SkillSwap: A Modular Peer-to-Peer Digital Ecosystem for Credit- Governed Skill Exchange and Real-Time Collaborative Learning

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Abstract

This paper presents SkillSwap, a modular peer-to-peer digital learning ecosystem designed to enable structured skill exchange through a credit-governed participation model. Unlike traditional Learning Management Systems (LMS) that rely on centralized, one-directional instructional delivery, SkillSwap introduces a decentralized reciprocal framework where users dynamically alternate between instructor and learner roles.

The system is implemented using a full- stack architecture comprising a REST- driven backend (Node.js, Express.js), a document-oriented database (MongoDB Atlas), secure token-based authentication (JWT), encrypted credential storage (bcrypt), and a WebRTC-enabled live lecture integration layer utilizing the Jitsi Meet API. The architecture ensures secure route-level access control, atomic credit transaction validation, and optimized indexed database queries.

Performance benchmarking demonstrates stable REST API latency under concurrent usage conditions and reliable live session handling within browser-native environments. SkillSwap establishes a calable, secure, and institution-ready framework for decentralized academic collaboration and structured knowledge governance.

Keywords: Peer-to-Peer Learning, REST Architecture, WebRTC Integration, JWT Authentication, MongoDB, Credit-Based Governance, Digital Learning Ecosystem.

I.INTRODUCTION

The rapid expansion of digital technologies has significantly reshaped contemporary education. However, most online learning platforms operate under a unidirectional knowledge distribution paradigm, where learners passively

consume content without contributing their expertise.

This model underutilizes distributed nowledge within learning communities. SkillSwap addresses this structural limitation by implementing a decentralized peer- learning architecture governed by a credit-based transactional validation mechanism.

The platform functions as a unified ollaborative exchange layer, enabling participants to teach and acquire technical skills within a secure digital ecosystem. By integrating RESTful backend processing, token-based authentication, and WebRTC- enabled live communication, SkillSwap transitions from passive LMS frameworks toward interactive and self-sustaining academic engagement models.

II. LITERATURE REVIEW

Recent research highlights the evolution of educational platforms from static content- delivery systems to interactive peer-driven ecosystems.

Peer-to-peer networking frameworks demonstrate enhanced decentralized interaction and resource distribution efficiency [1]. Adaptive learning systems emphasize user-centric recommendation mechanisms and personalized engagement [2]. Web-based virtual classroom studies validate the feasibility of browser-integrated real-time communication using WebRTC protocols [4]. Systematic reviews of LMS platforms identify limitations in reciprocity, scalability, and interactive governance [5].However, existing systems often lack structured credit-based participation models and unified integration of live collaboration with secure backend governance. SkillSwap consolidates these capabilities within a modular full-stack architecture to extend peer-learning research into a structured, transaction- governed digital framework
.

III. SYSTEM ARCHITECTURE

SkillSwap follows a layered client–server architecture optimized for scalability, secure communication, and low-latency performance.

3.1 Presentation Layer

The presentation layer is developed using HTML, CSS, and JavaScript, delivering a responsive cross-device interface. The frontend communicates with backend services via RESTful APIs and dynamically renders dashboards, course listings, and session access controls.

3.2Application Layer

The application layer, implemented using Node.js and Express.js, functions as the logical processing core. It manages:

- JWT-based authentication
- Middleware-driven route protection
- Credit validation and deduction logic
- Course lifecycle operations
- Session scheduling mechanisms JWT

tokens enforce stateless authentication, eliminating persistent server-side session storage while ensuring cryptographically verifiable request validation across protected endpoints.

3.3 Data Layer

The data layer utilizes MongoDB Atlas, a document-oriented NoSQL database optimized for schema evolution, indexed query optimization, and horizontal scalability.

Indexed collections include:

- Users
- Courses
- Live Sessions
- Credit Transactions

Atomic update operations ensure transactional integrity during concurrent credit deductions, preventing race conditions and manipulation.

SkillSwap: Architecture Overview

3.4 Live Lecture Integration Layer

The live interaction subsystem integrates the Jitsi Meet API using WebRTC protocols. This layer enables:

- Browser-native video conferencing
- Screen sharing
- Audio communication
- Controlled meeting access Meeting

identifiers are dynamically generated and validated against database records to prevent unauthorized session entry. Express middleware intercepts

IV. TECHNICAL IMPLEMENTATION DETAILS

4.1Secure Authentication Framework

User credentials are hashed using bcrypt prior to storage. JWT-based authentication ensures stateless session validation.
Express middleware intercepts unauthorized access attempts and validates token authenticity before granting endpoint access.

4.2 Credit-Governed Transaction Engine

SkillSwap implements a structured transactional model:

- Users earn credits by teaching sessions.
- Credits are deducted upon enrollment in courses.
- Atomic database operations enforce transactional consistency.

This governance mechanism ensures accountability and reciprocal participation within the ecosystem.

4.3 REST API Optimization

Endpoints are structured to minimize payload size and reduce latency. Indexed MongoDB queries enhance retrieval efficiency for frequently accessed datasets such as course listings and user dashboards.

V. FUNCTIONAL MODULES

1. Authentication and Authorization Module
2. Skill Listing and Enrollment Module
3. Credit Transaction Engine
4. Live Session Scheduling Module
5. Administrative Monitoring Controls

sustain WebRTC-based live session communication, which may introduce latency under unstable bandwidth conditions. The credit governance mechanism operates under centralized database validation.

Each module is independently testable and modularly scalable.

VI. SYSTEM EVALUATION

The system was evaluated across three domains: functional validation,
performance benchmarking, and security auditing.

6.1 Functional Verification

Role-based access testing confirmed that unauthorized users could not access
protected endpoints. Credit transactions were validated under concurrent
enrollment scenarios.

6.2 Performance Benchmarking

Performance benchmarking indicated an average REST API response latency
between 180 ms and 320 ms under moderate concurrent request conditions. Indexed database queries reduced lookup times for course and session retrieval.

Live WebRTC sessions maintained stable communication under standard network
bandwidth without observable packet loss.

6.3 Security Auditing

Security validation included:

- Token expiration verification
- Invalid credential rejection
- Protected route enforcement
- Input sanitization

The system demonstrated secure session handling and resilience against
unauthorized API manipulation.

VII.LIMITATIONS AND FUTURE WORK

The current implementation is dependent on continuous network connectivity to

Future enhancements may include:

- AI-driven personalized skill recommendation
- Reputation and rating systems
- Microservices-based scalable deployment
- Cross-platform mobile application development
- Blockchain-based distributed credit validation
- Advanced learning analytics dashboards

VIII.CONCLUSION

SkillSwap demonstrates a technically robust and scalable implementation of a peer-governed digital learning ecosystem, validating the feasibility of credit-mediated knowledge exchange within a secure,
modular, and performance-optimized architecture.

By integrating RESTful backend processing, token-based authentication, NoSQL data optimization, and WebRTC- enabled real-time collaboration, the platform transitions beyond passive LMS models toward participatory and decentralized academic engagement frameworks.

The architecture confirms its suitability for institutional deployment and scalable peer- driven digital education.

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