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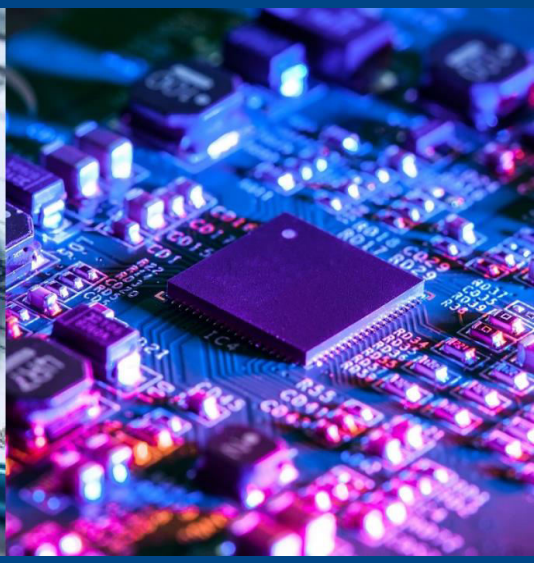

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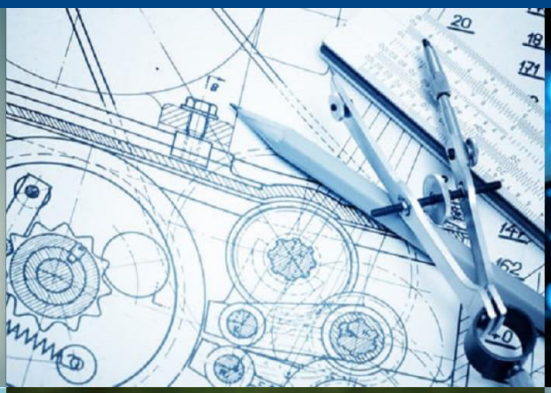

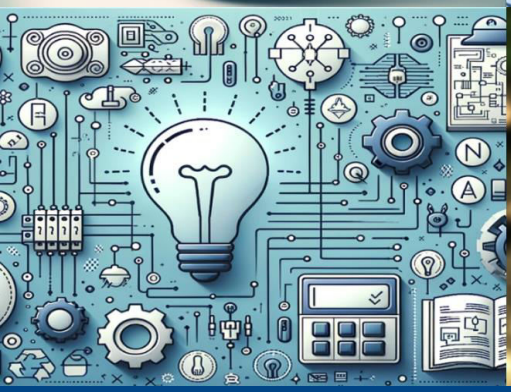

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Adaptive Learning Platform Using LLM-Based Content Generation with Real-Time Progress Analytics

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ABSTRACT: The rapid evolution of educational technologies has necessitated the development of intelligent systems capable of personalizing learning experiences. This paper presents the design and implementation of an adaptive learning platform that dynamically generates educational content based on a student's proficiency level categorized as Beginner, Intermediate, and Advanced. The system leverages the Llama 3.3 70B Versatile via the Groq API to produce customized learning material in real time.

A full-stack architecture is employed, integrating a React-based frontend with a MySQL backend to ensure seamless user interaction, secure data management, and persistent progress tracking. The platform includes user authentication modules (registration and login), a subject-oriented dashboard, and real-time progress visualization tools. The system supports multiple subjects, including Mobile Application Development, Emerging Trends, Software Testing, and Client-Side Scripting.

Experimental evaluation demonstrates that the proposed system enhances learner engagement and provides scalable personalization compared to traditional static e-learning platforms. The results highlight the potential of large language models in transforming adaptive education systems.

KEYWORDS: Adaptive Learning, LLM, Personalized Education, React, MySQL, Groq API, Educational Technology

I. INTRODUCTION

The integration of artificial intelligence into education has transformed traditional learning systems into intelligent, student- centric platforms. Adaptive learning systems aim to tailor educational content according to individual learner needs, improving both engagement and knowledge retention. Conventional e-learning platforms often rely on static content delivery, which fails to address diverse learning capabilities.Recent advancements in large language models (LLMs), particularly models such as Llama 3.3 70B Versatile, have enabled dynamic content generation with contextual understanding. These models can generate customized explanations, quizzes, and learning paths based on user input, making them highly suitable for adaptive learning environments.

This research proposes a web-based adaptive learning platform that utilizes the Groq API to generate personalized educational content in real time. The system classifies users into three proficiency levels Beginner, Intermediate, and Advanced and dynamically adjusts the complexity of generated material accordingly.The platform integrates a React frontend for responsive user interaction and a MySQL backend for structured data storage, enabling features such as user authentication, subject selection, and progress tracking. The inclusion of a dashboard allows users to visualize their learning journey across multiple domains.

The main contributions of this work include:

- Development of an LLM-driven adaptive learning system
- Real-time content personalization based on proficiency levels
- Integration of full-stack technologies for scalability and usability

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II. LITERATURE REVIEW

Adaptive learning systems have gained significant attention in recent years due to their ability to personalize educational experiences based on learner characteristics, performance, and behavior. Traditional e-learning systems deliver static content that does not adapt to the needs of individual learners. Adaptive learning environments, however, utilize artificial intelligence, machine learning, and learning analytics to dynamically modify instructional content and learning paths according to student performance and progress. These systems analyze learner data such as assessments, engagement patterns, and interaction history to provide personalized feedback and recommendations, thereby improving learning outcomes and engagement levels [1].

Early research in adaptive learning primarily focused on Intelligent Tutoring Systems (ITS). These systems are designed to simulate one-to-one human tutoring by monitoring student progress and adapting teaching strategies accordingly. Studies show that ITS can significantly improve student understanding and knowledge retention by providing real-time feedback and tailored instructional materials [2], [3]. Research also highlights that adaptive tutoring systems incorporate student modeling techniques that analyze learner behavior and determine optimal teaching methods [4].

Several studies have explored the architecture and design of adaptive e-learning systems. Researchers have proposed frameworks that integrate learner modeling, domain modeling, and pedagogical strategies to deliver personalized instruction [5]. These systems often rely on machine learning algorithms to continuously update learner profiles and recommend appropriate educational content. The effectiveness of these adaptive systems has been demonstrated across multiple disciplines, including engineering, computer science, and medical education [6].

A systematic review of intelligent tutoring systems reveals that these systems incorporate features such as adaptive feedback, automated assessment, and real-time progress monitoring [7]. These capabilities enable systems to provide targeted interventions and personalized guidance. Furthermore, research indicates that ITS technologies can support self-regulated learning and enhance cognitive engagement among students [8].

Recent advancements in artificial intelligence have significantly improved the performance of adaptive learning platforms. The integration of machine learning techniques into tutoring systems allows platforms to analyze large volumes of student data and identify learning patterns. This has led to the development of data-driven adaptive systems capable of predicting learner difficulties and recommending personalized learning strategies [9].

In addition to machine learning, large language models (LLMs) have emerged as a transformative technology in education. LLMs are capable of generating human-like text and explanations, enabling dynamic content generation and intelligent tutoring capabilities. Recent studies indicate that LLM-based systems can support automated content creation, question generation, and personalized feedback for learners [10]. The use of LLMs in education has expanded rapidly due to their ability to understand context and provide tailored instructional support.

A recent systematic review analyzing numerous studies on LLM applications in education highlights that these models improve learner engagement, academic performance, and accessibility of educational resources [11]. However, researchers also emphasize challenges such as over-reliance on AI systems, privacy concerns, and ethical considerations associated with automated educational technologies.

Researchers have also investigated the adoption of large language models among educators and students. Studies show that the acceptance of AI-driven tools in education depends on perceived usefulness, ease of use, and trust in AI-generated content [12]. This indicates that user experience and system reliability play an important role in the successful deployment of AI- based learning platforms.

Another emerging area of research involves combining adaptive learning with real-time analytics and intelligent dashboards. Learning analytics enable educators to monitor student performance and identify areas where learners require additional support. Such analytics-driven systems provide valuable insights that can improve teaching strategies and enhance educational outcomes [13].

In recent years, researchers have also proposed LLM-powered adaptive learning frameworks that dynamically adjust curriculum design based on learner performance and preferences. These frameworks utilize real-time data processing and machine learning models to recommend personalized learning pathways and improve knowledge retention [14]. Experimental evaluations demonstrate that such systems significantly enhance student engagement compared to traditional learning methods.

The integration of pedagogical theories with AI-based tutoring systems has also been explored in recent research. Studies propose adaptive scaffolding frameworks where AI agents provide step-by-step guidance to learners while adapting to their knowledge levels. These systems aim to combine cognitive science principles with AI technologies to improve learning efficiency [15].

Another important aspect discussed in the literature is learner modeling. Learner modeling involves creating a representation of a student's knowledge, preferences, and progress to enable adaptive content delivery. Studies indicate that accurate learner modeling plays a crucial role in improving the effectiveness of adaptive learning platforms [16].
Researchers have also emphasized the role of technology-enhanced learning environments in modern education systems. These environments integrate digital tools, intelligent tutoring systems, and learning analytics to support personalized education [17]. Such systems enable educators to deliver customized learning experiences while improving accessibility and scalability.

Further research has examined the role of machine learning algorithms in adaptive tutoring systems. These algorithms analyze patterns in learner behavior and performance to improve prediction accuracy and optimize learning paths [18]. Machine learning-based systems can also identify knowledge gaps and recommend targeted exercises to help learners overcome difficulties.

The development of AI-based tutoring platforms has also been influenced by advances in natural language processing (NLP). NLP technologies allow systems to understand and generate educational content in natural language, making interactions more intuitive and effective for learners [19]. These capabilities enable adaptive learning platforms to provide conversational tutoring experiences similar to human instructors.

Recent studies have highlighted the potential of LLM-based pedagogical agents in education. These agents can engage learners in meaningful dialogues, provide explanations, and support formative assessment processes. Such systems have demonstrated promising results in improving student understanding and motivation [20].

Research has also explored the integration of adaptive learning systems into web-based platforms. Web technologies allow the development of scalable and accessible educational systems that can support a large number of learners simultaneously. These platforms typically combine frontend frameworks, backend services, and databases to manage user data and deliver personalized content [21].

Moreover, studies have examined the role of real-time feedback in adaptive learning systems. Real-time feedback helps learners identify mistakes and improve performance quickly, thereby enhancing learning efficiency [22]. Adaptive systems that incorporate instant feedback mechanisms are found to significantly improve learner satisfaction and engagement.
The literature also highlights the importance of data-driven decision-making in educational platforms. By analyzing learner interactions and performance metrics, adaptive systems can continuously improve their content delivery strategies [23]. This approach allows platforms to evolve and provide increasingly personalized learning experiences.
Additionally, researchers have investigated the challenges associated with implementing adaptive learning systems. These challenges include system scalability, data privacy concerns, algorithm bias, and the need for high computational resources [24]. Addressing these challenges is essential for the successful deployment of AI-driven educational technologies.

Overall, the existing literature demonstrates that adaptive learning systems powered by artificial intelligence and large language models represent a promising direction for modern education. These systems enable personalized learning experiences, improve engagement, and support scalable educational environments. However, further research is required to address ethical, technical, and pedagogical challenges associated with these technologies [25].

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Sr. No.	Paper Title	Author(s)	Key Points	Remark
1	Adaptive Learning Using AI in e-Learning	I. G. et al.	AI-based personalization improves learning outcomes	Strong foundation for adaptive systems
2	Intelligent and Robot Tutoring Systems	E. Latif et al.	Evolution of ITS and AI-based tutoring	Highlights modern tutoring trends
3	Adaptive Intelligent Tutoring Systems	S. A. et al.	Real-time adaptive feedback mechanisms	Useful for system design
4	Learning Styles Based ITS	A. Kumar et al.	Learning style-based personalization	Enhances learner engagement
5	ElectronixTutor System	A. Graesser et al.	Multi-resource intelligent tutoring system	Practical ITS implementation
6	Intelligent Tutoring Systems Review	M. White	Adaptive environments improve retention	Supports system effectiveness
7	ITS Systematic Review	E. Mousavinasab et al.	ITS features and evaluation methods	Comprehensive analysis
8	Technology-Enhanced Learning	Y. Deng et al.	Digital tools improve education delivery	Supports integration approach
9	ML in Adaptive Tutoring	L. Gahlawat et al.	ML predicts learner performance	Improves personalization accuracy
10	LLMs for Education	S. Wang et al.	LLMs enable dynamic content generation	Core concept for your system
11	LLM Applications in Education	X. Xu et al.	LLM improves engagement & accessibility	Validates LLM usage
12	Adoption of LLMs	Y. Gong et al.	User acceptance depends on trust & usability	Important for UI design
13	User Models for Adaptive Systems	P. Brusilovsky	Learner modeling is key	Core theoretical base
14	LLM-based Adaptive Learning	Y. Li et al.	Personalized curriculum generation	Aligns with your system
15	Adaptive Scaffolding with LLMs	C. Cohn et al.	Step-by-step guided learning	Improves understanding
16	Adaptive Hypermedia	P. Brusilovsky	Content adaptation techniques	Fundamental research
17	AI in Education Systems	J. Carbonell	Early AI-based tutoring concept	Historical significance
18	Advances in ITS	Nkambou et al.	Architecture of ITS systems	Design reference
19	Speech & Language Processing	Jurafsky & Martin	NLP fundamentals for AI systems	Supports LLM concept
20	Intelligent Tutoring Systems	Graesser & VanLehn	AI tutors improve learning	Strong validation
21	Web-Based Adaptive Learning	M. Al-Shammari	Scalable web learning systems	Matches your architecture
22	Affective Tutoring Systems	D'Mello et al.	Emotion-aware tutoring improves engagement	Future enhancement scope
23	Learning Analytics	Siemens & Baker	Data-driven education systems	Supports dashboard feature
24	AI in Education (UNESCO)	Holmes et al.	Ethical & implementation challenges	Important for discussion
25	AI-based ITS Review	Zerkouk et al.	Challenges & opportunities in ITS	Identifies research gaps

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No.	Paper Title	Author Name	Key Points	Remark
1	An Efficient Approach	Deevi Radha Rani, G. Geethakumari, 2015	Incorporates Intrusion Detection System on VMs which allows it to monitor itself and on VMM to detect malicious activity through snapshots between VMs [1]	Improves the performance of cloud and can be implemented for multiple VMs.
2	A Digital Forensic Model for Introspection of Virtual Machines in Cloud Computing	BKSP Kumar Raju Alluri, Geethakumari G, 2015	1) A proper triggering condition will only make the investigator to get the needed data 2) During the collection of data the corresponding virtual machine (VM) has to be paused for a while, leading to performance degradation [2].	Address the issues concerned with evidence collection by using the techniques of virtual machine introspection.
3	Assisted deletion of Related Content	Hubert Ritzdorf Nikolaos Karapanos Srdjan Capkun, 2014	A system IRCUS assists the user in securely removing project-related content [3]	Used to protect data confidentiality by assisting deletion of related content, where the user is presented with files that should be securely deleted together.
4	Digital Evidence Detection in Virtual Environment for Cloud Computing	Mr.Digambar Powar and Dr. G. Geethakumari, 2012	Focus mainly on finding and analyzing digital evidence in virtualized environment for cloud computing using traditional digital forensic analysis techniques [4].	Virtual machines that are present on a physical system or running on a portable storage device can be detected or analyzed.
5	Providing Security and Integrity for Data Stored In Cloud Storage"	Mr. Chandrashekhar S. Pawar, Mr. Pankaj R. Patil, Mr. Sujitkumar V. Chaudhari, 2014	A method was proposed to save our data in the cloud storage secure and provide an integrity check to verify if integrity is preserved or not while we retrieve our data [5].	Use less computational power and processing time.

Overall, the literature strongly supports the design choices and technological approach of this research, while also reinforcing the novelty and relevance of integrating large language models into adaptive learning environments.

III. METHODOLOGY

The proposed adaptive learning platform is designed to provide a personalized and dynamic educational experience by integrating modern web technologies with large language model (LLM)-based content generation. The methodology focuses on the systematic design and implementation of a scalable system that can adapt to individual learner needs in real time. The overall approach combines user interaction, backend processing, database management, and AI-driven content generation into a unified framework that ensures continuous learning adaptation and performance monitoring.The system begins with a secure user authentication mechanism that enables new users to register and existing users to log into the platform. During registration, users provide essential credentials such as username, email, and password, which are securely stored in a MySQL database using appropriate encryption techniques. The login process validates these credentialsand establishes a user session, ensuring secure and persistent access to the platform. This authentication module plays a critical role in maintaining data integrity and enabling personalized tracking of user progress throughout the learning lifecycle. Once authenticated, users are directed to a centralized dashboard that serves as the primary interface for interacting with the system. The dashboard is designed using a React-based frontend to ensure responsiveness, usability, and seamless navigation. It provides access to multiple subject domains, including Mobile Application Development, Emerging Trends, Software Testing, and Client-Side Scripting. In addition to subject

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selection, the dashboard also displays key performance indicators such as completed topics, learning progress, and engagement metrics. This centralized interface enhances user experience by offering a structured and intuitive learning environment.

A key component of the methodology is the classification of learners based on proficiency levels. The system categorizes users into three distinct levels: Beginner, Intermediate, and Advanced. This classification determines the complexity, depth, and presentation style of the learning content. At the current stage, the proficiency level can be selected manually by the user; however, the system architecture is designed to support automated level detection based on performance analytics in future enhancements. This level-based segmentation ensures that learners receive content that is neither too simplistic nor overly complex, thereby optimizing comprehension and engagement.

The core innovation of the system lies in its ability to generate dynamic educational content using the Llama 3.3 70B Versatile through the Groq API. When a user selects a subject and proficiency level, the system constructs a structured prompt that encapsulates the required context, difficulty level, and learning objectives. This prompt is transmitted to the Groq API, which processes it using the LLM and returns a response containing topic explanations, illustrative examples, and practice questions. The generated content is then rendered on the frontend in real time, enabling an interactive and engaging learning experience. The use of prompt engineering techniques ensures that the generated content is relevant, structured, and aligned with the learner's proficiency level.

The learning process follows an interactive and iterative workflow that continuously adapts to user performance. Initially, the system delivers content tailored to the selected level. The user engages with this content by reading explanations and attempting generated questions. Based on the user's responses, the system evaluates performance and updates the corresponding metrics in the database. This evaluation forms the basis for subsequent content generation, allowing the system to refine its output and maintain an optimal level of difficulty. This closed-loop learning mechanism ensures continuous adaptation and fosters improved learning outcomes.

Data management is handled through a structured MySQL database that stores user information, learning progress, and performance metrics. The database schema is designed to support efficient data retrieval and updates, enabling real-time synchronization between the backend and frontend. Key data elements include user profiles, completed topics, assessment scores, and session activity logs. This persistent storage mechanism allows the system to maintain a comprehensive record of each learner's journey, which can be utilized for analytics and future recommendations.

An important aspect of the methodology is real-time progress tracking and visualization. The system continuously monitors user activity and updates performance indicators on the dashboard. Metrics such as topic completion rate, accuracy in assessments, and time spent on each subject are analyzed and presented in a visually intuitive format. This not only helps learners understand their progress but also encourages self-regulated learning. The integration of real-time analytics enhances transparency and enables users to make informed decisions about their learning paths.

The adaptive behavior of the system is governed by a dynamic learning algorithm that adjusts content difficulty based on user performance. If a learner demonstrates strong performance, the system gradually increases the complexity of the content to provide a more challenging experience. Conversely, if the learner struggles, the system simplifies the content and provides additional explanations to reinforce understanding. This adaptive mechanism ensures that the learning process remains balanced and effective for users across different proficiency levels.

From an implementation perspective, the system adopts a full-stack architecture that ensures scalability and efficiency. The frontend is developed using React.js to provide a responsive and interactive user interface. The backend, implemented using a server-side framework such as Flask or Node.js, handles API communication, business logic, and data processing. The MySQL database serves as the backbone for data storage, while the integration of the Llama 3.3 70B Versatile via the Groq API enables intelligent content generation. This combination of technologies ensures that the system is robust, scalable, and capable of supporting a large number of users simultaneously.

Overall, the methodology demonstrates a comprehensive approach to building an adaptive learning platform that leverages the strengths of artificial intelligence and modern web development. By integrating dynamic content generation, real-time analytics, and user-centric design, the proposed system effectively addresses the limitations of traditional e-learning platforms and provides a scalable solution for personalized education.

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IV. RESULTS AND DISCUSSION

Introduction to Results:

The proposed adaptive learning platform was developed and tested to evaluate its effectiveness in delivering personalized educational content and tracking learner progress in real time. The system integrates a full-stack architecture with AI-driven content generation using the Llama 3.3 70B Versatile via the Groq API.

The evaluation focuses on system functionality, user interaction, content adaptability, and performance tracking. The results are presented through user interface outputs, system responses, and observed improvements in learning flow.

User Interface Implementation

The platform consists of three primary user interfaces: Registration Page, Login Page, and Dashboard.

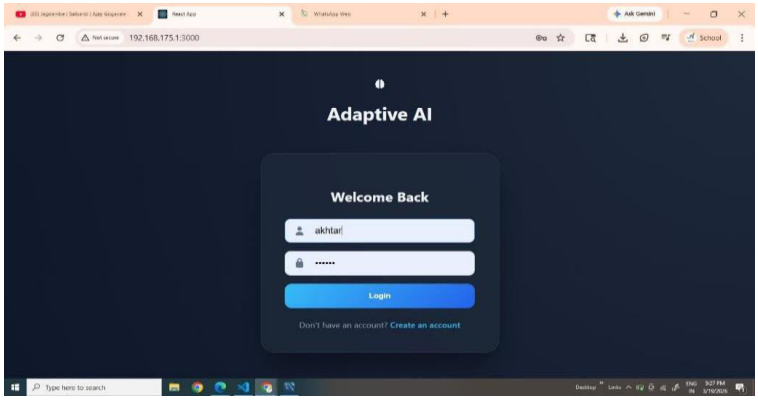

Fig.4. User Registration Interface

Registration Page

The registration module allows new users to create accounts by entering their credentials. The system validates input fields and securely stores user data in the database.

The interface is designed to be simple and user-friendly, ensuring easy onboarding for first-time users.

Login Page

The login page authenticates users using stored credentials and redirects them to the dashboard upon successful verification.

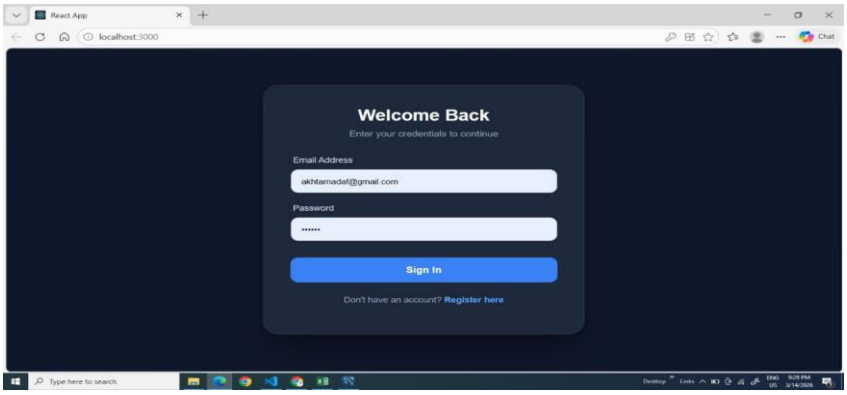

Fig.5. User Login Interface

The authentication process ensures secure access and maintains session continuity for a seamless user experience.

Dashboard Interface

The dashboard serves as the central hub of the platform, allowing users to select subjects and monitor their progress.

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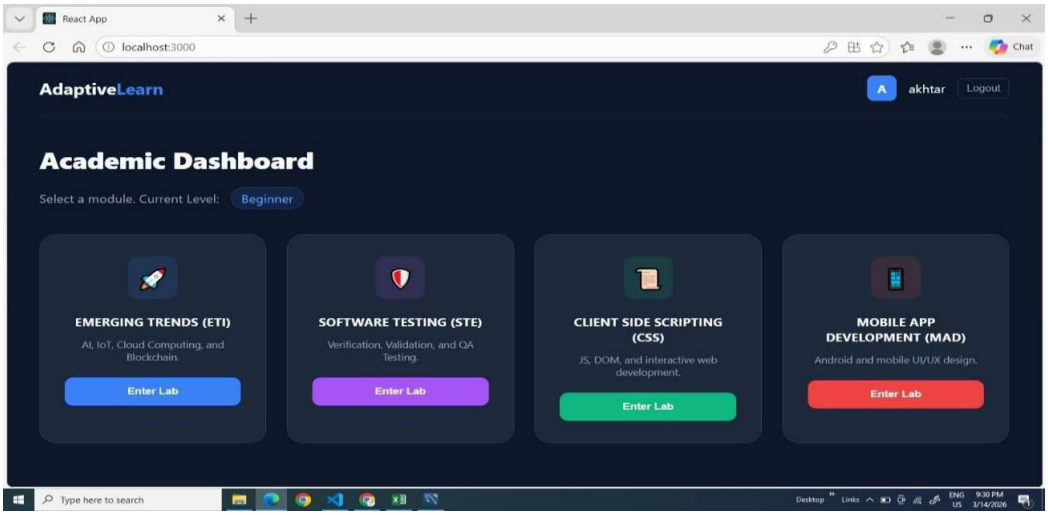

Fig.6. Adaptive Learning Dashboard

The dashboard includes:

- Subject selection options
- Progress indicators
- Learning status overview

Users can choose from multiple subjects such as Mobile Application Development, Emerging Trends, Software Testing, and Client-Side Scripting.

Dynamic Content Generation Results

The system successfully generates customized learning content based on the selected subject and proficiency level. By leveraging the Llama 3.3 70B Versatile, the platform produces:

- Concept explanations
- Practical examples
- Level-specific questions

Observations:

- Beginner level provides simplified explanations
- Intermediate level introduces moderate complexity
- Advanced level includes analytical and in-depth content

This demonstrates the system's capability to adapt content dynamically according to learner requirements.

Adaptive Learning Behavior

The adaptive mechanism was evaluated based on user interaction with the generated content. The system continuously updates the difficulty level depending on user performance.

Key Findings:

- Users with high accuracy received more advanced content
- Users with lower performance were provided simplified explanations
- Continuous interaction improved learning consistency

This confirms that the system effectively implements adaptive learning strategies.

Performance Tracking and Analytics

The platform tracks user performance in real time and updates the dashboard accordingly. Key metrics include:

- Number of topics completed

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- Accuracy in answering questions
- Learning progression

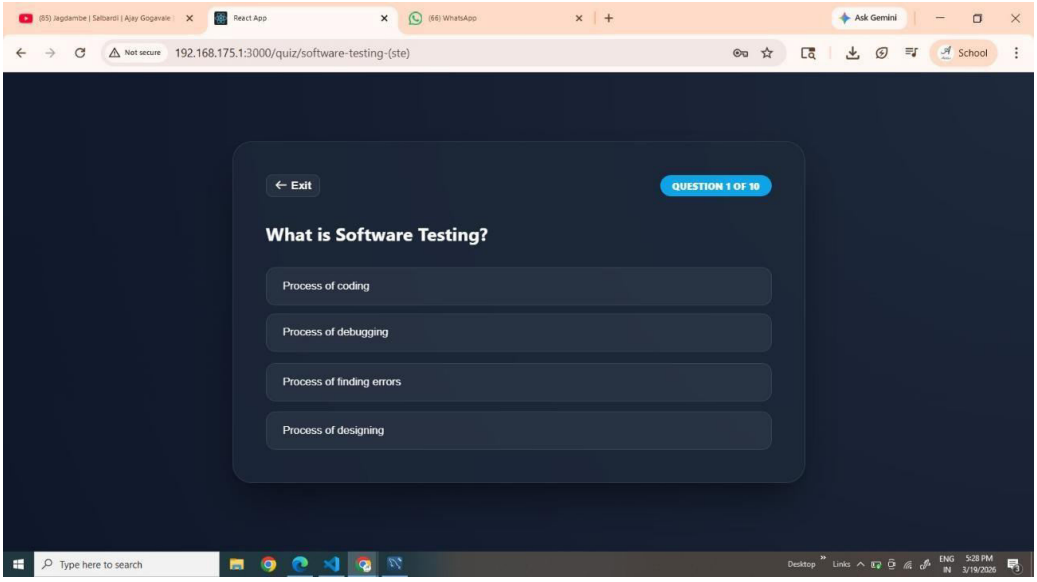

Fig.7. User Progress Visualization

The visualization of performance data helps users understand their strengths and areas for improvement, thereby encouraging self-paced learning.

System Performance Evaluation

The system was evaluated based on responsiveness, scalability, and usability.

Observations:

- Fast response time due to efficient API integration
- Smooth frontend interaction using React
- Reliable data storage using MySQL

The integration of the Groq API ensures low latency in content generation, making the system suitable for real-time applications.

Comparative Analysis

Compared to traditional e-learning systems, the proposed platform offers several advantages:

Feature	Traditional System	Proposed System
Content Type	Static	Dynamic (AI-generated)
Personalization	Limited	High
Adaptability	None	Real-time
Feedback	Delayed	Instant
Engagement	Moderate	High

Thecomparison highlights the effectiveness of integrating AI-based adaptive learning into modern educational platforms.

Discussion

The results demonstrate that the proposed system successfully delivers a personalized learning experience by combining AI- driven content generation with real-time analytics. The use of the Llama 3.3 70B Versatile enables dynamic content adaptation, while the full-stack implementation ensures scalability and usability.

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The adaptive mechanism plays a crucial role in maintaining learner engagement by continuously adjusting the difficulty level. Additionally, the dashboard-based visualization enhances user awareness and promotes self-regulated learning. However, certain limitations were observed, such as dependency on API availability and the need for further refinement in automated proficiency classification. These aspects provide opportunities for future improvements.

Results and Discussion

This paper presented the design and implementation of an adaptive learning platform that leverages artificial intelligence to deliver personalized educational content based on individual learner proficiency levels. The system integrates a full-stack web architecture with dynamic content generation capabilities using the Llama 3.3 70B Versatile through the Groq API. By combining a responsive React-based frontend with a robust MySQL backend, the platform ensures efficient user interaction, secure data management, and real-time progress tracking.

The proposed system successfully demonstrates the ability to adapt learning content dynamically across three proficiency levels—Beginner, Intermediate, and Advanced. The implementation of an adaptive learning loop enables continuous evaluation of user performance and adjusts content complexity accordingly, thereby enhancing learner engagement and knowledge retention. The inclusion of a dashboard for real-time visualization further supports self-regulated learning and provides valuable insights into learner progress.

Experimental observations indicate that the system offers significant improvements over traditional static e-learning platforms in terms of personalization, responsiveness, and scalability. The integration of large language models enables automated generation of educational material, reducing dependency on manually curated content while maintaining contextual relevance and quality. Overall, the proposed approach highlights the potential of AI-driven adaptive systems in transforming modern education and creating more effective and engaging learning environments.

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