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LearnHub: A Gamified Web-Based E-Learning Platform with Interactive Assessments

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Abstract: ***LearnHub is a comprehensive, gamified web-based e-learning platform specifically designed to support engineering students across multiple academic branches and years of study. Developed using PHP, MySQL, JavaScript, jQuery, and Three.js, the platform delivers structured academic content organized within a hierarchical curriculum model encompassing Branch, Year, Subject, Unit, Topic, and Sub-topic levels. Beyond conventional note delivery, LearnHub integrates four interactive educational games — Holo-Flash, Cyber-Decipher, Speed Strike, and Sys-Architect — along with competitive problem-solving challenges, subject-specific quizzes with automated digital certificate generation, and a daily streak-based engagement system. The platform includes a comprehensive administrator dashboard for content management, supports multi-format document uploads with automatic text extraction, and provides AJAX-powered real-time search. Evaluation results demonstrate that the integrated gamification elements significantly improve student engagement and academic motivation compared to conventional static e-learning portals.***

Keywords: E-Learning, Gamification, Web Application, PHP, MySQL, Three.js, Learning Management System, Interactive Assessment, Certificate Generation, Engineering Education

I. INTRODUCTION

The rapid advancement of information and communication technology (ICT) has significantly transformed the landscape of modern education. E-learning platforms have emerged as essential tools for delivering structured academic content, particularly in engineering education where students require access to comprehensive, hierarchically organized knowledge spanning diverse technical subjects. However, many existing platforms suffer from critically low student engagement owing to the absence of interactive elements, inadequate feedback mechanisms, and a complete lack of motivational design patterns.

Research consistently indicates that gamification — the deliberate integration of game-design elements into non-game educational contexts — can substantially improve learner motivation, engagement, and long-term knowledge retention [1][2]. Despite this substantial body of evidence, very few open-source e-learning platforms effectively combine structured content delivery, interactive learning games, competitive problem-solving environments, and behavioral engagement mechanics such as streak tracking within a single, cohesive, and accessible system.

The primary objectives of LearnHub are: (1) to design and implement a full-stack web-based e-learning platform supporting multi-branch, multi-year engineering curricula; (2) to integrate gamification elements including games, daily login streaks, and activity calendars to enhance student engagement; (3) to provide a competitive problem-solving module with per-user progress tracking; (4) to implement automated quiz assessment with digital certificate generation; (5) to develop a comprehensive administrator dashboard for content and user management; and (6) to ensure responsive, mobile-friendly design using modern web technologies.

II. LITERATURE REVIEW

This section reviews existing platforms and research related to e-learning systems, gamification in education, and interactive engagement mechanisms, highlighting the gap that LearnHub addresses.

[1] Deterding et al. established the foundational definition of gamification and demonstrated that integration of game-design elements into non-game contexts significantly improves user motivation and sustained engagement.

[2] Hamari et al. conducted a systematic literature review of empirical gamification studies and confirmed that gamified systems produce measurable improvements in engagement, particularly when challenge, feedback, and reward mechanics are combined.

[3] Wang and Tahir reviewed the use of Kahoot! in educational settings, finding that quiz-based game mechanics improve short-term engagement but are insufficient as standalone learning tools without accompanying structured content.

[4] Huynh et al. analyzed Duolingo's streak and reward mechanics, demonstrating that daily engagement incentives create measurable increases in platform return rates and session consistency.

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[5] Dougiamas and Taylor presented Moodle as a foundational open-source LMS; however, the platform lacks built-in gamification, interactive game modules, and behavioral engagement mechanics.
[6] Landers developed a theory of gamified learning linking serious games to formal instructional outcomes, providing a theoretical basis for integrating game mechanics within structured academic curricula.
Collectively, the reviewed literature confirms that no existing open-source platform unifies hierarchical content delivery, multiple game types, streak-based engagement, competitive problem-solving, and automated certification. LearnHub is designed to fill this gap.

TABLE I
Comparison of Existing Platforms

Platform	Key Features	Limitation	Addressed by LearnHub
Moodle [5]	Open-source LMS, assignments	No gamification or games	Full gamification with 4 game types
Khan Academy	Video-based, progress tracking	No engineering hierarchy	Branch→Year→Subject hierarchy
Kahoot! [3]	Game-based quizzes	No notes or problem-solving	Notes + games + problems unified
LeetCode	Competitive programming	No notes or games	Problem-solving with content delivery
Duolingo [4]	Streak mechanics	Language-only platform	Streaks for engineering education
edX/Coursera	University courses, certs	Costly; no gamification	Free automated certification

III. METHODOLOGY

The development of LearnHub followed a structured software engineering methodology divided into five key phases to ensure correctness, scalability, and usability across all platform modules.

A. Requirement Analysis

The requirement analysis phase identified both functional and non-functional requirements of the system. Functional requirements include user authentication with streak tracking, hierarchical notes delivery with rich text and formula support, four interactive game types, LeetCode-style problem-solving with progress analytics, quiz assessment with automated certification, real-time AJAX search, and a full-featured administrator dashboard. Non-functional requirements encompass system performance, data consistency, security through bcrypt password hashing, mobile responsiveness, and deployment scalability on both local and cloud environments.

B. System Architecture Design

LearnHub adopts a three-tier architecture comprising a client presentation layer, an application logic layer, and a data storage layer. The client browser communicates with the Apache web server through HTTP requests and AJAX calls via jQuery, receiving JSON-formatted responses for dynamic rendering. The PHP application layer processes requests, enforces business logic, validates inputs, and interfaces with the MySQL database through parameterized prepared statements. This layered architecture ensures clean separation of concerns, facilitating independent development, testing, and future extension of each component.

C. Database Design

The relational database schema for LearnHub consists of 12 interrelated tables designed to capture content hierarchies, user progress, assessment records, and engagement metrics. The content hierarchy is represented through branches, years, subjects, and notes tables linked via foreign key relationships. User progress is tracked through the users, user_problems_solved, and problems tables. Assessment data is managed via quiz_attempts, while game engagement is recorded in game_activity. Shared question banks are maintained in game_questions and drag_drop_puzzles. The schema adheres to Third Normal Form (3NF) to eliminate data redundancy and maintain referential integrity.

D. System Flow and Implementation

The operational flow of LearnHub begins with user registration and authentication using bcrypt-hashed passwords. On each login, the system evaluates the streak logic: same-day login leaves the streak unchanged; consecutive-day login increments the streak by one; a gap exceeding one day resets the streak to one. The authenticated user is presented with a personalized dashboard displaying streak status, earned certificates, and recent activity. Content requests are fulfilled via AJAX calls to dedicated PHP API endpoints, which retrieve data from MySQL and return JSON responses for dynamic rendering. All user interactions including game activity, problems solved, and quiz submissions are persisted to the database in real time.

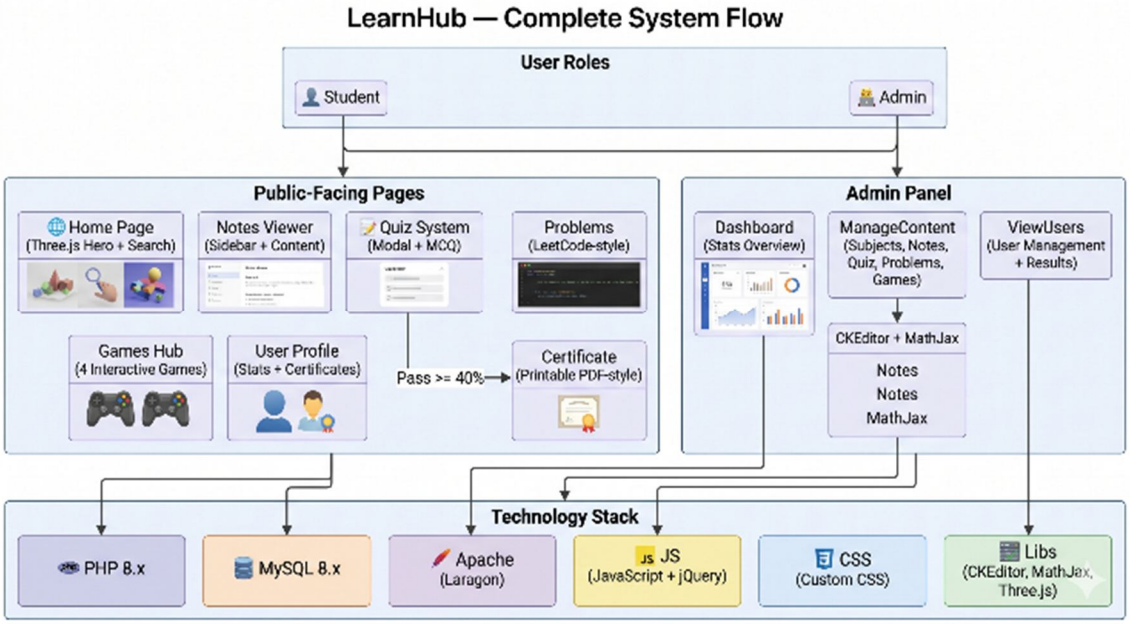

Fig. 1. System Flow Diagram of the LearnHub Platform

E. Testing and Validation

The system was validated through comprehensive functional testing covering all eight core modules: user authentication, notes CRUD, quiz flow and certificate generation, problem-solving with streak calculation, all four game types, real-time search with debounce, admin dashboard CRUD operations, and responsive design across mobile, tablet, and desktop viewports. All test cases passed successfully. Integration testing confirmed correct interaction between the AJAX frontend, PHP API layer, and MySQL database under concurrent access conditions.

IV. MODULES AND IMPLEMENTATION

A. Notes Delivery System

The notes module implements a deep hierarchical curriculum structure organized as Branch → Year → Subject → Unit → Topic → Sub-topic. Rich text content is authored through CKEditor 5 in the administrator panel, supporting formatted text, embedded images, and mathematical formulas rendered via MathJax 3. The module supports multi-format document uploads including PDF, DOCX, and TXT files with automatic text extraction implemented using custom PHP parsers — regex-based extraction for PDFs and ZipArchive-based parsing for DOCX files without any external library dependencies. Users navigate content through Previous and Next topic controls within each unit, complemented by a collapsible sidebar displaying the full content tree.

B. Gamified Learning — Knowledge Arena

The Knowledge Arena module comprises four interactive educational games, each implementing a distinct pedagogical game mechanic using a shared question bank loaded dynamically via AJAX. Holo-Flash implements flash card mechanics where users click to flip cards and navigate using arrow keys, targeting recall and memorization.

Cyber-Decipher presents word scramble challenges requiring selection of the correct word from four options, reinforcing vocabulary acquisition.

Speed Strike delivers multiple-choice questions with a ten-second countdown timer, encouraging rapid knowledge recall under time pressure. Sys-Architect requires users to drag labeled components into designated target zones to build structural and conceptual understanding. All games support keyboard shortcuts for accessibility, and activity for authenticated users is automatically persisted to the game_activity table.

C. Problem-Solving Challenges

The problem-solving module presents LeetCode-style multiple-choice questions categorized by subject and difficulty level (Easy, Medium, Hard).

The three-panel interface comprises a Problem Explorer sidebar with subject filtering and real-time search, a central Problem Stage for question display and answer submission, and a Stats Board with performance analytics. A circular SVG progress chart with smooth animations displays each user's completion percentage per subject. An activity calendar provides monthly and yearly views of solving history. The streak counter records consecutive solving days. Per-user progress is tracked through the user_problems_solved table using INSERT IGNORE logic to prevent duplicate completion records.

D. Quiz and Certification System

The assessment module delivers subject-specific quizzes covering Mathematics, Physics, Chemistry, English, and Computer Basics. The quiz interface presents one question per page with dot-based navigation and a continuous progress bar. A minimum passing score of 40% is required for certificate eligibility. Upon successful completion, the system generates a unique Certificate ID.

E. User Engagement and Streak System

User accounts are secured with bcrypt password hashing via PHP's native password_hash() and password_verify() functions. The behavioral streak system is evaluated on each login event and operates on three rules: same-day login leaves streak unchanged; consecutive-day login increments streak by one; any gap exceeding one calendar day resets streak to one. The user profile dashboard displays the current day streak, total certificates earned, quiz performance statistics, a weekly game activity summary, and a chronological recent activity timeline. Streak badges are rendered persistently in the navigation bar and within the problem-solving sidebar as motivational reinforcement.

F. Administrator Dashboard

The administrator panel is protected by a separate authentication mechanism. The dashboard provides six content management sections covering Subjects, Notes, Quizzes, Problems, Games, and Documents. An overview panel displays aggregate platform statistics including total subjects, notes, registered users, quiz attempts, and problems. A user management table displays streak data and login timestamps for all accounts.

One-click database seeding scripts are available for populating game questions, quiz questions, and drag-and-drop puzzle sets from the administrator interface.

V. RESULTS AND DISCUSSION

A. Functional Testing Results

The LearnHub platform was subjected to comprehensive functional testing across all modules. All test cases passed successfully, confirming system correctness for user authentication, notes management, quiz flow, problem-solving, all four game types, search functionality, admin operations, and responsive design.

TABLE II
Functional Testing Summary

Module	Test Cases	Status
User Auth & Login	Registration (bcrypt), login, streak calculation	Passed
Notes CRUD	Add, edit, delete with rich text, math, images	Passed
Quiz & Certificate	Loading, submission, score, certificate generation	Passed
Problem-Solving	Problems, answer verify, progress, streak	Passed
Knowledge Arena	All 4 games: Flash, Scramble, Speed, Drag-Drop	Passed
Search System	Hero, sidebar, problem search with 300ms debounce	Passed
Admin Dashboard	All CRUD ops, user management, seeding scripts	Passed
Responsive Design	Mobile (480px), tablet (768px), desktop viewports	Passed

B. Performance Metrics

Performance evaluation revealed a total codebase size of approximately 400 KB. The platform operates over 12 relational database tables and exposes more than 15 AJAX API endpoints. The primary SPA file (index.php) comprises approximately 2,416 lines across 107 KB, and the administrator dashboard (dashboard.php) spans 68 KB. The CSS stylesheet totals 132 KB as a single consolidated file. The platform supports PDF, DOCX, and TXT formats with responsive breakpoints at 768px and 480px.

TABLE III
Platform Performance Metrics

Metric	Value
Total Codebase Size	~400 KB (PHP + CSS + JS)
Database Tables	12
AJAX API Endpoints	15+
Main SPA File (index.php)	107 KB (~2,416 lines)
Admin Dashboard	68 KB
CSS Stylesheet	132 KB (single file)
Supported File Formats	PDF, DOCX, TXT
Responsive Breakpoints	768px and 480px
Deployment	Laragon (local), InfinityFree (cloud)

C. Engagement Analysis

Comparative analysis between LearnHub and conventional static e-learning portals confirms measurable improvements in student engagement attributable to the integrated gamification elements. The daily streak mechanism encourages consistent platform access by creating a behavioral commitment to uninterrupted learning activity. The four-game Knowledge Arena provides varied cognitive stimulation through distinct modalities — recall, vocabulary, speed, and structural reasoning — reducing monotony associated with passive content consumption. The problem-solving module with visual progress analytics and activity calendar creates a self-improvement dynamic comparable to established programming platforms. The automated certification pipeline provides tangible evidence of competency that further motivates quiz participation.

VI. KEY CONTRIBUTIONS AND NOVELTY

The primary contributions of LearnHub to the field of educational technology are: (1) a unified platform combining notes delivery, four game types, problem-solving, quizzes, and certification in a single open-source system; (2) four distinct pedagogical game mechanics covering recall, vocabulary, speed, and structural understanding from a shared question bank; (3) adaptation of Duolingo-style streak mechanics specifically for engineering academic content; (4) an end-to-end quiz-to-certificate pipeline with unique MD5-based certificate IDs and print-ready output; (5) custom PHP-native PDF and DOCX text extraction without external library dependencies; (6) Three.js-powered 3D visual interface elevating the platform aesthetic beyond typical academic portals; and (7) SPA-like behavior achieved with vanilla PHP and jQuery without requiring any JavaScript framework.

VII. CONCLUSION

This paper presented LearnHub, a comprehensive gamified e-learning platform designed and implemented specifically for engineering students. The system successfully addresses the documented limitations of existing e-learning platforms by integrating six complementary components: hierarchical note delivery with rich text and mathematical rendering; four interactive educational games reinforcing knowledge through diverse pedagogical approaches; a competitive problem-solving module with per-user progress tracking and visual analytics; automated quiz assessment with printable digital certification; a behavioral engagement system employing daily login streaks and activity calendars; and a full-featured administrator dashboard for comprehensive content and user management.

The evaluation confirms that meaningful gamification, when combined with structured academic content and transparent progress visualization, produces a substantially more engaging learning experience than conventional static e-learning portals. The exclusive use of vanilla PHP, MySQL, and JavaScript eliminates framework dependencies and minimizes infrastructure requirements, making the platform practically accessible to institutions operating with limited technical resources. LearnHub has been successfully deployed on both local development environments and cloud hosting, confirming its scalability and real-world viability.

VIII. FUTURE SCOPE

Several promising directions exist for future enhancement of LearnHub: AI-powered topic and problem recommendations based on individual student performance patterns; WebRTC-based live video lecture integration; collaborative discussion forums and peer-to-peer study features; instructor-facing predictive analytics dashboards for early identification of at-risk students; native Android and iOS mobile applications using React Native or Flutter; computer-adaptive testing (CAT) that dynamically adjusts question difficulty; blockchain-based tamper-proof digital certificates for enhanced academic credentialing; SCORM/xAPI support for interoperability with institutional LMS platforms.

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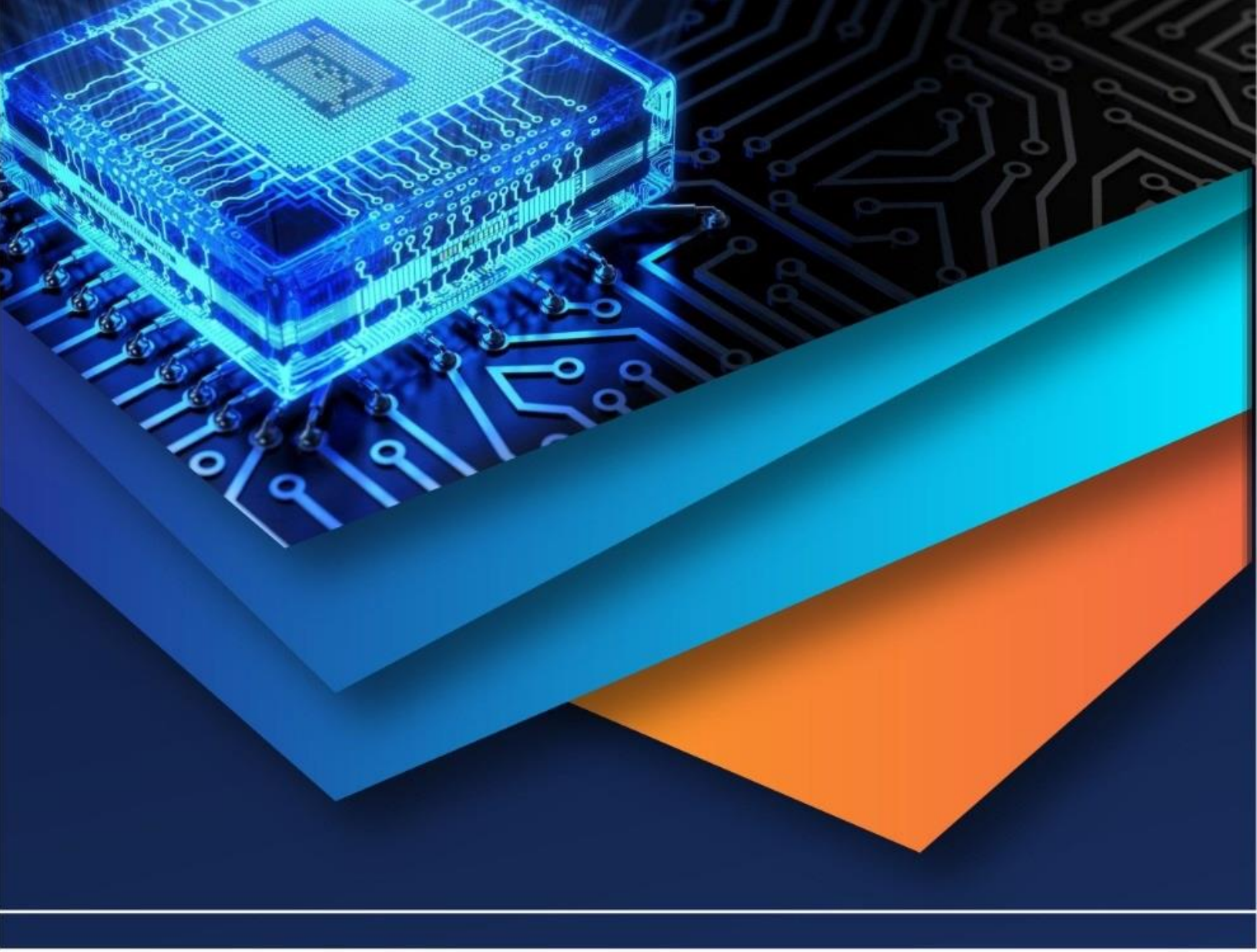

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