

Development of a Comprehensive Learning Management System using Full Stack Technology: A Modern Approach to Educational Platforms

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Abstract - Using the advantages of modern web technologies, this project utilizes powerful data modelling characteristics of Prisma and dynamic front-end capacities of Next.js to design a Learning Management System (LMS). The aim of this project is to create a comprehensive platform that would effectively facilitate the organization of educational resources and assignments, as well as student cooperation, ensuring scalability and performance at the same time. Many software engineering practices are utilized during this project for code maintainability, security, and performance. The full cycle of software development consists of testing and iterative adaptation of the developed systems based on the opinions of end-users. Ultimately, the LMS is improved through thorough testing and feedback from the users in an iterative and progressive process. The findings of this research are pertinent to the future developments of educational technology that will seek to implement modern, full-featured, and user-friendly LMS.

Keywords— Learning Management System, Full-stack development, Prisma, Next.js, Educational technology, Software engineering, Scaling, User-friendly.

I. INTRODUCTION

In the current educational system, it is hard to find a learning management system (LMS) that can satisfy the needs of all the stakeholders of the product and at the same time provide a collaborative, effective and user-friendly learning management. The platforms that are available currently lack facilities for smooth assignment submission, classroom management, and good efficient communication. To be able to build a fully integrated learning management system unlike the ones currently available that lack all-inclusive modules, one needs to provide functions such as automated student enrollment, editable class templates for teachers and dynamic navigation.

A full-stack solution is necessary to solve this problem because in addition to solving these issues it also adds extra special features such as plagiarism checks, easy assignment upload, result analysis for student's grades etc. An LMS where teachers can analyze and customize class templates individually for different students based on their performances and be able to share the results with the parents can be an essential function that provides clarity and solves a lot of previously present problems along with configurable grading method. Adding the ability to replicate classes for future academic years is missing and can be added as a function.

Therefore, the need is to develop a full-stack educational platform that caters to the needs of the stakeholders present in the LMS that includes the teachers, students, guardians and administrators, providing smooth and comprehensive experience for managing the classes, assignments, grades and enabling communication between the teachers and students. The problem to be solved is to build this platform and prioritize user-friendly navigation, offering advanced features such as plagiarism checks, preventing tab changing during tests and quizzes and providing support with efficient collaboration between all stakeholders. Additionally, priority should be given to data security and privacy while allowing administrators to set user permissions, which is a challenge to the success of this system. The goal of such LMS should be to create an innovative and inclusive educational ecosystem that enhances the teaching experience for the teachers and the learning experience for the student.

II. MOTIVATION

A. Centralized Learning Environment

The goal is to create a centralized hub where all the resources required for education such as the course materials, assignments, assessments and interactions can all be available and managed at one place, this is one of the main reasons for building a learning management system. This centralization is necessary as it makes sure that the students have easy access to the learning resources that they need while at the same time streamlining the administration of courses. This eliminates the dispersion the resources and information across several different platforms, which often can be a major learning obstacle.

B. Improved Accessibility and Flexibility

As in recent times, accessibility and flexibility hold the utmost importance in the educational environment. This is made possible by using an LMS which gives a student the freedom of accessing the educational resources from any location at any time and allows for a variety of schedules and learning preferences. For non-traditional students who may be working part-time and cannot indulge in traditional classroom settings and for those who may be living in different time zones this can be very helpful. In addition to this, an LMS can be accessed across a lot of different devices such as smartphones and tablets which further improves its accessibility.

C. Ability to Scale and be Cost-effective

Scalability is of at most concern in recent times for most educational institutions. Organizations can expand their products to educational institutions using LMS without having to experience any expenses or resources. An LMS is flexible and can accommodate more students across its courses.

D. Enhanced Cooperation and Communication

For successful learning, two of the essential components are cooperation and communication. This can be achieved using an LMS which allows for effective communication in real time along with the ability to collaborate which includes peer review, group projects, and discussion boards. This habit along with improving educational process, also helps students get ready for contemporary workplaces where digital cooperation and communication skills are highly regarded and necessary.

E. Data-driven Understanding to Improve Learning Outcomes

The student activities are monitored by the LMS, which include the amount of time spent on the platform, the resources utilized, and the time spent on them, the results of the tests and assessments etc. This data can be used to determine how a student is learning and if the learning is effective. The area of difficulty can be pinpointed and focused intervention can be used to maximize the learning outcomes. The information is invaluable to the administrators and educators.

F. Regulatory Compliance and Quality Control

Educational institutions oftentimes must follow strict rules pertaining to the curriculum delivery and control of the quality. An LMS can be used to standardize these procedures, maintain records, and ensure compliance with relevant laws. It can help in keeping accurate records of interaction with children and their progress which can be an essential component for internal assessments and accreditation.

G. Future-proofing Education

LMS also require systems that can continue the ongoing education and skill development due to the rapid change in technology every day and the increasing lifelong learning. Investing in an LMS is as good as investing in a long-term educational infrastructure independent of the physical infrastructure that can change according to educational and technological needs at any given point of time.

H. Innovation in Education

Along with creating an LMS one can get the chance to use cutting-edge instructional strategies and technologies like artificial intelligence, gamification and adaptive learning technologies. Students can be provided with a platform that can cater to their individual needs, this can help increase engagement and learning retention.

III. LITERATURE SURVEY

The contemporary educational environment is characterized by the growing importance of Learning

Management Systems due to the rising demands for comprehensive, reliable, and adaptable online learning solutions. The following review of recent academic sources synthesizes several authors' insights associated with selected problems and concerns of LMS implementation, design, and evaluation.

Medushevska thoroughly explores the subsystem as an avenue for stakeholder success in the LMS market [1]. Such guidelines are especially relevant considering the rapid global shift from traditional classroom settings to digital learning and the expected expansion of the LMS market due to continuous technological developments in education and use in both traditional and non-traditional education spheres. While the guide promotes a systematic approach to the creation of the LMS, it also uncovers a topic of enormous difficulty of forecasting the development project's financial side due to the high level of variance. Multiple factors come into play when defining these costs – such as a choice of technology stack, several third-party services and tools whose functionality must be integrated, and the features' complexity, which is evident in the work discussed by Piyumantha et al. [2]. Using the MERN stack (MongoDB, Express.js, React.js, and Node.js), these authors created an LMS to provide free, ongoing education during times when traditional educational opportunities are severely disrupted, like during the COVID-19 pandemic. Furthermore, they do not only focus on the technological capabilities of the MERN stack, allowing for developing a system economical in terms of scalability and endeavor but also on the system's attributes in terms of reliability and availability, which are critical for a system designed for many users supporting at the time when the traditional educational services are at their most unavailable points.

Abu Shawar et al. synthesizes the relationship between LMS and knowledge management and demonstrates the impact of well-performing LMSs on knowledge sharing, collaboration, and learning outcomes, as indicated above [3]. Indeed, the article specifically defines the importance of LMS in narrowing the gap between knowledge management and e-learning, including a review of how information quality and system usability per se affect the effectiveness of these platforms. Additionally, while reviewing the limitations of the current studies, the author mentions a sparse investigation on the relationship between instructor characteristics and the richness of LMS features on the one side and the success of the system on the other, indicating these areas as necessary for future research. This perspective opens a discussion about the need for LMS platforms to not only facilitate education but also to manage knowledge in a way that enhances the learning experience.

Jafari et al. emphasizes information quality and system usability as the most crucial success factors among university students while learning management system is being used [4]. The study repeatedly highlights the importance of improving user engagement and interactive tools in LMS platforms to maximize their use by educators. The analysis of this study reveals two

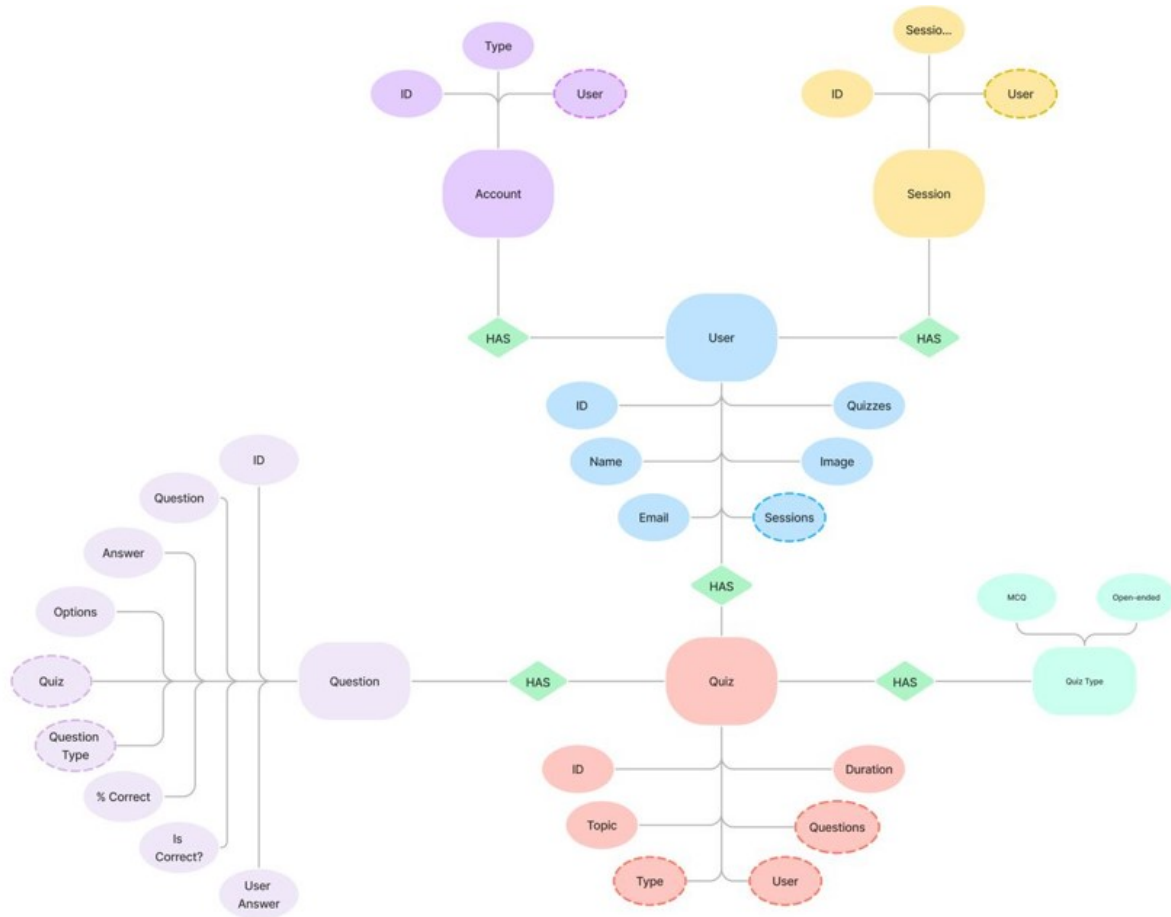


Fig. 1 Schema Design

facts. First, the core idea of an LMS supports the recognition of the significance of the technological basis as a key aspect. However, other issues, such as the perception of the end-users, play an important role especially when the learning environment may require learners to keep a safe distance while studying. In their discussion on LMS, Boppi et al. describe using Java Spring as a foundation for LMS development. They highlight the selection of modern web technologies that follow the MVC pattern to manage courses, enroll students, and enhance security features such as CAPTCHA, Google reCAPTCHA, and email verification [5]. The exploration of full stack concepts in existing literature inspires the implementation of the proposed Learning Management System in this work [6][7][8].

The expansion plans for this LMS include capacity planning, CDN integration, and advanced cybersecurity measures to ensure that the system remains functional and resilient against attacks at varying levels of load conditions [9][10]. In these studies, different topics come up frequently, mostly including but not limited to the challenges of reliability, scalability and cost efficiency in LMS platforms which are the main obstacles in this process. Apart from being interwoven with the concerns, these complications are worsened in the backdrop of the

spreading of the diseases like the COVID-19 outbreak that calls for collaborative thinking and reliability [11][12].

IV. SYSTEM DESIGN

The LMS discussed in this paper relies on a certified technology stack that is supposed to be interactive, safe, and scaled for many users [13]. Through React and JavaScript, the front-end development of the LMS was executed, and thus the interface provided by them became responsive and dynamic. This interface was central to the proper facilitation of course materials and the capture of learners' attention. Backend also has Kotlin as its main programming language that gives more compactness and increases safety [14][15]. The Mobile Cloud Service (MCS) backend structure benefits from Micronaut's lightweight and responsive approach in combination with Netty, that is, creating a high-performance microservice-oriented application with the MCS in mind. To accomplish an effective LMS which is responsible for efficient transaction as well as strong analytical, Clickhouse DB is used to generate queries of analytical nature while PostgreSQL is preferred for storage support. The solution of Chart is only focusing on visualization needs factor. Enhancing education through JS technology enables visual representation of educational data and metrics, boosting user engagement and improving administrative monitoring. Authentication is handled by

Auth0, for providing users with a secure and flexible authentication system that supports modern authentication protocols, including multi-factor authentication. GitHub provides a range of tools to manage source code, apply version control, and automate continuous integration and deployment using GitHub Actions. The testing is done using efficient tools, that being JUnit for unit testing and Micronaut's built-in testing capabilities for integration testing, guaranteeing the LMS functionality and stability on both the micro and the macro levels. This integrated design thus not only facilitates the general requirements expected from an advanced LMS, such as course management, user interaction, and performance monitoring, but it also conquers the obstacle of handling the increasing number of users in the higher user demand scale.

V. SYSTEM IMPLEMENTATION

The proposed Learning Management System created to simplify educational procedures and improve the learning process is presented in Fig. 1. Students can self-enroll with shareable links. The proposed LMS provides the ability to create quizzes and tests using open AI. These quizzes and tests are AI generated and need not be created by the teacher. The hot-topics are highlighted in a word cloud. The history of the tests and quizzes and the marks received can be seen in the history section. There is light and dark mode for the user interface. There is a help menu to guide on how to use the application.

The proposed LMS has a login page, dashboard, quiz creation module, help menu etc. which is expected in every elearning module. Additionally, students will not be allowed to switch tabs while taking the quiz, providing an extra layer of security compared to existing systems. Few of the snapshots of the implementation are presented in Figs. 2 to 5.

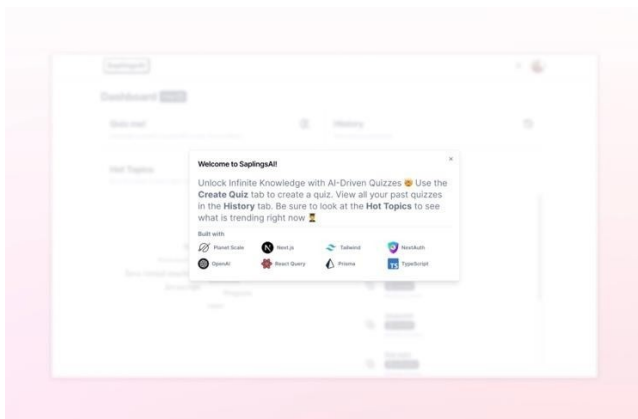


Fig. 2 UI for Help menu

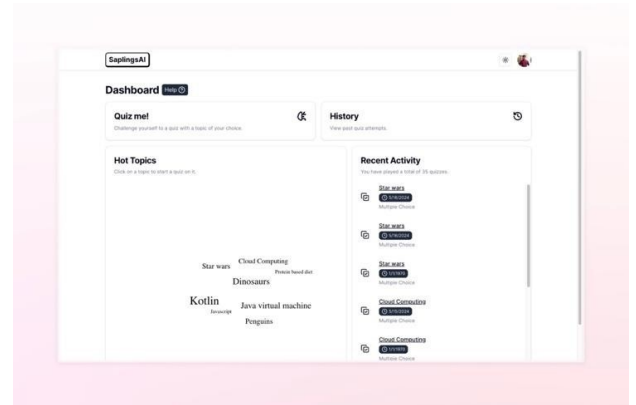


Fig. 3 UI for Dashboard

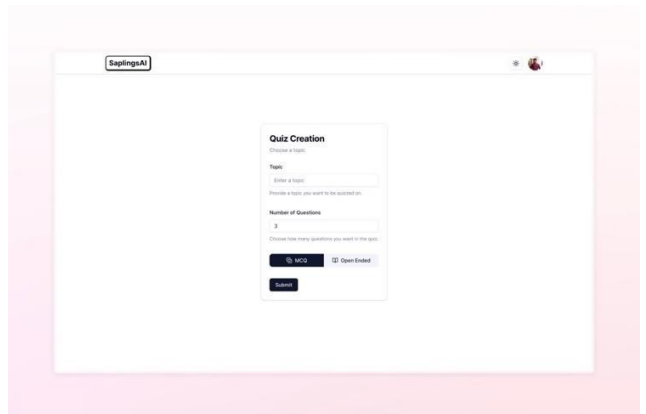


Fig. 4 UI for Quiz creation form

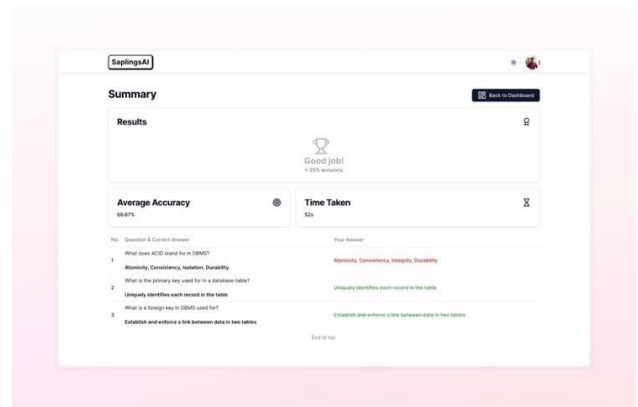


Fig. 5 UI for Test Summary

VI. RESULTS AND ANALYSIS

The process of building LMS using the technology stack has a couple of surprising points, especially in terms of performance, user engagement, scaling, and security.

- A. System Performance and Reliability: Through the React and JavaScript mix applied to the frontend, the interface turned out to be not only responsive but easy to use and understand both by learners and educators. Being one of the most significant challenges, React's proficient update machinery used in creating smooth and dynamic UI changes without the page refreshing, thus greatly improved the user's experience. Students using Kotlin in

Micronaut framework and Netty as asynchronous web servers proved very responsive and good throughput within the system. An authentic instance of this setup demonstrated its commitment to providing timely responses to users when multiple interactions happen simultaneously, a usual situation for the LMS platforms, particularly in clinical or corporate environments when large institutions are involved.

- B. Scalability: As the LMS consisted of the modular structure of Docker, the architecture approach of microservices made scaling the LMS easy. This flexible expansion separates different parts of the system, which is especially useful during times of high demand, like exam periods or the release of new courses. The database tier was powered by PostgreSQL's robustness and Clickhouse DB's ability to deal with massive data loads. The scaling efficiency could be achieved without compromising on performance by the database layer to ensure the increasing demands of data.
- C. User Engagement and Interaction: Chartjs, which is applicable to create interactive charts and graphs, was used, as they are key tools in reporting and analytics. The visualizations enabled the teacher to monitor the students' progress and engagement, allowing them to adjust the learning materials and the interventions as needed. Additionally, the combination of Auth0 with the site ensured a smooth authentication experience for users thereby ensuring the user security. It was developed with an aim of diversity platform support. Social media and enterprise integrations were to be supported by login methods. This ensured the system's flexibility and ability to reach a wider user-base.
- D. Security: Security being the utmost priority, this work designed robust security mechanisms to prevent data breaches in educational fields that are highly confidential by nature. The integrated security features from Micronaut protect our system into PostgreSQL amplifying our security against SQL injection and other common threats. Besides that, Auth0 added a virtually impassable security barrier that multi-factor authentication works with resulting in a tremendous decrease in the probability of unauthorized access [16].
- E. Testing and Quality Assurance: Frequent integration of code by GitHub Actions tools, run the test on an auto-based manner, which is instrumental in the maintenance of code quality and in reduction of time of detecting and fixing bugs. JUnit for unit tests and Micronaut testing for integration tests ensured that all system aspects have been covered. This was important for retaining optimum performance.
- F. Prospective Amplification of Data Analytics and Integration of Machine Learning: By incorporating a more powerful data analytics system that comprises of the latest data mining tools and classifiers, it is possible to give the revolutionary predictive analysis on student achievement and learning behaviors. This could enable pro-activity in educational support as

well as appropriate learning experiences designed for individuals [17].

- G. Extension of Multilingual and Multicultural Support: With time, integration of Online Translation services puts in the picture the possibility of tackling the challenge of communication barrier that can be conquered by non-English understanding users. It not only provides a translation service but also involves adapting both the content and the UI to more effective work in cultural situations [18].

Consequently, the LMS proposal met all the needs having prioritization for productivity, security and scalability with an enjoyable interface which also contributes to the continuous development of learning. The technological choices made at the beginning of the project were the ones that determined these results with a great effect on their efficiency, modernity, and power. This confirms the effectiveness of their overall toolkit and framework system. The result emphasizes that this type of design needs a thoughtful approach and the right technologies to effectively address the unique needs of educational institutions and corporate training programs. However, there is a scope for the use of immersive technology to make the LMS more efficient and interactive [19][20].

VII. CONCLUSION

The implementation of a learning management system that integrates various modern technologies demonstrates a highly reliable, scalable, and secure online learning environment. The back end whose development was done with Kotlin, Micronaut framework and the support of Docker containers proved that the system could manage real usage loads with reduced latency, while the front end with the use of JavaScript and React made the system dynamic and responsive. The facts that Clickhouse DB and PostgreSQL contributed to the data storage/analytics demands were shown as an important factor not only on the operational but also on the analytical roles. In future, Blockchain could be used to secure documents and records. The immersive learning environment could also be developed using AR/VR technology.

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