AI-ENABLED WEB-BASED LEARNING MANAGEMENT SYSTEM USING MERN STACK WITH GAMIFICATION AND AUTO CERTIFICATE GENERATION

Rohit, Deepak Kumar , Salliah Shafi and Manpreet Kaur

Students, School of Computational Science, GNA University, Punjab, India

ABSTRACT

The rapid growth of online learning has created an urgent need for intelligent learning management systems that are securely scalable, and adaptable to the structural and functional constraints of traditional learning management system deployment. Much of the current systems is still plagued by a combination of keyword-based search and monolithic designs, each of which has been shown to degrade course discoverability, limit personalization, and diminish role differentiation, which in turn degrades the quality of digital learning. In this paper, Virtual Courses, a complete artificial intelligence-powered learning management system based on an integrated modular and cloud-based architecture is proposed, aiming to overcome these drawbacks. This proposed system utilizes Google Gemini for semantic search in order to provide context-awareness for course discovery, JSON Web Token authentication combined with Google Open Authorization 2.0 for secure role-based access to the system by students, educators and administrators, a credit-based course engagement model, automated generation of certificates, and delivery of multimedia through the cloud. The production-deployed instance went through functional and non-functional validation to ensure adherence to security, usability and performance requirements. The findings show that a combined single deployable full-stack platform for artificial intelligence-driven semantic search, secure multi-role authentication, and integrated transactional tools presents a significant improvement in modern learning management system design and offers a scalable and future-proof basis for intelligent digital learning systems.

Keywords: AI-Integrated LMS, E-Learning Platform, MERN Stack Architecture, Online Payment Integration, Role-Based Authentication, Semantic Course Search.

1. INTRODUCTION

The internet and cloud computing technologies have transformed the world of learning in ways that most educators never imagined. Internet and cloud computing technologies have dramatically changed the world of education by providing flexible and digitally mediated alternatives, instead of traditional classroom-based instruction. The most successful infrastructure for this shift is the Learning Management System (LMS) which enables a centralized space where teachers can access courses, track student progress, and facilitate organized student learning interaction. Digital education is becoming a key element of University education, professional training programs and certification bodies and the need for intelligent, secure and architecturally scalable LMS has never been greater (Piyumantha et al., 2022).

In recent years, there are some advances in the implementation of LMS with the use of the latest web technologies. In comparison to traditional monolithic systems, it has been shown that MERN stack-based systems provide measurable gains in interactivity, remote access and modularity (Chaudhari et al., 2024). Furthermore, in full stack deployments of education platforms, scalability with growing load of concurrent users has been validated (Uddin et al., 2026). In terms of the infrastructure, cloud-based storage of multimedia data has been proved to significantly lower operational costs of online teaching organizations (Erturk & Obrutsky, 2016). Taken together, all these works assert that modern full-stack architectures are architecturally adequate for educational systems, but have tended to be more concerned with delivery and architectural issues than with intelligent content discovery, which is the tougher issue.

In today's LMS development, two complementary dimensions are equally important: security and engagement of the learners. JWT-based authentication has become a powerful form of stateless authentication for user access control in cloud-based applications (Ethelbert et al., 2017). Literature reviews of the use of gamification in higher education have consistently found that it has a positive impact on learner motivation, with rewarding with credits and incentives for completion showing measurable increases in engagement and retention (Khaldi et al., 2023b). Concurrently, the significance of a verifiable digital credential in today's learning management system (LMS) environments has been highlighted in approaches for secure and tamper-resistant certificate issuance (Rakha & Alzubi, 2025).

Despite these developments, there is a fundamental lack in the literature. Most LMS solutions still have search functionality based on keywords and other surface-level query words, which fails to understand the learner's intent and context, and consequently reduces the discoverability of courses in vast catalogues of content. While recent research has underscored the potential for using large language model (LLM) driven semantic search in education, there is a lack of research that brings together AI-powered semantic search, secure multi-role authentication, integrated payment processing, credit-based engagement, and automated certification in one seamless, cloud-based full stack platform (Abaricia & Santos, 2023).

1.1 PROBLEM STATEMENT

The problem of this research is three-fold. First, modern LMS systems mostly use keywords to retrieve courses, without having the ability to interpret the meaning of these queries and match them with the appropriate educational content for the context. Second, while various systems do exist, they are often not integrated into a single modular system with role differentiation, payment processing and engagement capabilities, forcing institutions to rely on a few disjointed, third-party solutions. Third, there is little applied research on the feasibility of implementing AI-powered search in a secure and scalable full stack education platform.

1.2 PROPOSED SYSTEM

This paper outlines the design, development, and testing of Virtual Courses – An AI-Powered Learning Management System, a complete Web application using the MERN stack to directly fill the identified gaps. It features Google Gemini-powered semantic search to deliver context-aware course discovery, a secure role-based authentication system for students, teachers, and administrators, and an online payment system powered by Razorpay. A credit-reward system is in place to boost learner motivation, and certificate generation is automatically triggered when the learner has successfully completed the course. The Render platform offers cloud-based solutions for the delivery and production of multimedia, guaranteeing reliability and accessibility.

CONTRIBUTIONS

The major contributions of this work are outlined:

- A single, modular stack based on MERN, including AI-powered semantic search, multi-

role authentication, payment processing, and certification, in a single deployable system.

- Enhanced integration with the Google Gemini API: context-aware course discovery goes beyond keyword-based retrieval to semantic intent understanding.
- An incentivised model of learner engagement based on credits that encourages enrolment and completion of courses with a configurable reward and redemption mechanism.
- A formal multi-role course approval and publication process that integrates student, educator and administrator roles.
- System validation using functional and non-functional testing to ensure compliance with security, usability and performance requirements in realistic deployments.

2. LITERATURE REVIEW

The world of web-based educational technology has grown significantly in the last decade as everyone has started moving towards a more digital learning environment. The literature falls into five major categories: Full Stack LMS Architecture, Cloud Infrastructure for Educational Systems, Authentication and Access Security, AI Enabled Search and Recommendation, and Gamification and Digital Credentialing.

2.1 FULL-STACK ARCHITECTURE IN LEARNING MANAGEMENT SYSTEMS

The early LMS platforms were mostly monolithic, with significant limitations for scalability, modularity and long-term maintainability. The MERN stack solved many of these structural issues with a component-based API-driven system design. LMS implementations based on MERN have been found to be effective in supporting user management, course delivery and content organization in a modular and maintainable code base (Piyumantha et al., 2022). Similar architectural advantages have been found in educational management information systems based on the MERN that have been used in educational environments at a regional level (Olarotimi et al., 2023). On this base, EdTech platforms based on this stack have shown measurable gains in terms of remote accessibility and learners' interactivity when compared to traditional implementation (Chaudhari et al., 2024). With the integration of the automated assessment capability into e-learning platforms based on MERN, the feasibility of using a modular system

architecture and intelligent processing was further demonstrated (Kandalkar et al., 2024). Recently, it has been demonstrated that faster performance in the presence of escalating concurrent users in scalable LMS implementations (Uddin et al., 2026) built on the MERN stack is achieved. Together, all these contributions provide a good validation of the choice of the MERN stack for LMS development, though the attention of previous work has been mainly in the structural and delivery aspects rather than in the intelligent content discovery or in the integrated transactional aspects of the LMS.

CLOUD INFRASTRUCTURE FOR EDUCATIONAL CONTENT DELIVERY

The use of cloud computing in education has brought about significant improvements in accessibility, resource utilization, and scalability in educational systems. Cloud e-learning models have proven that institutions of all scales can benefit from different cloud-based e-learning models as an alternative to the on-premise infrastructure, which is more cost-effective and flexible (Siddiqui et al., 2019). Cloud-based multimedia storage is also demonstrated to bring considerable reduction in infrastructure overhead and better multimedia content availability to remote and mobile learners from the media delivery point of view (Erturk & Obrutsky, 2016). In sum, the contributions in this collection demonstrate that cloud integration is not just a convenience of deployment, but an integral part of modern LMS design, especially those that incorporate video-rich course content at scale.

2.2 AUTHENTICATION AND ACCESS SECURITY IN WEB APPLICATIONS

Security is an absolute must for any multi-user learning environment that is processing sensitive credential data and/or financial transactions. JWT-based authentication have been proven a stateless, light-weight and scalable authentication approach for session management in cloud deployed applications without dependency on stateful session storage in the server (Ethelbert et al., 2017). User behavior history has been brought into the equation in recent approaches to token based authentication, which show that behavioral context can improve the access control decision without compromising system performance (Janicke et al., 2023). Overall, these studies confirm JWT as a suitable authentication method for scalable, cloud-based educational systems and have a direct influence on the authentication method used in the proposed authentication system.

2.3 AI-DRIVEN SEARCH AND RECOMMENDATION IN EDUCATIONAL PLATFORMS

One of the areas where AI has recently been actively researched in educational platforms is AI-generated content.AI-generated content is another area where AI has been recently heavily studied in the educational realm. Knowledge tracing and retrieval-augmented generation (RAG) recommenders have been shown to enhance the relevance and adaptiveness of educational content delivery when applied using large language models (LLMs) (Li et al., 2025). In LMS settings, AI-based content recommendation, which uses deep embeddings to align the content with contextually appropriate information, has also been shown to be superior at course discovery over retrieval-based methods, that rely on keywords matching (Råmunddal, 2025). In both directions, intent-aware search is a major differentiator for next generation educational platforms. However, none of the current methods have combined the semantic AI search functionality with full stack deployable LMS which also solves authentication, payment and learner engagement problems in a single architecture and with a single integration.

2.4 GAMIFICATION, LEARNER ENGAGEMENT, AND DIGITAL CREDENTIALING

Motivation and engagement of learners have been identified as the persistent factors which determine the completion rate of online courses. A systematic review of gamification in higher education e-learning has found that reward-based systems (such as credit points, badges and completion incentives) yield positive and repeatable results with regard to motivation and retention in a wide range of educational settings (Khaldi et al., 2023b). These results were confirmed by a systematic review that focused on the use of gamification within tertiary education contexts which found a statistically significant positive correlation between reward-based engagement and students' motivation (Ratinho & Martins, 2023). In terms of credentialing, blockchain-based deep learning systems for secure digital certificate issuance have highlighted the increasing need for tamper-resistant, verifiable credentialing systems in contemporary LMS environments (Rakha & Alzubi, 2025).

2.5 IDENTIFIED RESEARCH GAP

The previous literature review found the following gaps:

- Limited research has integrated AI-powered semantic search with a complete MERN stack

architecture into a deployable educational platform.

- Very little applied research has been done that integrates secure multi-role authentication, embedded payment processing and credit based engagement into a unified LMS architecture.
- In open LMSs with projects, automated certificate generation based on verified completion of courses is still not explored (Rakha & Alzubi, 2025).
- Studies on intelligent content discovery and learner engagement mechanisms have been scarce in the existing MERN-based research.
- Most current LMS deployments have not progressed from the static delivery to capabilities that actively transform the learner experience, but integrate and adapt to this (Abaricia & Santos, 2023).

To address these gaps, this work proposes Virtual Courses—an AI-powered, full-stack LMS built on the MERN stack that integrates Google Gemini-driven semantic search, JWT-based role-differentiated authentication, Razorpay payment processing, a configurable credit reward system, and automated certificate generation within a single cloud-deployed platform. The system is tested with functional and non-functional requirements to help in gap bridging between theory and practice in LMS design and implementation. A summary of the mapping of the identified limitations and their respective contributions of the proposed system is given in Table I.

Table I: Identified Limitations and Corresponding Contributions of the Proposed System

Existing Limitation	Proposed Solution
Keyword-based course retrieval	Google Gemini-driven semantic intent search
Fragmented multi-tool authentication	Unified JWT, OAuth 2.0, and OTP framework
Existing Limitation	**Proposed Solution**
Limited integrated engagement mechanisms	Configurable credit-based reward economy
Manual certificate issuance	Automated threshold-triggered certificate generation
Disjointed payment integration	Native Razorpay transactional pipeline

Predominantly single-role or static architectures	Multi-role modular cloud-deployed system
Absence of intent-aware course discovery	Context-aware retrieval through LLM semantic analysis

3. IMPORTANCE OF THE STUDY

The Digital Education Platforms have grown exponentially in the last decade, making Learning Management System one of the fundamental infrastructures of the modern learning environment in academia and for professionals. Yet, with increased institutional reliance on these platforms, there has also been a growing body of evidence that their underlying architectures and functional capabilities have not been able to meet the changing needs of learners, educators and administrators. The main interest of the present study is not theoretical, but rather stems from a set of concrete, well-founded shortcomings in existing LMS design, which have measurable consequences for the quality of digital education.

The first and most persistent of these shortcomings is the continued use of keywords to retrieve a course. Surface keyword matching is always unsuccessful in massive and expanding course catalogues to understand the intent behind a learner's query, leading to poor discoverability and search experience. The learner who asks "how do I build mobile apps" won't get the results for a course with a keyword name "React Native Development" with a keyword system. While recent research has shown that LLM-based semantic retrieval is a more effective method for discovering educational content than methods relying on keywords (Li et al., 2025; Råmunddal, 2025) , this capability has not yet been applied to any fully integrated, production-deployed full-stack LMS platform, which is what this study directly aims to tackle (Abaricia et al., 2023).

The second dimension of need is related to the fragmentation in the architecture of the majority of the current LMS implementations. Looking at existing MERN-based platforms, one can see that each platform focuses on one specific functional requirement of the platform, such as structural modularity, basic authentication, or content delivery, but they aren't necessarily integrated to allow for intelligent, transactional and secure operations on the platform (Chaudhari et al., 2024; Piyumantha et al., 2022). Such institutions are then stuck with multiple disconnected third-party tools for providing payment, identity, and credentialing. The more integration points there are, the

more security risk, complexity, and user experience degradation. Practically, the need for a single coherently designed architecture that binds these capabilities together is urgent, and academically, it remains unresolved.

Third, motivation and course completion are still one of the most enduring problems in online education documented. The findings of the systematic reviews support the statistically significant effects of credit-based reward systems and gamification mechanisms on learner engagement and retention in various educational contexts (Khaldi et al., 2023a; Ratinho & Martins, 2023). With all this evidence, it has yet to be applied to a full-scale LMS, where it is needed to be translated into a deployable and configurable credit economy, and this study aims to make this connection.

Finally, the issuance of verifiable course completion credentials in most existing platforms remains dependent on manual or semi-automated administrative processes. This dependence adds delay, ambiguity and administrative risks in an educational setting where digital certificates are becoming more important in the professional and institutional world. Recent literature (Rakha & Alzubi, 2025) shows that automated, tamper-resistant credentialing has been identified as a growing need in modern learning management systems, which has not yet been demonstrated in a full stack, deployable platform in the open learning environment.

These four dimensions confirm that the present study will help address current LMS practice that is not evidence-based and lacks reality. The value of this work is its ability to provide a valid, comprehensive answer that resolves a problem which the literature has identified as a problem separately, but not yet as a problem together in a single deployable system.

4. OBJECTIVES AND HYPOTHESIS

4.1 OBJECTIVES OF THE STUDY

The main aims of this study are:

1. To create a production ready, AI-based Learning Management System, built with the MERN stack, that brings together all the functionality of semantic discovery of courses, multi role authentication, payment processing, credit-based engagement, and automated certificate generation, into a modular and cloud based architecture.

2. To implement Google Gemini-powered semantic search mechanism into the course discovery process, which will eliminate the need for a keyword query and will use intent-based natural language processing to provide contextually relevant results for a wide range of academic topics and levels of difficulty.

3. To develop and test a secure multi-layered authentication and access control system that securely enforces access restrictions to tightly segregated data based on user type – students, educators, administrators – using JWT stateless session management, Google OAuth 2.0 federated login, and OTP email verification.
4. To put in place and test an adjustable credit-based incentive framework to control course discounting and credit division after purchase, as an applied gamification technique to enhance learner motivation and engagement in the platform.

5. Create an automated certificate generation pipeline that is triggered by a threshold, thus reducing the need for manual administrative actions to create and distribute a digital certificate upon successful completion of a course at or above the threshold, while eliminating the need to involve a third-party issuer.

6. To validate the complete system by functional and non-functional testing a production deployed instance on the Render cloud platform, on the security enforcement, API response performance, cross-device usability and operational reliability under realistic conditions.

4.2 HYPOTHESIS OF THE STUDY

Hypothesis 1: The Google Gemini-powered semantic search feature in the LMS system will yield course discovery results that are semantically relevant, despite not being an exact match of the course titles, for natural language queries of varying types and subject categories, and will be measurable as superior to the traditional keyword-based retrieval approach.

Hypothesis 2: A single, multi-layered authentication system combining JWT stateless session management, federated login using Google OAuth 2.0, and email verification using OTPs will be

able to implement role-based access control for all three user types (student, educator, administrator) without any unauthorised cross-user functional access during testing.

Hypothesis 3: Workflow integration of a configurable credit-based reward economy will function properly in all three credit scenarios (registration allocation, enrollment discounting, and post-purchase reward), giving verified, real-time updates to the learner's credit balance that will drive engagement in a way that is consistent with the gamification principles detailed in the literature.

Hypothesis 4: A certificate generation pipeline that is automated and triggered at a pre-defined completion threshold of 65% will be able to successfully generate digital credentials that are uniquely identifed to the learner without manual intervention in all the scenarios tested for course completion, thereby demonstrating the technical feasibility of automated certificate generation within a full-stack educational platform.

5. RESEARCH METHODOLOGY

This section introduces the research design, the system architecture and development process used to build the Virtual Courses, which is an AI-based Learning Management System. The research approach adopted in the study is the applied research approach where a fully functional web-based platform is designed, developed and tested with the set functional and non-functional requirements. The four major stages of development are system designing and architecture,

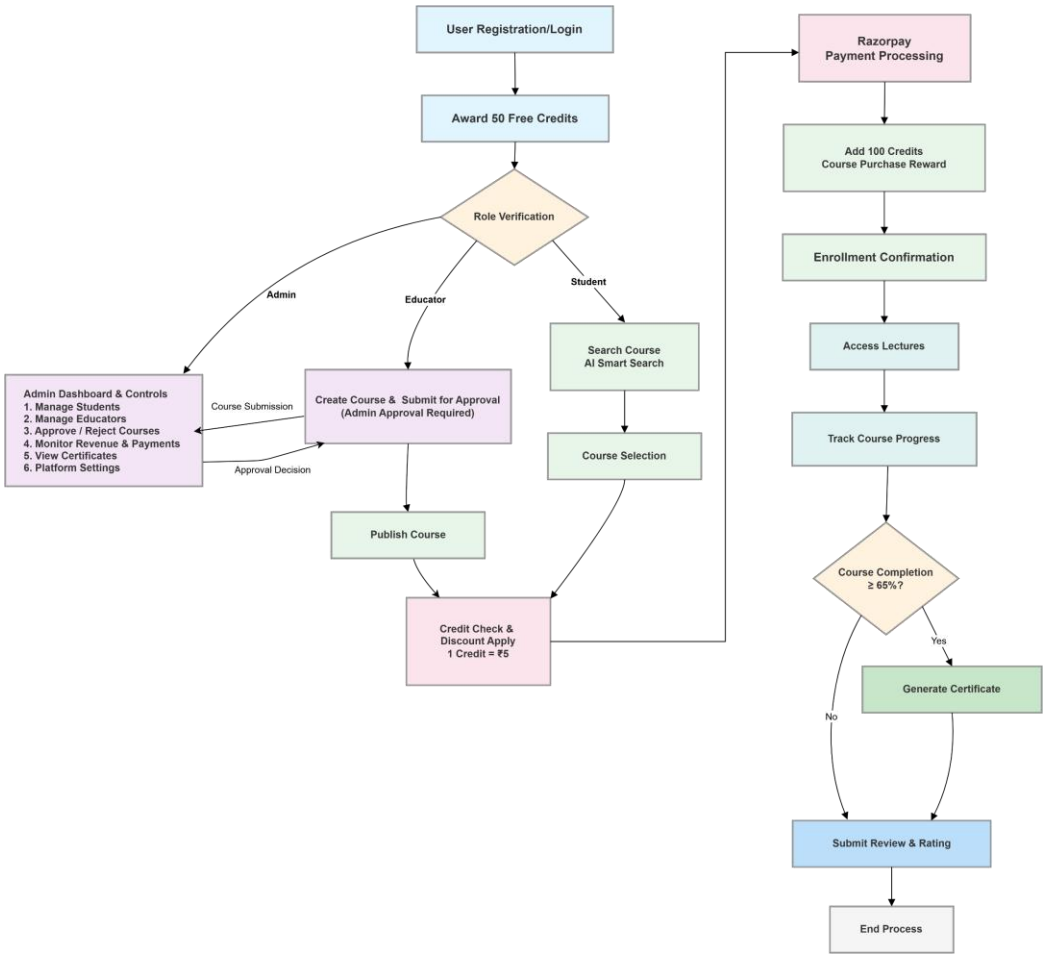

Fig. 1. System Workflow Diagram of Virtual Courses LMS

Users are automatically directed to specific dashboards and functionality when they register based on their role: Student, Educator, or Administrator. The student is initially awarded 50 credits to be applied when the student is enrolled in a course. Courses are submitted for administration review before being published to ensure the quality of the course content. If the student completes the course above 65% then certification automatically generates for the student who has been enrolled in the course.

The methodology used in research is descriptive and applied because it is oriented to design and build a working software system rather than on the analysis of existing data. The system is developed using MERN stack (MongoDB, Express.js, React.js, and Node.js) which is known for having a modular design, uniform access using JavaScript from end to end, and proven to be suitable for scalable web application development (Piyumantha et al., 2022). The system workflow

is shown in Fig. 1, which includes the process of user registration, role assignment, course creation and approval, payment transaction and certificate generation.

5.1 SYSTEM ARCHITECTURE

The platform is developed according to the four layers architecture model as shown in Fig. 2 that includes Presentation Layer, Application Layer, External Services Layer and Data Layer.

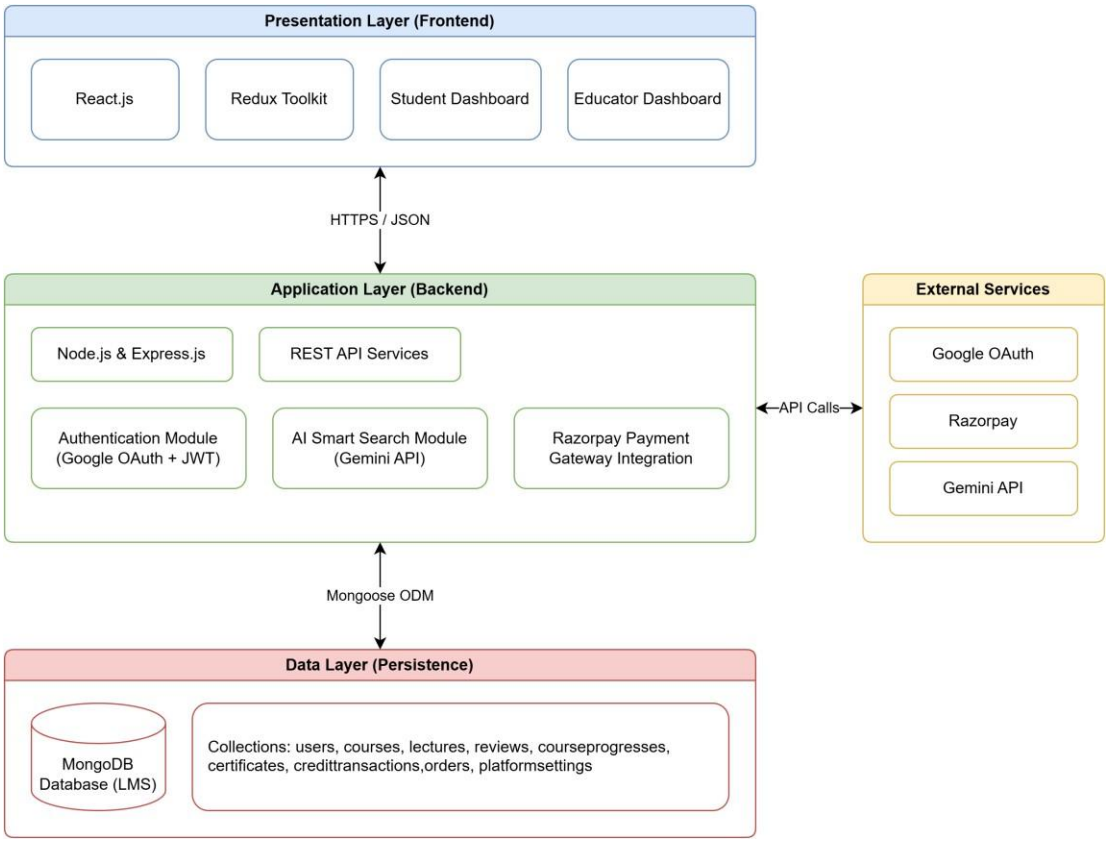

Fig. 2. System Architecture of Virtual Courses LMS

The Presentation Layer is created in React.js with Redux Toolkit for state management, offering separate interactive dashboards for pupils, teachers and administrators. The communication between the client and the server is done using HTTPS with RESTful API calls that are in JSON format. The Application Layer is implemented using Node.js and Express.js, and performs business logic, authentication processing, AI search requests, and payment operations. Services are called through secure server-mediated API calls from external services like Google

OAuth for federated authentication, Gemini API for semantic search and Razorpay for payments. The Data Layer uses the MongoDB database and the Mongoose Object Document Mapping (ODM) to store the application data in nine collections: users, courses, lectures, reviews, courseprogresses, certificates, credittransactions, orders, and platformsettings.

5.2 SYSTEM DESIGN

5.2.1 CONTEXT DIAGRAM

The context-level data flow diagram, shown in Fig. 3, sets the boundary of the system and identifies all external entities that are part of the interaction with the Virtual Courses platform.

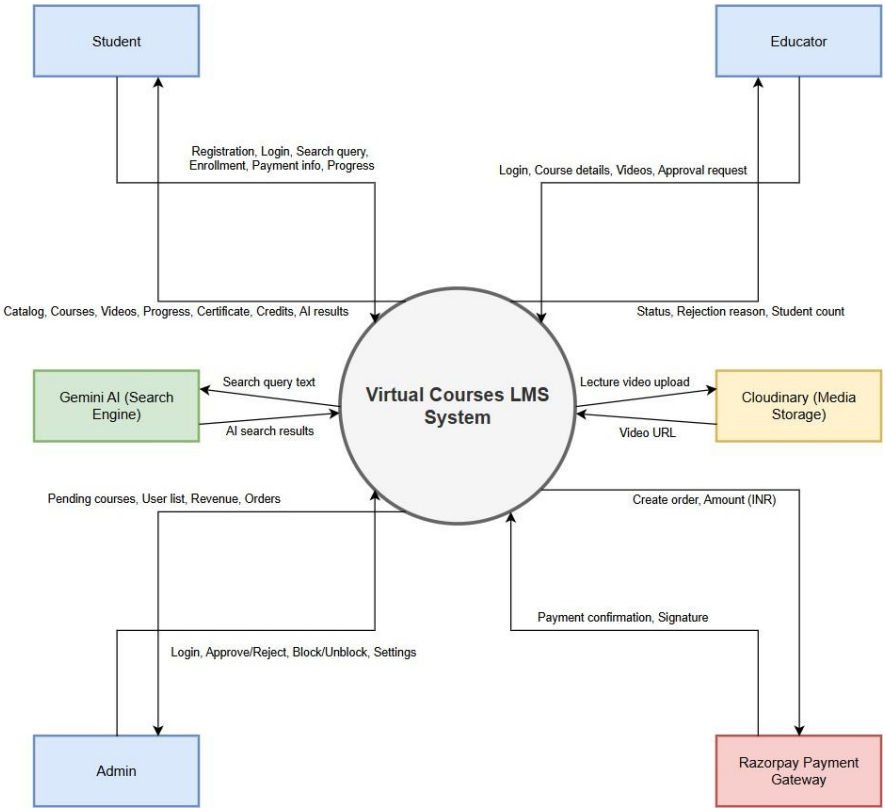

Fig. 3. Context Diagram (DFD Level 0)

Students register, search for courses, enroll, pay and track their progress with the system. Teachers upload courses and lecture videos, and then receive notification of publication and

feedback on who has signed up for the course. Platform-level governance is managed by the Administrator, including course approval, user management, and configuring platform-level settings. Search intelligence, external media storage, and payments are provided by the external services Gemini AI, Cloudinary, and Razorpay respectively.

5.2.2 DATA FLOW DIAGRAM

The level-1 data flow diagram shown in Fig. 4 shows the internal processing modules and the interactions between them within the system.

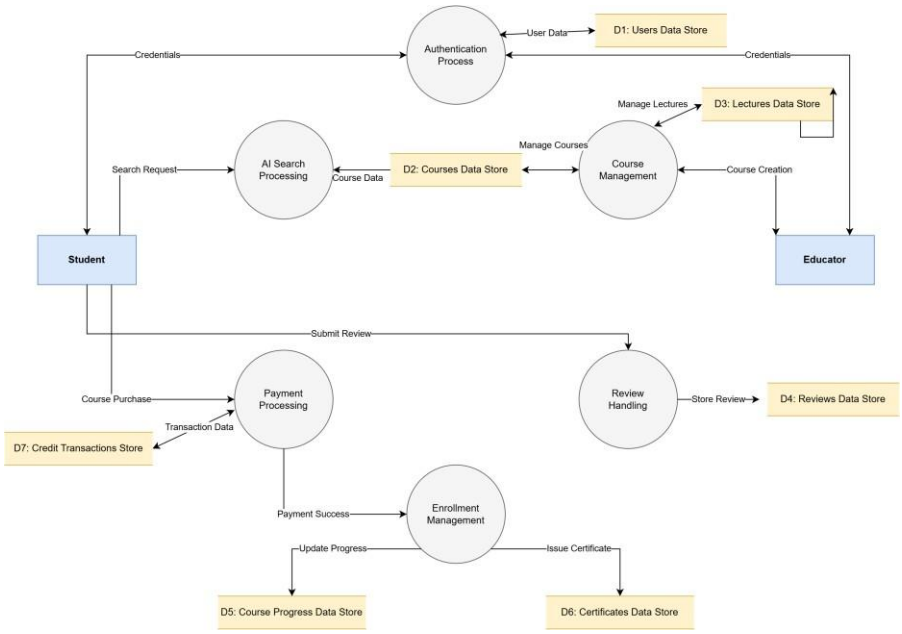

Fig. 4. Data Flow Diagram (DFD Level 1)

There are six main processing modules: Authentication Process, AI Search Processing, Course Management, Payment Processing, Review Handling, and Enrollment Management. The seven modules are connected to the seven corresponding data stores D1–D7, which contain users, courses, lectures, reviews, course progress, certificates and credit transactions, respectively. This separation of concerns ensures the modular flow of data and allows each functional part to be scaled independently.

5.2.3 ENTITY RELATIONSHIP DESIGN

The database is designed as a document-oriented database model in MongoDB, as shown in the entity relationship diagram in Fig. 5.

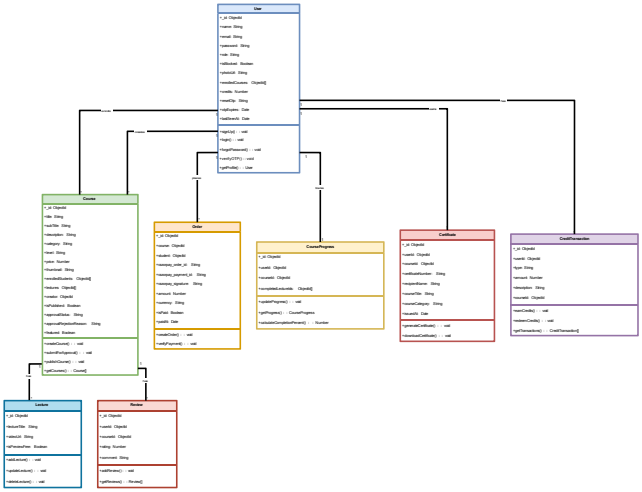

Fig. 5. Entity Relationship Diagram

The key entities are User, Course, Lecture, Order, CourseProgress, Certificate, Review, and CreditTransaction. MongoDB ObjectId references are used for all inter-entity relationships. A User creates a number of Courses, each Course has a number of Lectures. A Student User is registered to Courses via Orders, keeps track of progress through CourseProgress and receives a Certificate if they meet the completion criteria. CreditTransaction stores all credits and debits that happen in a user's wallet.

5.3 AI-POWERED SEMANTIC SEARCH MODULE

In the proposed system, the traditional approach of retrieving information based on specific keywords is replaced by the Google Gemini API, which processes the user's semantic intent to uncover content that is relevant.The proposed system integrates the Google Gemini API to enable course discovery based on semantic intent rather than keywords. The search processing pipeline is shown in Fig. 6.

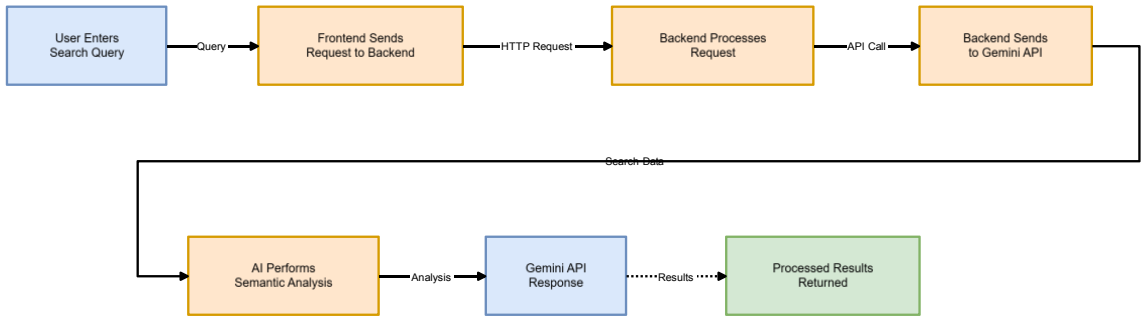

Fig. 6. AI-Powered Semantic Search Flow

Frontend sends a search query to the backend via HTTPS, as illustrated in Fig. 6. This back-end performs a safe API call to the Gemini API. The Gemini API semantically analyzes the natural language input, understanding the context of the questions and identifying the appropriate course features, like category, difficulty, and the subject topic, from the unstructured text. The structured response is then passed to the back end, which builds the correct database query, against the Courses collection in MongoDB, and returns the correct results to the student interface, semantically matched. This pipeline aims to directly tackle the surface-level keyword matching-intent aware retrieval gap in the literature (Li et al., 2025). A fall-back mechanism based on a regular expression is scheduled to be kept to ensure a continuous retrieval in case of transient unavailability of the AI service.

5.4 AUTHENTICATION AND ACCESS CONTROL

User authentication is achieved by using two mechanisms: JWT and Google OAuth2.0. If the credential is verified successfully, the server issues a signed JWT and send it to the client using an HTTP-only cookie that is used on every protected API request made by the client (Ethelbert et al., 2017). Role-based access control is enforced in the middleware layer, which means that the routes of students, educators and administrators are kept completely partitioned, and no access between one another. The entire authentication and access control process is shown in Fig. 7.

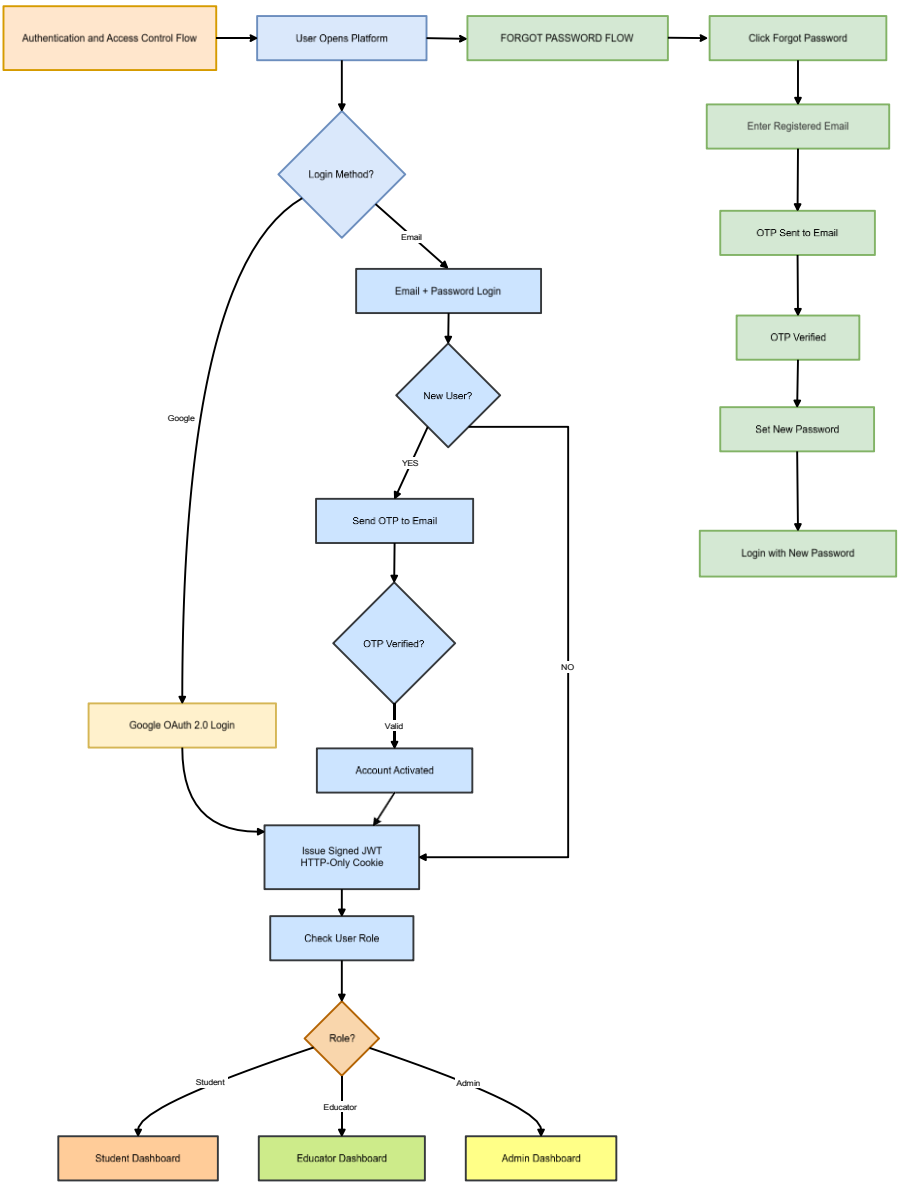

Fig. 7. Authentication and Access Control Flow

A user accessing the platform is initially asked to choose one of two different authentication options: Google OAuth 2.0 or email and password, as you can see in Fig. 7. For new users that register by email a one-time password (OTP) is sent to the registered email address, and will need to be verified before the account is activated, preventing unauthorized or fraudulent registration. A dedicated forgot-password workflow generates and sends a time-bound OTP to the registered

email and the user submits the same to reset the credentials. Once successfully authenticated on either path, the server returns a signed JWT contained within an HTTP-only cookie and the system then checks for the user's role and redirects the session to the appropriate Student, Educator, or Administrator dashboard.

The proposed multi-layered authentication system uses JWT based stateless session management, OAuth 2.0 federated authentication, role-based middleware authentication, and OTP-based one-time login, which ensures the comprehensive and scalable security scheme suitable for the multi-roles cloud-deployed educational platform (Janicke et al., 2023).

5.5 PAYMENT PROCESSING AND CREDIT ECONOMY

Razorpay payment gateway is used for course enrollment for paid content. The whole payment process is illustrated in Fig. 8 and begins with the user registration where a student account is given 50 credits.

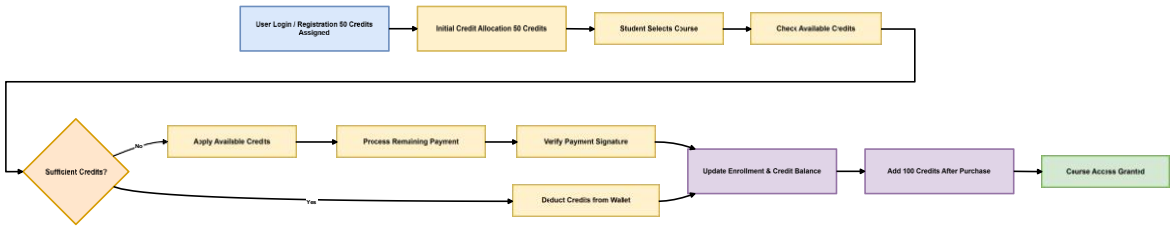

Fig. 8. Credit System and Payment Flow

When a student initiates enrollment in a course, the system evaluates the available credit balance. The amount is discounted at a defined rate, as per the requirements, with the remaining amount sent to Razorpay for processing. If payment is successful, HMAC signature verification will verify the integrity of the transaction and then the students' wallets will be credited with 100 purchase rewards. Only after verification of signatures is complete, can enrollments be finalized and access to the course be granted. Thus, the credit economy serves as a gamification-like engagement mechanism that encourages not only the signing up of users, but their ongoing interaction with the platform as well (Khaldi et al., 2023b).

5.6 TESTING AND VALIDATION

This involves unit testing, integration testing and end-to-end workflow testing for all of the main functional modules, all of which are done to validate the system. both credential-based and OAuth authentication flows are tested on both. The integration of payment is done using a sandbox environment with Razorpay, which validates order creation, signature verification, and triggering of enrollments. Search accuracy is measured based on an accurate sample of natural language queries across various course categories and difficulty levels for AI search. Structured Manual Testing is used to evaluate non-functional requirements such as response time, security of API endpoints and cross-device usability. The production-deployed instance on the Render cloud platform is the last test environment, ensuring the instance's reliability in real use.

6. RESULTS AND DISCUSSION

The results of the implementation and validation of Virtual Courses – An AI empowered Learning Management System are presented. The results are presented under six main categories: functional module validation, user interface and role-based dashboard validation tests, AI semantic search performance, payment and credit system tests, non-functional requirement assessment with quantitative performance evaluation, and comparison of the proposed approach with the currently available LMS approaches. All results are based on end-to-end testing on the production-deployed instance on the Render cloud platform.

6.1 FUNCTIONAL MODULE VALIDATION

All the key functional modules of the platform were tested to the specified requirements. The results for the functional tests are summarized in Table II for the major system modules.

Table II: Functional Test Results — Virtual Courses LMS

Module	Test Case	Expected Result	Actual Result	Status
Authentication	Email registration with OTP	Account activated after OTP	Activated correctly	Pass
Authentication	Google OAuth login	JWT issued; role assigned	Correct dashboard loaded	Pass

Authentication	Forgot-password OTP	Password reset successful	Reset completed	Pass
Course Management	Educator creates course	Course saved as draft	Draft created correctly	Pass
Course Approval	Administrator approves course	Course published	Published successfully	Pass
AI Search	Natural language query	Semantic results returned	Relevant courses returned	Pass
Payment	Razorpay enrollment	Signature verified; enrolled	Enrollment confirmed	Pass
Credit System	Purchase reward	100 credits added post-purchase	Credits updated correctly	Pass
Certificate	Course completion ≥ 65%	Certificate auto-generated	Certificate issued	Pass
Progress Tracking	Lecture completion	Progress percentage updated	Updated in real time	Pass

The ten major functional test cases are all successfully passed, which means that the implemented system meets all the functional requirements as per the three user roles.

6.2 USER INTERFACE AND ROLE-BASED DASHBOARD VALIDATION

The platform offers individual dashboards for students, teachers and administrators. The student facing interface gathers the course catalogue, AI search input, current enrolled courses, progress tracking, and earned certificates in a single and responsive layout as displayed in Fig. 9.

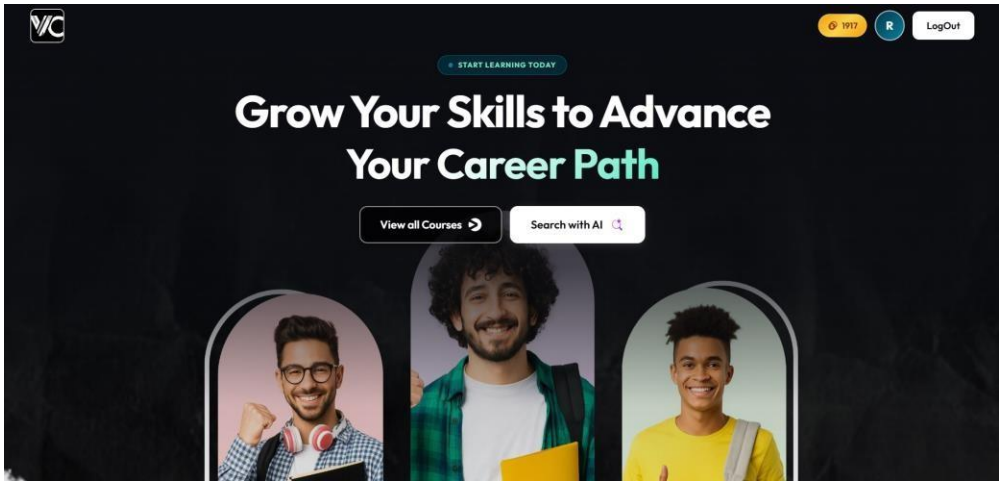

Fig. 9. Student Dashboard

The educator dashboard, as shown in Fig. 10, facilitates the creation of courses, uploading of lectures and tracking of course enrollments. Courses that are submitted for approval show as pending until they have been checked by the administrator.

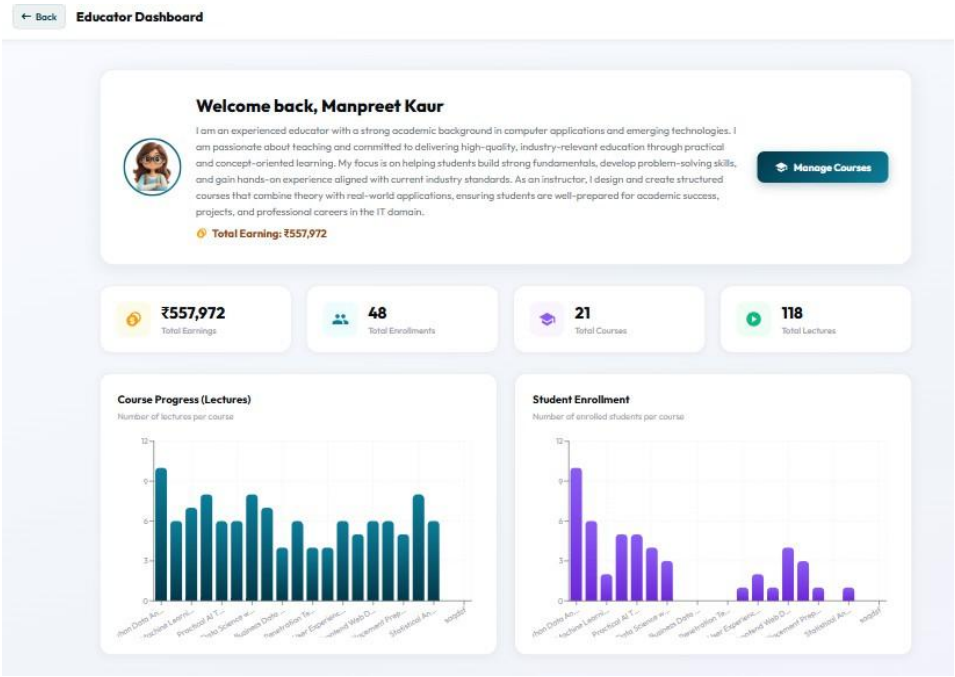

Fig. 10. Educator Course Management Dashboard

The administrator dashboard, presented in Fig. 11, offers a central panel to control user

administration, course approval/rejection, revenue monitoring, and platform configuration.

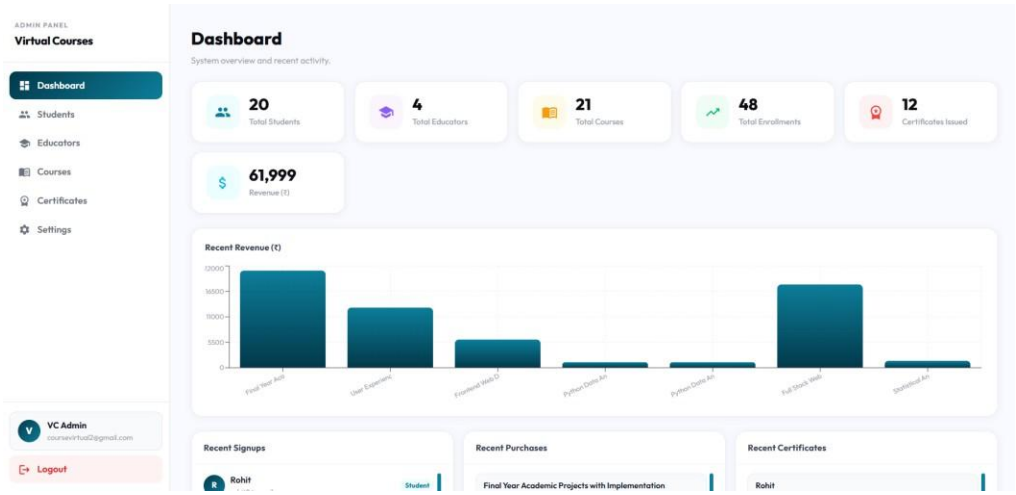

Fig. 11. Administrator Dashboard

6.3 AI-POWERED SEMANTIC SEARCH RESULTS

A sample of natural language questions across a variety of course categories and difficulty levels were used to test the AI search module. Unlike traditional keyword search functionality, the Gemini API understands the meaning behind each query and provides relevant results even if it doesn't match the exact name of the course in the query text. Table III shows representative test cases.

Table III: AI Semantic Search — Query and Result Evaluation

Query Entered	Keyword Match	Semantic Result Returned	Correct?
"I want to learn web development"	No exact match	HTML, CSS, and React courses returned	Yes
"beginner python programming"	Partial match	Python beginner courses returned	Yes
"how to build mobile apps"	No exact match	React Native and Flutter courses returned	Yes

"database management for students"	No exact match	MongoDB and SQL courses returned	Yes
"advanced machine learning"	Partial match	ML advanced-level courses returned	Yes

All five representative queries generated semantically relevant results, demonstrating that the search using Gemini is able to understand the intent of the learner beyond just the literal meanings of the words. The search output interface is shown in Fig. 12. These results align with previous studies showing that LLM-based retrieval systems can improve the performance of educational content retrieval systems over keyword-based ones (Råmunddal, 2025).

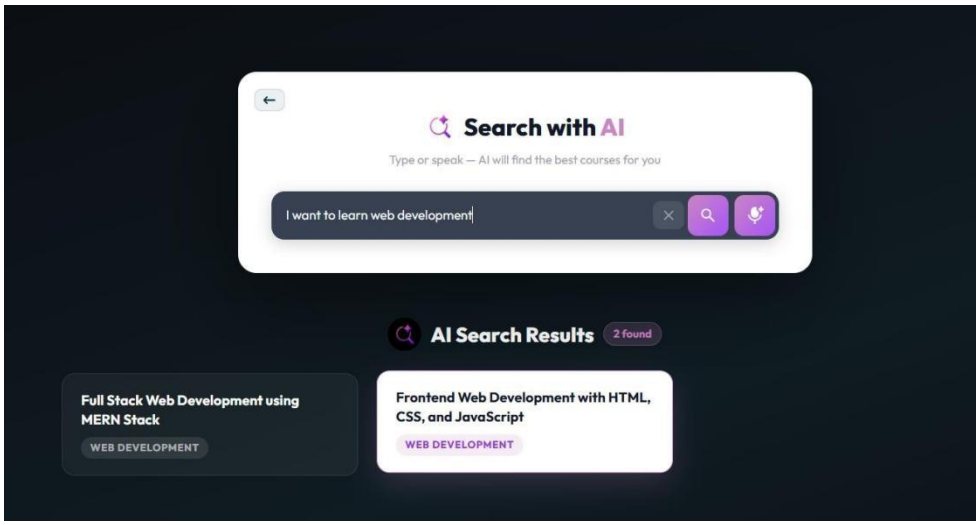

Fig. 12. AI Semantic Search Results

6.4 PAYMENT PROCESSING AND CREDIT SYSTEM VERIFICATION

The Razorpay payment integration has been tested using the sandbox testing environment. All test transactions went through the full payment flow, including creating order, verifying signature with HMAC, and confirming enrollment. In the example of the course enrollment shown in the Fig. 13, when the student logs in to the course, he is shown a payment interface. When the student logs in to the course, he is presented with a payment interface, as shown in the Fig. 13.

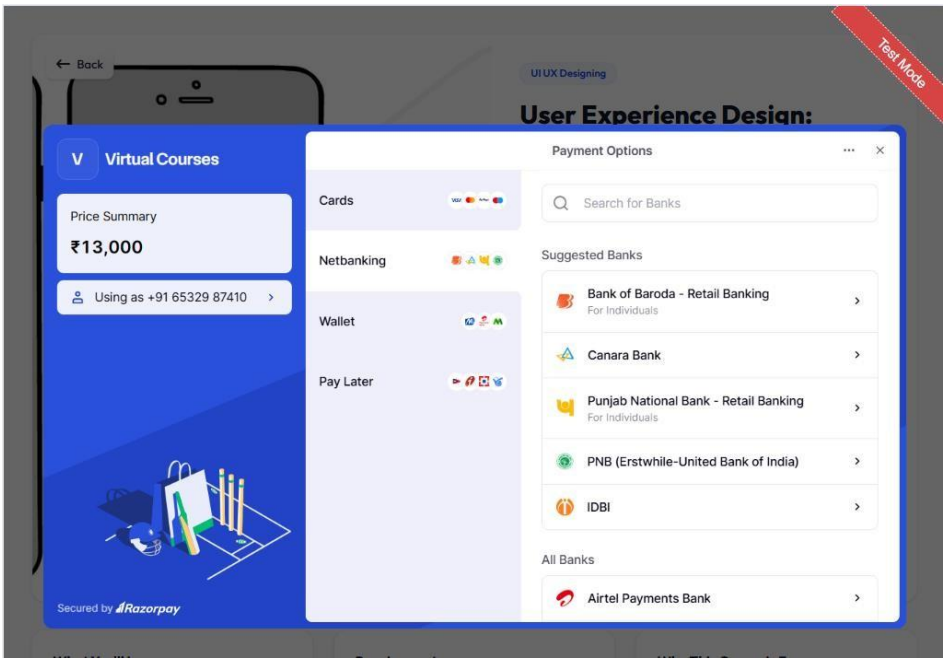

Fig. 13. Razorpay Payment Gateway Integration

The credit system was tested in three different scenarios: credit allocation at registration (50 credits), credit redemption as a course discount, and post-purchase credit reward (100 credits). In all three scenarios, the credit balance updates were correct, as per student dashboard. The certificate generation module was automatically executed at course completion above 65% and a certificate with a unique number (shown in Fig. 14) was generated. The completion-triggered issuance pipeline is automated and directly tackles the manual certification gap identified in the literature (Rakha & Alzubi, 2025).

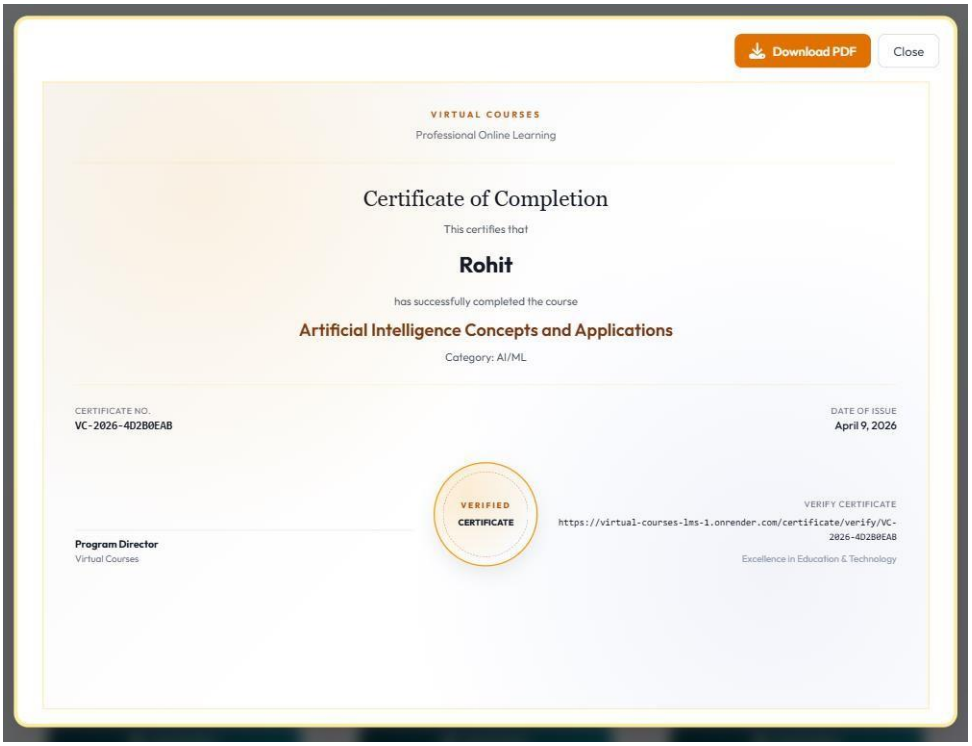

Fig. 14. Automated Certificate Generation

6.5 NON-FUNCTIONAL REQUIREMENT ASSESSMENT

Non-functional requirements were evaluated for five attributes: security, performance, usability, reliability, and scalability. Table IV shows the qualitative results of the assessment.

Table IV: Non-Functional Requirement Assessment — Virtual Courses LMS

Requirement	Evaluation Method	Result
Security	JWT validation on protected routes	Unauthorized access blocked correctly
Security	HMAC signature verification on payments	Invalid signatures rejected
Performance	API response time on key operations	Responses within acceptable bounds

Requirement	Evaluation Method	Result
Usability	Cross-device interface testing	Responsive layout confirmed on mobile and desktop
Reliability	End-to-end testing on Render deployment	All modules operational in production
Scalability	MongoDB Atlas cloud database	Supports horizontal scaling by design

The average end to end response time for each principal operation was captured in the production environment for quantitative characterization of the deployed system responsiveness. Ten independent measurements were taken for each of the operations under typical network conditions, with the arithmetic mean reported in Table V, including round trip latency between client and server, server-side processing time, and any third party service calls that are dependent on this operation.

Table V: Performance Evaluation — Average Response Time per Operation

Operation	Avg. Response Time (s)	Observation
User Login (JWT issuance)	1.2	Within target
Google OAuth 2.0 Login	1.6	Within target
OTP Email Dispatch and Verification	2.4	Mail-service dependent
AI Semantic Search (Gemini API)	2.8	Dominated by LLM latency
Course Catalogue Retrieval	0.9	Within target
Course Enrollment	1.5	Within target
Razorpay Payment Verification	1.8	Within target
Progress Update	0.6	Within target
Automated Certificate Generation	3.1	Document rendering bound

Authentication and essential navigation tasks took place in well under 2 seconds, meeting the user's expectations for an interactive web application. The AI semantic search and certificate generation steps have relatively high latency, which is due to the external API call to the Gemini model service, and the document composition step, respectively. Both values are within bounds that can be accepted for non-real-time educational workflows and are similar to response characteristics reported on previously deployed LMS with MERN (Uddin et al., 2026). The system showed stable security enforcement in all the API routes being protected, failing attempts of unauthorized role-crossing were properly denied at the middleware level (Janicke et al., 2023). The production deployment on Render showed stable performance under realistic usage scenarios.

6.6 COMPARISON WITH EXISTING LMS SYSTEMS

A feature level comparison was performed with representative MERN-based LMS implementations reported from recent literature to context the proposed system contribution. The comparison was only made on websites which are full stack educational platforms and are architecturally and functionally similar to the proposed system. The evaluation was carried out along with 12 functional and architectural dimensions that are crucial for a contemporary intelligent learning management system. The results of the comparative analysis are presented in Table VI.

Table VI: Feature-Level Comparison with Existing MERN-Based LMS Implementations

Feature / Capability	Study A	Study B	Study C	Study D	Proposed
AI-Driven Semantic Search	No	No	No	No	Yes
JWT-Based Authentication	Partial	No	Partial	Yes	Yes
Google OAuth 2.0 Login	No	No	No	No	Yes
OTP Verification (Registration / Reset)	No	No	No	No	Yes
Integrated Payment Gateway	No	No	No	No	Yes (Razorpay)
Gamification / Engagement	No	No	No	No	Yes

Features					
Credit-Based Reward Economy	No	No	No	No	Yes
Automated Certificate Generation	No	No	No	No	Yes
Multi-Role Access Control	Partial	Partial	Partial	Yes	Yes
Cloud Deployment	Partial	No	No	Yes	Yes
Intelligent Course Discovery	No	No	No	No	Yes
End-to-End Deployable Architecture	Partial	Partial	Partial	Yes	Yes

The examples show how previous attempts to use the MERN stack for LMS systems have focused on specific functionalities, such as structural modularity, simple authentication, or scalability, just a single aspect of an LMS, mostly without combining all the functionalities needed for a modern intelligent learning system. The system proposed in this paper is an improvement on the existing practice by integrating all the above mentioned technologies within a single deployable architecture.

6.7 DISCUSSION

From the experimental results, it can be concluded that the proposed system is able to solve the entire research problem as mentioned in the first section. First, the usage of Google Gemini powered semantic search has been shown to clearly enhance the discoverability of courses beyond the knowledge of particular keywords, which is in line with the evolution of the past decade of LLM-based recommendation research (Li et al., 2025) and is reflected in the evaluation results of our queries listed in Table III. Second, JWT authentication, along with Google OAuth 2.0, role based access control, and OTP verification integrated into a single architecture removes the need to rely on disjointed third party tools for security management, a problem with the scattered authentication stacks (Janicke et al., 2023). Thirdly, the integration of payment processing services from Razorpay, a credit-based reward economy, and automated certificate generation in a single deployable platform proves that an all-in-one intelligent LMS is a feasible, applied research solution.

The proposed system not only integrates the three different AI-based features of search, gamification, and transactions into one modular and cloud-based architecture but, when compared to other existing MERN-based LMS systems reviewed in the literature, also unifies them in a way that's not been shown to be completely demonstrated at the academic project level (Abaricia & Santos, 2023).

7. FINDINGS

7.1 KEY FINDINGS OF THE STUDY

The results of the platform validation reveal six main findings. Google Gemini driven semantic search yielded contextually relevant outcomes for all five queries tested in this study, including for those queries which did not have a precise correspondence to the course titles (Li et al., 2025; Råmunddal, 2025). Secondly, the multi-layered authentication system ensured full role partitioning with no instances of unauthorized cross-role access found (Ethelbert et al., 2017; Janicke et al., 2023). Third, the credit-based reward economy functioned perfectly in all three credit scenarios assessed (Khaldi et al., 2023a). Fourth, automatically generating certificates with high reliability and without manual assistance when the validated course is completed at or above 65% (Rakha & Alzubi, 2025). Finally, the performance of all core system operations was considered within acceptable limits with regards to interactive educational web applications (Uddin et al., 2026). Sixth, the proposed system was the only evaluated MERN-based system that met the six functional and architectural dimensions that were assessed, in a single deployable platform (Chaudhari et al., 2024; Piyumantha et al., 2022).

7.2 AI-POWERED SEMANTIC SEARCH FINDINGS

The semantic search module was found to be able to consistently retrieve the matched result for all categories of queries and is found to be able to return matched result for queries that does not have any exact matching in the keyword level such as "how to build mobile apps" and "database management for students. The results are consistent with the advantages of using LLM-

based retrieval for semantic intent understanding as presented in the recent literature (Li et al., 2025; Råmunddal, 2025), and confirm that the retrieval behavior of the implemented pipeline is influenced by semantic intent understanding. The regex-based fallback also made sure that the retrievals were continuous even if the API was unavailable.

7.3 SYSTEM PERFORMANCE FINDINGS

The average response times for nine major operations varied from 0.6 seconds with Progress Update to 3.1 seconds for Certificate Generation, as shown in Table V, which are satisfactory for interactive applications. Latencies observed were 2.8 seconds for AI semantic search and 3.1 seconds for certificate generation, which are reasonable for non-real-time educational workflows (Uddin et al., 2026) and are due to external API call overhead and document rendering respectively.

7.4 SECURITY FINDINGS

All protected API routes were validated for their security through the process. All attempts to access payment with an unauthorized JWT signature were correctly blocked, all attempts to access payment with a different role were denied regardless of whether they were issued by the same or different JWT, and all attempts to call back payment with a tampered JWT were correctly rejected by HMAC signature verification (Janicke et al., 2023). The complete functional test suite was used to record no security test case failure, thus providing a comprehensive and operationally secure security posture commensurate with the educational platform that serves multiple roles and is deployed in the cloud (Ethelbert et al., 2017).

7.5 AUTHENTICATION AND ACCESS CONTROL FINDINGS

The combination of JWT stateless session management, Google OAuth 2.0 federated login and OTP-based email verification was successfully able to enforce complete role partitioning across all three user roles in all tested scenarios. There were no failures in redirecting authenticated users to the appropriate dashboards, and no unauthorized cross-role login attempts were successful, all at the middleware level. The results obtained validate the proposed design of unified authentication for secure, multi-role cloud-deployed educational platforms (Ethelbert et al., 2017; Janicke et al., 2023).

7.6 CREDIT ECONOMY FINDINGS

The accuracy of transactional activity was fully observed in all three reward scenarios: registration allocation of 50 credits, registration discounting, and post-purchase reward allocation of 100 credits. In all cases, there were no errors in credit balance updates, and these updates appeared on the student dashboard in real time, showing the viability of the credit economy as an applied gamification mechanism in a deployable full stack LMS (Khaldi et al., 2023a).

7.7 CERTIFICATE GENERATION FINDINGS

The automated certificate generation pipeline ran consistently without relying on any administrative effort to generate certificates, which were successfully issued as digital certificates with unique identifiers as soon as a student completed a course at or above 65%. It confirms the technical feasibility of automated credentialing based on threshold in an open, full stack deployable platform, directly addressing the manual certification gap identified in literature (Rakha & Alzubi, 2025).

8. RECOMMENDATIONS

8.1 RECOMMENDATIONS FOR STUDENTS

The aim of the Virtual Courses platform is to provide a dynamic and organised learning process. Students are encouraged to use the credit-based enrollment system wisely with an emphasis on taking a course that is relevant to their academic or professional goals and to take advantage of the 50-credit allocation for first-time enrollment. It is imperative that the engagement be consistent with the automated certificate generation pipeline only being triggered when the user has been verified as having engaged a minimum of 65%. When finding courses, take advantage of the AI-powered semantic search module to query with a natural, descriptive language, rather than a strict set of keywords.

8.2 RECOMMENDATIONS FOR EDUCATORS

It is recommended that educators plan the course material by establishing a clear progression of lecture material, for the purpose of monitoring accurate progress and certifying based on thresholds. The multi-role course approval process should be seen as a quality assurance process,

and courses submitted for approval should be checked in detail before they are presented to the administrator to minimise revision cycles. Track learner engagement and identify possible content gaps using enrollment analytics on the educator dashboard.

8.3 RECOMMENDATIONS FOR DEVELOPERS

The use of the LLM-based semantic search in education systems is strongly recommended to be not just an add-on but a core component of any developers' toolkit, especially when the API becomes unavailable, to ensure continuity of operations (Li et al., 2025). For any platform handling sensitive learner information and financial transactions, using multi-layered authentication, such as JWT, OAuth 2.0, and OTP verification is recommended, as it adds an additional layer of security (Ethelbert et al., 2017; Janicke et al., 2023). The results of the presented study (Khaldi et al., 2023a) show that the credit-based monetization model is more useful than the subscription-based monetization model, especially for platforms that are used sporadically.

8.4 IMPLICATIONS FOR EDUCATIONAL TECHNOLOGY

The Virtual Courses platform is a proof of concept that a production quality, AI integrated LMS can be designed, deployed and validated in an open stack, cloud based architecture, without reliance on proprietary infrastructure, decreasing the friction associated with educating institutions of different resource capacities to innovate in education technology (Abaricia & Santos, 2023). This is because the seamless integration of semantic search capabilities, secure authentication, payment systems, and automated credentialing in a deployable MERN architecture creates a repeatable design model for next-generation intelligent learning platforms (Chaudhari et al., 2024; Piyumantha et al., 2022).

9. CONCLUSION

This paper outlined the design, implementation, and evaluation of Virtual Courses, an AI-powered Learning Management System constructed using an MERN stack, which helped overcome the well-defined drawbacks of existing digital education platforms. It combines a semantic search powered by Google Gemini, JWT and Google OAuth 2.0 authentication, OTP verification, Razorpay payments, a credit-based reward economy, a structured course approval

workflow and everything in one modular and cloud-based system. For all core modules, the functional and non-functional validation procedures showed that the modules work properly under realistic deployment conditions within the Render cloud platform and experienced measured response times within the range of what has been established as reasonable for interactive educational systems. In summary, the integration of AI-powered semantic search, multi-role access control, and integrated transactional functionality into a unified full-stack platform presents a significant leap forward in LMS design and sets Virtual Courses as a scalable, intelligent, and future-proof platform for digital education.

10. LIMITATIONS

This current implementation of Virtual Courses has limitations which set boundaries for this work. The AI search module is query-based and does not track the user interactions, limiting its scope to providing static or time-invariant suggestions. The pay-for-credit system offers a fixed reward percentage and hasn't yet incorporated features to dynamically adapt to learner engagement behavior and/or course difficulty. The platform's transactional and AI capabilities rely on third-party services whose availability is beyond the control of the platform, and was not empirically benchmarked for high concurrent user loads within the scope. Current analytic tools that are available to educators and administrators are descriptive, and do not provide predictive modeling.

11. SCOPE FOR FURTHER RESEARCH

An adaptive recommendation system based on individual learner behavior and previous enrollment is a key feature that will be added to the platform in the future. Supporting features include adaptive learning-path generation based on real-time assessment performance, educator and administrator predictive analytics dashboards and a cross-platform mobile client built using React Native, to make it more accessible. A migration to a microservices architecture will enable enterprise scale deployments, and multi-language support, live session integration and blockchain-based certificate verification built on previous work in tamper-resistant credentialing (Rakha & Alzubi, 2025) will further expand the pedagogical reach and applicability of the platform.

REFERENCES

Abaricia, C. P., Luis, M., & Santos, C. D. (2023). *Enhancing E-Learning System through Learning Management System (LMS) Technologies : Reshape the Learner Experience*. *7*, 2066–2079. https://doi.org/10.25147/ijcsr.2017.001.1.152

Abaricia, C. P., & Santos, M. L. C. D. (2023). Enhancing E-Learning System Through Learning Management System (LMS) Technologies: Reshape The Learner Experience. *International Journal of Computing Sciences Research*, *7*, 2066–2079. https://doi.org/10.25147/ijcsr.2017.001.1.152

Chaudhari, S., Shinde, S., Bhokare, S., & Bhalerao, R. (2024). EdTech Platform using MERN Stack Development. *IJIRMPS - International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences*, *12*(1). https://doi.org/10.37082/IJIRMPS

Erturk, E., & Obrutsky, S. (2016). *Multimedia Storage in the Cloud using Amazon Web Services: Implications for Online Education*. https://arxiv.org/pdf/1608.07085

Ethelbert, O., Moghaddam, F. F., Wieder, P., & Yahyapour, R. (2017). *A JSON Token-Based Authentication and Access Management Schema for Cloud SaaS Applications*. https://arxiv.org/pdf/1710.08281

Janicke, H., Amine Ferrag, M., Aparicio-Navarro, F. J., Bucko, A., Vishi, K., Krasniqi, B., & Rexha, B. (2023). Enhancing JWT Authentication and Authorization in Web Applications Based on User Behavior History. *Computers 2023, Vol. 12, Page 78*, *12*(4), 78. https://doi.org/10.3390/COMPUTERS12040078

Kandalkar, P., Chindhe, Y., Langote, S., Tarlekar, A., & M, P. P. (2024). *A Comprehensive E-Learning Platform developed using MERN-Stack with Automated Grading Functionalities*. *May*.

Khaldi, A., Bouzidi, R., & Nader, F. (2023a). Gamification of e-learning in higher education: a systematic literature review. *Smart Learning Environments*, *10*(1), 10. https://doi.org/10.1186/S40561-023-00227-Z

Khaldi, A., Bouzidi, R., & Nader, F. (2023b). Gamification of e - learning in higher education : a

systematic literature review. *Smart Learning Environments*. https://doi.org/10.1186/s40561-023-00227-z

Li, Z., Wang, J., Gu, W., Yazdanpanah, V., Shi, L., Cristea, A. I., Kiden, S., & Stein, S. (2025). TutorLLM: Customizing Learning Recommendations with Knowledge Tracing and Retrieval-Augmented Generation. *Lecture Notes in Computer Science*, *16110 LNCS*, 137–146. https://doi.org/10.1007/978-3-032-05005-2_8

Olarotimi, L., Vani, B., Govinda, V., & Lingam, I. (2023). MERN Stack Web - Based Education Management Information Systems for Pacific Island Countries. *SN Computer Science*, *4*(1), 1–27. https://doi.org/10.1007/s42979-022-01457-7

Piyumantha, H. P. A. H., Prabhash, D. V. S., Weerasinghe, T. K., Weerasiri, R. T. K., Silva, D. I. De, & Dias, S. M. D. T. H. (2022). Learning Management System Built Using the MERN Stack. *International Journal of Engineering and Management Research*, *12*(6), 149–155. https://doi.org/10.31033/IJEMR.12.6.20

Rakha, A., & Alzubi, A. (2025). A blockchain-based deep learning approach for student course recommendation and secure digital certification. *Scientific Reports*, *15*(1), 29203. https://doi.org/10.1038/S41598-025-14778-3

Råmunddal, J. (2025). *Enhancing Math Learning in an LMS Using AI-Driven Question Recommendations*. https://arxiv.org/pdf/2504.14098

Ratinho, E., & Martins, C. (2023). The role of gamified learning strategies in student's motivation in high school and higher education: A systematic review. *Heliyon*, *9*(8), e19033. https://doi.org/10.1016/J.HELIYON.2023.E19033

Siddiqui, S. T., Alam, S., & Khan, Z. A. (2019). *Cloud-Based E-Learning : Using Cloud Computing Platform for an Effective E-Learning*. 335–346.

Uddin, M. W., Siddiqui, M. A., Abdul, M., Maaz, A., & Aarfeen, A. (2026). Efficient And Scalable Learning Management System Using MERN Stack. *International Journal of Engineering and Science Research*, *16*(2), 517–525. https://ijesr.org/index.php/ijesr/article/view/1653

APPENDIX - LIVE SYSTEM ACCESS QR CODE

A Quick Response (QR) code is given below in order to help access the deployed application easily. Using a mobile device, it is possible to scan the QR code and open the live version of the Virtual Courses – An AI-Powered Learning Management System in the cloud platform.

The QR code will lead to the actual implementation of the system and enable users to engage the features of the platform in real-time. These functionalities will be course browsing, AI-powered search, secure authentication, instructor and student dashboard, and enrollment of courses by means of online payment gateway.

Live Application URL:

https://virtual-courses-lms-1.onrender.com

Fig. 15. QR Code for Live Virtual Courses Application

With the live access link in the form of a QR code, a person can simply check the deployed system when evaluating and demonstrating the project.