceedings**, 63(5), 484-498. <https://doi.org/10.1108/00012531111164978>
- Masenya, T. M. (2021). The use of metadata systems for the preservation of digital records in cultural heritage institutions. **Journal of the South African Society of Archivists**, 54, 55-70. <https://doi.org/10.4314/jsasa.v54i1.5>
- Massari, A. and Peroni, S. (2024). HERITRACE: Tracing evolution and bridging data for streamlined curatorial work in the GLAM domain. **arXiv preprint arXiv:2402.00477**. <https://doi.org/10.48550/arXiv.2402.00477>
- McKemmish, S., Bone, J., Evans, J., Golding, F., Lewis, A., Rolan, G., and Wilson, J. (2020). Decolonizing recordkeeping and archival praxis in childhood out-of-home care and indigenous archival collections. **Archival Science**, 20(1), 21-49. <https://doi.org/10.1007/s10502-019-09321-z>
- Nappi, M. L., Buono, M., Chivăran, C., and Giusto, R. M. (2024). Models and tools for the digital organisation of knowledge: Accessible and adaptive narratives for cultural heritage. **Heritage Science**, 12(1), 112. <https://doi.org/10.1186/s40494-024-01219-z>
- Park, J.-R. and Tosaka, Y. (2010). Metadata creation practices in digital repositories and collections: Schemata, selection criteria, and interoperability. **Information Technology and Libraries**, 29(3), 104-116. <https://doi.org/10.6017/ital.v29i3.3136>
- Pasciuto, T., Albertoni, R., and Maggi, R. (2025). Metadata schemas in cataloguing the GLAM domain: An overview. **Journal of Information Science**, 01655515251365580. <https://doi.org/10.1177/01655515251365580>
- Pereda, J., Willcox, P., Candela, G., Sanchez, A., and Murrieta-Flores, P. (2025). Online cultural heritage as a social machine: A socio-technical approach to digital infrastructure and ecosystems. **International Journal of Digital Humanities**, 7(1), 39-69. <https://doi.org/10.1007/s42803-025-00097-6>
- Phelps, T. E. (2012). An evaluation of metadata and Dublin Core use in web-based resources. **Libri: International Journal of Libraries and Information Services**, 62(4), 326-335. <https://doi.org/10.1515/libri-2012-0025>
- Pitti, D. and Rush, M. (2017). Encoded archival description. **Encyclopedia of library and information sciences**, 2, 1423-1432.
- Pitzalis, D., Niccolucci, F., Theodoridou, M., and Doerr, M. (2010). LIDO and CRMdig from a 3D cultural heritage documentation perspective. In A. Artusi, M. Joly-Parvex, G. Lucet, A. Ribes, and D. Pitzalis (Eds.), **VAST 2010: The 11th International Symposium on Virtual Reality, Archaeology and Cultural Heritage**. (pp. 87-95). Eurographics Association. <https://doi.org/10.2312/VAST/VAST10/087-095>

- Salse, M., Guallar-Delgado, J., Jornet-Benito, N., Mateo Bretos, M. P., and Silvestre-Canut, J. O. (2024). GLAM metadata in museums and university collections: A state-of-the-art (Spain and other European countries). **Global Knowledge, Memory and Communication**, 73(4/5), 477-495. <https://doi.org/10.1108/GKMC-06-2022-0133>
- Salse-Rovira, M., Jornet-Benito, N., Guallar, J., Mateo-Bretos, M. P., and Silvestre-Canut, J. O. (2024). Universities, heritage, and non-museum institutions: A methodological proposal for sustainable documentation. **International Journal on Digital Libraries**, 25(4), 603-622. <https://doi.org/10.1007/s00799-023-00383-0>
- Siliutina, I., Tytar, O., Barbash, M., Petrenko, N., and Yepyk, L. (2024). Cultural preservation and digital heritage: Challenges and opportunities. **Amazonia Investiga**, 13(75), 262-273. <https://doi.org/10.34069/AI/2024.75.03.22>
- van Berkel, N., Tag, B., Jacobsen, R. M., Russo, D., Purchase, H. C., and Buschek, D. (2024). Impact of interaction technique in interactive data visualisations: A study on lookup, comparison, and relation-seeking tasks. **International Journal of Human-Computer Studies**, 192, Article 103359. <https://doi.org/10.1016/j.ijhcs.2024.103359>
- Weagley, J., Gelches, E., and Park, J. R. (2010). Interoperability and metadata quality in digital video repositories: A study of Dublin Core. **Journal of Library Metadata**, 10(1), 37-57. <https://doi.org/10.1080/19386380903546984>
- Yasseri, T., Gildersleve, P., and David, L. (2022). Collective memory in the digital age. **Progress in Brain Research**, 274(1), 203-226. <https://doi.org/10.1016/bs.pbr.2022.07.001>
- Zeng, M. L. and Qin, J. (2020). **Metadata**. American Library Association.