IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, April 2025
Impact Factor: 7.67

ClassMate AI: AI-Based Smart Classroom

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Abstract: *ClassMate_AI is an intelligent classroom management system designed to transform the traditional learning environment into an AI-powered digital ecosystem. This system automates assignment analysis, provides AI-driven feedback, monitors attendance, and enables real-time communication between teachers and students. With role-based dashboards, voice-enabled chatbot, and personalized academic insights, the platform enhances student engagement and reduces teacher workload. The paper discusses the system architecture, implementation strategies, and integration of Natural Language Processing (NLP) and Machine Learning models that make ClassMate_AI a smart and scalable education solution.*

Keywords: Classroom Management System, AI in Education, Assignment Analysis, AI-Driven Feedback, Attendance Monitoring, Real-Time Communication, Role-Based Dashboards, Voice-Enabled Chatbot, Personalized Academic Insights, Student Engagement, Teacher Workload Reduction, System Architecture, Implementation Strategy, Natural Language Processing (NLP), Machine Learning (ML), Smart Education, Scalable Solutions

I. INTRODUCTION

The rapid advancement of Artificial Intelligence (AI) and web technologies has had a transformative impact across various sectors, and education is no exception. Traditional classroom settings, while effective in structure, often lack tools for dynamic engagement, instant feedback, and adaptive learning. With these challenges in mind, ClassMate AI was conceptualized as a smart classroom assistant designed to bridge the gap between conventional education methods and modern intelligent technologies.

ClassMate AI is a full-stack AI-powered platform aimed at enhancing teaching efficiency and student involvement through real-time data analysis, automation, and interactivity. It is specifically designed to assist educators in managing classroom sessions, evaluating student behavior, and offering on-demand AI assistance for academic support.

The system consists of three major components:

- Frontend Interface (ReactJS): A user-friendly, responsive interface that allows teachers and students to interact with features such as dashboards, live sessions, and chatbot support.
- Backend Engine (FastAPI): A high-performance backend that handles user authentication, session management, API routing, and data processing asynchronously.
- AI Module (Python/NLP): Responsible for chatbot interaction, sentiment analysis, and summarizing classroom activity using machine learning and natural language processing.

Unlike traditional Learning Management Systems (LMS), ClassMate AI introduces AI into the real-time classroom loop. It captures behavioral data and interprets it using custom-built AI modules to generate feedback and insights that improve educational outcomes. Teachers can monitor student engagement, identify passive learners, and even generate automated session summaries.

The AI chatbot, integrated within the system, assists students by answering queries and simplifying communication. The chatbot uses natural language understanding to deliver accurate and contextually relevant responses, reducing the teacher's burden in addressing repeated or general questions during sessions.

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Data visualization is another core feature. Dashboards for both teachers and students display progress metrics, sentiment trends, and historical records of classroom performance. These insights help tailor educational strategies for improved individual and group learning.

II. LITERATURE SURVEY

The advancement of Artificial Intelligence (AI) and Natural Language Processing (NLP) has catalyzed the development of intelligent educational systems, transforming traditional classroom environments into dynamic learning platforms. Several existing research efforts have laid the foundation for projects like **ClassMate AI**, focusing on automation, behavioral analytics, and personalized assistance in classroom settings.

A smart classroom architecture combining IoT and AI to automate attendance and environmental control. While effective for hardware integration, their approach lacked a robust interactive feedback mechanism or intelligent chatbot systems for real-time student support. ClassMate AI builds on this by emphasizing software-based engagement tools using NLP and sentiment analysis.[1]

AnAIchatbotfor resolving academic queries using machine learning and dialog flow models. Their system was limited to static FAQs and predefined responses. In contrast, ClassMate AI uses custom NLP models to interpret student sentiment, track classroom behavior, and generate adaptive responses, offering a deeper integration into learning workflows.[2]

Zhou et al. (2019) focused on behavioral analysis in MOOCs using data mining and emotion tracking. Their system demonstrated that student engagement correlates strongly with retention. ClassMate AI applies similar techniques in a live classroom context using Python- based analysis (ai_analysis.py), enabling real-time feedback through FastAPI and dashboards.[3]

Anderson et al. (2018) described intelligent tutoring systems that adapt lesson flow based on individual performance. These systems typically rely on historical data. ClassMate AI advances this concept by generating live session summaries and engagement feedback in real time using lightweight, modular AI logic.[4]

A real-time attendance and activity tracker using image processing. While effective for physical monitoring, it lacked emotional context. ClassMate AI supplements this by integrating NLP-based emotional analysis, providing teachers with real-time sentiment snapshots of the classroom.[5]

III. PROPOSED SYSTEM

The proposed system, ClassMate: AI Based Smart Classroom, aims to address the limitations of existing educational platforms by integrating Artificial Intelligence(AI),NaturalLanguage Processing (NLP), and intelligent automation to create a personalized, efficient, and interactive learning environment.

AI-Driven Assignment Analysis and Feedback

The system utilizes NLP models to analyze student-submitted assignments for grammatical correctness, plagiarism detection, and concept coverage. It generates automated grades along with constructive feedback, helping students improve their academic writing and conceptual understanding.

Smart Chatbot with VoiceInput and Personalized Responses

An AI-powered chatbot is integrated to assist students with academic queries in real-time. It supports voice input and provides course-specific answers, assignment deadlines, and reminders. The chatbot maintains user context to offer personalized guidance.

Teacher Dashboard with Role-Based Features

Teachers can securely log in and access a dedicated dashboard to upload assignments, evaluate submissions, assign grades, and post announcements. The system uses JWT-based authentication to ensure secure and role-based access.

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Data Visualization and Trend Monitoring

The dashboard includes charts and graphical analytics to present assignment submission trends, student performance, and topic coverage. Attendance data is visually represented using color-coded indicators for quick insights.

Real-Time Attendance Tracking Module

The attendance tracker monitors student participation across subjects and visualizes the data as per defined thresholds: green (above 75%), yellow (between 60% and 75%), and red (below 60%).

Modular and Scalable Architecture

The system is built with a modular architecture, consisting of independently functional components like Assignments, Chatbot, Course FAQs, Teacher Panel, Attendance Tracker, and Analytics. This allows for easy maintenance, testing, and future expansion of the application.

The proposed system significantly enhances the teaching and learning experience by automating manual tasks, offering data-driven insights, and personalizing student support through intelligent AI models. It not onlyreduces the burden on educators butalso empowers students with real-time feedback and self-paced learning tools.

IV. TOOLS AND LANGAUGES USED

ReactJS (Frontend Framework)

ReactJS is a powerful JavaScript library used tobuild dynamicand responsive user interfaces. In ClassMate AI, it powers the entire frontend application, including dashboards,login/signup screens, chatbot views, and session analytics pages. It enables the system tooffer real-time updates and component-based architecture, improving maintainability. React's virtual DOM optimizes rendering, ensuring fast performance. Its component reusability and strong ecosystem help developers build interactive UIs with minimal code repetition. State management (e.g., with hooks or Redux) allows smooth handling of user inputs and session data. The frontend also connects to the backend using Axios for API calls. Its responsive design supports access from desktops, tablets, and mobile devices.

FastAPI (Backend Framework)

FastAPI is a modern, high-performance Python web framework designed for building APIs quickly and efficiently. It serves as the backbone of ClassMate AI's server-side logic, handling requests like user login, session management, and AI analysis. FastAPI supports asynchronous request handling, making it ideal for real-time classroom applications. With built-in support for automatic data validation using Pydantic, it reduces boilerplate code and improves reliability. Its clear documentation and schema generation (via OpenAPI) make testing and integration straightforward. The project uses FastAPI routers (ai_analysis_router) to organize code by functionality. It's also lightweight and easy to deploy in various environments.

Python(Core Programming Language)

Python is the primary language for backend development and AI module implementation in ClassMate AI. Its simplicity and extensive libraries make it ideal for integrating machine learning, NLP, and webservices. Python scriptslikeai_analysis.pyand fastapi_bot.py handle sentiment analysis, chatbot interaction, and data interpretation. It also supports logging, exception handling, and session tracking. Python allows for rapid development and iteration, which is essential in educational tools that require feedback loops and adaptability. It integrates well with libraries like spaCy and scikit-learn, forming the core of the system's intelligence layer.

Natural Language Processing(NLP)Libraries–spaCy & NLTK

NLP enables machines to understand and interpret human language. In ClassMate AI, libraries like **spaCy**and **NLTK** are likely used (as inferred from naming conventions and structure) to analyze student queries and extract emotional sentiment from chat input. The AI chatbot uses these tools to process user input, identify intent, and provide accurate responses. Sentiment detection helps track student mood during sessions, allowing instructors to adjust teaching styles

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accordingly. These libraries also assist in generating summaries or insights post-session. NLP transforms plain text intoactionable educational data.

Axios(API Communication Library)

Axios is a promise-based HTTP client for the browser and Node.js. It's used in the frontend (ReactJS) to send and receive data from the FastAPI backend. It allows asynchronous communication between the client and server, enabling features like real-time chat, session tracking, and user authentication. Axios simplifies error handling and response formatting.

It also supports request/response interceptors for handling authentication tokens (JWT). This seamless communication is key to making ClassMate AI responsive and data-driven.

JSON Web Token (JWT)– Authentication

JWT is used to securely transmit informationbetween parties. In ClassMate AI, JWTenables stateless, token-based user authentication and session management. When users log in, they receive a signed token that must be included in all subsequent requests. This ensures secure and consistent access control. It's lightweight, encrypted, and easy to implement with FastAPI. JWT plays a critical role in differentiating user roles (e.g., student vs. teacher) and securing API routes.

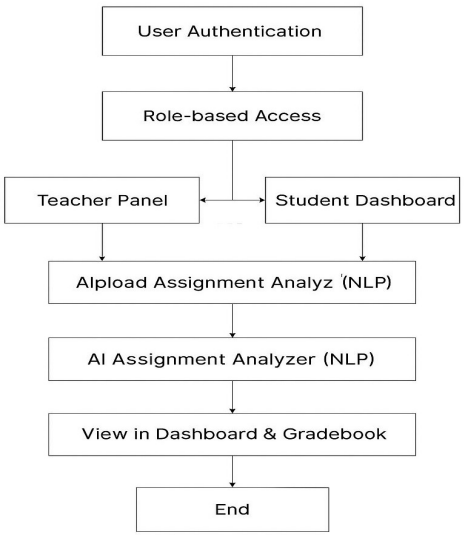
Git & GitHub–Version Control

Git is used to track changes in the project's source code, and GitHub serves as the remote repository for collaboration and code management. It helps the team maintain different modules (frontend, backend, AI) in sync and manage version control effectively. Featureslike branching, pull requests, and commits streamline development and teamwork. GitHub also acts as a backup and review system for code integrity and improvement.

HTML/CSS & JavaScript (Core Web Technologies)

Alongside ReactJS, HTML and CSS define the structure and styling of the frontend. They control layout,color themes, responsiveness, and interactivity. JavaScript provides core logic that connects UI elements to backend data. These foundational technologies ensure that the user interface is accessible, intuitive, and visually appealing. Custom styling and animation enhance the user experience during classroom sessions and dashboard navigation

Flowchart:



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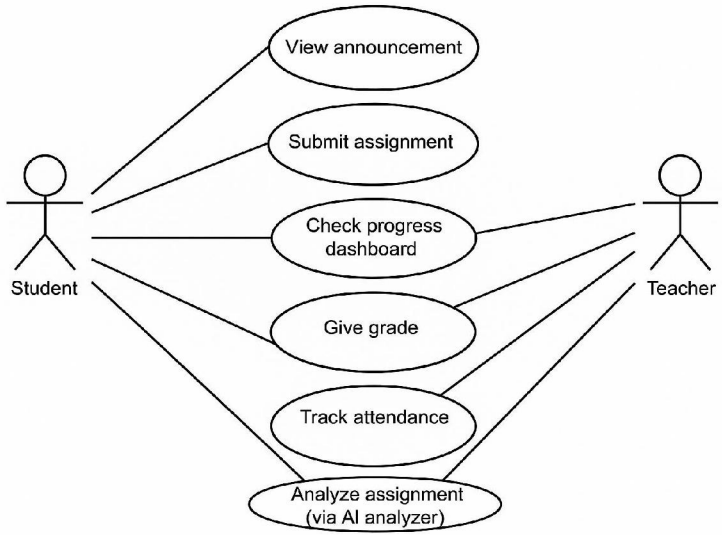
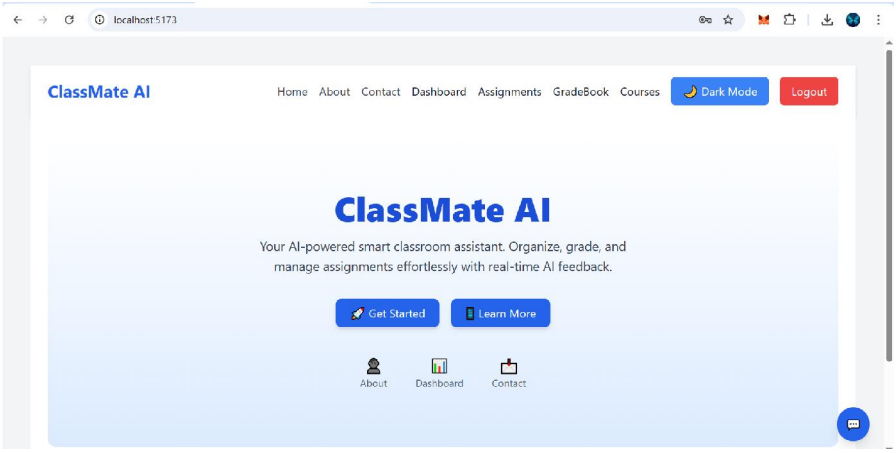
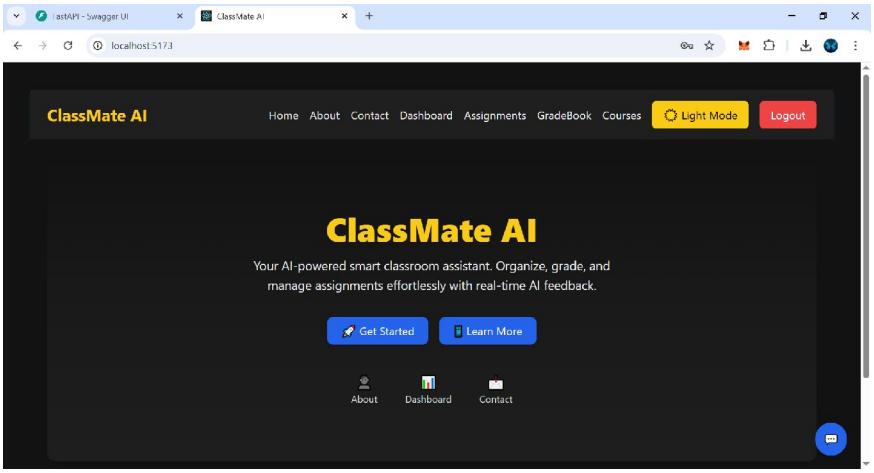


V. RESULT

Homepage: (Light Mode)



Homepage: (Dark Mode)



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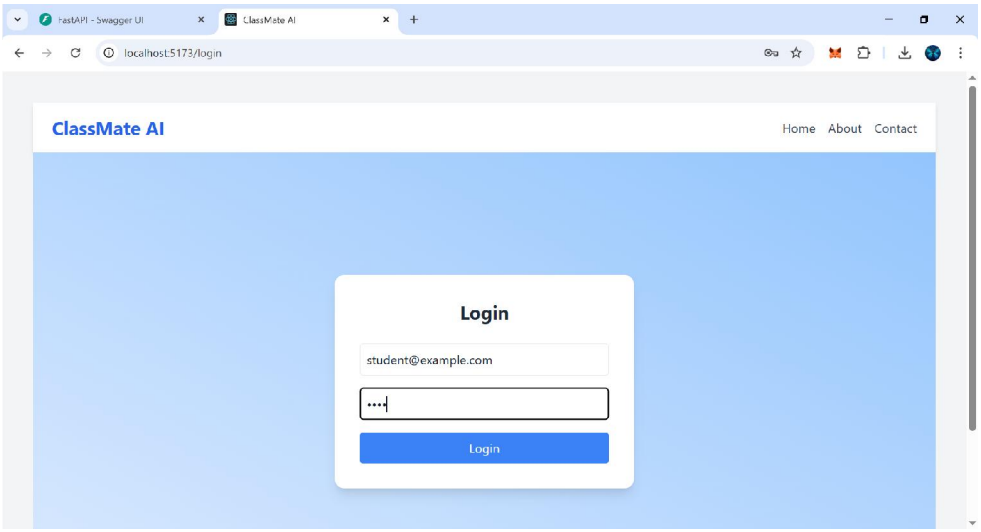
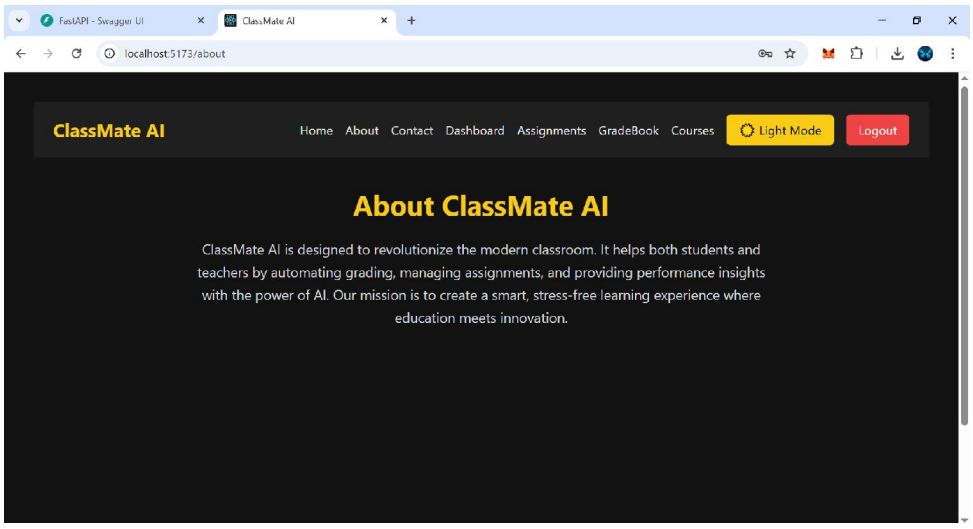
Student Section:

Student Login: JWT-based user authentication is implemented for secure role-based access. The login module ensures that only authorized users can access personalized dashboards.





Assignment Upload: Students can upload PDF/DOCX assignments, which are securely stored and queued for AI processing via backend API endpoints.

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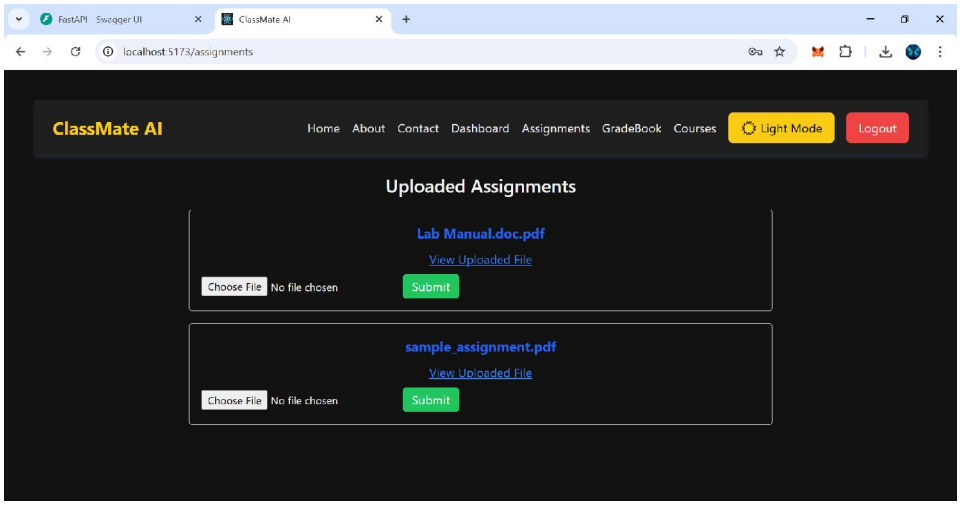
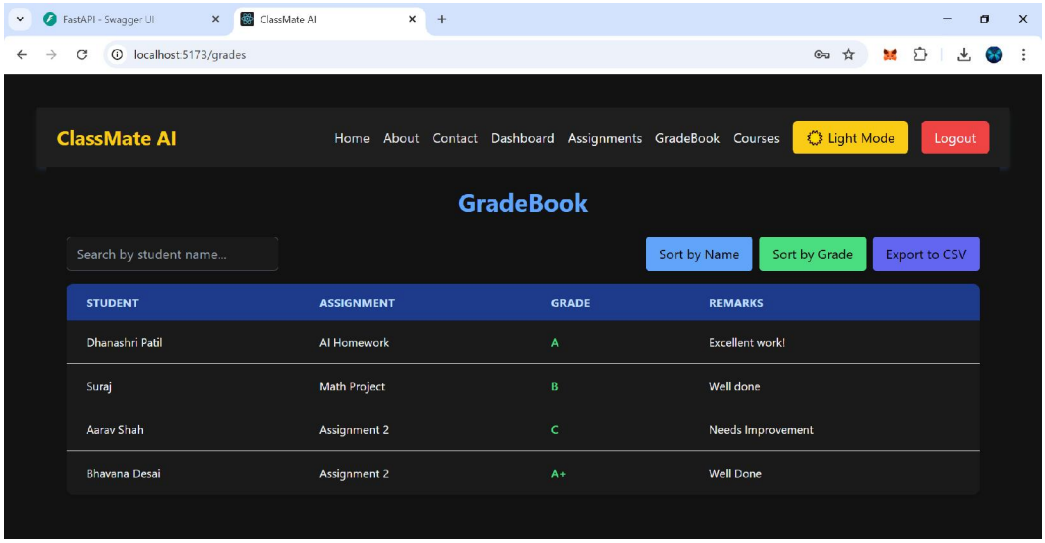


Feedback & Grading: AI assigns an initial grade and provides line-by-line feedback on grammar, structure, and subject relevance. This is displayed on the dashboard for student and teacher review.



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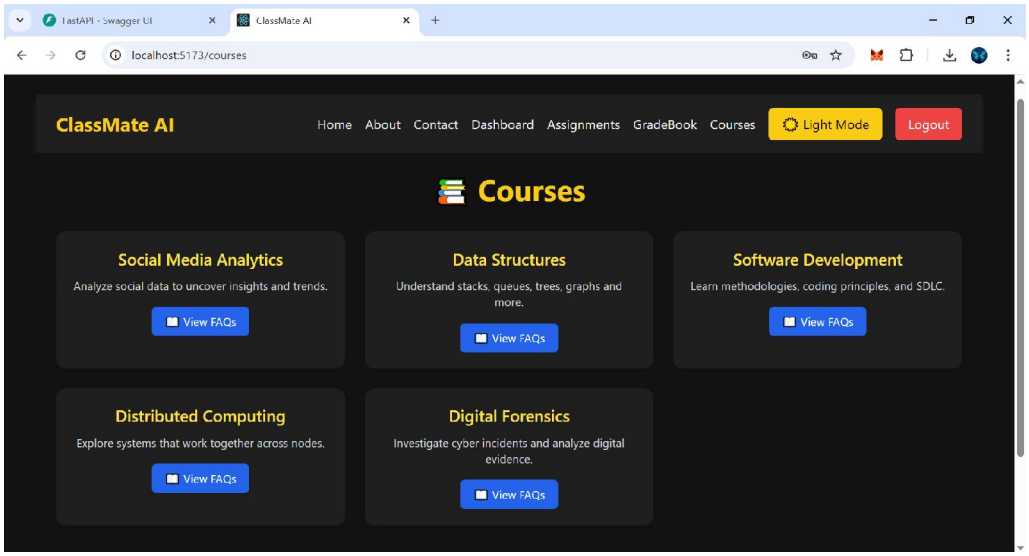

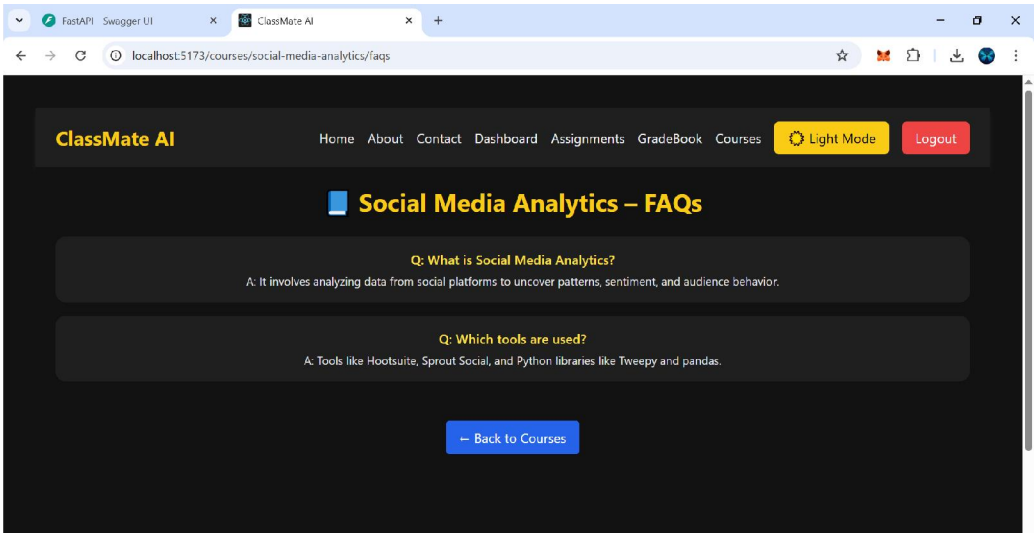

Chatbot Integration: The AI-powered chatbot uses NLP-based intent recognition to provide real-time answers to academic queries, enhancing student engagement.
Chatbot: ClassMate_AI

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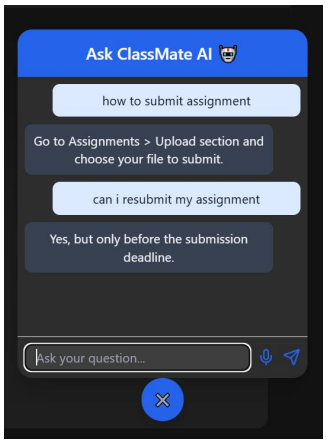
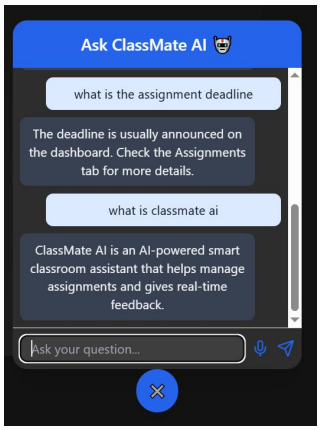
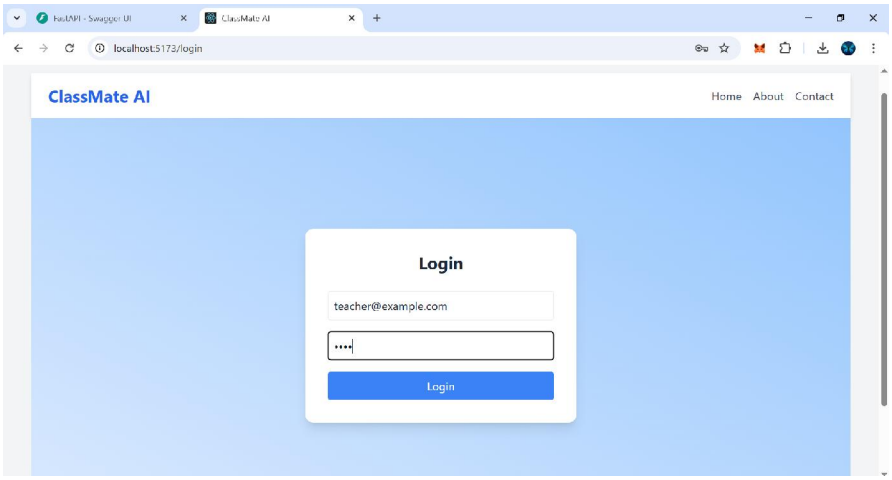
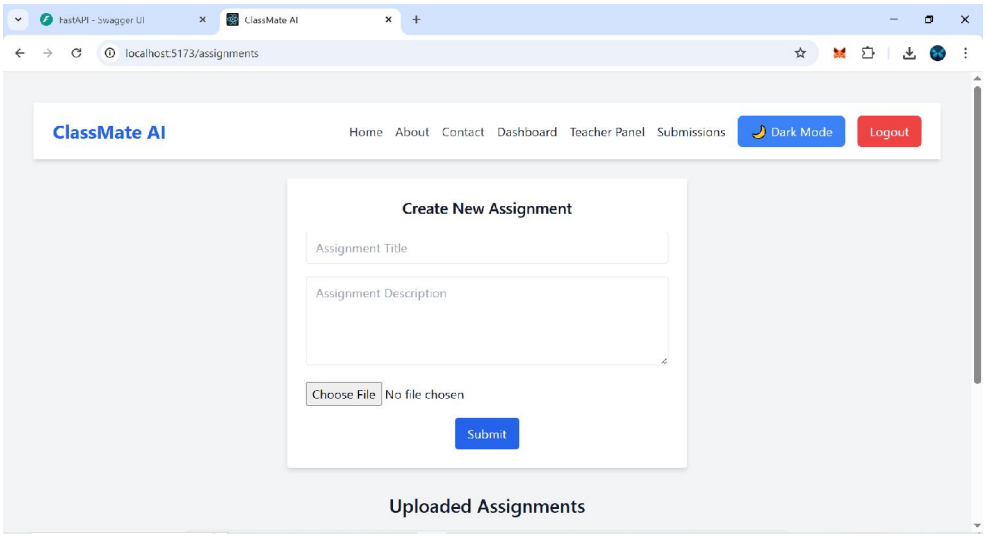




Teacher Section:





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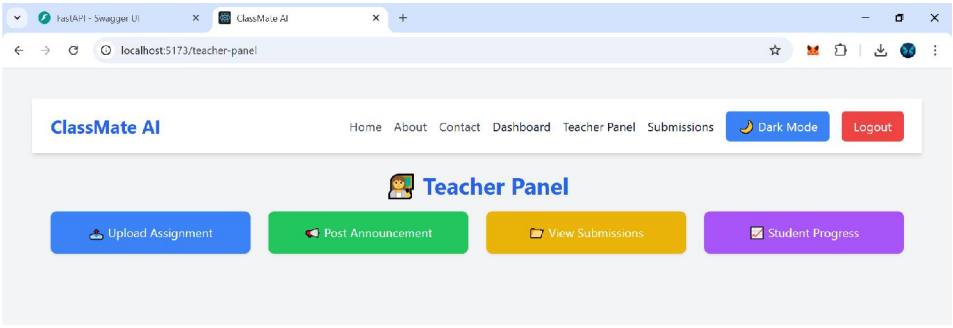
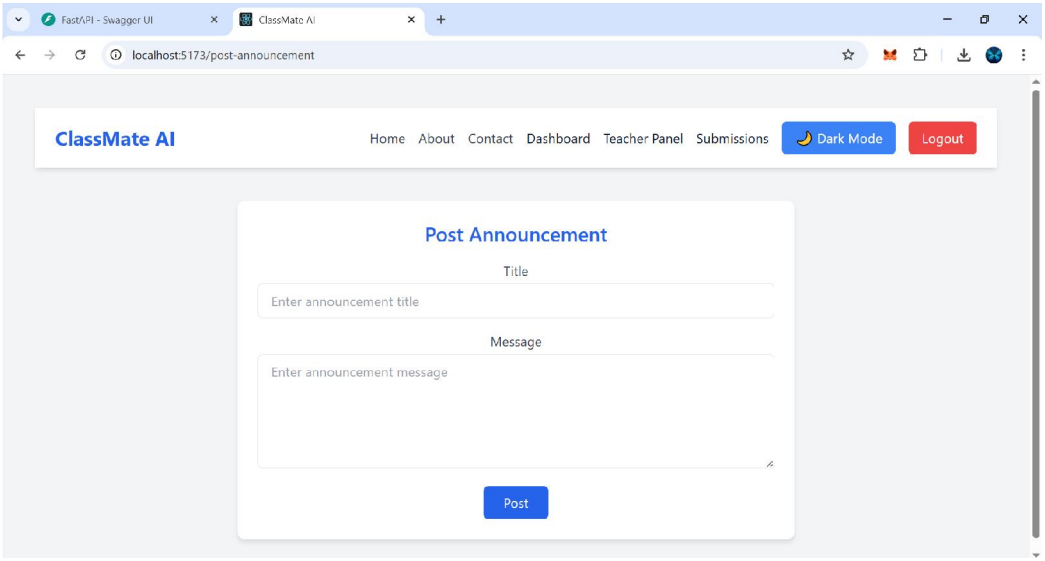
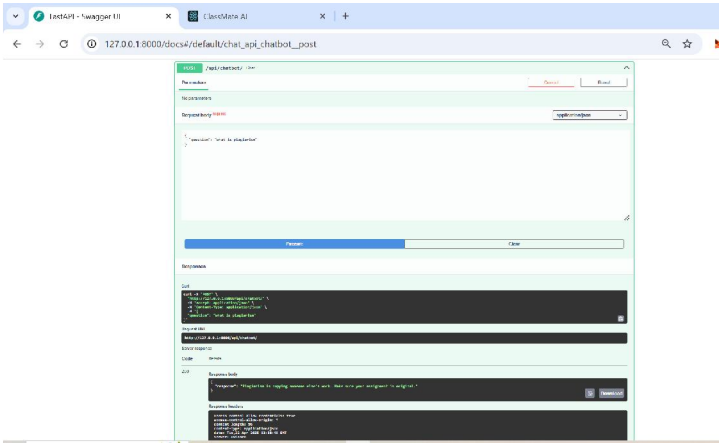
Teacher Panel: Teachers can upload new assignments, view and grade submissions, override AI feedback if needed, and post course-specific announcements.





Backend Endpoint Testing(FastAPI -Swagger UI):

Backend Testing: All API endpoints are documented and tested using Swagger UI, ensuring proper system integration, debugging, and performance verification.



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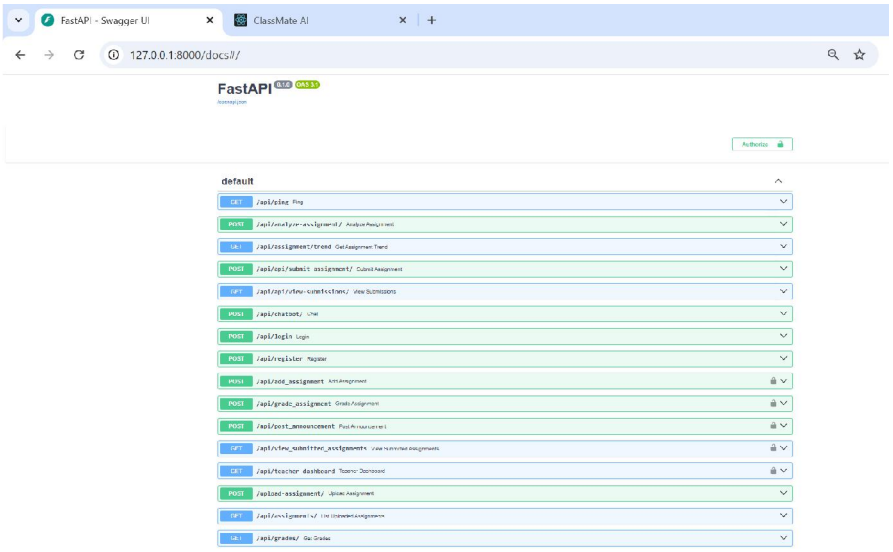

VI. CONCLUSION

The development of ClassMate AI marks a significant step toward transformingconventional classrooms into intelligent, adaptive, and interactive learning spaces. By integrating modern web technologies such as ReactJSfor the frontend and FastAPIfor the backend, along with AI-driven modules using Natural Language Processing (NLP), the system provides a holistic and scalable solution for classroom management and engagement.

The core functionalities—AI chatbot assistance, real-time sentiment analysis, behavioral monitoring, and session-wise feedback—create a responsive educational environment where both students and educators can interact meaningfully. The system dashboard offers visual insights into session performance, participation, and mood trends, enabling teachers to take informed actions. By processing natural language input through custom modules like ai_analysis.py and fastapi_bot.py,thesystem ensuresintelligentresponses thatmimichuman- like assistance.

Unlike traditional LMS platforms that focus on static content delivery, ClassMate AI introduces intelligent interactivity and emotional awareness, closing the loop between instruction, feedback, and adaptation. The architecture, being modular and lightweight,allows easy deployment and extension. Security is managed through JWT-based authentication, ensuring safe and role-based access to the platform.

Pilot-level testing through simulated classroom sessions demonstrates that the platform handles real-timeinteractions smoothlyand generates accurate session analytics. Its open and adaptable design makes it suitable for integration with other digital education platforms.

VII. ACKNOWLEDGMENT

We are profoundly grateful to Prof. Sachin Chavan for his expert guidance and continuous encouragement throughout to see that this project rights its targets since it commencement to its completion.

We would like to express deep appreciation towards Dr. GeetaLathkar(Director of Mahatma Gandhi Mission's College of Engineering and Technology), Dr. Rajesh Kadu (Head of Department of Computer Engineering) whose invaluable guidance supporting us in completing this project.

At last we must express our sincere heartfelt gratitude to the all staff members of Computer Engineering Department who helped us directly or indirectly this course of work.

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