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Personalized AI Tutor Using Language Models and Learning Analytics

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Abstract: ***This research proposes a comprehensive AI tutoring framework that leverages the capabilities of large language models (LLMs) and learning analytics to create a personalized and adaptive learning environment. Unlike traditional Intelligent Tutoring Systems (ITS), which are constrained by static rules and predefined flows, the proposed framework offers dynamic content generation, contextual responsiveness, and real-time performance monitoring. It integrates generative AI technologies with microservice-based architecture to enhance the learning experience through quizzes, feedback, and lesson adaptation. The system is built using modern web technologies such as FastAPI for the backend and React for frontend interaction. A four-week experimental evaluation with undergraduate students indicated significant improvements in engagement, knowledge retention, and learner satisfaction. This study demonstrates that generative AI, when combined with analytics and ethical safeguards, can scale personalized learning to diverse educational contexts.***

Keywords: Personalized Learning, Artificial Intelligence, Large Language Models, Learning Analytics, Intelligent Tutoring Systems, Generative AI.

I. INTRODUCTION

The advancement of Artificial Intelligence (AI) has ushered in new paradigms in the field of education, fundamentally transforming the delivery and accessibility of instructional content. Among these developments, the use of Large Language Models (LLMs) for tutoring has emerged as a particularly promising application. These models have shown the potential to replicate the reasoning and responsiveness of human tutors by generating text-based explanations, assessments, and personalized feedback. Traditional Intelligent Tutoring Systems (ITS), while effective in domain-specific scenarios, often lack the flexibility to adapt to the individual learning trajectories of students. This rigidity arises from reliance on hardcoded rules and decision trees, which cannot accommodate real-time changes in learner behavior or needs. In contrast, LLMs like Google's Gemini have demonstrated the capacity to dynamically tailor content and instruction based on user input and context [1], [2], [3]. The primary aim of this paper is to introduce and evaluate a new AI tutoring framework that integrates generative AI with learning analytics. The system is designed to offer personalized instruction by continuously assessing student progress and adapting instructional strategies accordingly. Through this hybrid approach, the framework aspires to deliver a scalable, engaging, and data-driven learning experience that rivals traditional human tutoring in effectiveness and accessibility.

II. LITERATURE REVIEW

Recent years have witnessed a surge in AI-driven educational systems aimed at enhancing personalized learning. Hany et al. [1] introduced Nexia Tutor, an AI-powered system designed to support students with dyslexia. This system integrates BERT-based models with gamified interfaces to improve learner engagement and reading skills. Meng and Yang [2] addressed the challenge of enhancing feedback in ITS using LLMs with data distillation, which refined the quality of responses based on prior learner interactions. Shahri et al. [3] explored the potential of GPT-4 in educational settings, emphasizing the importance of real-time adaptability and detailed feedback mechanisms. The use of LLMs in programming education has also been explored by Zönnchen et al. [4], who analyzed the effectiveness of the CS50 Duck assistant. Their findings highlight that while generative AI can improve self-paced learning, it may also lead to over-reliance among struggling students. Bonde [5] developed a generative AI tutor specifically for structured university courses, leveraging personalized learner profiles. Qureshi et al. [6] conducted a systematic review that underscored the significance of inclusivity and bias mitigation in AI education systems. Further contributions by Ratul et al. [7] outlined ethical concerns, including the opacity of LLM decisions and potential misuse of data. Frank et al.

[8] demonstrated the feasibility of using GenAI models like GPT-3.5 and GPT-4 to build intelligent tutoring systems for R programming, evaluating them based on accuracy and adaptability. Despite these advancements, existing solutions often fall short in achieving a comprehensive blend of personalization, domain scalability, and ethical responsibility. Our proposed framework builds upon these insights by combining the strengths of generative AI, real-time analytics, and modular system design to offer a more holistic solution.

III. METHODOLOGY/EXPERIMENTAL

The AI tutoring framework proposed in this study is developed using a modular microservice architecture that allows for flexibility, scalability, and efficient maintenance. At its core, the system is composed of three primary modules: user interface, backend services, and AI integration, each of which is optimized for specific functions within the learning cycle. The frontend interface is built using React and Next.js to offer an intuitive, responsive, and accessible learning experience. It allows students to select topics, answer dynamically generated quizzes, and receive contextual feedback in a real-time chat-based format.

The backend is developed using FastAPI, a lightweight Python framework optimized for asynchronous API handling. It manages key operations such as user session control and API communication with LLMs. No dedicated database was used; instead, all user interactions and performance evaluations were processed in-memory during session runtime. This setup simplified the system architecture and ensured lightweight, efficient execution.

Integration with LLMs such asGemini 1.5 is facilitated through secure API endpoints. These models are used to generate explanatory content, assess student responses, and adapt quiz complexity using knowledge tracing and Bloom's taxonomy. Sentiment analysis is also applied to the user's interactions to adjust the motivational tone of feedback. This multi-layered personalization ensures that learners receive not only relevant but also emotionally resonant responses, mimicking the empathy and adaptability of a human tutor.

IV. RESULTS AND DISCUSSIONS

To assess the impact of the developed AI-based tutoring platform, a four-week controlled study was conducted involving 60 undergraduate students from an introductory engineering course. Participants were equally divided into an experimental group that utilized the AI system and a control group that followed traditional learning practices, including textbooks and PDF-based resources. Both groups completed identical pre-test and post-test assessments aimed at evaluating their conceptual understanding, knowledge retention, and ability to apply learned material.

The experimental results were significant. Students using the AI-driven platform achieved an average post-test score improvement of 31%, compared to an 18% increase observed in the control group. Furthermore, the AI group reported an average engagement duration of 22 minutes per session, which was notably higher than the control group's average. Survey feedback revealed that over 80% of the AI users expressed satisfaction with the system, emphasizing benefits such as immediate feedback, relevant content, and intuitive interaction.

To complement these findings, visual demonstrations of the platform's interface were captured. As shown in Figure 1, the home dashboard provides users with access to multiple AI-powered tools including PDF summarization, quiz creation, chatbot interaction, and YouTube transcript summarization—all aimed at supporting personalized learning pathways.

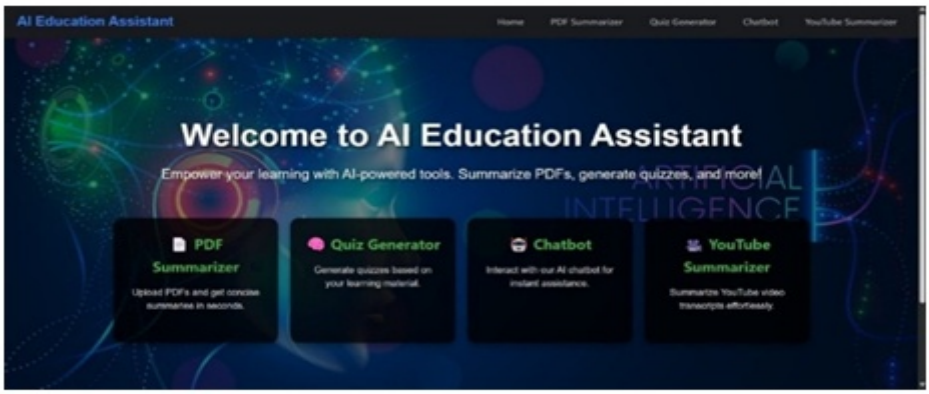

Fig. 4.1 Main Website
The main landing page of the website.

Figure 2 presents the quiz generation module in action. Users input a desired topic and difficulty level, and the system dynamically produces multiple-choice questions. The quiz interface includes automatic answer checking and real-time explanations to reinforce understanding and correct misconceptions, enhancing active learning.

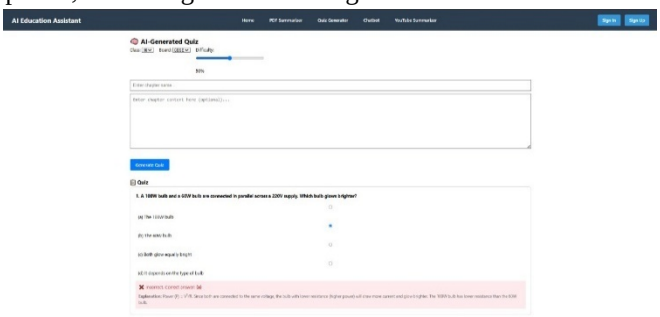

Fig. 4.2 Quiz Module
Adaptive quizzes with instant AI-generated feedback and encouragement.

These outcomes substantiate the effectiveness of integrating large language models and learning analytics within a modular, web-based tutoring platform. The solution not only improved academic performance but also enhanced user satisfaction and time-on-task—key indicators of learner engagement. The personalized and adaptive features of the system were instrumental in bridging conceptual gaps, thereby making the learning process more efficient and learner-centered.

V. CONCLUSION

This research presents a robust and scalable AI tutoring framework that synthesizes generative language models with real-time learning analytics. Through a carefully designed architecture and empirical validation, the system demonstrates notable improvements in student learning and engagement. Unlike traditional ITS, this model accommodates diverse learner needs and provides timely, relevant feedback. Moreover, continued exploration into ethical AI practices will be essential to ensure inclusive, secure, and transparent educational experiences.

VI. FUTURE SCOPE

Future developments of this AI tutoring framework will focus on incorporating multimodal input methods such as speech and handwriting, integrating with institutional Learning Management Systems (LMS), and implementing long-term knowledge modeling for sustained personalization. Another promising direction includes refining explainability features in the AI feedback loop and introducing adaptive curriculum sequencing based on user proficiency. These enhancements aim to strengthen the tutor's pedagogical soundness, promote accessibility, and support lifelong learning through advanced human-AI collaboration.

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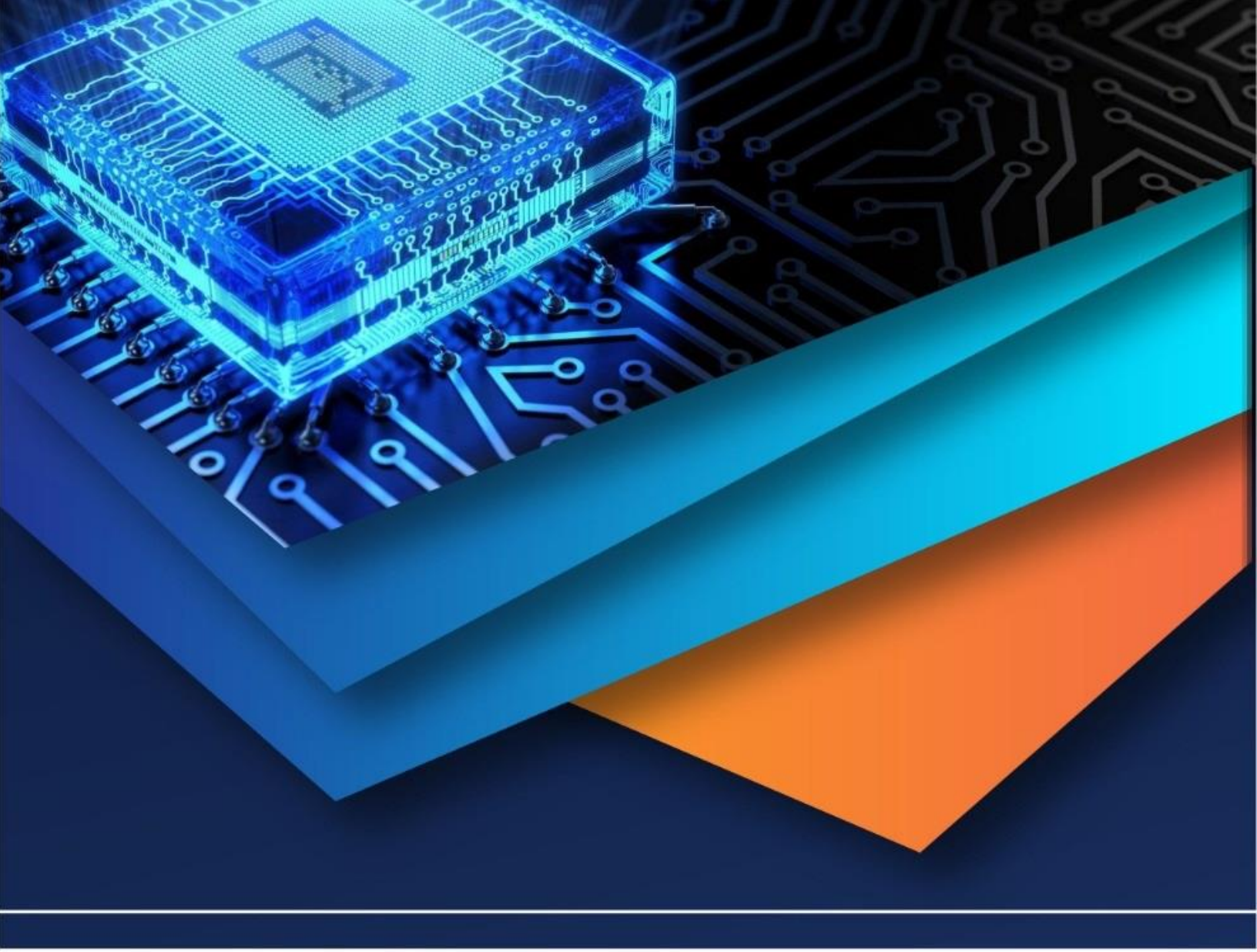

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