International Journal of Engineering Research and Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 22, Issue 11 (November 2026), PP 106-115

AI for Personalized Education System

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ABSTRACT
The AI-Based Personalized Education System is an intelligent platform developed to provide a customized learning experience for every student based on individual abilities, interests, performance and learning progress. In traditional education, students are generally provided with the same learning materials and teaching methods, even though each student has a different level of understanding and learning speed. This work uses Artificial Intelligence and Machine Learning techniques to analyze student data such as quiz scores, assessment results, learning activities and progress in order to identify strengths and weaknesses. Based on this analysis, the system can recommend suitable study materials, personalize learning paths, and adjust the difficulty of questions according to the student's performance. It can also include an AI-based virtual tutor that helps students understand difficult topics by answering questions and providing simple explanations. The system provides continuous feedback and tracks student progress, helping both students and teachers understand learning improvements and areas that require more attention. Teachers can use the system to monitor individual student performance and provide additional support when needed. By combining personalized recommendations, adaptive assessments, progress tracking and AI-based assistance, the proposed system aims to make education more engaging, flexible and effective. Overall, this work demonstrates how Artificial Intelligence can be used to support student-centered learning and improve the quality of education by providing the right learning content to the right student at the right level.

Keywords: *Artificial Intelligence (AI), Personalized Learning, Adaptive Learning, Machine Learning, Intelligent Tutoring System, Student Performance Analysis*

Date of Submission: 15-10-2026 Date of acceptance: 10-11-2026

I. INTRODUCTION

The AI-Based Personalized Education System is an intelligent learning platform designed to provide customized education according to the individual needs of each student. Every student has different learning abilities, interests, strengths, weaknesses and learning speeds, but traditional education systems generally provide the same learning content and teaching methods to all students. This work uses Artificial Intelligence and Machine Learning techniques to analyze student performance, quiz results, learning patterns and areas of difficulty. Based on this analysis, the system identifies the strengths and weaknesses of students and recommends suitable learning materials, topics, exercises and assessments. It can also adjust the difficulty level of questions according to the student's performance and provide personalized feedback. The system continuously monitors student progress and updates recommendations to support better learning outcomes. By providing an adaptive and personalized learning experience, the proposed system helps students learn at their own pace, improve their weak areas, and develop a better understanding of different subjects.

The system collects information such as quiz scores, completed activities and areas where students face difficulties, and uses it to recommend study materials, topics, exercises and assessments. Students receive personalized feedback to understand their progress and improve their learning, and the system helps them focus more on topics where they need improvement. Teachers can use the system to monitor student progress and identify areas requiring additional attention. The use of AI makes the learning process more adaptive, efficient and engaging. The main goal of this work is to make learning more personalized, adaptive and effective. By combining educational content with AI-based analysis, the system can help students focus on areas where they need improvement while allowing them to learn at their own pace, which can improve student engagement, learning outcomes and the overall educational experience.

A. Problem Statement

Traditional education systems generally follow a common teaching approach where the same content, assignments and assessments are provided to all students. However, students have different learning abilities,

interests, backgrounds and levels of understanding, so a single teaching method may not be effective for everyone. Some students may learn quickly, while others may struggle with certain topics and require additional explanations and practice. Teachers also have difficulty providing individual attention to every student because of limited time and large class sizes. In addition, identifying each student's strengths and weaknesses manually can be time-consuming and may not provide continuous and accurate feedback. There is therefore a need for an intelligent system that can understand individual learning patterns and provide suitable educational content based on each student's requirements. The proposed AI-Based Personalized Education System aims to solve this problem by using Artificial Intelligence to analyze student performance and learning patterns, identify learning difficulties, recommend appropriate study materials, adjust the difficulty of learning content, and provide personalized guidance. The system also helps teachers monitor student progress and identify areas where additional support is required, making the learning process more personalized, effective and student-friendly.

B. Scope of Research

The scope of this research is to develop an AI-Based Personalized Education System that provides customized learning based on individual student performance and learning needs. The system analyzes students' activities, quiz results, assessments and learning progress to identify their strengths and weaknesses. It recommends suitable learning materials, adjusts question difficulty, and provides personalized guidance and useful feedback to help students improve their understanding. The system can also help teachers track student performance and identify areas that require additional support. The research focuses on using Artificial Intelligence to make the learning process more adaptive, interactive, flexible and effective for both students and teachers.

C. Research Hypothesis

- AI-based personalized learning can improve students' academic performance over time.
- Continuous personalization can help students develop better learning habits.
- The system can increase student engagement and motivation in the long term.
- AI-based feedback can help students continuously improve their weak areas.
- Personalized education can support better learning outcomes compared with traditional methods.
- The system can help teachers provide effective support based on individual student needs.

D. Objectives

1. To develop an AI-based personalized education system that provides learning support according to each student's individual needs.
2. To analyze student performance, learning activities and assessment results to understand their learning level.
3. To identify the strengths, weaknesses and areas where each student needs improvement.
4. To recommend suitable study materials, topics and exercises based on student performance.
5. To adjust the difficulty level of questions according to the student's learning ability.
6. To provide continuous feedback and guidance to help students improve their academic performance.
7. To help teachers monitor student progress and provide better support when required.
8. To improve student engagement, understanding and overall learning experience.

E. Organization of the Paper

Section I introduces the system and presents the problem statement, scope, research hypothesis and objectives. Section II reviews existing research on Artificial Intelligence in education and identifies gaps in existing solutions. Section III describes the system architecture, block diagram, operational flowchart, use cases and algorithms. Section IV presents the implementation, including the tools, technologies and modules. Section V presents the test cases, performance analysis and screenshots of system execution. Section VI concludes the paper, lists the limitations of the study and discusses future scope.

II. SYSTEM DESIGN AND METHODOLOGY

A. System Architecture

The AI-Based Personalized Education System is designed using a layered architecture that connects students, teachers, application services, Artificial Intelligence modules and the database to provide a personalized learning experience. The system begins with the user interface, where students can register or log in, access learning materials, attend lessons, complete quizzes and assessments, receive personalized recommendations and view their learning progress, while teachers can manage educational content and monitor student performance. The application layer manages user requests, learning activities, assessments, progress tracking and communication between different parts of the system. The AI layer is the main component of the system, where

student performance and learning behavior are analyzed using Artificial Intelligence and Machine Learning techniques to identify strengths and weaknesses, recommend suitable learning resources, provide feedback and adjust the difficulty of questions according to the student's learning level. The database stores important information such as student profiles, quiz results, assessment scores, learning history, course content, recommendations and progress records. Whenever a student interacts with the system, the collected data is processed and analyzed by the AI module, and the results are used to provide suitable learning content and recommendations. This continuous process allows the system to adapt to the changing needs of students and provides a more effective, flexible and personalized learning environment while also helping teachers understand and support individual students.

B. Block Diagram

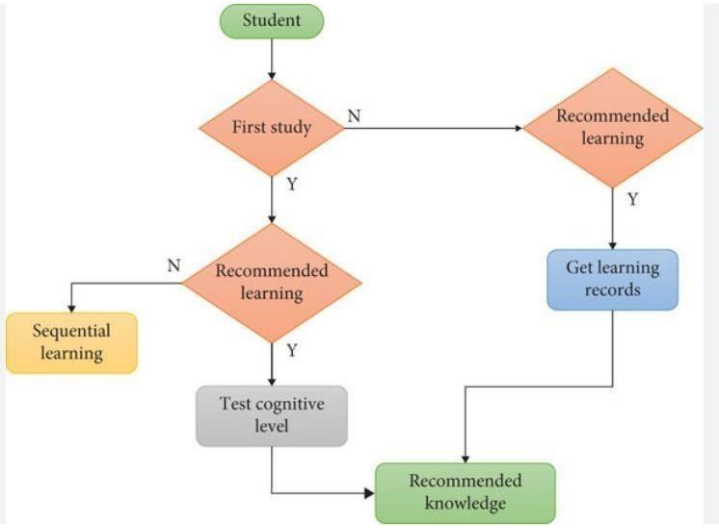


Figure 1: Block Diagram of the Proposed System

The block diagram of the AI-Based Personalized Education System shows how information flows from the student and teacher through the system to the AI module and database. Students and teachers interact with the system through the user interface. Student information, quiz results, assessments and learning activities are sent to the application module, which communicates with the database for storing and retrieving information. The AI module analyzes the collected data to identify student strengths and weaknesses and generates personalized recommendations, adaptive questions and feedback. The results are then provided back to the student through the user interface, while teachers can access student performance and progress reports.

C. Flowchart

The operational execution of the proposed system follows a sequential methodology:

1. **User Authentication & Access:** Admin, Faculty and Student users access the system through the React-based frontend using their respective roles.
2. **Quiz & Assessment Management:** The Node.js and Express REST API manages quiz creation, question delivery, assessment services and student responses.
3. **Data Collection & Storage:** Quiz responses, assessment results and proctoring telemetry such as focus loss, tab switching and response time are collected and stored using the Local Database and Google Cloud Firestore.
4. **AI/ML Processing:** The collected data is processed by the Python AI/ML engine using 1-PL IRT with Bayesian Updating, Logistic Regression, K-Means and Z-Score Analysis for adaptive assessment, risk prediction, student segmentation and anomaly detection.
5. **AI Analytics & Insights:** The outputs of the ML models are combined to generate AI-based analytics, student performance insights and an Exam Integrity Score.
6. **Adaptive Assessment & Feedback:** Based on the analysis, the system provides adaptive question routing, while the Gemini LLM supports question generation and AI-based feedback.
7. **Actionable Output:** Finally, the system provides automated grading, Faculty Dashboard insights, Student Dashboard results and exam integrity/risk information.

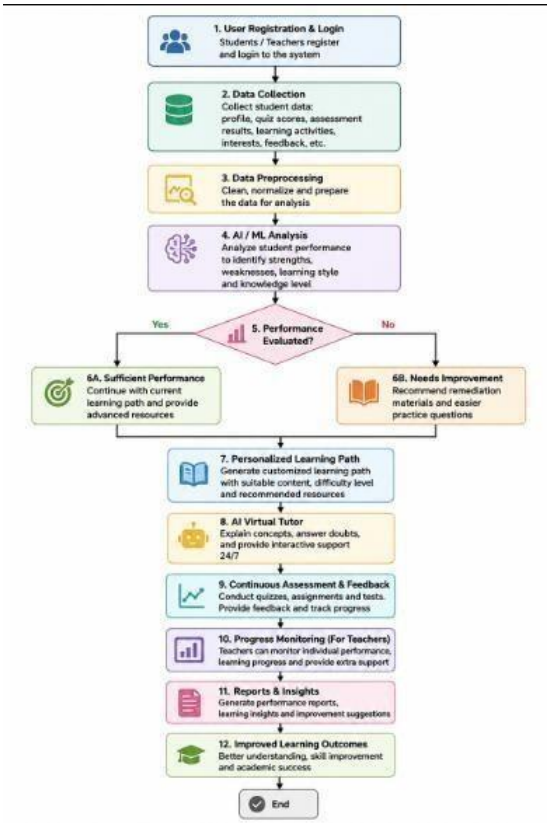


Figure 2: Operational Flowchart

D. Use Case Description

The system is designed to provide students with a personalized learning experience based on their individual needs and performance. Students can register and log in, take assessments and quizzes, access study materials, get personalized recommendations, ask questions to the AI tutor and track their learning progress. Teachers can manage learning materials, create assessments, monitor student performance and identify students' strengths and weaknesses. The admin manages users, courses, content and system settings. The AI system analyzes student performance and learning behavior to create personalized learning paths, recommend suitable study materials, adjust the difficulty of quizzes, provide feedback and help students improve their learning outcomes. The actors are:

- **Student –** takes assessments, learns through personalized content, interacts with the AI tutor and tracks progress.
- **Teacher –** monitors students, manages educational content and reviews performance.
- **Admin –** manages users, system settings and reports.
- **AI System –** analyzes student data and generates personalized learning recommendations.

E. Algorithm Explanation

The algorithm starts with user login and authentication, followed by collecting student information such as assessment scores, quiz results, learning activities and subject preferences. The steps are as follows:

1. **User Login and Authentication:** The user enters login details and the system verifies the credentials. After successful verification, the user is given access based on their role.
2. **Student Data Collection:** The system collects student details, assessment scores, quiz results, learning activities and subject preferences, and stores them for further analysis.
3. **Data Processing:** The collected data is cleaned, organized and prepared for analysis. The system removes incorrect or unnecessary information before processing.
4. **Performance Analysis:** The AI analyzes the student's marks, quiz results and learning activities and determines the current performance level in different subjects.
5. **Identify Strengths and Weaknesses:** The system identifies topics where the student performs well and topics where improvement is required, which helps the AI understand individual learning needs.
6. **Personalized Recommendation:** The AI recommends suitable study materials, videos, exercises and practice questions based on the student's performance and learning level.

7. **Adaptive Learning:** The system adjusts the difficulty of quizzes and learning activities according to the student's progress. Easy questions are provided when the student needs practice, while difficult questions are provided when performance improves.
8. **AI Tutor:** Students can ask questions to the AI tutor and receive answers and explanations, which helps clear doubts and understand difficult concepts.
9. **Progress Tracking:** The system records scores, completed lessons, quiz results and other learning activities, which students and teachers use to monitor improvement.
10. **Continuous Improvement:** The AI continuously uses new performance data to update recommendations and learning paths, making the learning experience more accurate, personalized and effective over time.

F. Algorithm Implementation Details

The Python implementation contains the following components, as defined in the project source code:

- **Generative AI assessment engine:** generates multiple-choice questions (options A–D, correct answer, explanation and optional code snippet, returned as JSON) for a given topic, difficulty and course context, and generates personalized feedback containing an overall assessment, areas of improvement and a recommended action. In the listed code the generated output is a fixed sample.
- **Student risk predictor (logistic regression):** trained by gradient descent with a sigmoid function (default learning rate 0.05, 1000 epochs). The pass probability is classified as "Safe / High Probability" (≥ 0.70), "Moderate Risk" (≥ 0.40) or "High Risk", and intervention is recommended when the pass probability is below 0.50.
- **Cohort clusterer (K-Means):** groups students into k = 3 clusters (default), named "High Performers (Advanced Concepts)", "Consistent Learners (Standard Track)" and "Remedial Support Required (Foundations)".
- **Adaptive difficulty engine (1-PL IRT with Bayesian-style updating):** maintains an ability estimate θ and maps Easy, Medium and Hard to difficulties of -1.0, 0.0 and 1.2. The probability of a correct response is $1 / (1 + e^{-(\theta - \beta)})$, and θ is updated by $\theta \leftarrow \theta + 0.4$ (outcome $-$ p). The next difficulty is "Hard" when $\theta \geq 0.8$, "Medium" when $\theta \geq -0.3$, and "Easy" otherwise.
- **Proctoring anomaly detector (Z-score analysis):** computes the time Z-score against peer statistics (default mean 1200 s, standard deviation 300 s), flags attempts that score above 85% in under 25% of the allotted time, and flags three or more tab switches. An integrity score is computed as 100 minus a penalty (15 per tab switch, plus 30 when $|Z| > 2.5$ and the score exceeds 90%); scores below 70 require manual review.

III. IMPLEMENTATION

A. Tools and Technologies Used

The system uses various tools and technologies to develop an effective and user-friendly application. Python is used for AI and machine learning, while HTML, CSS and JavaScript are used to design the web interface. Flask is used for backend development, and MySQL is used to store student and academic data. Pandas and Scikit-learn are used for data processing and machine learning, while Visual Studio Code is used as the development environment.

B. Hardware and Software Requirements

Table 1: Hardware and software requirements

Item	Requirement
Processor	Intel Core i3 or equivalent processor for running the application smoothly
RAM	Minimum 4 GB; 8 GB recommended for better performance
Storage	At least 100 GB of available storage for the system, database and project files
Internet & peripherals	Stable internet connection with keyboard, mouse and monitor/display
Operating system	Windows 10/11, Linux or macOS
Programming language	Python for AI, machine learning and backend development
Database	MySQL for storing student, course and performance data
Development tools	Visual Studio Code, Flask, Pandas and Scikit-learn

C. Frameworks, Programming Languages and Databases

Flask is used as the main backend framework; it connects the user interface with the AI model and database and handles user requests, login and system operations. Python is the primary programming language, used for artificial intelligence, machine learning, data processing and system logic, including analyzing student performance and generating recommendations. HTML creates the structure of the web pages, CSS designs and styles the interface, and JavaScript adds interactive and dynamic features. MySQL stores and manages student details, login information, quiz results, learning materials, assessment records and performance data, and allows the system to securely retrieve and update student information. Together these technologies create a user-friendly, efficient and personalized education system.

D. Module-wise Explanation

1. **User Management Module:** manages the registration and login of students, teachers and administrators, stores user details and provides access according to the user role while maintaining secure user information.
2. **Student Profile Module:** maintains student information such as personal details, subjects, learning preferences and academic records, which the system uses to understand the student's learning requirements. Students can update their profile information when needed.
3. **Assessment Module:** allows students to take tests, quizzes and assessments. The system records the answers and calculates scores, which are used to evaluate the student's knowledge and performance.
4. **AI Analysis Module:** uses AI and machine learning techniques to analyze student performance and identify strengths, weaknesses, learning patterns and areas that require improvement.
5. **Personalized Learning Module:** creates a customized learning path for each student by recommending suitable study materials, videos, exercises and practice questions, updated according to the student's performance.
6. **AI Tutor Module:** allows students to interact with an AI-based tutor, ask questions and receive answers, explanations and guidance on difficult topics.
7. **Progress Tracking Module:** tracks student activities, marks, quiz scores, completed lessons and overall progress. Students can view their improvement over time and teachers can use the information to provide better guidance.
8. **Teacher Module:** allows teachers to manage learning materials and assessments, view student performance and identify areas where students need improvement.
9. **Admin Module:** manages the overall system and its users, including students, teachers, courses, learning materials and system settings.
10. **Database and Report Module:** stores and manages student, teacher, assessment and performance data, retrieves information when needed and generates useful reports for students, teachers and administrators.

IV. TESTING AND RESULTS

A. Test Cases and Their Outcomes

Table 2: Test cases and their outcomes

S.No.	Test case	Description	Outcome
1	Student Registration	Student enters valid details and creates an account	System successfully registers the student
2	User Login	User enters valid login credentials	System verifies the details and opens the dashboard
3	Invalid Login	User enters incorrect credentials	System displays an appropriate error message
4	Assessment Test	Student completes an assessment	System calculates the score and stores the result
5	Performance Analysis	AI analyzes the student's assessment and quiz results	System identifies the student's strengths and weaknesses
6	Personalized Recommendation	System analyzes student performance and recommends suitable learning materials	Recommended content is displayed to the student
7	AI Tutor	Student asks a question to the AI tutor	System provides a relevant answer or explanation
8	Progress Tracking	Student completes learning activities and quizzes	System records the results and updates the progress
9	Teacher Monitoring	Teacher views student performance and progress	System displays the required academic information
10	Admin Management	Administrator manages users and system data	System successfully performs the requested administrative operations

B. Performance Analysis

The system was evaluated based on its ability to analyze student performance and provide suitable learning recommendations. It collects assessment marks, quiz scores, learning activities and progress data to understand each student's learning level, identifies strengths and weaknesses, recommends appropriate learning materials, adjusts the difficulty of questions according to performance, and continuously updates the personalized learning path. The performance analysis helps students understand their progress and areas for improvement, while teachers can monitor student performance and provide additional guidance. The evaluation considered the following aspects:

1. **Student Performance:** marks, quiz scores and assessment results are analyzed to measure student performance.
2. **Strengths and Weaknesses:** the AI identifies topics where the student performs well and areas that require improvement.
3. **Personalized Recommendations:** based on performance, the system recommends suitable learning materials and activities.
4. **Progress Tracking:** the system continuously records student activities and compares current performance with previous results.
5. **Overall Effectiveness:** the system provides personalized and adaptive learning, helping students improve their knowledge and academic performance.

C. System Execution Process

Figures 3–7 show screenshots of the executing system. The teacher analytics dashboard (Figure 5) reports a Random Forest model performance of 74.44% accuracy, 75.11% precision, 74.44% recall and 74.08% F1 score, with an average score of 62.53 and average attendance of 81% across the five registered students. The prediction result screen (Figure 7) shows a predicted level of "Beginner" (confidence: Beginner 51.4%, Intermediate 46.1%, Advanced 2.5%) with the recommended quiz difficulty "Easy".

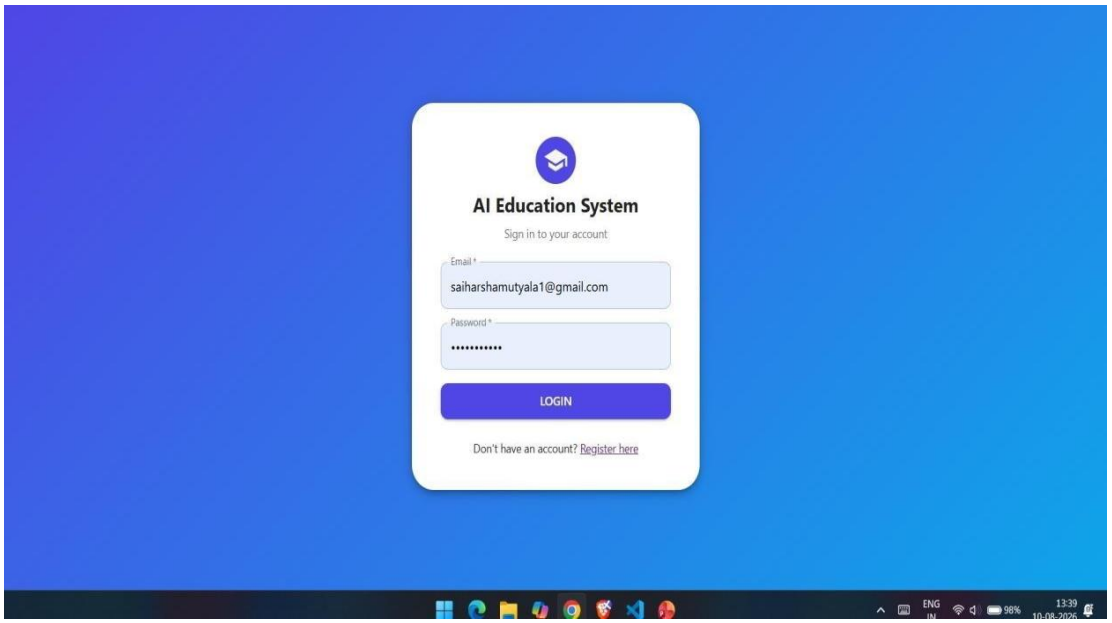


Figure 3: Login page

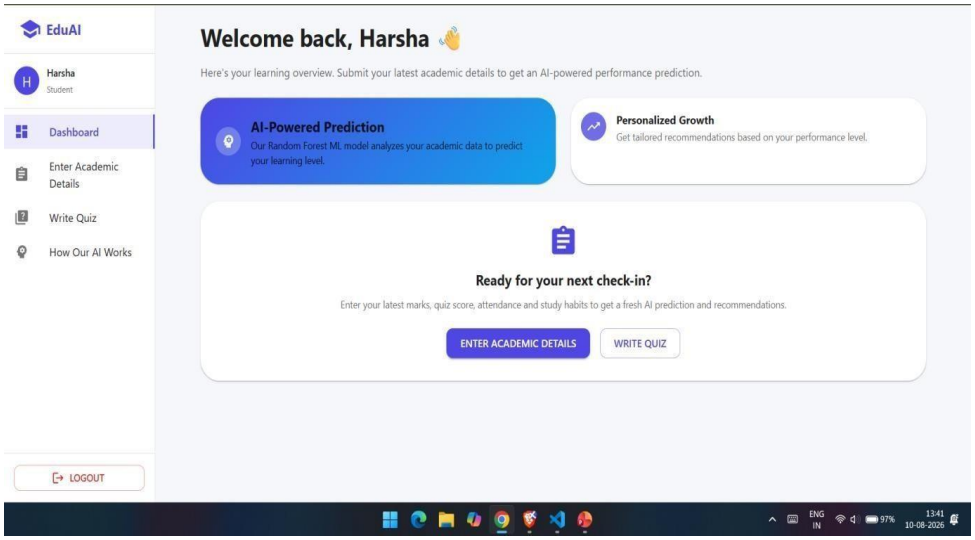


Figure 4: Student dashboard

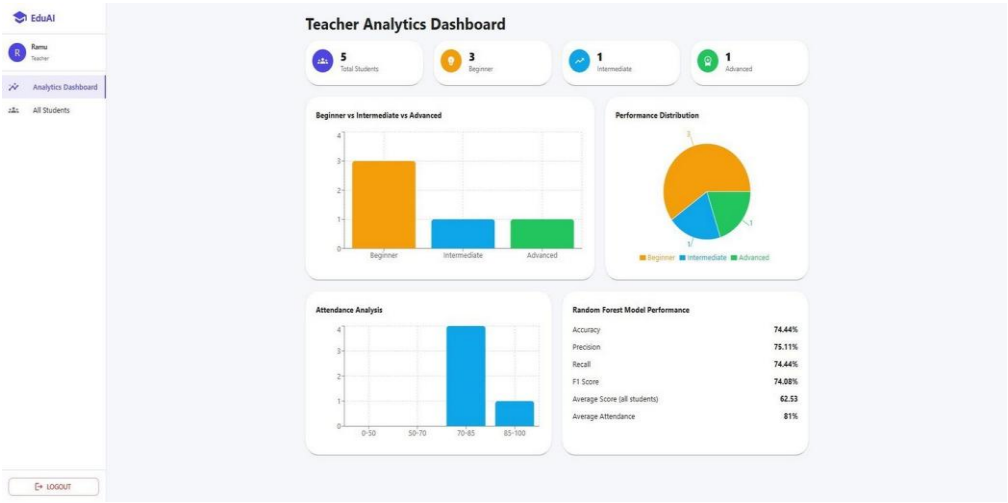


Figure 5: Teacher dashboard

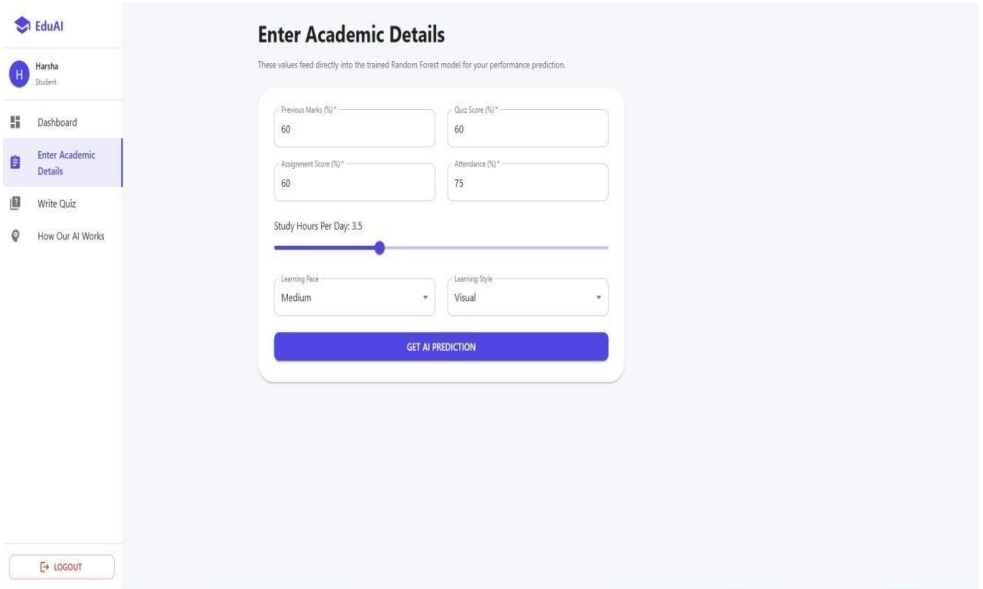


Figure 6: Entering academic details for performance prediction

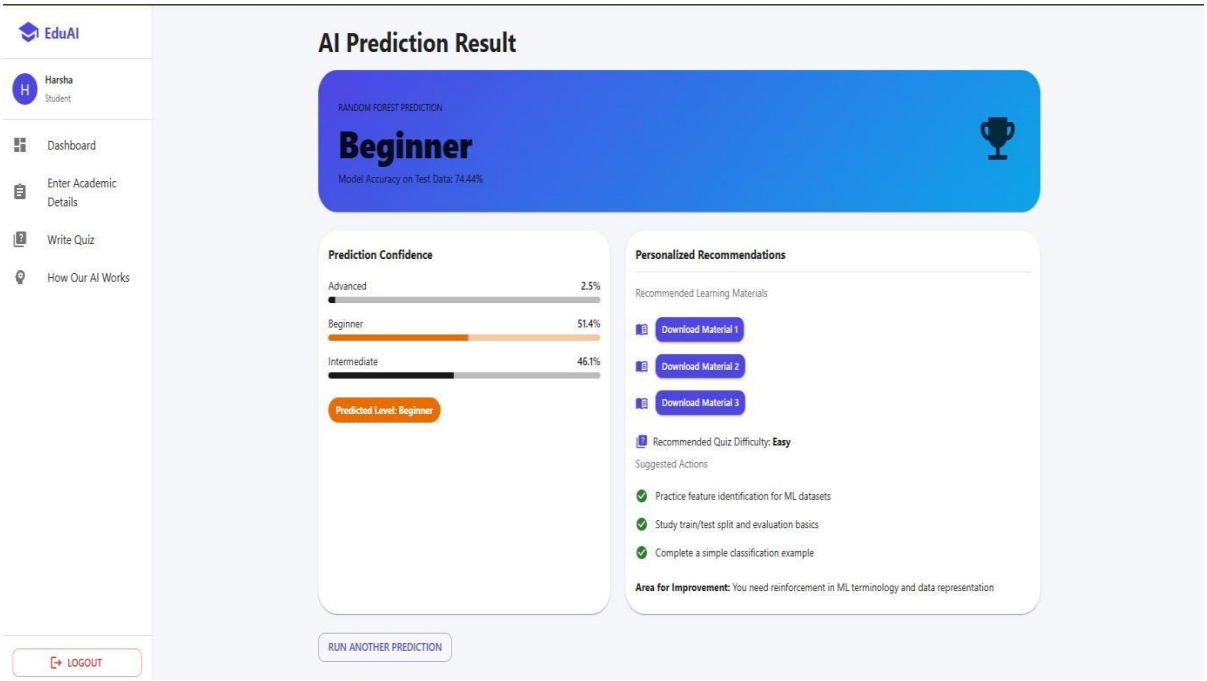


Figure 7: AI prediction result and personalized recommendations

V. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The AI for Personalized Education System provides an effective and intelligent approach to improving the learning experience of students. The system analyzes student performance, identifies strengths and weaknesses, and provides personalized learning materials and recommendations. It also supports adaptive quizzes, progress tracking and an AI tutor to help students understand difficult topics. Teachers can monitor student performance and provide suitable guidance, while administrators can manage users and system resources. Overall, the system helps make education more personalized, interactive, flexible and effective by using AI and machine learning technologies.

B. Limitations of the Study

1. **Data Dependency:** the accuracy of personalized recommendations depends on the quality and amount of student data available to the system.
2. **Internet Requirement:** the system requires a stable internet connection for accessing online learning resources and AI-based features.
3. **AI Accuracy:** the AI may sometimes provide incorrect recommendations or explanations, especially when insufficient learning data is available.
4. **Limited Subjects:** the current system may support only selected subjects and learning materials, which limits its use for all academic areas.
5. **Privacy and Security:** student personal and academic information must be properly protected to prevent unauthorized access or misuse.
6. **Technical Resources:** running AI and machine learning features may require sufficient computing resources, which may not be available on low-end devices.
7. **Limited Personal Interaction:** the AI system can provide automated guidance, but it cannot completely replace the personal interaction and emotional support provided by teachers.

C. Future Scope

The system can be improved with advanced artificial intelligence and machine learning technologies to provide more accurate and effective learning recommendations. In the future, a voice-based AI tutor can be added to allow students to ask questions and receive spoken answers. The system can also be developed as a mobile application so that students can access personalized learning materials anytime and anywhere. More subjects, courses and educational resources can be included to support different types of learners, and multilingual support can be introduced to make the system accessible to students from different regions. Advanced AI models can also predict student performance, identify learning difficulties at an early stage and provide suitable support. The teacher dashboard can be improved with detailed analytics and real-time progress monitoring. Integration with

online learning platforms and stronger data security can further improve the system. Overall, future developments can make the system more intelligent, accessible, secure, interactive and effective for personalized education.

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