Research on Architecture Design and Application of Intelligent Education Cloud Platform Oriented to Cultural Transmission

Hang Zhou*

College of Basic Military and Political Education, National University of Defense Technology, 410072, Changsha, Hunan, China

*zhouhang_9952@163.com

Abstract. Cultural transmission is fundamental to human civilization. In the digital age, this process faces three key challenges: fragmented cultural resources, insufficient support for personalized learning, and a lack of learning feedback. Existing platforms, such as digital museums, primarily focus on resource display rather than systematic learning guidance. To address these gaps, this paper proposes an intelligent education cloud platform architecture tailored for cultural transmission. The architecture adopts a five-layer structure (user, application, platform, data, and infrastructure) and integrates three core modules: resource integration, personalized recommendation, and learning analytics. Together, these components enable unified resource management, dynamic content adaptation, and visualized learning feedback, thereby establishing a data-driven, personalized cultural learning service system. This work provides a technical reference for the digital transformation of cultural education.

Keywords: Intelligent Learning Environment, Cultural Transmission, Cloud Platform, Personalized Recommendation, Learning Analytics.

1 Introduction

Cultural transmission sustains human civilization and social identity by passing collective memory, values, and knowledge across generations. In the digital age, information technologies have fundamentally expanded the channels through which cultural heritage is preserved, accessed, and shared. Digital museums, online archives, and virtual exhibitions now offer unprecedented opportunities for global audiences to engage with diverse cultural traditions, yet transforming rich digital resources into structured, personalized learning experiences remains a challenge.

Recent interdisciplinary research has advanced several dimensions relevant to this challenge. Educational cloud platforms are evolving from traditional resource-aggregation and course-delivery platforms into smart education service platforms [1]. Metadata standardization efforts have enhanced semantic interoperability across heterogeneous cultural collections, facilitating unified access to distributed

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resources [2]. Hybrid recommendation methods, combining content-based and collaborative filtering, have been extensively explored in online learning environments and offer promising directions for personalized content delivery [3]. AI-driven platforms such as Retrieval-Augmented Generation tools [4] and the EU's AI4Culture project [5] have demonstrated the value of multimodal and conversational interaction with cultural content. In parallel, calibrated instruments for assessing heritage learning outcomes in digital settings have provided foundational tools for evaluating educational effectiveness [6]. Collectively, these contributions lay important groundwork. At the same time, three functional requirements remain partially addressed in existing cultural platforms: unified organization of scattered resources, dynamic adaptation to individual learning profiles, and integrated behavioral feedback mechanisms to guide the learning process [7]. A systematic architecture that brings these three capabilities together within a coherent, closed-loop framework is still needed.

To address this need, this paper proposes an intelligent education cloud platform architecture tailored for cultural transmission. The architecture adopts a five-layer structure—user, application, platform, data, and infrastructure—and integrates three core modules: resource integration (unified modeling and knowledge graph construction), personalized recommendation (hybrid filtering with dynamic weighting), and learning analytics (behavioral data collection and visualized feedback). Together, these components enable unified resource management, dynamic content adaptation, and traceable learning feedback, thereby establishing a data-driven, personalized cultural learning service system. This work provides a technical reference for the digital transformation of cultural education.

2 Platform Architecture Design

To address the aforementioned challenges, this paper proposes a five-layer intelligent education cloud platform with three core modules: resource integration, personalized recommendation, and learning analytics.

2.1 Overall Architecture

As illustrated in Figure 1, the platform uses a five-layer architecture (top to bottom): User Layer, Application Layer, Platform Layer, Data Layer, and Infrastructure Layer. This design supports the shift from “resource-display-oriented” to “learning-guidance-oriented” services.

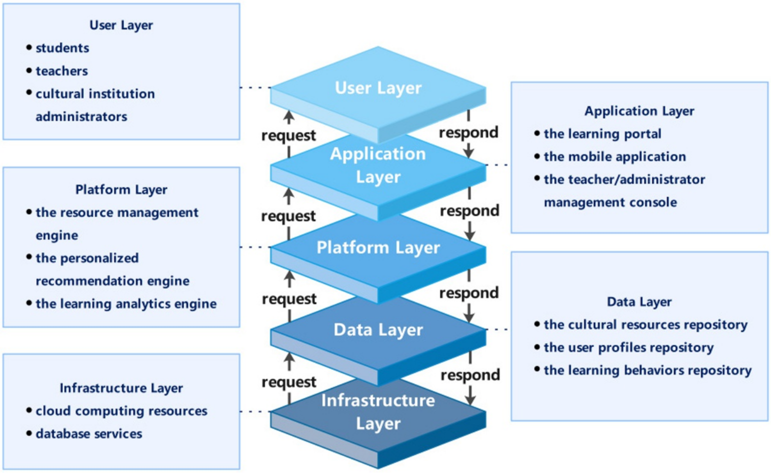


Fig. 1. Layered architecture of the intelligent education cloud platform.

Data flow: Users send requests at the Application Layer; the Platform Layer invokes engines for processing; the Data Layer provides data services; the Infrastructure Layer supplies computing and storage.

Layer functions:

(1) Infrastructure Layer: Provides cloud computing resources (servers, storage, networking) and database services for scalability and availability.

(2) Data Layer: Includes three repositories—cultural resources, user profiles, and learning behaviors—providing the data foundation for upper-layer intelligent services.

(3) Platform Layer: The core layer of the platform, comprising the resource management engine, personalized recommendation engine, and learning analytics engine, which enable resource organization, content adaptation, data mining, and feedback generation.

(4) Application Layer: The user-facing interface, including the learning portal (web-based), the mobile application (app-based), and the teacher/administrator management console.

(5) User Layer: The direct users of the platform, encompassing three roles: students (learners), teachers (instructional organizers), and cultural institution administrators (resource managers).

2.2 Core Module Design

The platform's core functionality is achieved through three interconnected modules: Resource Integration (knowledge graph construction and semantic organization), Personalized Recommendation (hybrid filtering with dynamic weighting), and Learning Analytics (a five-stage data pipeline and visualized feedback).

Resource Integration Module.

This module addresses resource fragmentation by unifying multi-source cultural resources and constructing a knowledge graph to support structured learning paths, as illustrated in Figure 2. Administrators upload multimodal resources (text, images, videos, 3D models) through the management portal; the system extracts descriptive metadata and assigns classification tags including cultural themes, historical periods, difficulty levels, and resource types. Resources are stored in the cultural resource repository while simultaneously triggering an update to the cultural knowledge graph.

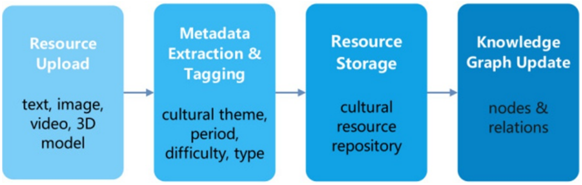


Fig. 2. Resource integration process of the intelligent education cloud platform.

The cultural knowledge graph is constructed based on a domain-specific ontology tailored for cultural transmission. The ontology defines four core entity categories and six semantic relation types, as summarized in Table 1 and Table 2.

Table 1. Entity Categories in the Cultural Knowledge Graph (Illustrated with Ancient Egyptian Civilization Examples).

Entity Category	Subtypes	Examples
Cultural Figure	Historical figures, mythological characters, artisans	Ramses II, Imhotep, Cleopatra
Historical Event	Wars, constructions, discoveries	Battle of Kadesh, Construction of the Great Pyramid
Artifact	Architecture, inscriptions, art-works	Rosetta Stone, Tutankhamun's Mask
Geographic Loca-tion	Ancient sites, museum locations	Giza, Thebes, Memphis

Table 2. Semantic Relation Types in the Cultural Knowledge Graph (Illustrated with Ancient Egyptian Civilization Examples).

Relation Type	Description	Example Triple
created	Cultural Figure → Artifact	Imhotep → Step Pyramid
participated_in	Cultural Figure → Historical Event	Ramses II → Battle of Kadesh
occurred_at	Historical Event → Geographic Location	Battle of Kadesh → Kadesh
unearthed_at	Artifact → Geographic Location	Rosetta Stone → Rashid
influenced	Historical Event → Historical Event	Pyramid Construction → Later Tomb Design
depicts	Artifact → Cultural Figure	Tutankhamun's Mask → Tutankhamun

The knowledge graph is constructed through a hybrid approach combining top-down ontology design and bottom-up entity extraction. During resource ingestion, a rule-based named entity recognition (NER) module extracts entities from textual metadata and automatically links them to existing graph nodes. A manual curation interface is provided for administrators to review and refine the linkage, ensuring semantic accuracy. This graph constructs an inferable and navigable network, transforming dispersed resources into cognitively coherent learning pathways.

Personalized Recommendation Module.

User profiles encompass static attributes (e.g., grade level, declared interests) and dynamic behaviors (e.g., browsing history, search queries, quiz performance). To address content homogeneity, this module employs a hybrid recommendation strategy integrating content-based and collaborative filtering [8]. As illustrated in Figure 3, the system retrieves the user profile upon a learning request and concurrently executes both strategies—matching resource tags with user interests and analyzing behavioral trajectories of similar users. The results are merged, ranked, and output as a personalized list, with user feedback (clicks, completion rates) continuously logged to update profiles and optimize the underlying models.

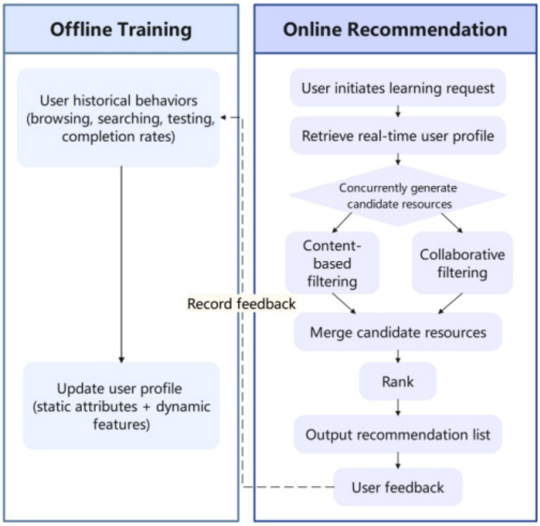


Fig. 3. Personalized recommendation process of the intelligent education cloud platform.

The hybrid recommendation engine implements the following technical mechanisms:

(1) Content-Based Filtering. This component calculates semantic similarity between resource metadata and user interest profiles. Resource tags are vectorized using TF-IDF weighting, and cosine similarity is computed to identify resources with high content relevance.

(2) Collaborative Filtering. This component identifies the Top-N users with similar interaction patterns (e.g., resource access sequences, dwell time distributions) and aggregates their preferences to generate candidate resources the target user has not yet encountered.

(3) Hybrid Fusion and Ranking. The final recommendation score for a resource *r* and user *u* is computed as:

$$\text{Score}\,(u, r) = \alpha \cdot \text{Sim}_{\text{CBF}}\,(u, r) + (1 - \alpha) \cdot \text{Sim}_{\text{CF}}\,(u, r) \tag{1}$$

where α is a dynamic weighting factor adjusted by cold-start status. For new users (α = 0.8 – 1.0), content similarity dominates; as behavioral data accumulate, α decreases to 0.3–0.5, allowing collaborative signals greater influence. User feedback continuously updates similarity matrices and optimizes the weighting parameter.

Learning Analytics Module.

Drawing on the data pipeline methodology of the A4L framework [9], this module systematically collects, processes, and visualizes learning behavior data to provide immediate feedback for learners and an optimization basis for teachers and administrators.

The analytics pipeline follows a five-stage data flow:

(1) Ingestion. Raw behavioral events are captured and transmitted via Experience API (xAPI) statements to ensure interoperability across learning systems.

(2) Preprocessing. Data cleaning and normalization are applied to handle missing values and standardize heterogeneous data formats.

(3) Organization. Processed data are aggregated and indexed by user identifier, learning session, and knowledge dimension.

(4) Analytics. Mastery scores and engagement metrics are computed using the formulas defined below.

(5) Visualization. Results are rendered as interactive dashboards for learners, teachers, and administrators.

The specific metrics collected at each interaction point are summarized in Table 3.

Table 3. Learning Analytics Metrics and Collection Points.

Metric Category	Collected Data	Analytical Purpose
Engagement Metrics	Session duration, resource access frequency, video playback position and annotation count	Quantify learner involvement and attention allocation
Performance Metrics	Quiz scores, task completion rates and response accuracy	Evaluate knowledge acquisition and skill proficiency
Progression Metrics	Topic coverage ratio and learning pace deviation	Track curriculum advancement and identify at-risk learners

Based on the collected data, the system generates three types of visual reports:

(1) Personal Learning Progress Bar. This visualization displays the learner's completion percentage for each thematic topic, enabling them to track their advancement through the curriculum.

(2) Knowledge Mastery Radar Chart. This multi-dimensional visualization displays the learner's mastery scores across five knowledge dimensions. The mastery score for each dimension d is calculated as:

$$\text{Mastery}_d = w_1 \cdot \text{Completion}_d + w_2 \cdot \text{Accuracy}_d + w_3 \cdot \text{Engagement}_d \tag{2}$$

where Completion_d denotes the proportion of resources completed in dimension d, Accuracy_d denotes the average quiz score in dimension d, and Engagement_d denotes normalized interaction depth. The weights w_1, w_2,and w_3 are configurable parameters that instructors can adjust according to pedagogical priorities. The radar chart presents these scores on a unified 0–100 scale, enabling learners to identify knowledge gaps and self-regulate their subsequent learning.

(3) Recommendation Acceptance Rate Statistics. This report tracks click-through rates and completion rates on recommended items, providing a quantitative basis for evaluating and optimizing the recommendation algorithm.

Teachers can access aggregated class-level dashboards to view overall mastery distribution and adjust instructional strategies accordingly. Administrators utilize system-level analytics to monitor resource utilization patterns and optimize the cultural resource repository through targeted content acquisition and metadata refinement.

2.3 User Interaction Process

As shown in Figure 4, this process centers on the student user and embodies the closed-loop collaboration mechanism among the three modules: resource integration, personalized recommendations, and learning analytics.

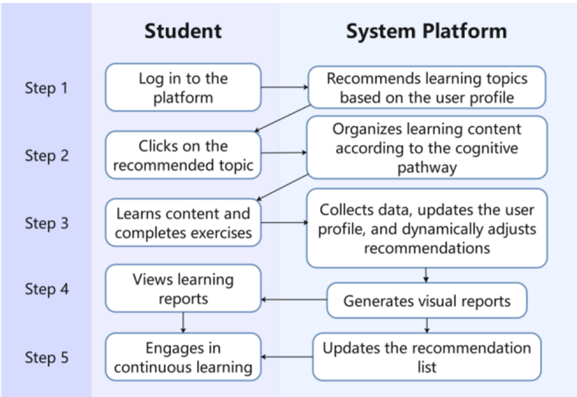


Fig. 4. User interaction process of the intelligent education cloud platform.

Step 1: Login and Initialization. After a student logs into the platform, the system invokes the personalized recommendation module to recommend 3 to 5 suitable topics on the homepage based on the user profile.

Step 2: Topic Selection and Structured Presentation. When a student clicks on a recommended topic of interest, the system extracts the cognitive pathway for that topic from the knowledge graph. Unlike the collection-based classification logic of traditional resource websites, this information is presented in a structured format, aiming to reduce the learner’s cognitive load.

Step 3: Learning Activities and Real-Time Tracking. During learning, the analytics module continuously collects behavioral data, updating the profile to dynamically adjust subsequent recommendations.

Step 4: Learning Feedback and Self-Regulation. Students can view visual reports to identify their strengths and weaknesses and adjust their subsequent learning plans.

Step 5: Continuous Learning and Iterative Cycle. After completing the current topic study, the system regenerates a recommendation list based on the updated user profile, forming a “Recommendation-Learning-Feedback-Re-recommendation” loop.

Simultaneously, teachers view class mastery distributions to adjust strategies.

3 Validation and Discussion

To validate the functional feasibility of the proposed architecture, this section presents a proof-of-concept prototype with ancient Egyptian civilization as the learning domain. The prototype demonstration illustrates how the three core modules—resource integration, personalized recommendation, and learning analytics—operate in concert to form a closed-loop learning workflow. Following validation, a comparative discussion positions the proposed platform against traditional digital cultural platforms, highlighting key architectural distinctions. The section concludes by summarizing the platform's broader implications for cultural transmission.

3.1 Proof-of-Concept Validation

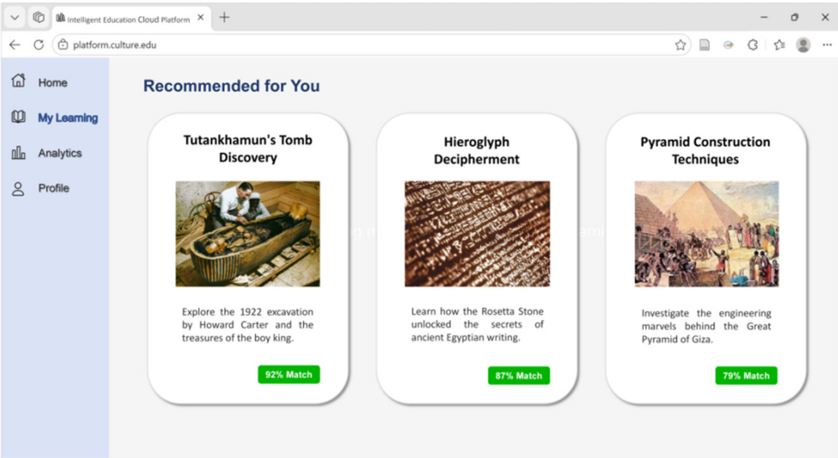
Ancient Egyptian civilization, with iconic heritage like pyramids and hieroglyphs, is suitable for the platform's structured learning paths. Existing platforms operate in isolation; for instance, the AI tool Manetho focuses on inscription translation [10], while the Grand Egyptian Museum website offers virtual tours [11]. Lacking personalized recommendations and behavioral feedback, they fail to provide systematic guidance.

To validate the functional feasibility of the proposed architecture, a proof-of-concept prototype was developed, with ancient Egyptian civilization serving as the learning domain. The prototype demonstrates the closed-loop coordination of the three core modules: resource integration, personalized recommendation, and learning analytics.

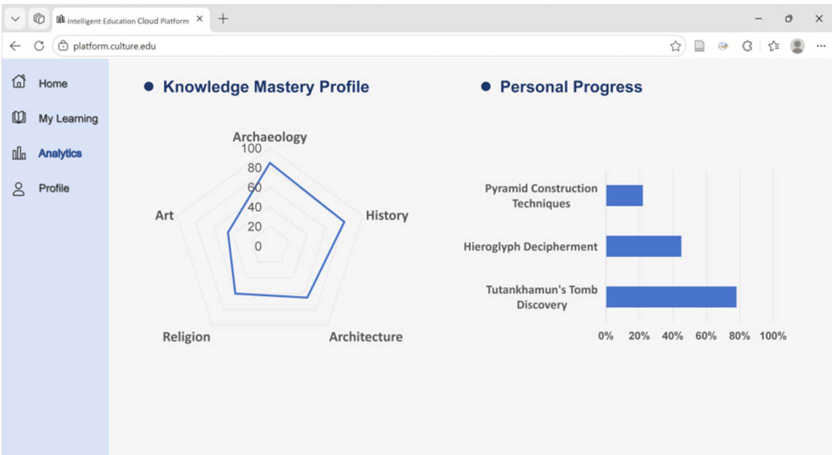
Figure 5(a) shows the learner homepage with personalized recommendations. Based on a simulated user profile with declared interest in archaeological discoveries, the system generates topics such as “Tutankhamun’s Tomb Discovery” (relevance score: 0.92) and “Hieroglyph Decipherment” (0.87). Upon topic selection, the knowledge graph supplies structured cognitive pathways, presenting related entities and semantic relations.

Figure 5(b) displays the learning analytics dashboard. The five-dimensional knowledge mastery radar chart visualizes the simulated learner ‘s profile—high proficiency in Archaeology (85) and History (80), moderate in Architecture (65) and Religion (60), and lower in Art (45)—computed using the formula defined in Section 2.2. The dashboard also includes a personal progress bar and recommendation acceptance statistics.

This proof-of-concept validation confirms that the architectural components integrate coherently to support the intended closed-loop learning workflow. Empirical evaluation with real users is reserved for future work.



(a) Personalized recommendation homepage.



(b) Learning analytics dashboard.

Fig. 5. Prototype interfaces of the intelligent education cloud platform.

3.2 Comparative Discussion

Although existing platforms such as digital museums and intangible cultural heritage websites provide abundant cultural resources, they still fall short in content comprehensiveness, contextual depth, and personalized study. There are fundamental differences between traditional platforms and the proposed platform (Table 4).

Table 4. Comparison of Traditional Digital Cultural Platforms and the Intelligent Education Cloud Platform.

Comparison Dimensions	Traditional Digital Museum/ Library website	Intelligent Cloud Platform
Target positioning	Resource display and information inquiry	Learning guidance and knowledge internalization
Content organization	Classified by Collection/Holding	Organized by cognitive pathways
Personalization	Same for all users	Dynamic recommendation based on user profiles
Learning tracking	None	Learning analytics dashboard
Resource integration	Each library is independent	Unified aggregation of multiple sources

Thus, rather than replacing existing digital museums, the proposed platform builds an intelligent learning layer on top of them, transforming scattered resources into organized, personalized, and traceable educational services.

3.3 Implications for Cultural Transmission

The proposed platform promotes cultural transmission through three synergistic mechanisms: (1) Systematic learning: unified metadata and knowledge graphs aggregate dispersed resources into structured cognitive pathways; (2) Enhanced motivation: dynamic content adaptation lowers entry barriers and increases learner engagement; (3) Knowledge internalization: visualized analytics reports trigger self-regulated learning, shifting users from passive browsing to active knowledge construction. Together, these mechanisms drive the transformation from a resource-display model to a learning-guided model, offering a scalable technical pathway for the digital preservation of cultural heritage.

4 Conclusion

Addressing the challenges of scattered resources, a lack of personalization, and insufficient feedback in cultural transmission, this paper proposes an intelligent education cloud platform architecture. It adopts a five-layer design integrating resource integration, personalized recommendation, and learning analytics to build a data-driven, personalized service system.

The main contributions are: (1) proposing an architecture specifically bridging resource platforms with intelligent learning technologies; (2) designing a closed-loop mechanism integrating knowledge graphs, hybrid recommendations, and learning analytics; (3) validating the architecture' s rationality and effectiveness in promoting cultural transmission through case studies. Future work will involve developing a prototype system and conducting usability testing and learning effectiveness evaluations targeting students, teachers, and cultural enthusiasts.

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