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Smart Digital Library Model in The Context of Digital Transformation in Vietnamese General Education: Design, Implementation, And Empirical Evaluation

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Abstract
In the context of the profound digital transformation of education, school libraries are no longer confined to their traditional role of storing and providing learning materials. Instead, they are required to be restructured into intelligent digital knowledge hubs capable of meeting the evolving demands of teaching and learning in digital environments.
In response to this imperative, the primary objective of this study is to design, evaluate the effectiveness and feasibility, and propose policy recommendations for the scalable and sustainable implementation of the SmartEduLib model—an intelligent digital library solution integrating artificial intelligence (AI), semantic search technology, an academic advisory chatbot, and biometric authentication for teachers and high school students.
Employing a mixed-methods research approach that combines theoretical analysis, field surveys, and pedagogical experimentation at Phan Huy Chu High School, the study not only examines the operational effectiveness of SmartEduLib but also provides empirical evidence supporting the role of intelligent digital libraries in advancing educational digital transformation, fostering reading culture, and promoting lifelong learning within schools. The findings serve as a foundational basis for practical recommendations aimed at bridging the gap between national digital education policies and school-level implementation.
Keywords: *Intelligent digital library; Artificial intelligence in education; Semantic search; School library; Educational digital transformation.*

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I. Introduction

The digital transformation of education is accelerating worldwide and is widely regarded as a strategic pillar for restructuring education systems toward greater openness, flexibility, and personalization. According to UNESCO (2023), the integration of artificial intelligence (AI) and digital technologies into education not only reshapes teaching and learning practices but also redefines knowledge governance ecosystems, in which data infrastructure and digital learning resources serve as foundational components. Similarly, the UNESCO Institute for Information Technologies in Education (2022) emphasizes that many developed countries are transitioning from isolated digitization of resources toward the construction of intelligent education ecosystems built upon big data, AI, and interoperable multi-platform connectivity.

Within this context, digital libraries are no longer perceived merely as repositories of electronic documents; rather, they are increasingly recognized as core knowledge infrastructures of digital education ecosystems. Recent studies affirm that AI can significantly enhance information service delivery through automation, intelligent resource recommendation, and user behavior analytics (Ben Edidiong & Raphael, 2024; Wang & Xia, 2025). In particular, context-aware recommender systems enable the personalization of content

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based on users' profiles and learning behaviors (Adomavicius et al., 2011), thereby fostering lifelong learning and facilitating access to open knowledge resources.

International practices demonstrate that countries such as the United States, Japan, South Korea, and Singapore have proactively implemented smart library and smart school models integrating AI, big data, and cloud computing. In Japan, the GIGA School Program, launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), aims to achieve the goal of "one device per student," thereby establishing a digital foundation for learning resource management and technology-enhanced instruction (MEXT, 2020). Concurrently, the strategic vision of building a "super-smart society" (Society 5.0) underscores the role of AI and data integration across all sectors, including education and libraries (Fujii et al., 2018; Nagahara, 2019). Across ASEAN countries, the adoption of AI in libraries has also become increasingly evident, although the level of implementation remains uneven (Xu et al., 2025).

From a technological perspective, numerous studies have demonstrated the feasibility of applying deep learning algorithms and biometric recognition technologies to user management and secure authentication (Schroff et al., 2015; Shorten & Khoshgoftaar, 2019). In addition, academic libraries have progressively incorporated AI into learning resource management and librarian competency development (Dei Patris et al., 2025; Islam et al., 2025). However, most existing research focuses primarily on higher education contexts, while the general education sector—characterized by distinct infrastructure conditions, resource constraints, and user profiles—still lacks empirically validated models that integrate multiple AI technologies in ways suitable for practical school-level implementation.

In Vietnam, the digital transformation of education has been clearly articulated through national-level policies, including Decision No. 749/QD-TTg approving the National Digital Transformation Program and Decision No. 131/QD-TTg on digital transformation in the education and training sector. Furthermore, Resolution No. 52-NQ/TW of the Politburo emphasizes proactive participation in the Fourth Industrial Revolution, identifying education and human resource development as key strategic domains. Domestic studies have begun to address digital education management and smart school libraries (Le & Bui, 2020; Phan et al., 2024). Nevertheless, practical implementation in many general education institutions remains fragmented, largely confined to basic digitization without integrated systems or effective utilization of AI technologies.

The gap between policy orientation and practical implementation is evident in the continued predominance of traditional library models in schools, where borrowing and returning procedures remain manual, remote access is limited, and semantic search or personalized recommendation tools are largely absent. Meanwhile, international research consistently highlights the pivotal role of AI in enhancing information service efficiency and optimizing user experience (Wang & Xia, 2025; Ben Edidiong & Raphael, 2024).

In response to these practical demands and research gaps, this study proposes the SmartEduLib model—an intelligent digital library solution integrating core AI technologies, including semantic search, an academic support chatbot, context-aware learning resource recommendation, and biometric authentication. The study pursues three primary objectives: (1) to design an intelligent digital library model suitable for implementation in Vietnamese upper secondary schools; (2) to evaluate the model's effectiveness through pedagogical experimentation using both quantitative and qualitative indicators; and (3) to propose recommendations for scalable and sustainable deployment within the general education system.

Through this approach, the study contributes to the theoretical foundation of intelligent digital libraries in general education contexts and provides empirical evidence aimed at narrowing the gap between national policy orientations and the practical realities of educational digital transformation in Vietnam.

II. Literature Review

2.1. Digital Libraries in the Context of Educational Digital Transformation

The digital transformation of education has generated profound changes in the organization, management, and utilization of learning resources within schools. In this context, digital libraries are recognized as a critical component of the digital learning environment, ensuring access to knowledge, facilitating resource sharing, and supporting innovation in teaching and learning through information and communication technologies (Wang & Xia, 2025).

A growing body of research indicates that digital libraries expand learning spaces beyond physical boundaries, reduce dependence on time and location, and enhance the efficiency of resource utilization compared to traditional library models (Islam et al., 2025). However, early-generation digital library models primarily focused on the digitization and storage of resources. Functions that support learning processes, personalize user experiences, and leverage data analytics for educational governance have not been fully developed (Wang & Xia, 2025).

2.2. From Digital Libraries to Intelligent Digital Libraries

Advances in artificial intelligence (AI), big data, and cloud computing have accelerated the transition from conventional digital libraries to intelligent digital library models. In this emerging paradigm, AI technologies are employed to automate professional workflows, enhance information service quality, and personalize users' learning experiences (Islam et al., 2025).

Research on learning resource recommender systems demonstrates that leveraging behavioral and contextual learning data can significantly improve the relevance of recommended materials, thereby increasing learning effectiveness and learner engagement (Adomavicius et al., 2011). Additionally, chatbots and virtual learning assistants powered by natural language processing are regarded as promising tools for supporting resource retrieval, guiding system use, and fostering self-directed learning.

Nevertheless, most existing studies focus on university libraries or online learning platforms. Empirically validated intelligent digital library models tailored specifically to general education contexts remain relatively limited, particularly at the whole-school implementation level (Dei Patris et al., 2025).

2.3. School Digital Libraries within the Digital Education Ecosystem

School digital libraries represent a specialized form of digital library designed to directly support general education. They are closely aligned with curriculum frameworks, competency-based educational goals, and the cognitive and psychological characteristics of school students. Therefore, a school digital library should not be viewed solely as a technological infrastructure but also as an essential pedagogical tool that assists teachers in organizing instructional activities and supports students in self-directed learning (Wang & Xia, 2025).

International evidence suggests that effective school digital libraries must be integrated into a broader digital education ecosystem, including learning management systems (LMS), student databases, and other educational technology platforms. Such integration enables the creation of a unified learning resource environment and interoperable data systems that support educational governance and data-informed decision-making (Government of Japan, 2018; Fujii et al., 2018).

2.4. Artificial Intelligence Applications in Libraries

In Southeast Asia, recent studies have documented a growing trend toward the adoption of AI in library operations, particularly within academic and research libraries. Xu, Idaya A. M. K., and Kassim (2025) report significant variation in the level of AI implementation across ASEAN countries, influenced by national policies, technological infrastructure, and human resource capacity.

Although most research concentrates on academic libraries, these findings provide important implications for school libraries, especially regarding the potential of intelligent search systems, user-support chatbots, and data analytics to optimize resource management and utilization. At the same time, the literature highlights common challenges, including limited technical infrastructure, data quality issues, and the absence of comprehensive AI governance frameworks—factors that must be carefully considered when adapting such models to general education settings (Xu et al., 2025).

2.5. Research Gap

A review of existing studies indicates that while digital libraries and AI applications in education have been extensively explored, a significant gap remains concerning intelligent digital library models specifically designed for general education. In particular, there is a lack of multi-AI integrated models tailored to the pedagogical characteristics of schools and empirically evaluated through quantitative and qualitative indicators of learning outcomes and library management effectiveness (Dei Patris et al., 2025).

This gap underscores the need to design and empirically validate intelligent school digital library models that both align with the objectives of educational digital transformation and accommodate the practical conditions of Vietnamese schools. In response, the SmartEduLib model is proposed to help bridge the gap between national policy orientations and the practical implementation of school digital libraries in the current era of digital transformation.

III. Research Methodology

This study adopts a mixed-methods approach, integrating both qualitative and quantitative methods to clarify the theoretical and practical foundations of school digital libraries and to evaluate the effectiveness of the SmartEduLib intelligent digital library model within a general education context. This approach enables the study not only to describe the current situation but also to empirically verify the feasibility and effectiveness of the proposed model through pedagogical experimentation and measurable performance indicators at Phan Huy Chu High School.

3.1. Theoretical Research Method

The theoretical research method was employed to establish the scientific foundation of the study. Relevant documents were collected and analyzed, including national directives, strategies, and policies of the Party and Government concerning educational digital transformation, as well as domestic and international research on digital libraries, intelligent digital libraries, artificial intelligence applications in education, and learning resource management.

Based on this review, the study systematizes key concepts, models, and prevailing research trends, thereby providing a conceptual and analytical framework for proposing and designing the SmartEduLib model in alignment with the specific conditions of Vietnamese upper secondary education.

3.2. Survey and Field Investigation Method

The survey method was utilized to collect empirical data on library operations at Phan Huy Chu High School. Research instruments included structured questionnaires and in-depth interviews administered to 220 participants, comprising 200 students and 20 teachers. These participants represent the primary users of the school library and thus play a central role in assessing the relevance, effectiveness, and acceptance of the intelligent digital library model within the general education environment.

The survey focused on the following aspects: the current organization and management of the school library; procedures for searching, borrowing, and returning learning materials; the level of information technology application; users' demand for digital learning resources; and user satisfaction with the traditional library model. These data served as a baseline for comparison before and after the implementation of SmartEduLib.

3.3. Experimental Implementation and Evaluation

An experimental method was applied to test the feasibility and effectiveness of the SmartEduLib model in an authentic school setting. The study involved the design, development, and pilot implementation of the SmartEduLib system within the school library over a defined period.

The model's effectiveness was evaluated using both quantitative and qualitative indicators, including: resource search time, borrowing and returning time, library usage frequency, user satisfaction levels, and the volume of digitized learning materials. Experimental results were compared with baseline data from the traditional library model to assess the degree of improvement and the practical value of SmartEduLib in supporting teaching, learning, and school library management.

3.4. Research Procedure

The research process was organized into five main phases over a six-month period (from June to November 2025). The procedure was implemented in a continuous, iterative, and progressively refined manner, with each phase defined by specific objectives and deliverables to ensure logical coherence and cumulative development throughout the study.

Phase 1 (June 2025): Needs Assessment and Problem Identification

Methods included situational surveys, direct observation of library workflows, and semi-structured interviews with librarians, teachers, and students. Data were collected on search time, borrowing and returning procedures, and the current state of digitization, with particular attention to difficulties in accessing and utilizing learning resources.

Outcomes: A baseline status report; validated survey and interview instruments; a consolidated set of user requirements; and a clearly defined central research problem.

Phase 2 (July 2025): Literature Review and Model Proposal

The research team conducted a systematic review and comparative analysis of domestic and international digital library models using a unified set of criteria:

(i) level of digitization (full-text vs. metadata-based systems);
(ii) search capability (keyword-based vs. semantic search);
(iii) remote access mechanisms and user authorization;
(iv) automation of professional workflows and usage analytics; and
(v) infrastructure requirements, operational costs, scalability, and interoperability.

Based on this analysis, the team evaluated advantages and limitations and selected technologies appropriate to the Vietnamese upper secondary school context, characterized by uneven IT infrastructure, limited budgets, constrained technical personnel, and the need for simplified yet secure system operation. International models were examined primarily in terms of data standardization, storage architecture, and access mechanisms, and were cross-referenced with widely used library management systems to establish both a theoretical foundation and a technical orientation for the proposed model.

Outcomes: A comprehensive set of functional and non-functional requirements (including security, authorization, usability, and scalability); a formal proposal of the SmartEduLib model; and preliminary system design documentation, including architectural and structural diagrams.

Phase 3 (August–September 2025): System Design and Development
The research team designed the user interface, developed the database structure and authorization framework, and programmed and integrated key modules, including an AI-powered chatbot, semantic search engine, automated analytics, and facial recognition authentication.
The system was developed iteratively, with internal testing conducted based on standardized operational scenarios. Minimum technical performance indicators—such as response time and system stability—were evaluated and refined prior to experimental deployment.
Outcomes: A beta version of the SmartEduLib system and a comprehensive testing log.

Phase 4 (October 2025): Pilot Implementation and Evaluation
SmartEduLib was deployed in the school library, accompanied by user training and technical guidance. Empirical data were collected from system logs and user surveys, including access frequency, search and borrowing/return time, and user satisfaction levels.
A pre–post comparison was conducted using equivalent operational scenarios under both the traditional and SmartEduLib models to assess improvements in efficiency and applicability.
Outcomes: A comprehensive evaluation report presenting quantitative and qualitative findings on the effectiveness and feasibility of SmartEduLib.

Phase 5 (November 2025): Consolidation, Refinement, and Scaling Proposal
Experimental data were analyzed using both quantitative and qualitative approaches to identify strengths, limitations, and areas for further improvement. The SmartEduLib system was refined based on empirical feedback. Drawing upon the achieved performance indicators, the research team developed a scaling strategy outlining minimum implementation conditions, operational and training procedures, and guidelines for data standardization and interoperability. The plan also included recommendations for integration with learning management systems (LMS) in accordance with principles of role-based access control and data security.
Outcomes: A final research report and a strategic roadmap for scaling and sustaining SmartEduLib in general education institutions.

IV. Results

4.1. Design of the Intelligent Digital Library Model

SmartEduLib is an intelligent digital library model that integrates artificial intelligence (AI) technologies to automate library management processes and personalize the user experience.
To address the identified challenges of traditional school libraries, SmartEduLib is developed upon four core AI technological pillars:

- **Digitization and Optical Character Recognition (OCR):**

The system employs computer vision models such as *Gemini Vision* to convert physical documents (books, newspapers, printed materials) into searchable and analyzable digital text. This process enables the creation of full-text digital resources that support indexing and advanced retrieval.

- **Large Language Models (LLMs):**

SmartEduLib leverages the capabilities of advanced language models such as *GPT-4* and *Gemini* to develop an AI assistant capable of reading, comprehending, summarizing, and answering questions related to document content. The system applies Retrieval-Augmented Generation (RAG) techniques to ensure responses are grounded in the digitized learning materials.

- **Semantic Search (Vector Search):**

Textual data are transformed into numerical vector representations (embeddings) and stored in vector databases such as *ChromaDB* or *FAISS*. This enables semantic similarity-based retrieval, allowing the system to return results based on meaning and contextual relevance rather than exact keyword matching.

- **Face Recognition:**

The system integrates *MediaPipe* for face detection and *FaceNet* for generating facial embeddings ("facial fingerprints"), enabling fast and secure biometric authentication for users.

Operational and Usage Workflow of the SmartEduLib System

SmartEduLib is designed as a closed-loop workflow, spanning from document digitization to the point where students can efficiently locate and utilize the desired learning materials. The process includes the following steps:

Step 1. Full-Text Digitization of Materials

Documents are comprehensively captured (photographed or scanned page by page) and converted into machine-readable text using OCR technology. The resulting digital files are structured into chapters and sections to facilitate efficient indexing and retrieval.

Step 2. Standardization and Storage of Digital Learning Resources

Each digitized document is assigned standardized metadata, including title, subject, grade level, topic, and keywords. The materials are then stored in a centralized digital repository, forming the foundation for systematic management, search optimization, and future scalability.

Step 3. User Access and Role-Based Authorization

Users access the system via account login or facial recognition authentication. SmartEduLib applies Role-Based Access Control (RBAC) with three primary levels:

- **Level 1 – Students:**
  Access age- and grade-appropriate content; receive personalized learning resource recommendations based on usage history, with built-in safeguards limiting access to advanced or sensitive materials.
- **Level 2 – Teachers:**
  Access an expanded repository; upload instructional materials; view aggregated statistics by class or subject (without access to detailed personal data).
- **Level 3 – Librarians / System Administrators:**
  Manage user accounts; assign permissions; update learning materials; and monitor overall system statistics and performance.

Step 4. Semantic-Based Book Search According to Learning Needs

Users submit queries in natural language. The system performs semantic search across the digitized repository, retrieving documents based on contextual meaning rather than strict keyword correspondence. This approach significantly enhances search accuracy and relevance.

Step 5. Accessing and Utilizing Learning Materials

Users can read full-text materials online, conduct in-document searches, bookmark or save content for continued study. The entire process is instantaneous and fully digital, eliminating manual procedures such as physical catalog cards, borrowing slips, or waiting for book retrieval typical of traditional library models.

Through this integrated technological architecture and streamlined workflow, SmartEduLib establishes a data-driven, intelligent, and user-centered digital library ecosystem tailored to the needs of contemporary general education.

Description of the SmartEduLib Model

SmartEduLib is designed based on a four-layer architecture, including **Client**, **Application**, **AI/ML**, and **Data/Storage** layers. This layered architecture ensures modularity, maintainability, scalability, and flexibility for future expansion and integration.

System Architecture and Technology Stack

- **Backend:** Python 3.11, Flask 2.3.3
- **Databases:** PostgreSQL 15, ChromaDB 0.4.15, FAISS 1.7.4
- **AI/ML Frameworks and Libraries:** LangChain, Sentence-Transformers, MediaPipe, Facenet-PyTorch, OpenCV, PyTesseract
- **API Models:** OpenAI (GPT-4), Google (Gemini)
- **Deployment Environment:** Docker (containerized deployment for portability and scalability)

The following hardware configuration was used to perform document digitization and facial authentication tasks::

- Mini PC Intel NUC 12 Pro NUC12WSHi5 (Figure 4.1):
  CPU: Intel® Core™ i5-1240P (12 cores, 16 threads), Turbo Boost up to 4.40 GHz
  GPU: Integrated Intel® Iris® Xe Graphics, supporting hardware acceleration for image processing and lightweight AI/ML edge tasks
  RAM: Supports up to 64GB DDR4-3200 (experimental configuration: 24GB)
- Camera (Input): IMX335 5MP USB Camera (A). (Figure 4.2)
- The camera ensures high-quality image capture for both document digitization (OCR) and biometric facial authentication, contributing to improved recognition accuracy and system reliability.

Figure *4.1 Mini PC Intel NUC 12 Pro NUC12WSHi5.*

Figure *4.2 Module camera IMX335 5MP USB Camera (A).*

The project is organized according to a clear, modular, and systematically structured architecture, facilitating ease of development, maintenance, and future scalability, as illustrated in Figure 4.3.

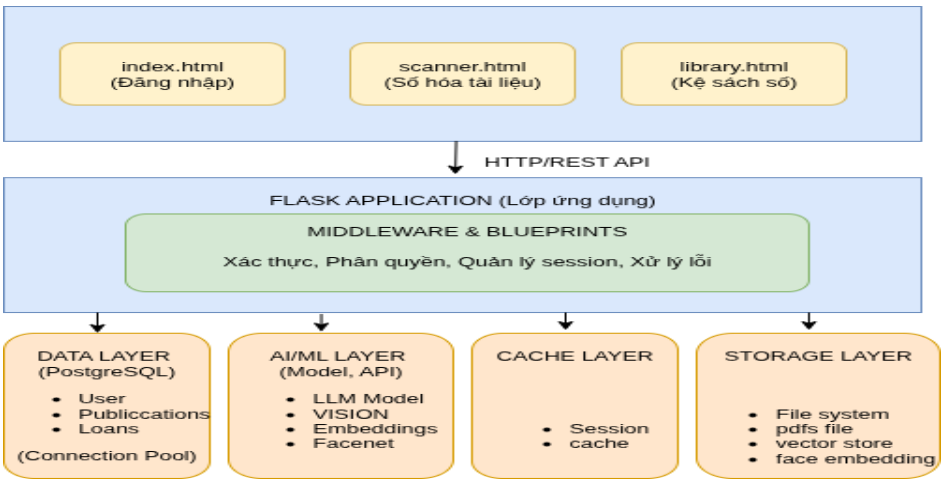

Figure 4.3. Overall Architecture of the SmartEduLib System

4.2 Development and Implementation of Core Modules

4.2.1 Document Digitization Module

The proposed workflow is designed to automate the acquisition, processing, recognition, and semantic representation of document content from image sources or PDF files. This module provides the foundational data layer for semantic search systems and AI-driven knowledge extraction applications.

Step 1. Input Data Acquisition: The system accepts input data in the form of document images captured via camera devices or digital files in PDF format. These inputs may contain noise, perspective distortion, inconsistent lighting conditions, or uneven quality. Therefore, a preprocessing stage is required prior to text recognition to ensure data reliability and accuracy.

Step 2. Image Preprocessing: Image preprocessing is performed using the OpenCV library to enhance input quality before text recognition. The following techniques are applied.

1. Contour Detection for document boundary identification and cropping;

2. Perspective Transform to correct geometric distortion;
3. Deskewing to align textual content properly;
4. Contrast Limited Adaptive Histogram Equalization (CLAHE) to improve local contrast;
5. Noise reduction to eliminate artifacts that may reduce OCR accuracy.

The processed images are then stored for subsequent processing stages.

Step 3. Text Recognition and Extraction: Following preprocessing, textual content is extracted from images or PDFs using a Vision Parser module built upon the Gemini model. This module integrates Optical Character Recognition (OCR) with document layout analysis, enabling the transformation of unstructured visual data into machine-readable and structured textual content suitable for automated processing.

Step 4. Text Segmentation and Semantic Representation: The extracted text is segmented into smaller semantic units (chunking) to optimize storage and downstream processing. Each text segment is converted into a semantic vector representation using the pretrained embedding model *text-embedding-3-small*. This process maps textual content into a high-dimensional vector space, preserving semantic relationships between documents.

Step 5. Data Storage and Utilization: The generated embeddings are stored in a vector database (ChromaDB) in conjunction with a relational database (PostgreSQL). This hybrid storage architecture enables efficient semantic querying, similarity search, and seamless integration with large language models (LLMs) for analytical, retrieval, and decision-support applications.

4.2.2 Semantic Search Module

This module fundamentally transforms the way users retrieve information, delivering significantly more intelligent and context-aware results. It describes the mechanism for processing user queries and retrieving relevant information based on vector-based semantic representations. The module serves as the core component of semantic search and LLM-based question–answering systems.

This represents the most innovative feature of SmartEduLib, enabling users to engage deeply with knowledge rather than merely conducting surface-level keyword searches.

Step 1. User Query Reception

The system receives a natural language query from the user (e.g., “Books on artificial intelligence for beginners”). Such queries are typically unstructured textual inputs and must be converted into semantic representations for comparison with stored data.

Step 2. Semantic Representation of the Query

The query is transformed into a semantic vector using a pretrained embedding model. This process maps the query into the same vector space as the stored document embeddings, enabling semantic similarity measurement between the query and existing materials.

Step 3. Similarity Search in the Vector Database

The query vector is compared with all document embeddings stored in the vector database. Similarity scores are computed using the cosine similarity algorithm to measure proximity within the semantic space.

Based on these similarity scores, the system retrieves a Top-K set (e.g., K = 20) of text segments or documents exhibiting the highest semantic similarity to the original query.

Step 4. Result Reranking and Response Generation

The retrieved result set is further reranked based on a combination of vector similarity scores and additional criteria, such as document popularity, recency, or contextual weighting factors.

After reranking, the system selects a refined Top-N subset (where $N < K$) containing the most relevant results and presents them to the user in the form of a ranked document list or contextually appropriate responses.

Through this multi-stage semantic retrieval pipeline, SmartEduLib ensures high precision, contextual relevance, and an enhanced knowledge discovery experience for users within the digital library environment.

4.2.3 User Facial Authentication Module

The facial authentication module enhances both usability and security by enabling fast and reliable biometric login to the SmartEduLib system. The module is designed to ensure accurate identity verification while maintaining computational efficiency suitable for a school environment.

Registration Procedure

During the enrollment phase, the system captures and processes multiple facial samples to generate a stable biometric representation for each user. The procedure consists of the following steps:

1. The camera captures five facial images from different angles to account for variations in pose and lighting.
2. MediaPipe detects the face and extracts key facial landmarks.
3. The detected face is aligned and normalized to a standardized resolution of 160 × 160 pixels.
4. FaceNet generates a 512-dimensional embedding vector for each facial image.
5. The system computes the average of the five embedding vectors to create a single, robust “facial fingerprint” representing the user.

6. The resulting embedding is securely stored in the database and linked to the corresponding user account.

This multi-sample averaging strategy improves stability and reduces the impact of noise or minor pose variations.

Login Procedure

During authentication, the system verifies the user's identity by comparing the current facial embedding with stored embeddings. The process includes:

1. The camera captures a real-time facial image of the user.
2. Steps 2–4 of the registration process are repeated to generate a query embedding vector.
3. The query embedding is compared against all stored embeddings in the database using the cosine similarity metric.
4. If the highest similarity score exceeds a predefined threshold (e.g., 0.6), authentication is granted; otherwise, access is denied.

By combining landmark detection, embedding-based representation, and similarity matching, the facial authentication module provides a secure, contactless, and efficient login mechanism suitable for intelligent digital library systems.

4.2.4 Library Management Interface

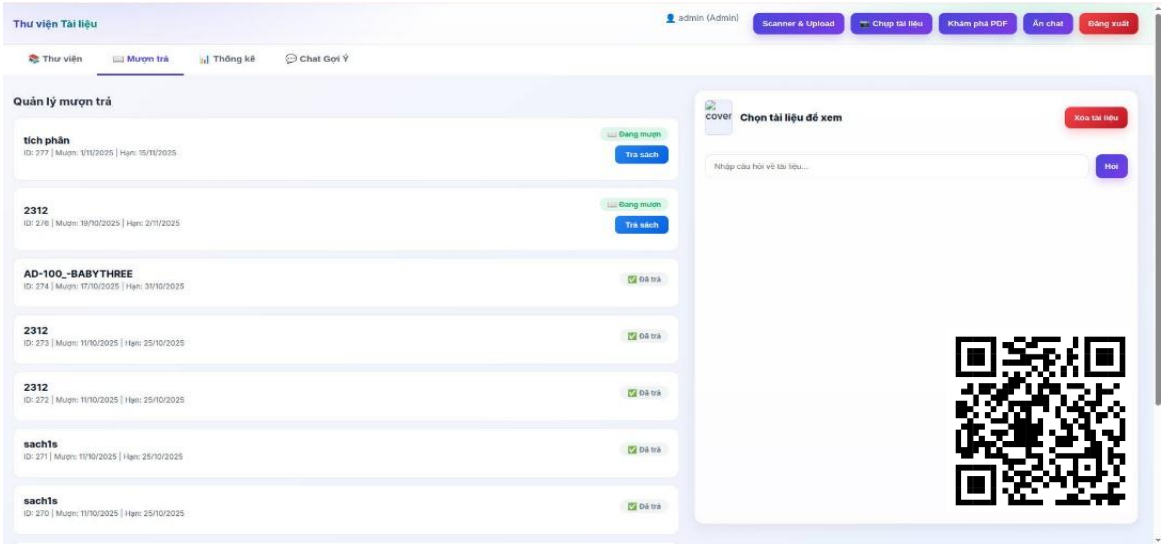

Figure 4.4. Individual Borrowing and Returning History

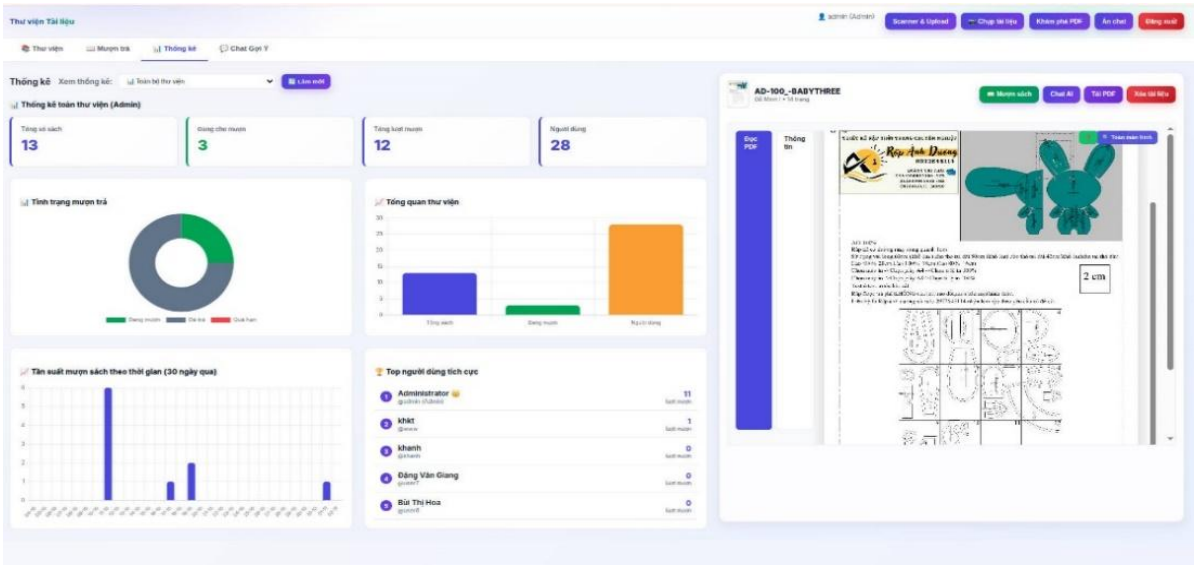

Figure 4.5. Administrator Library Management Interface

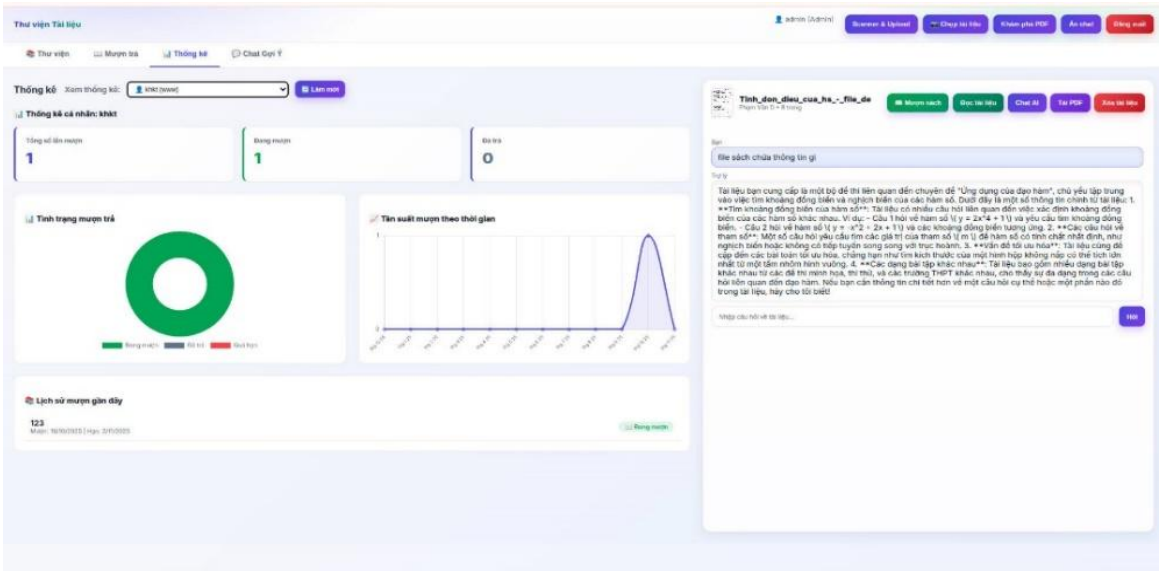

Figure 4.6. User Statistics Dashboard Interface

4.2.5 Extension: Digital Library Integrated with Indoor Positioning and Multimodal Biometric Recognition

In the next phase of development, the research team proposes integrating advanced recognition technologies to enhance user experience and strengthen interaction between readers and the physical library space.

• *Multimodal Biometric Authentication and Learning Resource Recommendation (Face + Fingerprint)*

The system is designed to support multimodal biometric authentication, combining facial recognition and fingerprint verification to ensure both security and convenience during login.

Upon successful authentication, the AI engine applies deep multimodal learning models to analyze users' academic profiles and reading behaviors. Based on these data, the system generates highly accurate and personalized learning resource recommendations. This approach improves recommendation precision by leveraging both behavioral analytics and identity-based personalization within a secure authentication framework.

• *Indoor User Positioning and Context-Aware Recommendation*

Each book section within the library is equipped with positioning sensors, such as Bluetooth beacons or RFID tags. As users move within the library space, their location is detected via a mobile application or wearable smart card.

Based on real-time positioning data, the system provides context-aware recommendations tailored to the user's current physical location. For example, when a user enters the Science and Technology section, a wearable device or connected headset may automatically deliver suggestions such as:

"You are currently in the Science and Technology area. The book *AI for Education* is highly selected by Grade 12 students."

This integration of indoor positioning and AI-driven contextual intelligence transforms the traditional library into an interactive smart learning environment, bridging digital intelligence with physical space and promoting immersive, personalized learning experiences

Connection *Beacon* *Product*

Interactive Reading Experience:

Users can issue voice commands to request additional related materials from the AI system or bookmark books for future borrowing. These interaction behaviors are recorded and incorporated into the recommendation model, enabling continuous learning and progressively improving recommendation accuracy and personalization over time.

Overall Objective:

This development direction transforms the library from a static physical space into a context-aware interactive learning ecosystem. In this model, AI functions not merely as a retrieval tool but as an intelligent companion that actively supports readers, fostering a seamless and engaging connection between the physical and digital environments

V. Discussion

The survey results and quantitative experimental findings indicate that the SmartEduLib intelligent digital library model demonstrates high feasibility and significant effectiveness when implemented in a high school setting. With a sample size of 220 participants (200 students and 20 teachers), the collected data provide a relatively comprehensive perspective encompassing learners, educators, and library staff, thereby offering reliable empirical evidence for evaluating the model.

First, user satisfaction serves as a critical indicator of technology acceptance. The results reveal that 215 respondents rated their experience at the level of "satisfied" or above on a four-point Likert scale. Notably, the combined proportion of "very satisfied" and "satisfied" responses for the SmartEduLib model reached 97.73%, substantially higher than that of the traditional library model. This significant difference suggests that SmartEduLib not only enhances the overall user experience but also more effectively meets users' needs for accessing information and learning resources in the context of digital education.

Table 5.1. Comparison Between the Traditional Library Model and SmartEduLib

Criteria	**Traditional Library**	**SmartEduLib**
Average borrowing–return time	8–10 minutes	3 minutes
Search method	Manual catalog / local computer	AI-powered semantic search
User satisfaction rate (%)	55.45%	97.73%
Remote access capability	No	Yes

The detailed comparison between the two models (Table 5.1) demonstrates that SmartEduLib significantly outperforms the traditional library model across multiple core criteria. The average borrowing–return time was reduced from 8–10 minutes to approximately 3 minutes, representing a reduction of more than 70%. This improvement highlights the role of automation and artificial intelligence in optimizing library workflows while minimizing reliance on manual procedures.

Furthermore, the method of resource retrieval has shifted from manual catalogs or standalone local computers to AI-driven semantic search and intelligent recommendations, thereby enhancing the efficiency of learning resource utilization. The proportion of users who rated the system as "easy to use and intuitive" reached 86.5%, indicating that the interface design and user experience of SmartEduLib align well with the psychological characteristics and technological proficiency of high school students and teachers. This factor is crucial in determining the sustainability and scalability of the model in real-world educational settings.

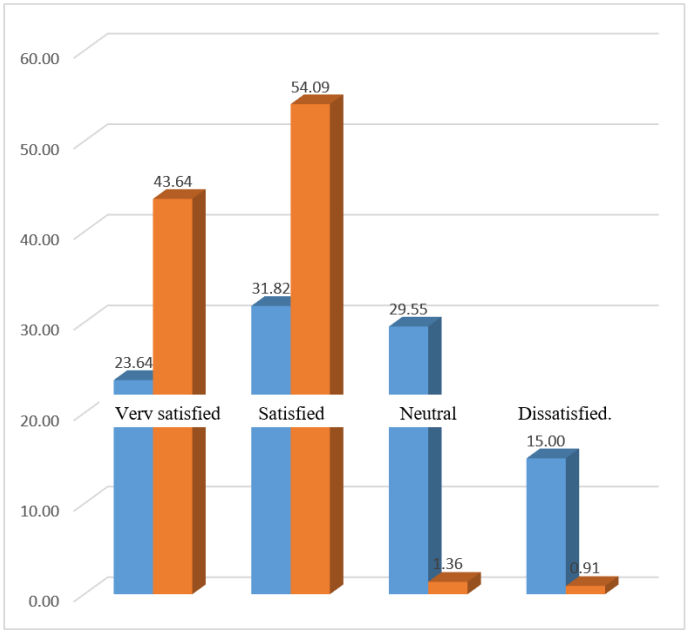

Figure 5.1. Comparison of User Satisfaction Levels Between the Traditional Model and SmartEduLib

The survey results on user satisfaction (Figure 5.1) further demonstrate a marked improvement in library service quality. While the traditional model still recorded a considerable proportion of users rating their experience as "neutral" or "dissatisfied," SmartEduLib showed only 3 neutral responses (1.36%) and maintained a very low dissatisfaction rate (0.91%). These findings indicate that the intelligent digital library model not only enhances operational efficiency but also generates positive perceived value among users.

From an implementation perspective, the successful completion of the SmartEduLib pilot model demonstrates the capacity to integrate multiple advanced digital technologies within a unified platform that simultaneously meets library management requirements and users' learning needs. Core functionalities—including document digitization, online reading, AI-powered advisory chatbot, facial authentication, and automated borrowing–return management—are not isolated features but are designed with integrated data flows and interoperable processes. This architecture establishes a highly automated and personalized intelligent digital library system. The model reflects a transition from a conventional digital library to a smart library paradigm, in which technology plays a central role in enhancing both user experience and managerial effectiveness.

The stable operation of SmartEduLib across both desktop and mobile devices is particularly significant in the current context of educational digital transformation. Multi-platform accessibility broadens the reach of learning resources, enabling students and teachers to access the library anytime and anywhere, beyond the physical constraints of a traditional library space. This flexibility aligns with contemporary learning habits characterized by personalization, autonomy, and adaptability within digital environments, while also promoting reading culture and lifelong learning within schools.

Another noteworthy outcome is the digitization and standardization of library data, resulting in the initial establishment of an electronic repository containing over 1,000 categorized and thematically organized titles. Data standardization not only enhances searchability and accessibility but also creates a structured data foundation to support advanced intelligent technologies in subsequent development phases. On this basis, enhanced functionalities such as personalized resource recommendations, reading behavior analytics, and user learning needs assessment can be implemented effectively and on a sound scientific basis.

Beyond its impact on students and teachers, SmartEduLib has demonstrated significant improvements in school library management and operations. Automation of borrowing–return procedures, statistical reporting, and inventory control substantially reduces manual workload for library staff, minimizes data management errors, and improves transparency and accuracy. Consequently, the role of library personnel shifts from repetitive administrative tasks toward learning support, resource consultation, and participation in higher value-added professional activities.

From a broader perspective, the findings affirm the transformative role of digitalization in the library–education sector, not only in terms of technological application but also in reshaping management thinking and organizational practices. The library is no longer merely a repository of materials; it increasingly functions as an open knowledge hub that supports lifelong learning and fosters students' self-directed learning competencies. The SmartEduLib model demonstrates strong potential for replication across secondary schools, particularly in rural areas, due to its relatively low implementation cost, flexible system architecture, and adaptability to varying infrastructural and resource conditions.

However, it should be noted that the study remains limited to an initial pilot implementation at a single school. Further expansion in sample size and implementation duration is necessary to comprehensively evaluate long-term sustainability, effectiveness, and potential impact on learning outcomes. Future development directions—such as expanding document digitization, establishing inter-library connectivity, and integrating with Learning Management Systems (LMS)—represent essential steps toward completing a comprehensive digital learning ecosystem within schools.

VI. Conclusions and Recommendations

6.1. Conclusions

This study successfully proposed, designed, and piloted the SmartEduLib intelligent digital library model within the context of Vietnamese general education, thereby clarifying the role of digital transformation in innovating school library operations. Experimental results indicate that SmartEduLib significantly improves search efficiency, borrowing–return processes, and user satisfaction, while simultaneously reducing manual workload for library staff and enhancing the effectiveness of learning resource management and utilization.

The integration of technologies such as artificial intelligence, semantic search, advisory chatbots, and intelligent user management has progressively transformed the library model from a traditional storage space into an open knowledge hub that supports flexible and lifelong learning. Moreover, the digitization and standardization of learning resource data establish a critical foundation for the future development of advanced functionalities, including personalized learning pathways and reading behavior analytics.

Although implemented on a pilot scale at a single educational institution, the initial findings affirm the feasibility, effectiveness, and scalability potential of the SmartEduLib model within the secondary school system,

particularly in localities with limited infrastructure and financial resources. These results provide both scientific and practical grounds for further refinement and broader application of the model in subsequent phases.

6.2. Recommendations

For SmartEduLib to realize its full potential as an effective intelligent digital library solution—contributing to the development of reading culture and the enhancement of teaching, learning, and research outcomes at the upper secondary level—coordinated efforts among educational management authorities at multiple levels are required. Accordingly, the research team proposes the following recommendations:

For Schools

Schools should implement, sustain, and progressively refine the SmartEduLib model as an integral component of the digital learning ecosystem. This includes strengthening technical infrastructure (hardware devices, network connectivity, servers) and organizing training activities to enhance digital competencies among librarians, teachers, and students. Incorporating SmartEduLib into institutional development plans will help ensure the model's long-term sustainability and operational effectiveness.

For Departments of Education and Training

Provincial and local Departments of Education and Training should establish supportive mechanisms for deploying intelligent digital library models in general education institutions, particularly those demonstrating high feasibility such as SmartEduLib. In addition, policies should promote digital resource sharing and gradually develop interconnected school library networks at the local level, thereby optimizing resource utilization and minimizing redundant investment across schools.

For the Ministry of Education and Training

The Ministry of Education and Training should issue unified national standards for digital learning resource data to facilitate digitization, storage, sharing, and interoperability among library systems and educational platforms. Furthermore, a regulatory and technical framework should be developed to enable integration between digital libraries and Learning Management Systems (LMS), contributing to the formation of a coherent, interoperable, and sustainable national digital education ecosystem.

In the next phase, the research team will continue refining SmartEduLib toward enhanced intelligence and personalization, with particular emphasis on improving recommendation algorithms and reading behavior analytics. Efforts will also focus on expanding digitized resources, diversifying learning materials, and deepening LMS integration to strengthen the model's practical value and scalability in general education.

These recommendations aim to ensure that SmartEduLib extends beyond a pilot initiative and evolves into a sustainable, scalable solution at the national level, thereby contributing to the realization of Vietnam's educational digital transformation goals and the development of a future-oriented digital learning society.

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