LLM-Based AI Tutor for Personalized Learning

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***Abstract*—The mission provides the development of an AI tutor specially tailored for engineering college students using a large language model (LLM), including generative models and masked language models, to provide personalized learning experiences. The AI tutor harnesses the power of advance natural language processing algorithms, such as GPT (Generative Pre-trained Transformer) to understand the unique needs of each student. Engineering students often face challenges in mastering complex topics such as mathematics, physics, and programming, where a one-size-fits-all approach to education is inadequate. The AI tutor addresses this issue by analyzing individual student interactions, problem solving strategies, such as root cause analysis and brainstorming, and comprehension levels to provide customized learning paths. Through continuous adaptation to the student's performance, the AI tutor offers personalized quizzes and open-ended exercises, which help to breakdown complex concepts into manageable steps. Additionally, the system integrates adaptive learning and real-time feedback to the enhance student engagement and academic performance.**

***Index Terms*—AI Tutor, Personalized Learning, Generative Models, Adaptive Learning, Real-Time Feedback, Interactive Problem-Solving, Root Cause Analysis, Brainstorming.**

I.INTRODUCTION

Large Language Model (LLM)-based AI tutor represents a transformative innovation in engineering education, it provides students with a learning experience that's personalized and adaptable to their specific needs, using advanced natural language processing, capabilities, these AI tutors dynamically adjust their explanations, problem-solving strategies, and guidance based on the learner's progress and comprehension. This enables real-time feedback, clarification of complex engineering concepts and mastery of topics spanning mathematics, physics, and specialized fields like electrical, mechanical, and software engineering. Operating 24/7, the AI tutor empowers students to learn at their own speed, tackle problem sets, and explore practical applications of theoretical knowledge. Through adaptive learning algorithms, the system identifies areas of weakness or confusion and provides targeted support to address these gaps, fostering deeper understanding and retention. AI tutors make learning more engaging by creating interactive experiences tailored to each student's learning style. This personalized approach helps students develop problem-solving skills while also preparing them for real-world challenges through practical simulations. Furthermore, the scalability and accessibility of such systems democratize education by making high-quality tutoring available to a broader audience. However, integrating LLMs into education requires addressing challenges related to accuracy, ethical considerations, and the need for human oversight to ensure content quality and academic integrity. By enhancing traditional teaching methods with advanced AI capabilities, this technology redefines the educational landscape, making learning more efficient, engaging, and effective while aligning with the goals of Education 4.0 technologically dynamic world.

II.BACKGROUND

A. Adaptive Learning

AI-powered adaptive learning is transforming personalized education by using smart algorithms to adjust lessons based on each student's progress and engagement. These systems continuously analyze student behavior—such as time taken to answer questions, areas of difficulty, and subjects of proficiency. For example, a student excels in algebra but struggles with geometry, the AI tutor prioritizes geometry-related exercises while incrementally increasing the difficulty of algebra problems to maintain engagement and challenge. This flexible approach allows students to learn at their own pace,

focusing more on the areas where they need the most help. The underlying algorithms utilize techniques like reinforcement learning, clustering, and neural networks to optimize learning paths and recommend targeted resources. By providing real-time feedback and understanding how students think, these systems help improve learning, boost retention, and keep students engaged with interactive and relevant materials. Furthermore, adaptive learning platforms democratize education by providing scalable solutions that transcend geographical and economic barriers, ensuring equitable access to high-quality tutoring for diverse learners. These systems also help teachers by providing data-driven insights into student performance, allowing for more effective support and intervention. However, challenges like ethics, data privacy, and ensuring the accuracy of AI recommendations remain important areas of research. As adaptive learning advances, it has the potential to reshape traditional education.

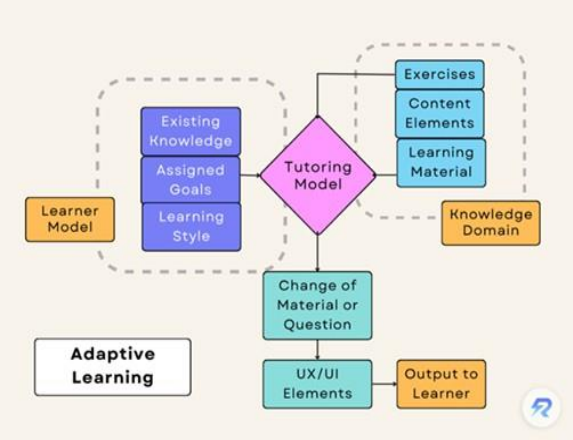

Figure 1: Adaptive Learning Architecture

1) Input from the Learner Model: The student's knowledge, goals, and learning style feed into the tutoring model.

2)Tutoring model: The tutoring model adapts lessons and exercises based on the student's progress and the subject being learned.

3) Adaptive Learning Process: The system adapts the content in real-time (via changes of material or questions) based on student performance.

4) Output: The learner receives tailored exercises, explanations, and other materials, improving engagement and retention.

B. Real-Time Feedback

Real-time feedback is important compelling advantages of AI tutors over traditional teaching methods. Im- mediate feedback is indispensable for effective learning as it allows students to rectify mistakes promptly reinforcing their understanding before misconceptions can take hold. In a traditional classroom setting students often have to wait for their teacher's feedback, which can drastically slow down the learning process. This delay can lead to confusion and frustration, as students may continue to build upon incorrect assumptions or methods. In contrast, AI tutors eliminate this lag by providing instant evaluations and guidance, ensuring that students can correct their mistakes and solidify their understanding in real-time. With AI tutors, students receive immediate feedback, questions, or tackling complex math problems. For instance, if a student makes an error while solving an equation, the AI tutor can pinpoint the exact point of the mistake and offer targeted hints or explanations to guide the student toward the correct solution. This instant reinforcement not only accelerates the learning process but also enhances accuracy and comprehension. By receiving feedback in real-time, students can learn more effectively, as they are able to address and correct their mistakes before they become ingrained. This approach fosters a more engaging and interactive learning environment where a students feel supported and motivated to continue improving their skills and knowledge.

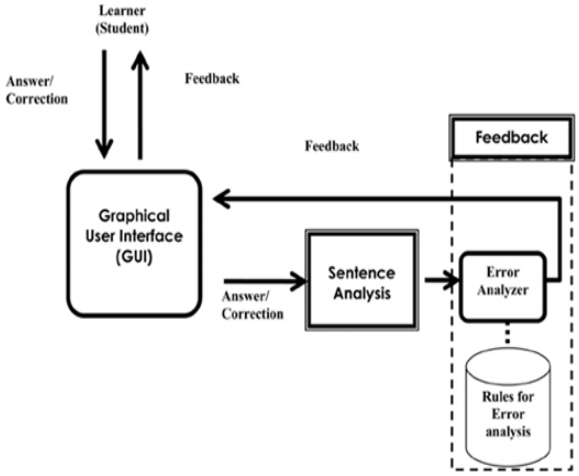

Figure 2: Real-Time Architecture

1. Learner Submits an Answer: The student provides aresponse through the graphical user interface (GUI).

2. Sentence Analysis: The system checks for errors in the submission.
3. Error Analysis: Detected errors are compared against predefined rules.
4. Feedback Generation: Corrective feedback is created based on the analysis.
5. Feedback Provided: The system returns feedback to the learner via the GUI.
6. Learner Reviews and Corrects: The learner reviews the feedback and corrects their answer or proceeds with learning. This cycle ensures immediate correction and reinforcement of understanding.

III.LITERATURE REVIEW

AI tutors have significantly transformed education by enabling personalized learning, automating assessments, and enhancing teacher-student collaboration. AI-based quiz systems analyze students' learning behaviors and provide customized content to improve retention and engagement [1]. Additionally, AI tutors facilitate structured feedback, combining AI-generated insights with peer evaluations to enhance critical thinking and comprehension [2]. Adaptive learning technologies dynamically adjust instructional content to match students' abilities, leading to improved academic performance [3]. AI-generated question systems further personalize learning by tailoring quizzes based on individual progress, reinforcing concepts more effectively [4]. While AI tutors offer numerous benefits, challenges such as data security, ethical concerns, and the evolving role of teachers require further research to ensure the sustainable and ethical implementation of AI in education.

IV.PROBLEM STATEMENT

The growth of effective AI tutors faces several crucial difficulties that must be tackled to enhanced their functionality and impact in educational settings. The growth of effective AI tutors faces several crucial barriers that must be addressed to enhance their functionality and impact in educational settings. One key issue is accurately assessing the student's knowledge level, learning style, and areas of difficulty to provide personalized instruction. This requires creating a dynamic learner model that tracks progress, identifies weaknesses, and adapts content accordingly. Additionally, AI tutors must handle complex and open-ended questions requiring critical thinking and nuanced reasoning by enhancing natural language processing (NLP) potential to interpret diverse or incomplete student inputs and generate thoughtful, contextually relevant responses. Key challenges include accurately assessing the student's knowledge level, handling complex and open-ended questions, and ensuring continuous improvement and learning. quiz service (handling quiz data), and AI evaluation service (assessing responses via GPT-based models); and the AI engine, powered by GPT-based NLP models, which generates dynamic quizzes, evaluates responses, and delivers personalized feedback.

V. IMPLEMENTED SYSTEM

Artificial intelligence (AI) has transformed the education sector by making learning more interactive, adaptive, and personalized. One exciting advancement is the development of smart tutoring platforms that adapt to each student's needs. Our project aims to develop an AI- powered tutoring system that generates quizzes dynamically based on user prompts. This system will make learning more engaging while offering different types of questions including multiple choice questions (MCQs) and open-ended questions, ensuring a comprehensive assessment process. By leveraging GPT based language models, the platform will ensure high-quality, contextually relevant quizzes tailored to individual learning needs. To achieve a seamless and efficient implementation, the system will be built using next.js for the frontend, node.js for the backend, postgres SQL for data storage, and google OAuth for authentication. The AI functionalities, including quiz generation and evaluation, will be powered by GPT based language models. This AI-driven tutoring platform integrates advanced technologies to automate quiz generation, evaluation, and feedback, creating an interactive and efficient learning experience. The system comprises three core components: the frontend, developed using next.js, react, tailwind CSS, and react query, which provides a seamless user interface for authentication, quiz creation, display, and progress tracking; the backend, built with node.js and express.js, which acts as an intermediary to manage API requests for authentication, quiz processing, and AI evaluation through dedicated services like the authentication

service (google OAuth)

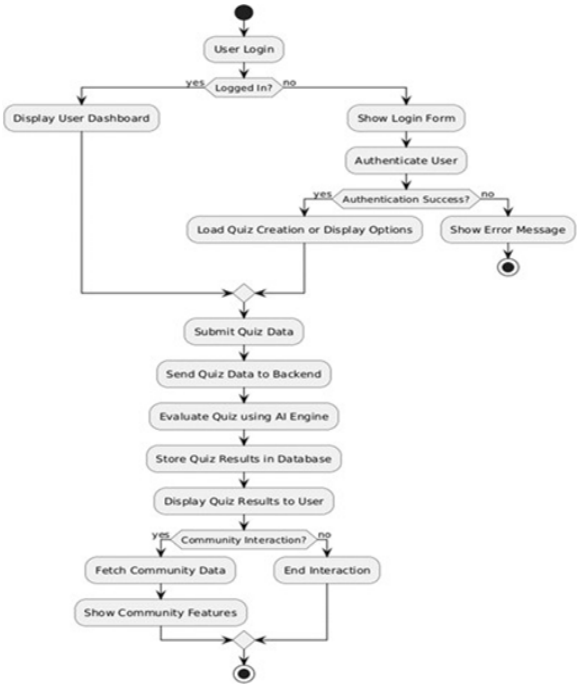

Figure 3: Implemented System Flowchart

followed by quiz creation or selection, quiz attempt and Figure 3: Implemented System Flowchart submission, AI evaluation, and result storage and display. This approach enhances the learning process by providing AI powered quiz generation, multiple question formats, automated evaluation and feedback, secure authentication via Google OAuth, and a modern UI/UX with optimized performance. By leveraging AI for intelligent assessment and feedback, this system streamlines learning, improves engagement, and offers a scalable and secure solution for digital education

VI. METHODOLOGY

Our AI-powered tutoring system follows a structured approach to create an interactive and personalized learning experience. First, users register and log in securely using Google OAuth authentication. The system then collects basic user data to create a personalized learning profile. Once logged in, students can generate quizzes based on their chosen topics. The AI engine, powered by GPT-based language models, creates questions in multiple formats, including multiple-choice and open-ended questions. The difficulty level of the questions adjusts based on the user's knowledge and performance. The user interface, developed using Next.js, React, and Tailwind CSS, ensures a smooth and engaging experience. Students can attempt quizzes, receive real-time feedback, and track their progress. The backend, built with Node.js and Express.js, manages authentication, quiz processing, and AI evaluation, while PostgreSQL stores user data and quiz results securely. Once a student submits an answer, the AI evaluates it instantly, providing immediate corrections, explanations, and personalized feedback. This real-time feedback helps students understand mistakes and improve their learning. The system continuously analyzes user performance, adjusting future quizzes based on strengths and weaknesses. A dedicated progress tracking dashboard allows students to monitor their improvement over time. To ensure security and scalability, the system uses authentication and encryption mechanisms to protect user data. The platform is designed for future expansion, allowing integration with external learning tool sand additional AI-driven tutoring features. By leveraging AI for quiz generation, evaluation, and feedback, this system makes learning more efficient, engaging, and tailored to individual needs.

VII. RESULTS

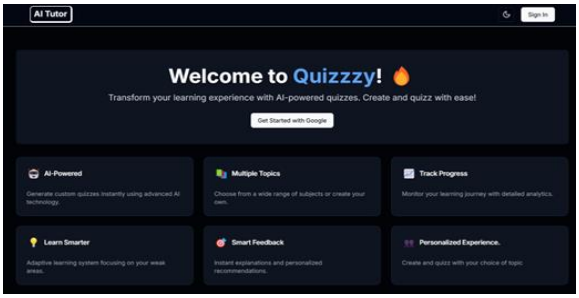

Figure 4. Landing Page

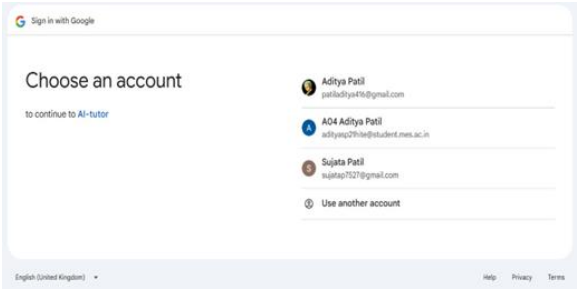

Figure 5. Login Page

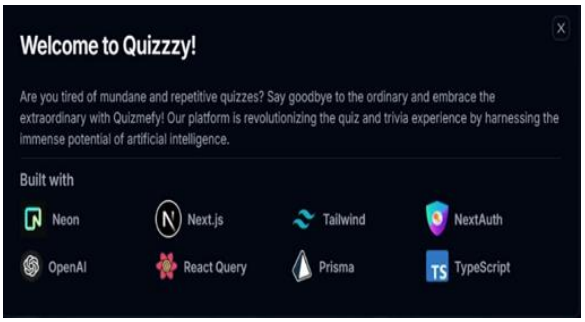

Figure 6. About Page

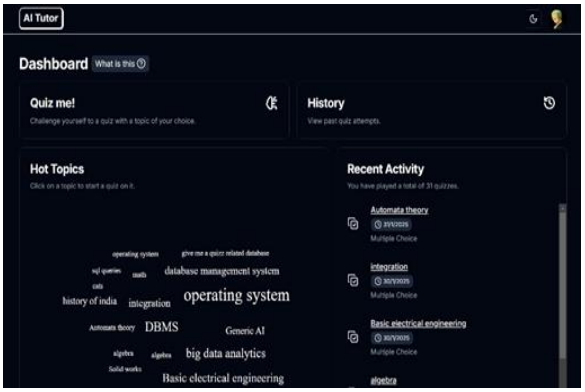

Figure 7. Dashboard

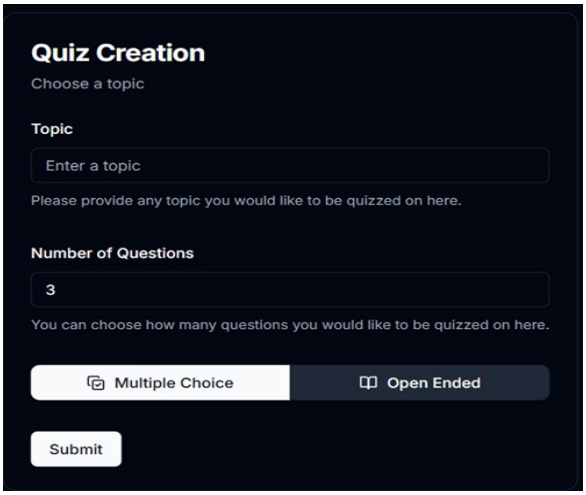

Figure 8. Quizz Creation Page

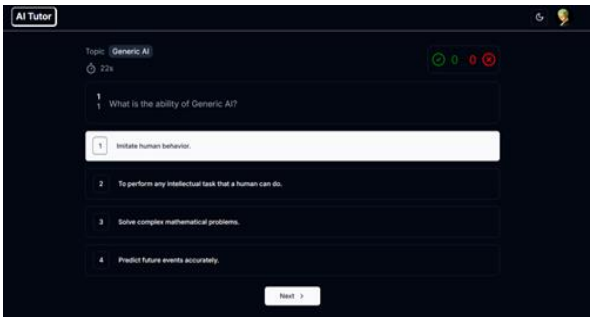

Figure 9. Multiple Choice Question Page

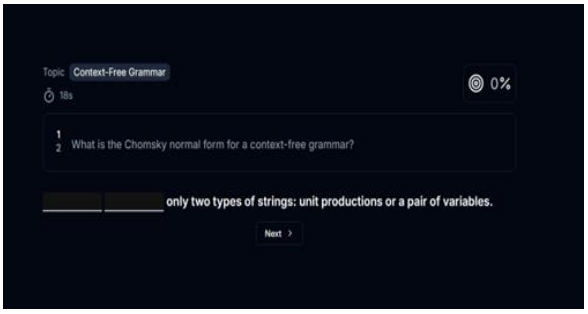

Figure 10. Open-ended Question Page

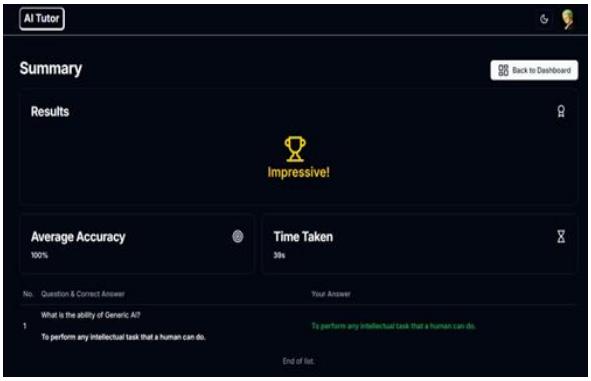

Figure 11. Results Page

VIII.CONCLUSION

In conclusion, AI tutors play a crucial role in enhancing student learning by providing personalized, interactive, and accessible educational experiences. They adapt to different learning styles, offer real-time feedback, and help bridge educational gaps. Our project incorporates AI-powered quizzes with adaptive difficulty and instant feedback, enabling students to improve their problem-solving skills and track their progress effectively. Additionally, the system boosts engagement through interactive learning, fostering time management and critical thinking skills. By integrating AI-driven assessments with human guidance, our system creates a balanced and effective learning environment that enhances student success and prepares them for future challenges. Looking ahead, this platform can be implemented within a Learning Management System (LMS) to further expand its accessibility and impact

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