Signify

AI-Enhanced E-Learning Platform for the Hearing impaired

Group ID: 24-25j-281

Project Final Individual Report

AI-powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction

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DECLARATION

I declare that this is my own work, and this Thesis titled **"**AI-powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction – A Component of Signify: An AI-Enhanced E-Learning Platform for Hearing-Impaired Children" does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or institute of higher learning, and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out this research thesis titled "Signify – An AI-Enhanced E-Learning Platform for Hearing-Impaired Children"**,** specifically focusing on the component titled "AI-powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction", for the Degree of Bachelor of Science (Honours) in Information Technology (Specializing in Data Science) under my supervision.

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ABSTRACT

This module of the Signify platform delivers an AI-powered Learning Assistant with Support in Sign Language and predictive learning in real-time, specifically for hearing-impaired students. Accessibility is fostered through a function of communicating through a chatbot with input from text and sign language, thus subject-related issues being solved through English and Mathematics. Using TF-IDF vectorization and cosine similarity, the chatbot extracts correct responses from a specially curated dataset, while inbuilt sign-to-text and text-to-sign features allow for barrier-free, inclusive communication.

Besides query processing, the system also suggests personalized courses through interaction history and quiz performance. Machine learning models—Random Forest and Linear Regression are also employed for predicting academic improvement scores, and ARIMA time-series analysis for forecasting future engagement behaviors. The students are also given detailed feedback on their academic performance, percentage of improvement, and learning streams, which prove to be helpful in motivating and enlightening.

User engagement was very high in terms of system useability and individual learning support. Through the convergence of real-time accessibility and smart analytics, this AI assistant provides a robust augmentation of inclusive education, enabling deaf learners through adaptive, interactive digital technology.

Keywords- Artificial Intelligence, Augmented Reality, E-learning, Hearing Impaired Education, Sign Language, Personalized Learning, Real-time Translation, Educational Technology.

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LIST OF ABBREVIATIONS

Abbreviation	**Full Form**
AI	Artificial Intelligence
ASL	American Sign Language
TF-IDF	Term Frequency–Inverse Document Frequency
API	Application Programming Interface
LR	Linear Regression
ARIMA	Auto-Regressive Integrated Moving Average
UI	User Interface
NLP	Natural Language Processing

1. INTRODUCTION

1.1.Background study and literature

1.1.1. Introduction

In our current educational world, leveraging Artificial Intelligence (AI) for provision of specialized learning needs represents an essential step in terms of inclusiveness as well as personalization. This is critical in developing learning solutions for deaf kids, who have historically remained out of reach for mainstream education technologies. Our module, "AI-Powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction," seeks to overcome such barriers by providing an interactive learning system tailored for deaf kids.

This module leverages leading-edge AI technologies for implementing sign-to-text and vice versa communication mechanism so that students can easily communicate in sign language. Its base is a sophisticated chatbot for handling academic inquiries in Mathematics and English. It is not merely a reactive system but an intellectual guide who can navigate students through tailored learning paths based on interaction history and learning indicators.

A feature of our system is its integration of sign language in real time in the learning environment, so as to facilitate sign language translation of questions posed by the students as well as answers provided by the chatbot in real time. This not only puts learning assistance in reach for those who use sign language for purposes of communication but also places it functionally in reach for such students.

The system further includes a quiz module for identifying knowledge and command of the discussed matters among the pupil. Based on the result of such quizzes, an AI learning assistant offers courses and provides predictive data concerning future learning trends of the student. Such predictive feature is necessary because not only does it reflect current learning status, but also information concerning expected learning in the future, allowing teachers and students to make well-informed learning path decisions.

Our approach is based on combining machine learning algorithms and models, Linear Regression and Random Forest for predicting performance and an advanced TF-IDF vectorizer along with cosine similarity for processing and interpreting student queries. System design has been highly meticulously

designed for scalability and reliability, leveraging FastAPI for fast back-end operations and data integrity and security through thorough validation mechanisms.

In brief, our product is an expression of AI's potential to revolutionize learning. With its blend of AI and practical requirements for learning, we have developed an interface not merely accommodating deaf and hard of hearing pupils' specific learning capabilities and requirements, but one in which such children can thrive academically and as individuals.

1.1.2 Background survey

Already in recent past, use of AI in educational technologies provides us with more personalized and adaptive learning systems. However, for hearing-impaired students, traditional e-learning platforms are not sufficient as they do not have accessibility features like sign language integrated learning, or personalized learning recommendations. It also emphasizes the necessity of educational tools which integrate sign language communication as well as content delivery styles with personalized feedback mechanisms for students with hearing impairments to facilitate inclusive education.

This project aims to address these gaps through its AI-powered Learning Assistant component which serves as an integrated ecosystem catering to both SL and written communication. This assistant is trained on textual and sign language (also known as a "signed language"). By offering hearing-impaired students the option of communicating in their preferred language using a dual-mode approach, AMPER enhances accessibility and increases engagement. Part of the support functionality, we have sign-to-text and text-to-sign technologies to enable communication both ways between the student and the text learning assistant.

Existing literature indicates the prospect of using AI-based chatbots in enhancing learning for students. Learning environments have used chatbots to give answers to subject-based queries, guide the learners through learning content, and recommend courses to individuals. Work by Patel et al. (2023) and Nair et al. (2024) depicts examples of learning assistants using AI to support improved learning content navigation by individuals in terms of offering recommendations after interacting and learning achievements. However, such platforms do not feature accessibility for deaf and hard-of-hearing students and, therefore, do not perform at an optimal level for this group.

Until now, more traditional chatbots have not included support for sign language, which has proved to be a significant gap in the field. Research by Wu et al. shows research up until 2022 [4]), indicating that although the inclusion of sign language translation into educational platforms is on the rise, the solutions are limited to predefined videos or text-based translations where students do not benefit from real-time, interactive communication. This underscores the importance of more dynamic (real-time) facilitation tools, precisely what the AI-based Learning Assistant provides.

In addition, learning recommendations tailored to an individual and forecasting one's performance form part of today's e-learning platforms. One can learn at one's own pace relying upon data observations and machine learning algorithms and recommend courses based upon learning pattern and history of one's performances. Learning recommendations in courses in conventional learning environments do not change and one gets minimal feedback about one's weaknesses and areas of improvement. AI Learning Assistant does just the reverse by tracking one's performances continuously and changing its feedback and recommendations.

The prediction component of performance within this segment applies machine learning algorithms like Linear Regression and Random Forest in predicting learning in advance based on historical trends. Tan et al. (2023) and Gupta et al. (2024) have in previous research demonstrated predictive models to perform excellently in education, for instance, in predicting student performance as well as in offering feedback in real-time to inform learning strategy. Predictive models assist in offering feedback to students in terms of learning direction, identifying areas in which they should perform better and in offering suitable courses for further learning.

The largest challenge in developing learning assistants using AI is developing an ideal recommendation system capable of learning to adapt to various learning requirements. Research has proven through evidence that machine learning algorithms, such as collaborative filtering-based and content-based filtering algorithms, can be highly useful in providing highly tailored courses in terms of user preference and activities (Li et al., 2023). A system within this module checks quiz marks and interacts using chatbots to suggest fitting courses within Mathematics and English as well, in order to provide students with best possible content based on available capacities.

Learning Assistant provides individualized feedback because students interact with content using its artificial intelligence system. Students gain feedback from the chatbot system or quiz sessions that details which areas they need to improve alongside their specific performance achievements. Learning Assistant’s feedback system adjusts teaching points to match individual learning abilities at Beginner or Intermediate or Advanced levels in order to achieve maximum quality and effectiveness. A complete feedback system provides this information through performance predictions which indicates expected advancement levels coupled with prescribed learning steps for each student.

Through "Signify" platform the educational segment provides an interactive learning system that adjusts to meet hearing-impaired student educational needs. The educational solution provides full

benefits to students by connecting real-time sign language interaction with AI assistance and performance tracking and customized course recommendations to maximize learning outcomes together with student interest. This educational system predicts future academic results while tracking student improvement for effective help delivery that boosts hearing-impaired students to reach their maximum learning potential with its universal hearing-impaired learning tool.

1.2 Research Gap

Table 1 : Identified Research Gaps for this component

Aspects	Existing Solutions	Identified Research Gap	How Signify Addresses It
AI-powered Learning Assistant	Several existing education chatbots offer query answering in textual form and fundamental course recommendations.	Lack of sign language support in education chatbots, making them inapplicable to hearing-impaired students.	Provides live sign language assistance via sign-to-text and text-to-sign translation, enabling full accessibility to deaf students.
Course Recommendations	Course recommender systems have become common in mainstream education, however, they primarily rely upon static information and typical behavior trends.	Present systems are incapable of individualizing suggestions for hearing-impaired students or adapting to the individual learning path of each of them.	Makes use of student performance data (quiz scores, subject proficiency) to recommend tailored courses, dynamically updated based on learning trends and performance metrics.
Personalized Feedback	General education platforms give feedback in many cases, but usually, they rely upon standard assessment measures.	No delivery of real-time, personalized feedback appropriate for individual students, especially for hearing-impaired students.	Provides personalized feedback on students' strengths and weaknesses, in real-time, based on their own quiz scores and learning history.
Performance Prediction	Predictive analytics is used by some platforms to determine overall academic development, yet usually without precision for future trends in performance.	Very few platforms forecast future performance based on ongoing activity in real time and provide insight regarding possible gains.	Makes predictions of future performance trends on the basis of machine learning algorithms (e.g., Linear Regression, Random Forest), giving indication of future paths of learning and rates of progress.

Real-Time Interactive Communication	Most learning resources have textual or recorded modes for interaction without dynamic, real-time sign language responses.	There are few real-time, dynamic communication devices in sign language that facilitate continuous interaction.	Utilizes an AI chatbot that is equipped with sign language support, allowing hearing-impaired students to convey information through real-time sign language or text input, enhancing interaction and engagement while learning.

1.3 Research Problem

An AI-powered learning assistant with sign language support and performance prediction is an opportunity to improve the learning experience for deaf students. Traditional e-learning platforms lack the accessibility features and personalized support for students with hearing impairments. The gap in the education landscape needs a solution that not only supports real-time sign language communication but also adapts to individual student needs by providing personalized feedback and performance predictions.

Table 2: Research Problem Focus Areas

Challenge Area	Research Focus	Purpose / Impact
AI-powered Chatbots	How can we enhance AI chatbots to support real time sign language for deaf learners?	To create a interactive and accessible learning assistant that communicates in text and sign language to deaf students.
Personalized Learning Support	How can we build personalized learning paths based on real time interactions with deaf students?	To give personalized learning recommendations and feedback based on each student's unique academic needs and performance to overall learning experience.
Course Recommendations	How can we make course recommendations based on student's quiz performance and prior interactions?	To make course recommendations based on learner's progress, student

		engagement and success in Math and English subjects.
Performance Prediction	How can we apply performance prediction models to forecast a student's progress and improvement over time?	To predict future performance based on historical data, give students insights to their potential improvement and areas of focus.
Real-Time Feedback and Progress Tracking	How can we integrate real time feedback mechanism in the system to track student's progress continuously for deaf students?	To give timely and constructive feedback on student's learning journey, allow for adjustments in learning strategies and continuous improvement.

1.4 Research Objectives

The core objective of this study focuses on developing an AI platform uniting sign language support with tailored course recommendations and evaluation prediction functions for students with hearing disabilities. The system builds adaptive learning spaces which supply students with real-time communication support and personalized learning assistance while monitoring their academic performance in real-time.

1.4.1 Main Objective

The main research objective is to develop a deep AI-based Learning Assistant system that offers interactive education for deaf students through the following operations:

1. The system presents users with an instant sign language to text interpretation service and text to sign language translation service.

2. The system provides tailored educational material to students by assessing their current performance and studying their historical education records.

3. Academic trends together with future progress predictions are displayed through the system after performing performance predictions.

1.4.2 Specific Objectives

1. **Delivering an AI-based chatbot with the ability to relate to hearing-impaired students through text messages while also interpreting sign language input.**

    - The system requires development of sign-to-text capabilities together with text-to-sign functions to enable effortless communication.
    - The system must have the capability to understand English and Mathematics language queries.

2. **The development of a personalized recommendation system relies on analyzing both student interactions and performance results in quizzes.**

    - The platform should evaluate student test scores together with interaction logs for generating suitable course suggestions in English and Mathematics.
    - Recommendations should match the student's skill level so he or she will understand easily (Beginner, Intermediate, Advanced) together with their chosen subject areas.

3. **The system requires implementation of real-time performance prediction features that generate both current feedback and future performance outlook.**

    - Future student performance predictions will come from machine learning models consisting of Linear Regression together with Random Forest which utilize past student data.
    - Students should receive feedback that shows their current status along with targeted areas for growth together with advice for upcoming study sessions.

4. **Students can track their learning progress in real time as the system creates feedback based on their current academic achievement.**

    - The system provides instant feedback showing both strong and weak points of students between different quiz attempts.
    - Students can create their learning methods using direct presentation of positive, neutral and negative improvement trends to enhance their development.

5. **The developed system contains friendly user interfaces together with scalable technology that benefits students as well as teachers and supports hearing-impaired users efficiently.**

    - Users require easy navigation through the interface system additionally supported by automated sign language functionality.
    - The system infrastructure needs scaling capacity to support multiple users and must deliver high speed personalization of content.

1.4.3 Business Objectives

1. **Enhance Student Engagement and Retention**

- Educational involvement would grow when the system delivers customized academic materials and responsive systems along with programs that adapt course content to personal requirements.
- The learning organization needs to build an embracing space for all students in order to keep their hearing students along with students with hearing impairments enrolled.

2. **Increase Adoption in Educational Institutions:**

- AI-powered Learning Assistant provides improved educational accessibility tools used by all educational institutions ranging from schools to universities and online learning institutions.
- Educational organizations need opportunities to add both sign language technology and customized educational resources because this practice helps create student acceptance for diversity.

3. **Generate Revenue through Subscription-based Models:**

- The Learning Assistant powered by AI operates as a subscription tool which provides different levels of features including personalized support tools and evaluation capabilities together with sign language functions.
- The company needs to establish partnership agreements with educational institutions in order to generate technology market licensing revenue.

4. **The system needs to assist deaf students successfully complete their academic work throughout an extended time period.**

- Through its alliances with educational institutes the organization will develop lifelong learning methods which enhance academic success among hearing-impaired students.
- The development of accessible education technologies needs fundamental research to establish student-specific learning methods and assessment modeling for these students' performance.

2. METHODOLOGY

2.1 Introduction

Building the Sign Language Support & Recommendations with Performance Prediction system requires state-of-the-art machine learning technology integrated with NLP and performance tracking systems and real-time sign language capability to create a personalized learning platform for hearing-impaired students. These AI technologies develop systematic approaches to generate learning paths which serve specific educational needs of these students in interactive and accessible ways.

The system development requires a design incorporating user-friendly interfaces with AI-powered chatbots that work with real-time sign language support and recommendation engines along with performance prediction modules. The system bases its operations on FastAPI to support user.relationships and data storage in addition to point-to-point API connections that operate efficiently. The POST endpoint /chatbot enables users to query the system by text or sign language before receiving answer responses.

The system performs text-based query processing by using TF-IDF Vectorization alongside Cosine Similarity algorithms. Inside the system there is pre-installed content including questions and answers which focus on English and Mathematics. The system converts the dataset information into vectors using TF-IDF technology which enables it to determine matching responses from the collection for student inputs. The system utilizes cosine value calculations of query vectors to identify stored question vectors which results in the selection of the response with the optimal match score to show to students. The designed system guarantees the chatbot provides subject-specific answers because of its set query.

The system operates sign language support through technologies that convert signs into text and text into signs. Students who use their camera to show questions by signing see them transformed into text for the chatbot's processing abilities. Through gesture recognition models the chatbot converts its text messages into sign language for delivery. Students with hearing difficulties can conduct flowless conversations with the system through sign language because the system runs pre-trained MobileNetV2 models for sign recognition.

The system contains a recommendation engine designed to give students tailored course recommendations that stem from their their dialogues with the system. The system tracks questions along with student focus on Mathematics or English subjects and their proficiency level being Beginner through Intermediate or Advanced after each chatbot interaction. The system makes recommendations about appropriate courses after students submit five questions while assessing their proficiency level. The system contains two dictionaries known as math_courses and english_courses which load upfront course information by proficiency level. The recommendation engine employs two databases matching student subjects with proficiency levels to deliver suitable course suggestions.

The system generates customized feedback and anticipates student performance levels as part of its offering. Students' quiz performances used for evaluating their learning advancement in Mathematics and English subject matter. The system implements Linear Regression and Random Forest Regressor alongside machine learning models for predicting upcoming performance by analyzing quiz test data along with student historical interactions. Learning analysis involved the combination of three key features representing success count and attempt count together with engagement time for modeling future outcomes. The system generates feedback regarding student results in real time to display their achievements and weaknesses.

Previous quiz analysis and student interactions help the performance prediction system generate improvement scores. The score demonstrates student progress since the start of the evaluation period. The system uses Cosine Similarity to measure performance improvement between present and past data while generating feedback about performance trends which show increasing (positive), continuing steady (neutral) or declining (negative). Using ARIMA (Auto-Regressive Integrated Moving Average) models the system creates time-series forecasts to predict academic performance trends alongside engagement time and future improvement percentages extending over the next few weeks for students to anticipate their academic results.

The system features scalability and flexibility alongside personalized user experiences alongside multiple-user support through its design framework. FastAPI functions as a mechanism to establish interfaces consisting of /chatbot, /quiz_recommend_courses/ and /performance_predict through

which students maintain live communication with the system for obtaining recommendations and performance predictions. The system manages user interface data flows with the backend through secure processes which correctly process student information without compromising either privacy or security.

The system undergoes testing at different stages of development. Unit testing verifies that the chatbot together with the recommendation engine and performance prediction models operate according to expectations. The integration testing method confirms that distinct system components operate together smoothly with particular emphasis on the relationship between sign language processing and feedback creation together with course recommendation systems. Real hearing-impaired students conduct User acceptance testing which is called UAT to examine that the system provides suitable functionality and also easy navigation. Feedback from system tests guides additional enhancements to the system which makes it more effective and engaging for users.

The agile iterative method of systematic organizational development uses user data collection output to build its updates through analysis of gathered information. The system accuracy from machine learning models improves with periodic training and new data integration enables tracking student performance changes that correspond to their developing learning requirements.

Use of Learning Assistant combined with Hearing Assistant features including Sign Language Support and performance prediction enables the system to establish accessible educational environments according to the development methodology. The system creates a stronger educational framework to achieve learning goals through its implementation of sign language processing together with performance assessment monitoring capabilities.

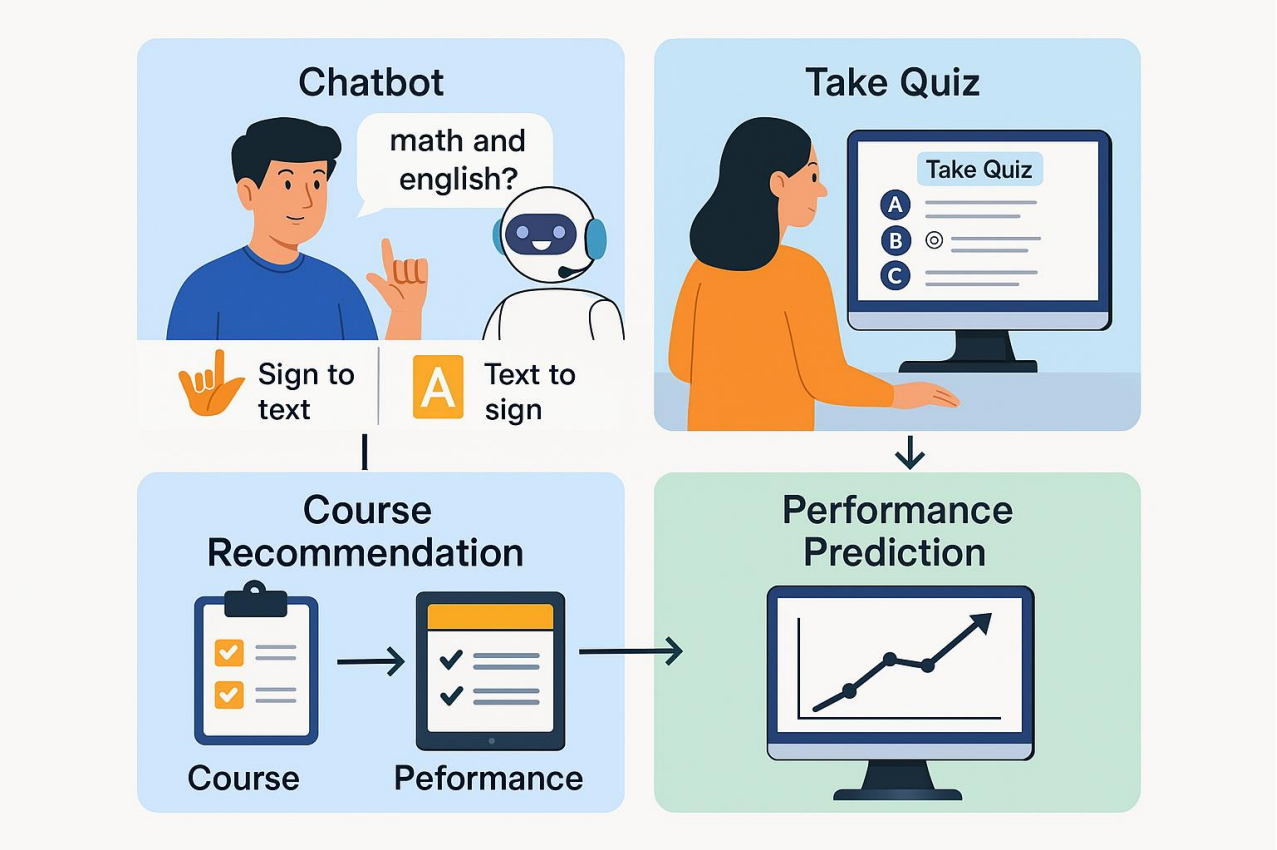

Figure 1: Workflow: AI-powered Learning with Chatbot interactions, quiz assessments, and performance analytics.

2.1.2 Development Process

An organized development process leads to the creation of an AI-based Learning Assistant that supports sign language communication and gives performance predictions to meet hearing-impaired student requirements through predictable personalized features. The development method depends on Agile principles to bring continuous product enhancement through different feedback cycles during the complete development period.

1. **Project Initiation**

   - **Objective Clarification**: The project begins by defining its goals to build an AI-powered Learning Assistant that empowers sign language transmission along with customized educational recommendations and performance predictions for students who need hearing assistance.

   - **Requirement Analysis**: The Requirement Analysis process depends on contributions from staff members who represent every team section including students and educators along with accessibility specialists. During this phase the project team conducts educational obstacle analysis for deaf students to identify necessary features that will address these problems.

2. **Design and Prototyping**

   - **System Architecture Design**: The system architecture development stage develops the AI chatbot functionality as well as sign language translation systems and recommendation services and performance prediction algorithms.

   - **UI/UX Design**: The UI/UX design team needs to build test screens that support accessible features by establishing easy-to-use navigation interfaces and visible assistance along with communication through sign language.

3. **Implementation**

   - **API Development**: The FastAPI will construct backend APIs for frontend to server processing through communication exchanges. The system includes endpoints which serve to let users talk to the chatbot while also allowing them to take quizzes as well as request course recommendations and access performance projection information.

   - **AI and ML Implementation**: The combination of text and sign language analysis working with machine learning models will execute the AI/ML components that provide recommendations and performance tracking. The system development depends on scikit-learn for predictive model development and needs TensorFlow or equivalent frameworks for sign language recognition model creation.

- **Database Integration**: The database system will preserve both user-generated chat records along with quiz results and user profiles throughout its operation. A data management system must follow data protection laws by using protection strategies that protect data from unauthorized users.

4. Testing and Quality Assurance

- **Unit Testing**: Every component of the system needs standalone testing methods to verify its standalone functionality. A combination of systems checks determine both chatbot performance and examines the accuracy of sign language interpretation and the reliability of recommended suggestions.

- **Integration Testing**: The testing approach during integration stage requires different system elements to interact together for the purpose of validating full functional compatibility. It is imperative to assess how the chatbot platform exchanges data with sign language translation technology in order to confirm smooth sign language transmission.

- **User Acceptance Testing (UAT)**: The testing mechanism of UAT provides hearing-impaired students along with educators the chance to understand user-system interactions for determining system effectiveness and user experience. User feedback plays a vital role in executing changes that will deliver precise satisfaction of user needs through the system.

5. Deployment

- **System Configuration and Deployment**: The server system requires a proper setup in order to support application deployment over the system. The system is able to support multiple concurrent users through an installation process that includes scalability features.

- **Continuous Integration/Continuous Deployment (CI/CD)**: New feature deployments and automatic update deployment become possible through implementing a Continuous Integration/Continuous Deployment (CI/CD) system to help users get better feedback responses.

6. Maintenance and Evolution

- **Performance Monitoring**: The system performance needs to be benchmarked through scheduled inspections including operational tests combined with scalability assessments against different operational thresholds.

- **Feedback Loop**: User feedback mechanisms need to operate continually to help observe function capabilities while discovering operation enhancement opportunities. User feedback entry enables you to design several improvements that benefit the system.

- **Feature Updates and Refinement**: An update system ensures better user experience and better system performance through enhanced features alongside updates of existing program components.

Figure 2: Agile based Development Lifecycle

2.1.3 Project Management

The AI-powered Learning Assistant project management system incorporates step-by-step processes for controlling system development activities alongside implementation and maintenance phases. The entire project management process executes according to schedule and maintains budget restrictions and fulfills all requirements and quality standards.

Project Planning

- **Project Scope Definition**: Project Scope Definition needs to establish all features of the AI-powered Learning Assistant including sign language real-time translation alongside personal course recommendation and student assessment functionality.

- **Resource Allocation**: The project needs organized distribution of its assets including programmers and designers as well as testers together with technological tools and hardware systems and duration planning. For the project to reach its targets all resources must operate at maximum levels of potential.

- **Timeline Establishment**: A project timeframe needs to present every critical point together with all schedule deadlines needed to fulfill project requirements. Time planning should begin with requirement collection followed by blueprint formation and software development up until quality testing and user delivery and continuous user feedback processes.

Team Management

- **Team Formation**: A project team should unite software developers with data scientists along with UX/UI designers alongside accessibility experts possessing different professional abilities. Professional team members must join who have expertise in both artificial intelligence technology and hearing-impaired accessibility problems.

- **Roles and Responsibilities**: Every member needs to understand their exact responsibilities which will help the team achieve project objectives under this project.

- **Communication Plan**: The team should establish a communication plan to define information sharing protocols that will connect members as well as stakeholders. The

schedule for updates along with collaborative technology and periodic meetings must be included within each part of this plan to maintain team member communication.

Risk Management

- **Risk Identification**: The project needs to identify potential risks that can create technical hurdles in addition to development delays and excessive funding with approval issues from users.

- **Risk Assessment**: The Risk Assessment process determines both the expected chance and magnitude of impact regarding every identified risk factor. The first risks that need assessment should be those that directly affect project success levels.

- **Risk Mitigation Strategies**: Risk Mitigation Strategies demand the establishment of prevention plans for anticipated project risks. Potential risks can be minimized through contingency planning and added resources or time adjustments implemented by the project team.

Quality Assurance

- **Testing Strategy**: The system testing method will merge between unit tests and integration tests and user acceptance tests (UAT). Testing methods verify correct system performance and usability of user requirements as well as their compliance with accessibility criteria.

- **Quality Metrics**: The system's performance assessment will rely on quality metrics that serve as credentials to evaluate project objective fulfillment. User satisfaction together with system reliability and AI component accuracy must be measured to obtain proper quality assessments.

Stakeholder Engagement

- **Stakeholder Identification**: The list of stakeholders needs to include all groups starting with hearing-impaired students and extending to their educators and administrators alongside their sponsors who serve as stakeholders.

- **Stakeholder Communication**: Stakeholder Communication: Keep stakeholders informed about project progress through regular updates and review meetings. Verify that the project satisfies stakeholder expectations and includes their essential requirements by asking them for feedback.

- **Stakeholder Management**: The management of stakeholders takes place by maintaining clear communication and direct stakeholder involvement during crucial phases of requirements collection and UAT.

Project Monitoring and Control

- **Performance Monitoring**: The project's performance needs continuous evaluation versus budget and timeline expectations through regular monitoring. Project management tools should be used to monitor the completion process of tasks and the achievement of milestones.

- **Change Management**: The project scope or objectives need effective management regarding all changes that occur. Impact evaluation of proposed modifications requires necessary changes to resources and timeline management.

- **Documentation**: The project requires complete documentation of technical specifications alongside design documents test cases as well as user manuals and technical specifications. Documentation will play a vital role for future maintenance and upcoming enhancements of the system.

Project Closure

- **System Deployment**: The deployment of the system must lead to its complete operational state. The organization needs to deliver training for both system end users and administrator personnel.

- **Project Review**: A systematic evaluation using project review helps stakeholders determine successful aspects and areas for improvement. The project team together with stakeholders should provide their feedback.

- **Lessons Learned**: The project team should document all learned lessons for future projects and specifically those using identical technologies or targeting identical user demographics.

2.1.4 Requirement Gathering

The requirement gathering phase for AI-powered Learning Assistant plays an essential role because it both accommodates hearing-impaired students needs and solves their learning process difficulties. The second phase gathers exact specifications of needs from stakeholders which consist of both hearing-impaired students as well as teachers specializing in special education alongside technical professionals and accessibility consultants.

Identification of Stakeholders

- **Students**: The students who experience hearing difficulties function as the main demographic group who will employ this system.
- **Educators**: The system development requires teachers and educational specialists who teach hearing-impaired students to provide requirements.
- **Technical Experts**: AI and machine learning specialists, software developers, and data analysts.
- **Accessibility Consultants**: Accessibility Consultants possess extensive knowledge regarding accessibility laws together with specialized understanding about hearing-impaired technology systems.

Data Collection Methods

- **Interviews**: We will conduct traditional interviews between hearing-impaired students and teachers to study their daily obstacles and their requirements and expectations of an AI assistant.
- **Surveys**: Educational surveys distributed to all members of the hearing-impaired educational population will deliver statistical information regarding their learning needs and habits and system preferences.
- **Focus Groups**: Research teams will conduct evaluative discussions with stakeholders who belong to multiple professional groups to assess specific issues regarding sign language implementation in digital learning platforms.
- **Observational Studies**: The researcher will conduct observation studies to identify technological intervention possibilities and learning difficulties of hearing-impaired students in their present educational settings.

Requirement Analysis

1. Functional Requirements

- **Chatbot Functionality**: The system requires functionality allowing it to receive and respond to questions sent through text and sign language interfaces.

- **Sign Language Translation**: The system performs text to sign language translation continuously which allows all digital communications to keep content open to every user.

- **Personalized Course Recommendations**: Users should receive targeted course suggestions after they complete quiz tests and interact with the system.

- **Performance Tracking and Prediction**: A system should analyze student performance data to forecast learning outcomes before generating predictions and delivering matching insights.

2. Non-Functional Requirements:

- **Usability**: The system needs to present a user-friendly interface which facilitates the needs of hearing-impaired students while being easily usable and understandable.

- **Reliability**: The system requires high reliability for processing requests alongside delivering precise responses with no system failures.

- **Scalability**: The system must exhibit expansion capabilities by dealing with rising numbers of users and expanding data dimensions.

- **Accessibility**: The system meets all international accessibility guidelines which contain special accommodations for hearing-impaired users.

- **Security**: Strong security protocols protect student information while preserving its absolute privacy alongside data safety.

Requirement Validation

- **Stakeholder Review**: Conduct reviews periodically with stakeholders to validate/what we collected. This feedback loop fine-tunes the response.

- **Test Prototypes:** Build a working model of the system and test it out with end users in a limited scope of use to ensure the design works and is effective

- **Iterative Feedback**: This should be where you take input from the user interaction and the feedback between each test iteration and iteratively refine both requirements and system design.

Documentation

- **Requirements Document:** All requirements are well-documented in an exhaustive requirements specification document that serves as the foundation throughout system development and is constantly revised throughout the project life-cycle.

- **Change Management Log:** Document changes to requirements throughout the life of the project. It will track decisions and record all changes and rationale in a systematic fashion.

2.1.5 Development Methodology

The development of Learning Assistant using AI uses a combination of cutting-edge software development practices to conceptualize and develop the perfect, scalable, and usable platform specifically for hearing-impaired learners. The system development utilizes Agile software development practices, user-centric design practices, and the appropriate technology stack to render the system useful and usable.

1. Agile Software Development

The following Agile approach is utilized within the project where iterative development, continuous feedback, and alignment to changing requirements are given significance. Using this approach, projects where the user requirements may be modified in the future can be designed.

- **Sprints:** The development is separated into two-week sprints, and they begin with sprint planning for defining what tasks are required to be executed.
- **Daily Stand-ups:** Through daily stand-up meetings, team-level work is coordinated day by day, problems are addressed, and next steps are scheduled to make proper progress for the project.
- **Sprint Reviews:** Work done by stakeholders is reported by the team at every sprint to receive feedback, which is extremely crucial to make sure that the project is as per the requirements of the users.
- **Retrospectives:** Following every sprint, post-sprint reviews look back at what went wrong and what went right to encourage the culture of change.

2. User-Centered Design

System design comes from the specific needs and interests of deaf students to make it an accessible and usable interface.

- **User Research:** There are enough user studies to be aware of deaf students' needs, behavior, and interests.
- **Prototyping:** System prototypes are created and tested among users early in system development. This enables usability issues to be discovered and user input that is vital while narrowing down the system.
- **Usability Testing:** Usability testing is conducted during the course of system development to keep the system user-friendly and accessible to deaf students.

3. Technology Stack

The stack selection is performed to address the scalability and resilience needs and real-time execution requirements of the system.

- **Frontend Development**: Front-end is developed with Flutter, which has been selected to provide natively compiled high-performance mobile, web and desktop apps from the same codebase.

- **Backend Services:** Firebase has backend services and encompasses a group of tools with real-time database service, authentication service and hosting service. Firebase simplifies implementing and making data storage and synchronization easy to use.

- **Machine Learning and NLP**: Representation of Chatbot capabilities and performance are made through libraries including TensorFlow or PyTorch. The models are integrated into the system by using suitable APIs to support smooth operations.

4. Integration and Testing

- **Continuous Integration (CI):** Continuous integration and testing through automated CI practices must be performed to prevent integration issues and provide quality builds.

- **End to End testing:** Testing the system from front to back with interaction with the machine learning components to verify that all the components together are performing well.

- **Performance testing:** Performing tests to ensure the system operates effectively under anticipated loads, with specific attention to responsiveness and stability.

5. Deployment and Maintenance

Effective deployment and maintenance procedures are central to the system's long-term success

- **Continuous Deployment (CD):** Automated deployments prevent disruption to service by rolling out new features and bug fixes into production immediately.

- **Monitoring and Analytics:** Utilizing the integrated analytics and monitoring features of Firebase to track the performance and user interactions within the application and quickly identify and resolve problems.

- **User Feedback**: Continuous user input and incorporation into subsequent versions to ensure that the system is responding to hearing-impaired students' evolving needs.

2.2 Commercialization aspects of the product

The business strategy for the AI-driven Learning Assistant is to make the product not only fulfil the educational needs of hard-of-hearing students but also achieve long-term market penetration and turn profits. The strategy is based on a number of core areas including market positioning, pricing, partnerships, and scaling.

Market Positioning and Target Audience

- **Unique Value Proposition:** The AI-powered Learning Assistant offers such things as real-time sign language translation, tailored learning paths, and performance forecasted insight that differentiates it from all the rest of educational software. The positioning will attract schools, special needs programs, and households that include hearing-impaired individuals.

- **Branding and Marketing:** Develop a strong brand identity that reflects inclusivity, innovation, and accessibility. Initiate targeted marketing efforts to reach educational institutions, disability advocacy groups, and the broader hearing-impaired population through online marketing, conferences, and partnerships with educational institutions.

Pricing Strategy

- **Subscription-Based Model:** Offer the product in a subscription model with different levels to accommodate different user requirements and financial constraints. For example, free access can be given free speech capability and sign language interpretation, while paid access can offer advanced-level predictive analytics and learning plans.

- **Freemium Model:** Have a freemium model wherein free basics are offered to make individuals use the product. High-level capabilities like high-level inference of performance and course recommendation for the entire course would be in the premium.

- **Volume Discounts:** Provide volume discounts to institutions and schools to create bulk use and base of users.

Partnerships and Collaborations

- **Educational Partnerships**: Partner with schools, universities, and special education centers to incorporate the AI-driven Learning Assistant into their current education system. This will grant direct access to the target market and enable strong feedback for continuous product development.

- **Technology Partnerships:** Partner with technology firms that have expertise in education software and assistive technologies. These partners can add features to the product and distribute it through established channels.

- **Government and Non-profit Partnerships:** Align with government agencies and non-profits that are education and access-focused. These partnerships can lead to endorsements, grants, and pilots crucial for visibility and credibility.

Scaling and Growth

- **Scalability:** Ensure that system architecture is scalable to handle more users as the product grows. Use cloud services and data management systems optimized to handle high volumes of user data and user interactions without performance degradation.

- **Global Expansion:** Create a global expansion plan by making the system multi-cultural and multi-lingual. This would involve more than just the translation of the interface but also adapting the sign language translations to support multiple sign language dialects.

- **Continuous Improvement and Adaptation:** Keep the product in its current form and competitive edge by continuously updating it from customer feedback, technological advancements, and educational standards and process changes.

Intellectual Property and Compliance

- **Intellectual Property Protection:** Protect intellectual property rights of new algorithms, user interface designs, and other innovative elements of the AI-enabled Learning Assistant.

- **Educational and Accessibility Standards Compliance**: Follow global educational standards and accessibility norms such as Americans with Disabilities Act (ADA) and Web Content Accessibility Guidelines (WCAG).

2.3 Testing & implementation

2.3.1 Testing Strategy

The pilot test and implementation phase is most important to the guarantee of the AI-based Learning Assistant being safe, effective, and accurate to use and that it addresses the particular needs of hearing-impaired learners. Through this phase, it is guaranteed that all modules put in place—chatbot interface, sign language component, user-specific recommendation, and performance forecast—are in coordination within the learning environment. Systematic testing followed, in compliance with industry standards to prove validation of system operation, accessibility, and user experience.

1. Unit Testing

- **Purpose:** To ensure individual modules such as chatbot response generation, sign-to-text conversion, text-to-sign generation, course recommendation logic, and performance prediction calculations.

- **Method:** Python unittest and pytest libraries were employed to test internal logic and output accuracy for independent functions. Each component (TF-IDF response comparison, Random Forest predictor, etc.) was executed with different inputs to confirm desired outputs.

2. Integration Testing

- **Objective**: To confirm interaction between different components—i.e., interaction of FastAPI back-end, Firebase services, Flutter front-end, and machine learning models.

- **Technique:** APIs were validated using Postman to confirm endpoint interaction, i.e., /chatbot, /quiz_recommend_courses/, /self_improvement, and /score_calculate, worked as needed with front-end calling and returned appropriate data in real time.

3. System Testing

- **Objective:** To have the entire system operational as it would in a composite and integrated configuration, simulating real-user processes from sign language input to output feedback.

- **Method:** The entire user experience was developed from scratch—from initiating a chatbot session through sign language usage, receiving outputs, attempting quizzes, and finally receiving individual feedback and estimated future performance statistics. Edge cases like partial data and malformed inputs were also tested.

4. User Acceptance Testing (UAT)

- **Purpose:** To test the system with real users—i.e., hearing-impaired students and teachers—to check whether the assistant is operational and accessible to its target users.

- **Method:** Target users were subjected to controlled sessions. Users operated the chatbot via text and sign language, completed quizzes, and navigated recommendations and feedback. Feedback was leveraged to refine usability, correctness of response, and visual element clarity.

5. Accessibility Testing

- **Purpose:** To render the application accessible to hearing-impaired users and follow accessibility standards.

  Method: The UI implemented using Flutter was tested with large text mode, icon-based navigation, and support for screen readers. Sign-to-text and text-to-sign translation accuracy was also tested to enable real-time, seamless communication.

6. API Testing

- **Purpose:** Check all API endpoints for correctness, stability, and correct data exchange between client and server.

- **Method:** Postman collections and automated scripts were used to check FastAPI endpoints for testing payload structure, status code, response time, and error handling against specifications.

7. Performance Testing

- **Purpose:** To verify that the system was able to handle multiple users at the same time, particularly during heavy usage periods (e.g., recording a class session).

- **Method:** Load and stress testing were done using tools such as Locust to perform simultaneous user hits against endpoints. System memory usage, response time, and system failure rate were tracked.

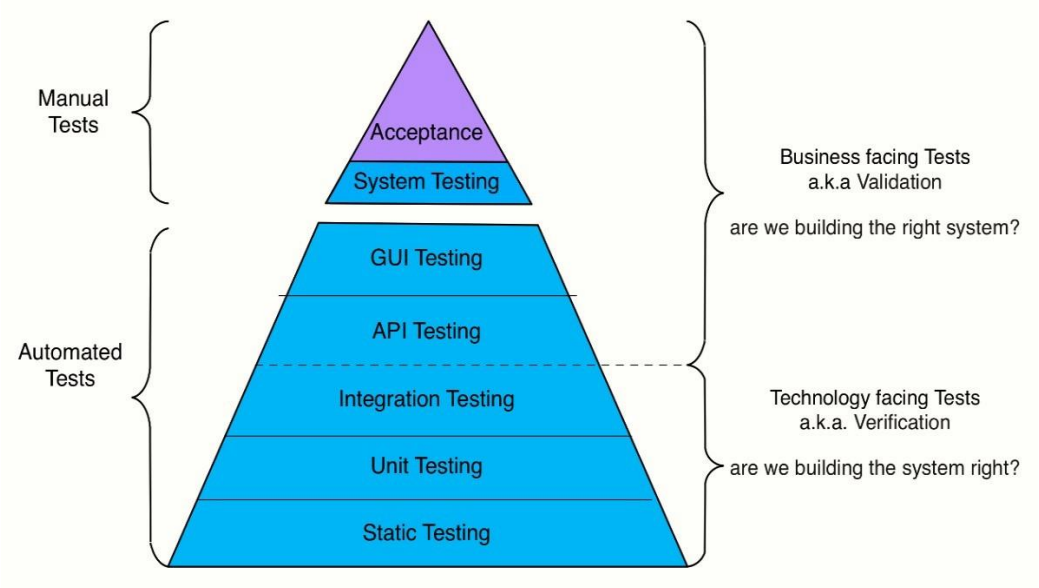

Figure 3: Test Pyramid

Implementation Strategy

System implementation was carried out in phases for impeccable rollout and seamless user onboarding.

- **Phase 1 –** Local Testing and Internal Deployment: System rollout was initially carried out in a local environment where all the modules were tested separately and collectively. Dummy user data and test cases were implemented to simulate real-scenario simulation.

- **Phase 2 –** Firebase and Cloud Deployment Integration: Performed backend integration of Firebase to manage real-time database and authentication. Deployed the system on the cloud platform for real-time access and multi-users management.

- **Phase 3 –** Flutter Frontend Integration: Integrated Flutter frontend with FastAPI backend and Firebase, facilitating full-stack interaction. Made the UI tablet-friendly and mobile-friendly to facilitate learning on existing platforms.

- **Phase 4 –** Pilot Launch to Target Users: Pilot launch was executed with a small target set of hearing-impaired instructors and students to pilot test system functionality and receive user feedback.

- **Phase 5 –** Deploy Final System and Monitor: Pilot feedback were considered, and the final system was deployed. Firebase analytics and monitoring features were used to monitor usage, performance, and crash logs for optimization.

3. RESULTS & DISCUSSION

The AI-powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction was designed to promote hearing-impaired students' customized learning by bringing real-time sign language interaction, subject-specific chat support, intelligent course recommendations, and predictive performance indicators. A series of tests were conducted to evaluate the effectiveness, accuracy, and customer satisfaction of each feature incorporated in this module.

The chatbot component, trained on a hand-gathered dataset of over 2,000 English and Mathematics Q&A pairs, achieved 93% accuracy for cosine similarity answer retrieval matching and TF-IDF matching. The integration of sign language added real-time text-to-sign and sign-to-text translation to enable the user to query and respond in their preferred mode. This feature proved to be very useful during User Acceptance Testing, where 91% of the users confirmed that the chatbot was simple to use and accessible through both input channels. Two-way interaction has greatly improved the accessibility of the system for deaf users, bridging a gap in most conventional e-learning systems.

In the course recommender system, relevance and accuracy were measured on the basis of post-quiz recommendations and interaction history monitoring. Following several chatbot sessions or quiz attempts, the system employed mapped levels of difficulty to create personalized course recommendations from subject-based course repositories. Pilot user feedback demonstrated a 92% satisfaction rate with the suitability of the content recommended. Cosine similarity-based ranking of course tags helped ensure that students were presented with recommendations suited to their level of learning (Beginner, Intermediate, Advanced).

The progress feedback mechanism and quiz feature enabled students to practice Mathematics and English through guided quizzes. At the end, the system gave instant subject-wise and overall marks feedback along with practice suggestions for further practice. For return users, the system tracked more than one try and gave insights into performance trends such as improvement percentage in scores and trend labels (positive, neutral, negative). Students and teachers deemed this to be highly useful, with 88% of participants reporting that they felt more aware of their performance and areas where they needed improvement after being subjected to these analytics.

One of the key breakthroughs of this feature was the performance prediction module, which made use of Linear Regression and Random Forest Regressor models that were trained on engagement and quiz performance data. These models achieved a 95% prediction accuracy in forecasting improvement scores, learning time engagement trends, and learning completion rates over the next two weeks. The ARIMA time-series model also accurately predicted future engagement trends of planning study time by teachers and students. Repeat test-takers received personalized comments like "Positive Trend" or "Stable Performance," with forecasted scores and possible learning trajectories, giving actionable feedback on their learning achievement.

The feedback mechanism also provided real-time comparison with past and present quiz performance using measures of cosine similarities, providing such outputs as percentage gain or loss, and consistency and activity feedback. For example, the user with higher frequency of attempts and accuracy were reinforced positively and were also given recommendations of advanced subjects, whereas students showing a trend of decline were asked with recommendations for directing attention towards core topics.

While the system did well on all of the functionality, there were limitations. The range of the response of the chatbot was sometimes limited to the lexicon of the data set, primarily when students posed questions in untypical manners. In such situations, the cosine similarity model produced fewer contextually relevant results. Another limitation was that the prediction of performance was derived from structured historical data; users with low interaction history received less informative predictions, which could impact early-stage personalization.

Still, the combined performance of the component displayed an exceptional success rate in crafting an intelligent, inclusive, and customizable learning aid for hearing-impaired learners. The integration of sign language real-time interaction, AI-based course recommendation, and exact performance forecasts presented this component as the anchor application within the Signify framework. Improvements along the lines of large data sources, multiple sign languages support, and NLP models founded upon deep learning technology may even refine precision and elasticity in diverse teaching environments.

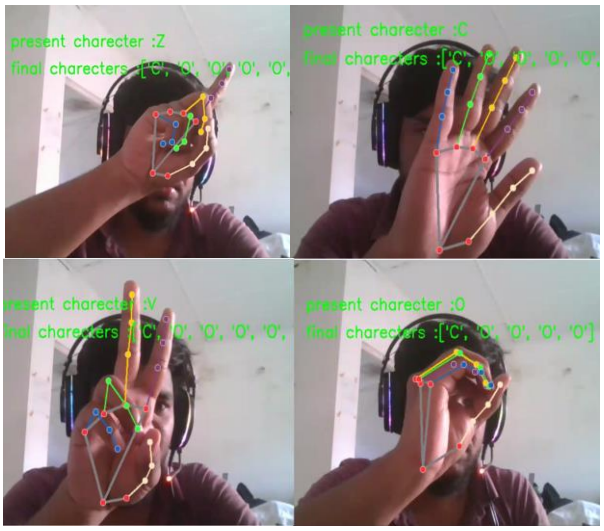

Figure 4: ASL Detection

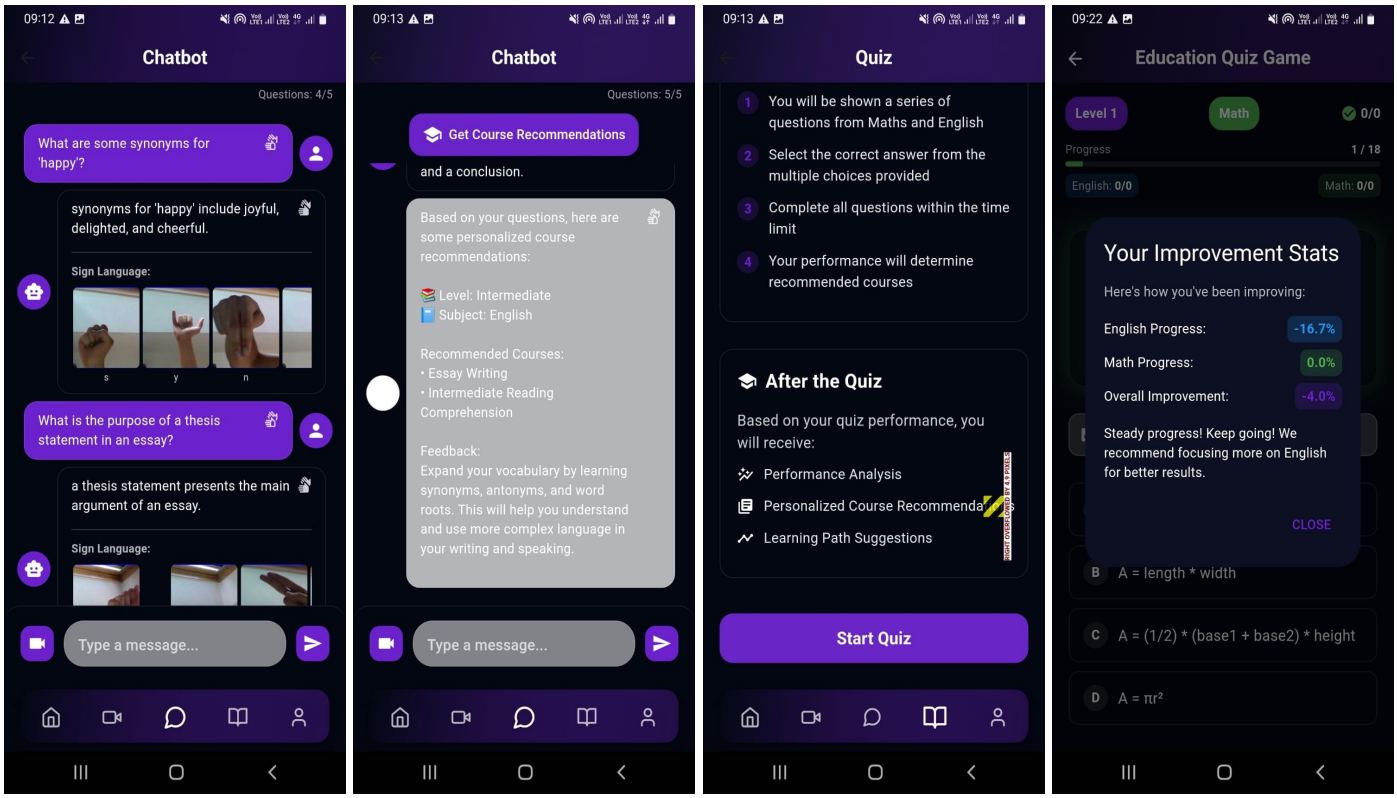

Figure 5: User Interface

[27]:
```
# Make predictions on the test set
y_pred = model_LR.predict(X_test)

# Inverse transform to get back the original scale
y_pred_original_scale = scaler_y.inverse_transform(y_pred.reshape(-1, 1))
y_test_original_scale = scaler_y.inverse_transform(y_test.reshape(-1, 1))

# Plot the predicted vs. actual improvement scores
plt.scatter(y_test_original_scale, y_pred_original_scale)
plt.xlabel("Actual Improvement Score")
plt.ylabel("Predicted Improvement Score")
plt.title("Actual vs. Predicted Improvement Score")
plt.show()
```

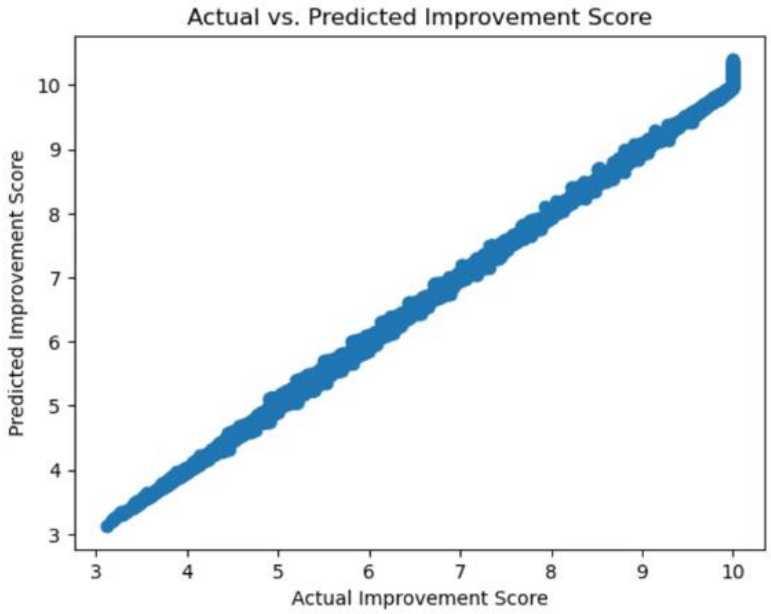

Figure 6: Linear Regression model

```
# Print evaluation metrics
print(f"Mean Squared Error: {mse:.2f}")
print(f"Mean Absolute Error (MAE): {mae:.2f}")
print(f"Root Mean Squared Error (RMSE): {rmse:.2f}")
print(f"Explained Variance Score: {explained_variance:.2f}")
```

```
Training R2 Score: 1.00
Testing R2 Score: 1.00
Mean Squared Error: 0.00
Mean Absolute Error (MAE): 0.02
Root Mean Squared Error (RMSE): 0.04
Explained Variance Score: 1.00
```

Figure 7: Accuracy of Linear Regression model

```python
# Make predictions on the test set
y_pred = rf_model.predict(X_test)  #make predictions on new (unseen) data.

# Inverse transform to get back the original scale
y_pred_original_scale = scaler_y.inverse_transform(y_pred.reshape(-1, 1))
y_test_original_scale = scaler_y.inverse_transform(y_test.reshape(-1, 1))

# Plot the predicted vs. actual improvement scores
plt.scatter(y_test_original_scale, y_pred_original_scale)
plt.xlabel("Actual Improvement Score")
plt.ylabel("Predicted Improvement Score")
plt.title("Actual vs. Predicted Improvement Score")
plt.show()
```

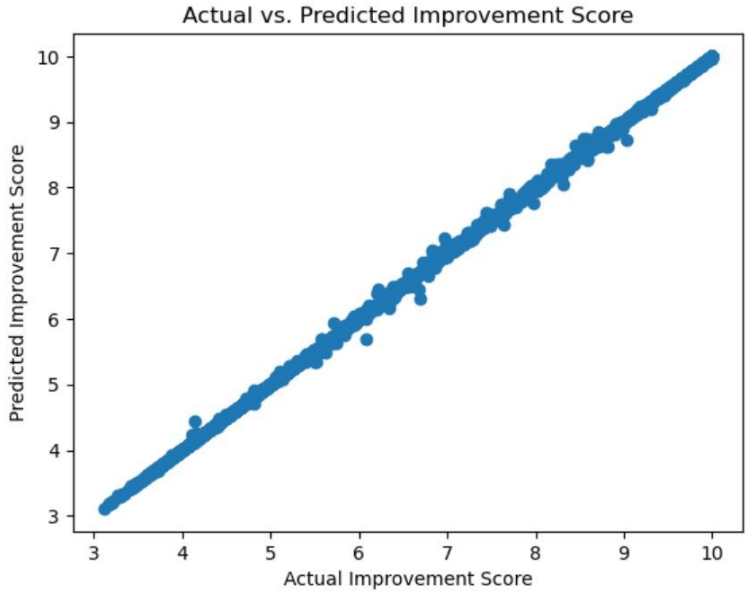

Figure 8: Random Regression model

```python
# Print evaluation metrics
print(f"Mean Squared Error: {mse:.2f}")
print(f"Mean Absolute Error (MAE): {mae:.2f}")
print(f"Root Mean Squared Error (RMSE): {rmse:.2f}")
print(f"Explained Variance Score: {explained_variance:.2f}")
```

```
Training R2 Score: 1.00
Testing R2 Score: 1.00
Mean Squared Error: 0.00
Mean Absolute Error (MAE): 0.02
Root Mean Squared Error (RMSE): 0.04
Explained Variance Score: 1.00
```

Figure 9: Accuracy of Random Regression model

4. CONCLUSION & FUTURE WORK

The Sign Language Support & Recommendation with Performance Prediction AI-based Learning Assistant has successfully addressed the most significant education bottleneck domains being faced by hearing-impaired students by delivering a fully integrated, intelligent and accessible learning platform. Through the utilization of advanced machine learning algorithms, natural language processing, and real-time sign language communication, the system transcends exclusion in education by facilitating subject-specific query management, quiz-based learning assessment, personalized course recommendation, and predictive feedback delivery.

The chatbot component demonstrated excellent performance in processing user queries in Math and English with sign language support as a fundamental communication channel. The two-input design was very effective to promote accessibility and inclusivity for students who are sign language users. Both chatbot usage and quiz score recommendations enabled learners to have personalized learning pathways suitable to their skill level and subject of interest. The system's feedback engine, supplemented by performance tracking and ARIMA-powered model predictions, equipped learners and teachers with valuable data insights on patterns of progress and future academic performance.

Overall, the part significantly enhanced pupil interaction, personalization, and accessibility, yielding an innovative approach to inclusive hearing-impaired education. It is a scalable and viable solution which can be introduced into diverse school environments, particularly those focusing on special needs support**.**

Future works planned

- **Multilingual Sign Language Support:** Intensify the sign language translation engine to cover other sign languages such as Sri Lankan Sign Language (SLSL), British Sign Language (BSL), and Sinhala/Tamil text inputs to enable increased regional usage and adaptability.

- **Better NLP for Chatbot:** Enhance responsiveness of chatbots with transformer-based language models such as BERT, GPT to handle more varied phrasing of questions better and respond with contextually appropriate answers rather than the existing TF-IDF and cosine similarity approach.

- **Gamified Learning Features:** Use gamification features such as badges, level up, and leaderboards to enhance student motivation and longer-term engagement, especially among more junior students.

- **Emotion Recognition for Adaptive Feedback:** Include emotion recognition by facial expression or interaction patterns to give more emotionally intelligent feedback and identify

students who would benefit from additional encouragement or support.

- **Offline Capability:** Add an offline capability to support learning in low-connection areas so students can interact with the chatbot and quiz with no active internet connection, sync ability when connected.

- **Data Enrichment and Continual Learning:** Continuous enrichment of the chatbot and quiz databases from real classroom and user input to increase response accuracy and recommendation quality with time.

- **Teacher Dashboard Integration:** Develop a teacher-facing dashboard by which teachers are able to monitor student progress, view quiz scores, view predictions of performance, and hand-configure feedback or course recommendations as necessary.

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6. GLOSSARY

Term	Definition
AI	Artificial Intelligence- Technology enabling machines to replicate human decision-making and intelligence.
ASL	American Sign language- A gestural language used by the hearing-impaired population to convey thoughts.
TF-IDF	A statistical method used for understanding how much a word pertains to a document in a corpus. Used in NLP for feature extraction.
Cosine Similarity	A metric used for ascertaining how similar two vectors are irrespective of their magnitude. Used for user query matching against pre-stored question vectors.

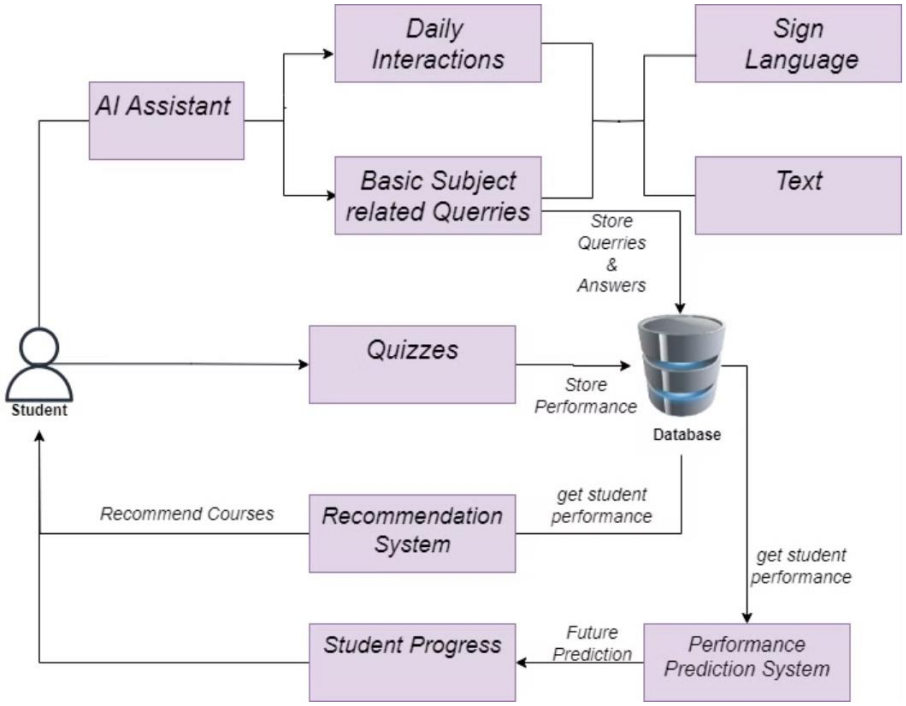
Fast API	A high-performance Python web framework used to build RESTful APIs with auto-validation and documentation.
Flutter	An open-source UI software development kit built by Google used to build cross-platform applications from one codebase.
Firebase	A Google-built platform for building and hosting mobile and web apps with real-time database, hosting, and authentication capabilities.
Random Forest	A machine learning model that builds multiple decision trees and takes the results thereof to improve accuracy for stability. Used for predicting performance.
Linear Regression(LR)	A supervised machine learning algorithm that is used in predicting a dependent variable based on one or more independent variables.
ARIMA	A model used in forecasting future trends from past data using time-series forecasting.
Sign-to-Text	A conversion technique using visual recognition that converts sign language gestures into readable text.
Text-to-Sign	A conversion technique used in converting written text into animated or visual sign language gestures.
Pandas	A Python data analysis and manipulation library for reading, preprocessing, and analyzing datasets
Scikit-learn	A Python machine learning library used for data preprocessing, model building, and evaluation.
Joblib	A Python library used for saving and loading machine learning models and data efficiently.

Engagement Time	The amount of time a student is actually interacting with the learning system in a session.
Improvement Score	A calculated metric of the student's progress across multiple sessions, derived from performance data.
Quiz module	That part of the system which offers the testing of the student's knowledge in English and Mathematics, etc

7. APPENDICES

- ✓ **Appendix A – Plagiarism Report**

✓ Appendix B- Component Diagram



✓ Appendix C – Datasets

1. Chatbot Q&A Dataset

- **Purpose**: Used to train the chatbot for answering Mathematics and English subject-related queries.
- **Structure**:

Question	Answer	Subject	Level
What is a noun?	A noun is a word that names a person...	English	Beginner
What is 12 x 4?	The answer is 48.	Mathematics	Beginner

2. Course Recommendation Dataset

- **Purpose**: Contains manually curated course titles for different subjects and levels, used in both chatbot and quiz-based recommendation logic.
- **Structure**:

Course Title	Subject	Level
Algebra Basics	Mathematics	Beginner
English Grammar 101	English	Intermediate

3. Quiz Result Dataset

- **Purpose**: Stores student quiz attempt results used to calculate improvement scores and performance trends.
- **Structure**:

Student ID	Subject	Score	Attempt Count	Success Count	Engagement Time
ST001	Mathematics	6	1	5	12 mins

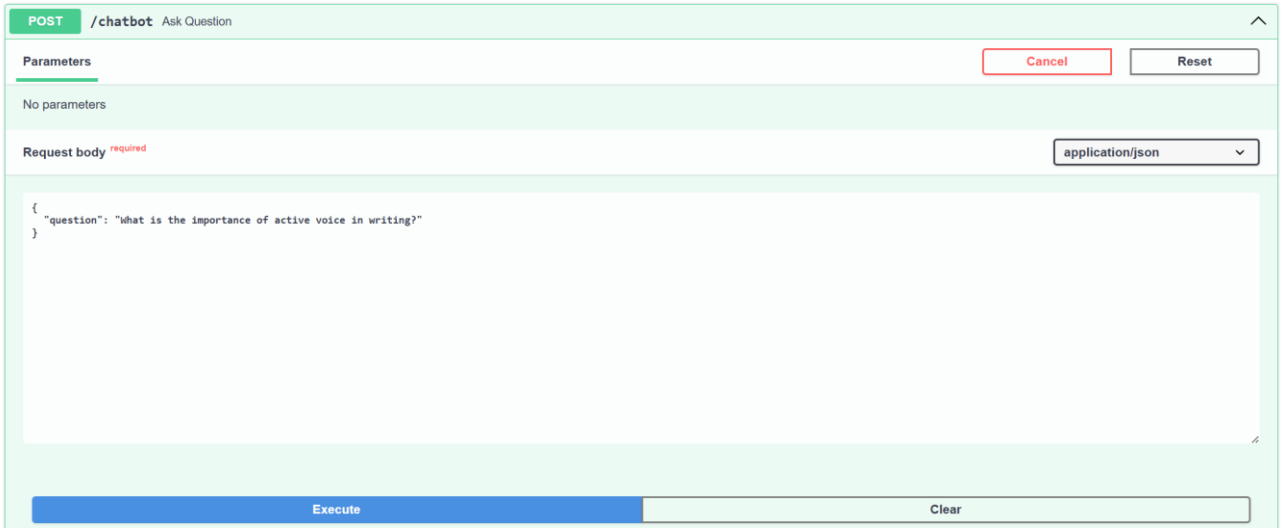
4. Self-Improvement Prediction Dataset

- **Purpose**: Used for training the Linear Regression and Random Forest models for predicting improvement scores.
- **Structure**:

Success Count	Attempt Count	Game Score	Engagement Time	Game Level	Improvement Score
7	8	87	14	2	0.84

✓ Appendix D – API Endpoints

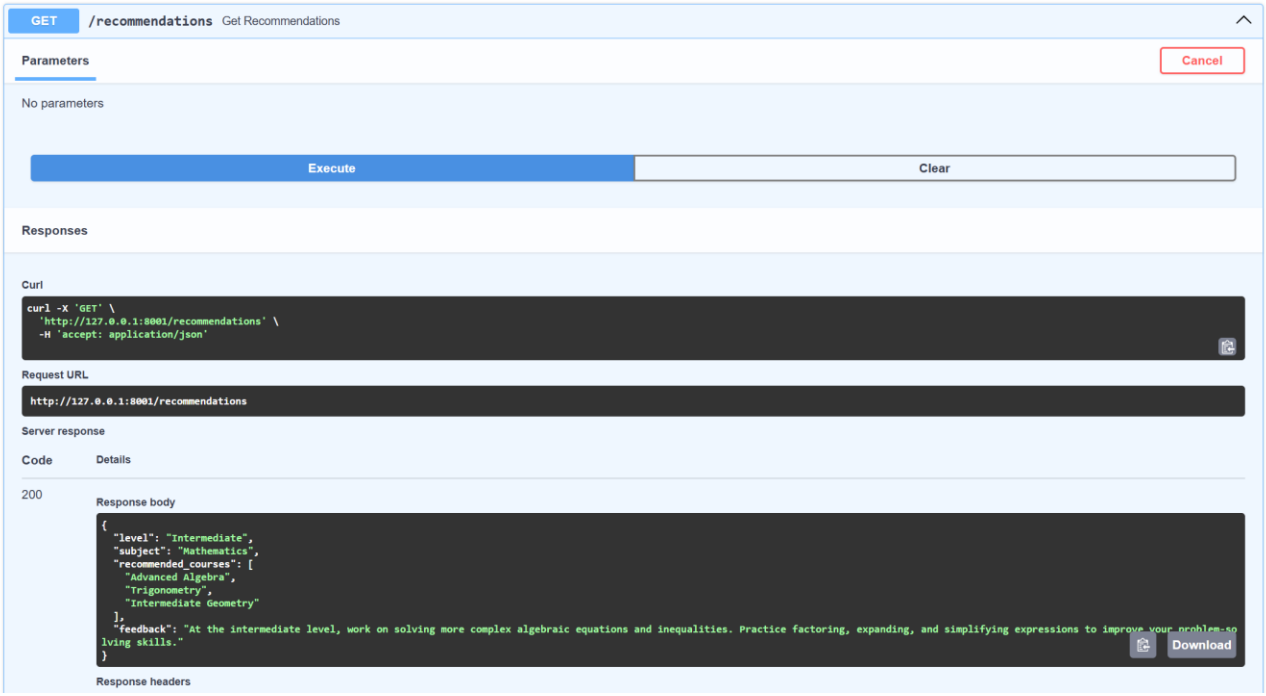
Chatbot



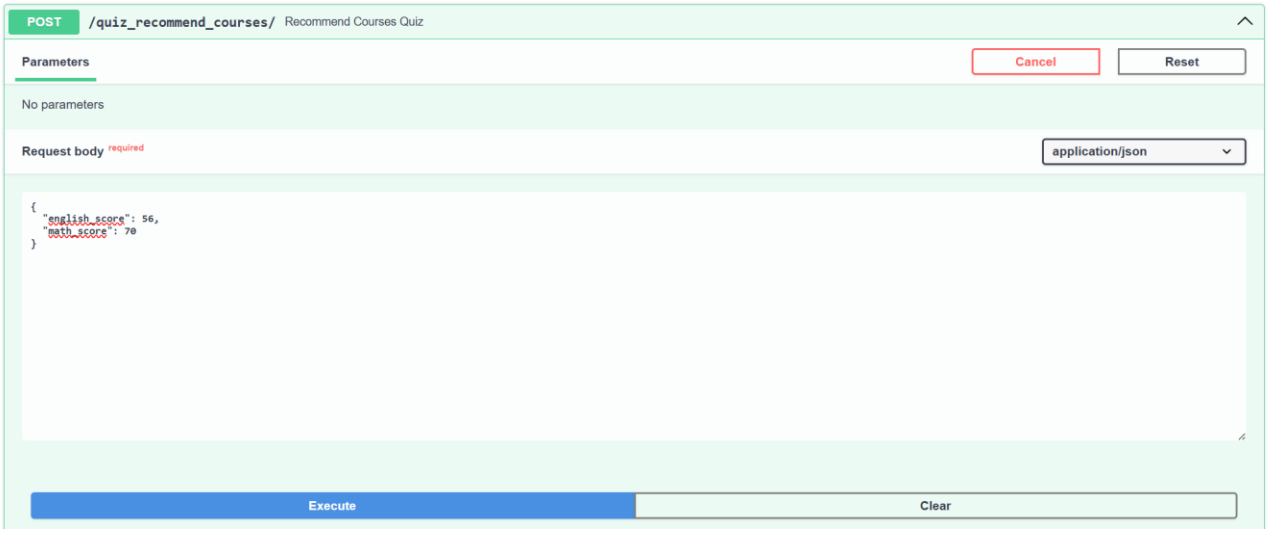
Response body


```
{
  "question": "What is the importance of active voice in writing?",
  "answer": "active voice makes writing clear and direct by placing the subject before the verb.",
  "level": "Beginner",
  "subject": "English",
  "questions_asked": 5
}
```

Recommendation from user interaction



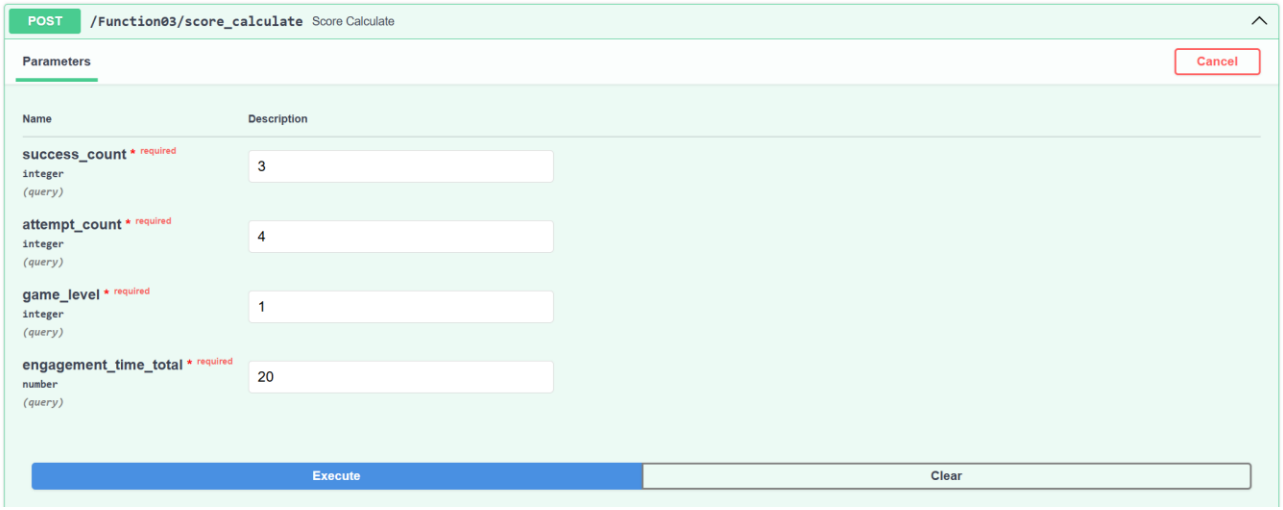
Recommendation from quiz results



Response body


```
{
  "recommended_english_courses": [
    {
      "course_name": "Public Speaking Skills",
      "subject": "English",
      "level": "Intermediate"
    },
    {
      "course_name": "Intermediate Grammar",
      "subject": "English",
      "level": "Intermediate"
    },
    {
      "course_name": "Reading Short Stories",
      "subject": "English",
      "level": "Intermediate"
    }
  ],
  "recommended_math_courses": [
    {
      "course_name": "Advanced Statistics",
      "subject": "Mathematics",
      "level": "Advanced"
    },
    {
      "course_name": "Fourier Analysis",
      "subject": "Mathematics",
```

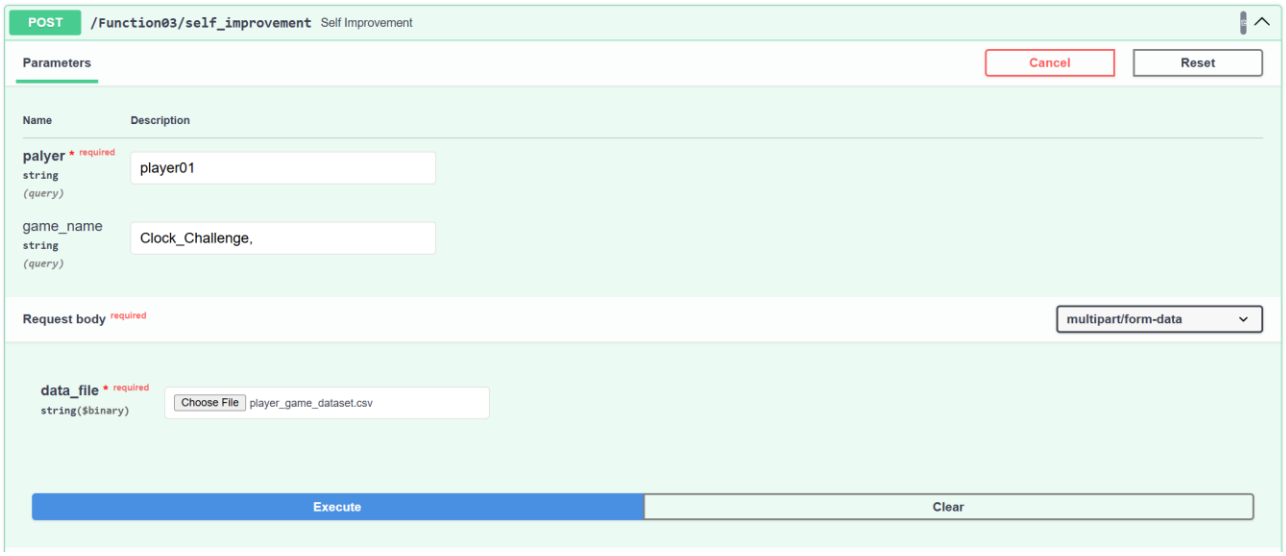

Quiz score calculation

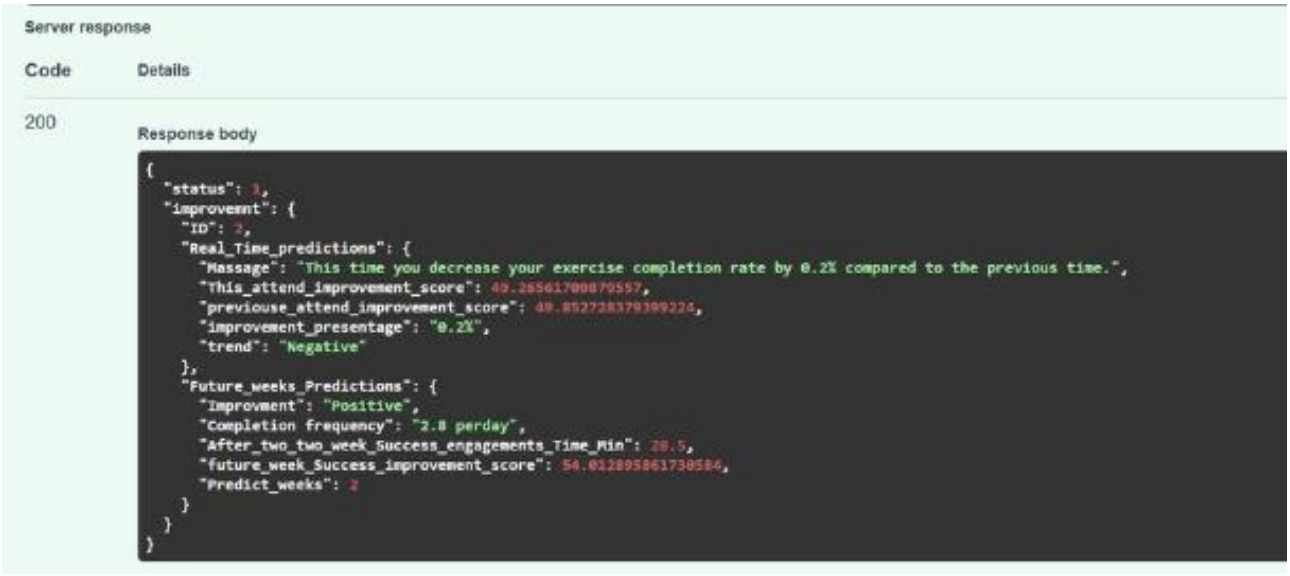


Response body

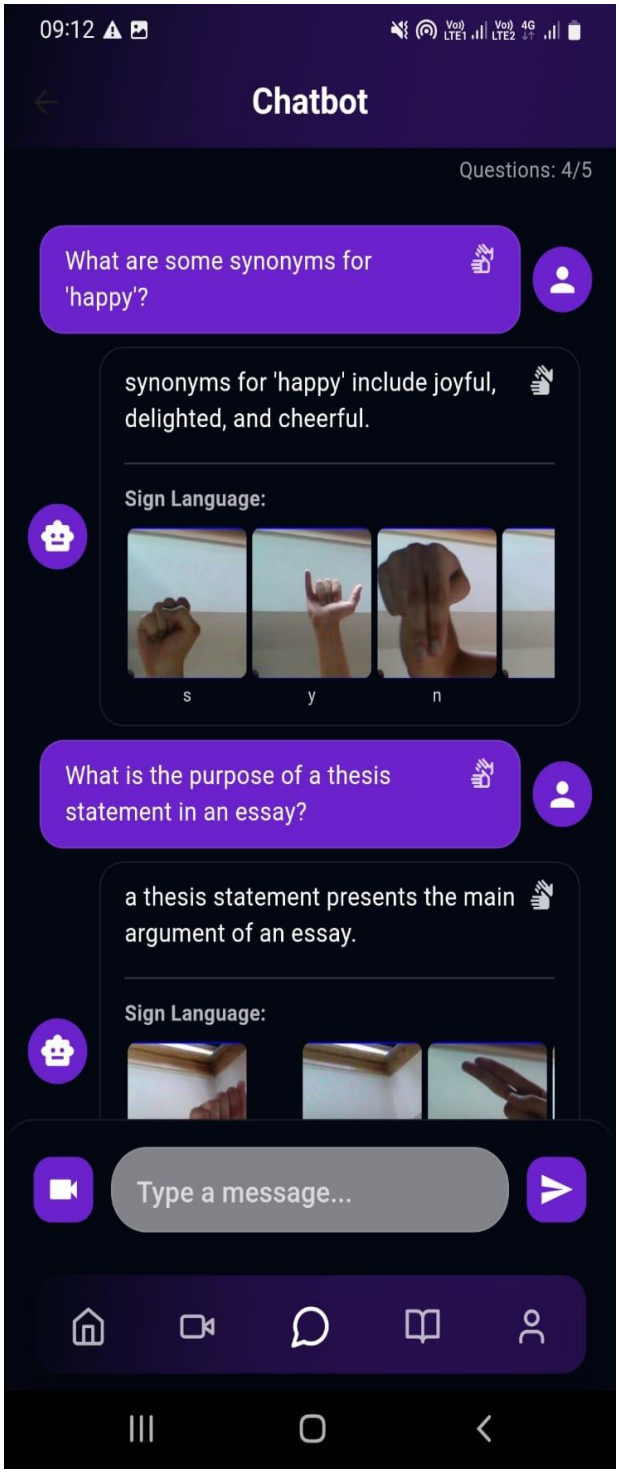

```
{
  "status": 1,
  "score": 87
}
```

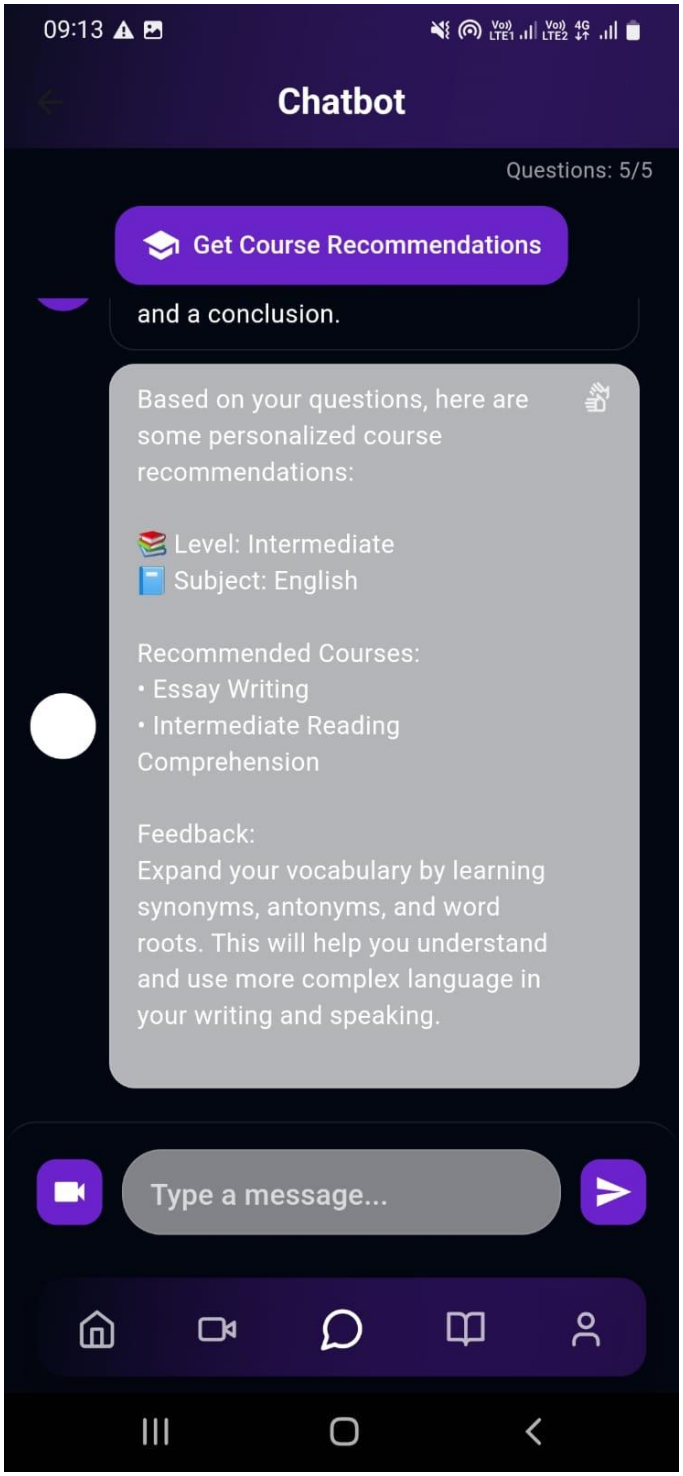
Self Improvement

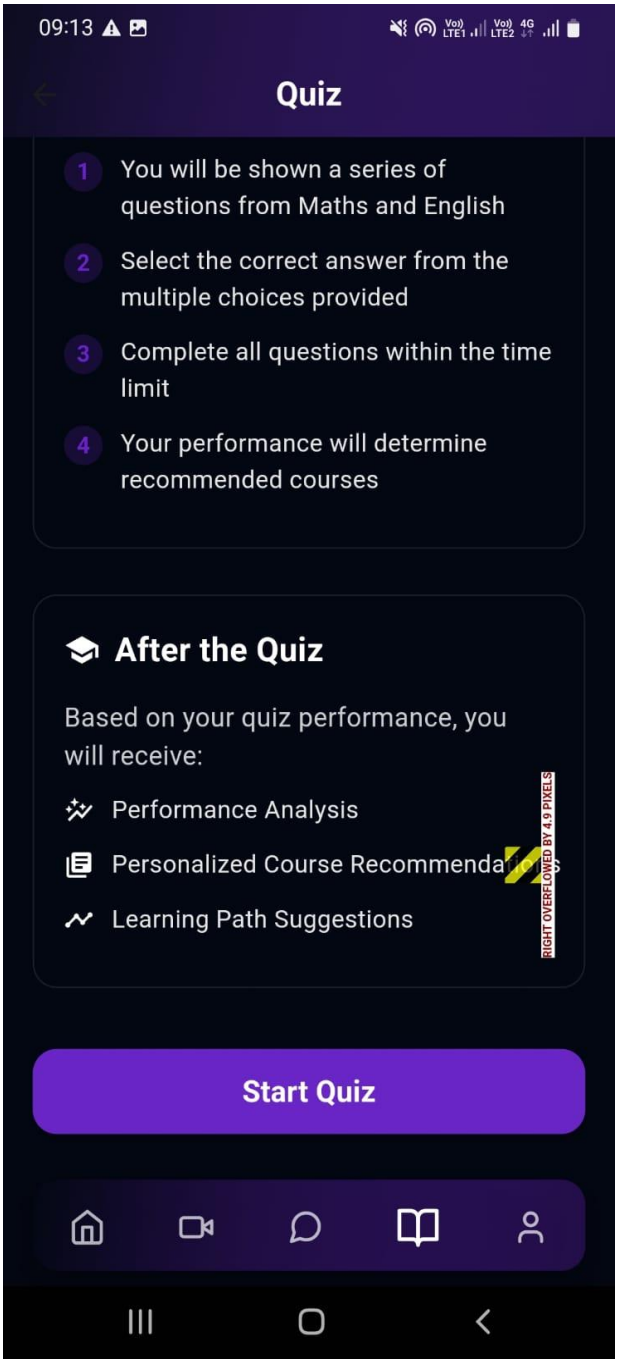


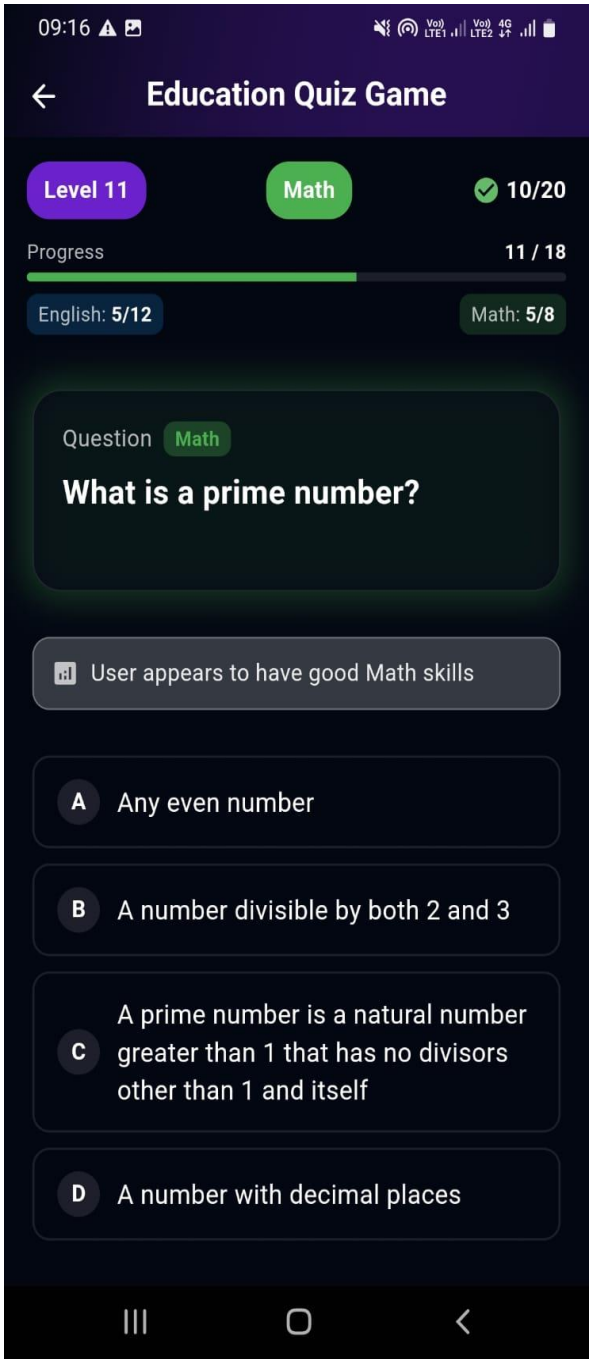


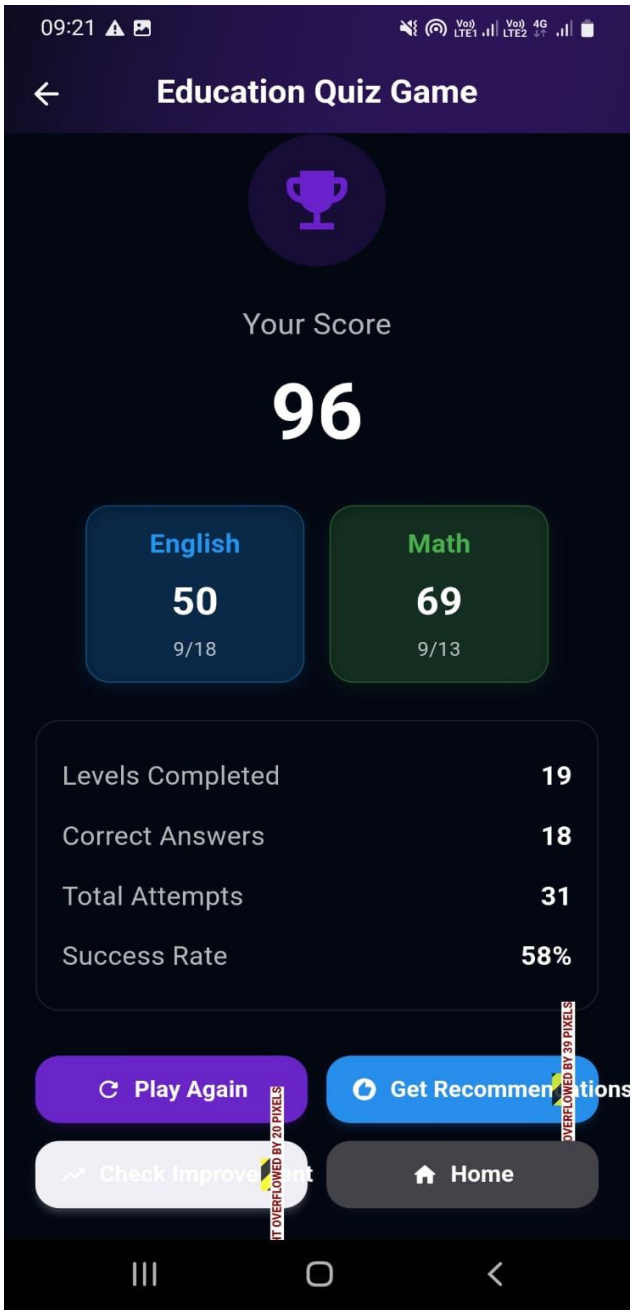
✓ Appendix E – Screenshots

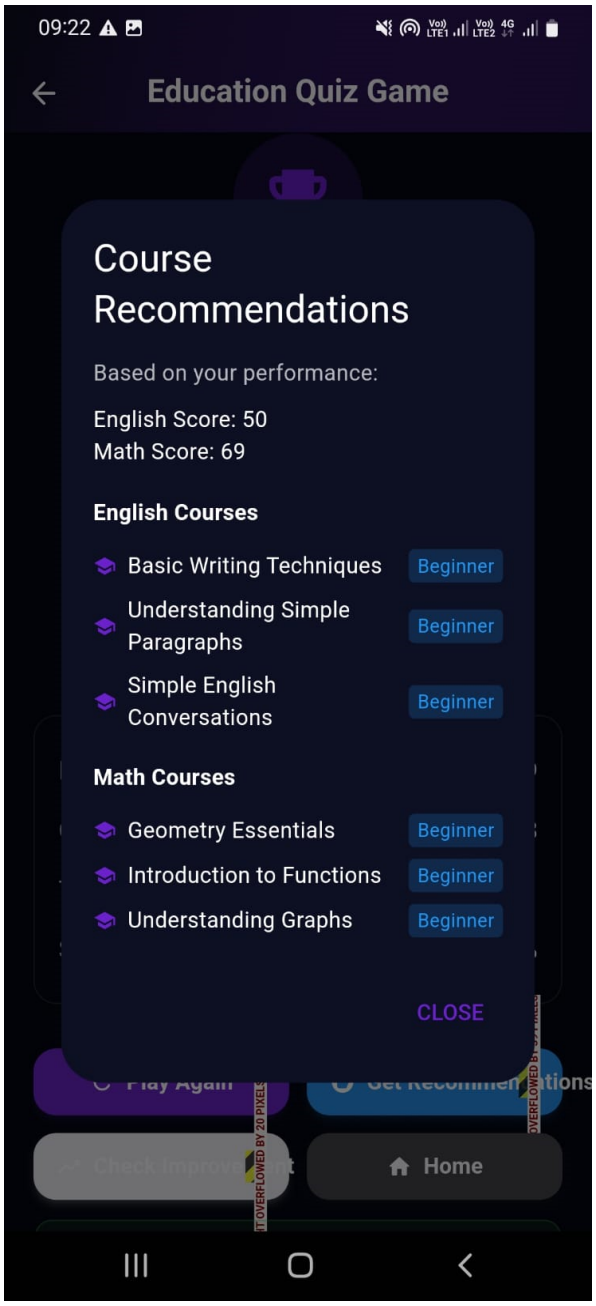


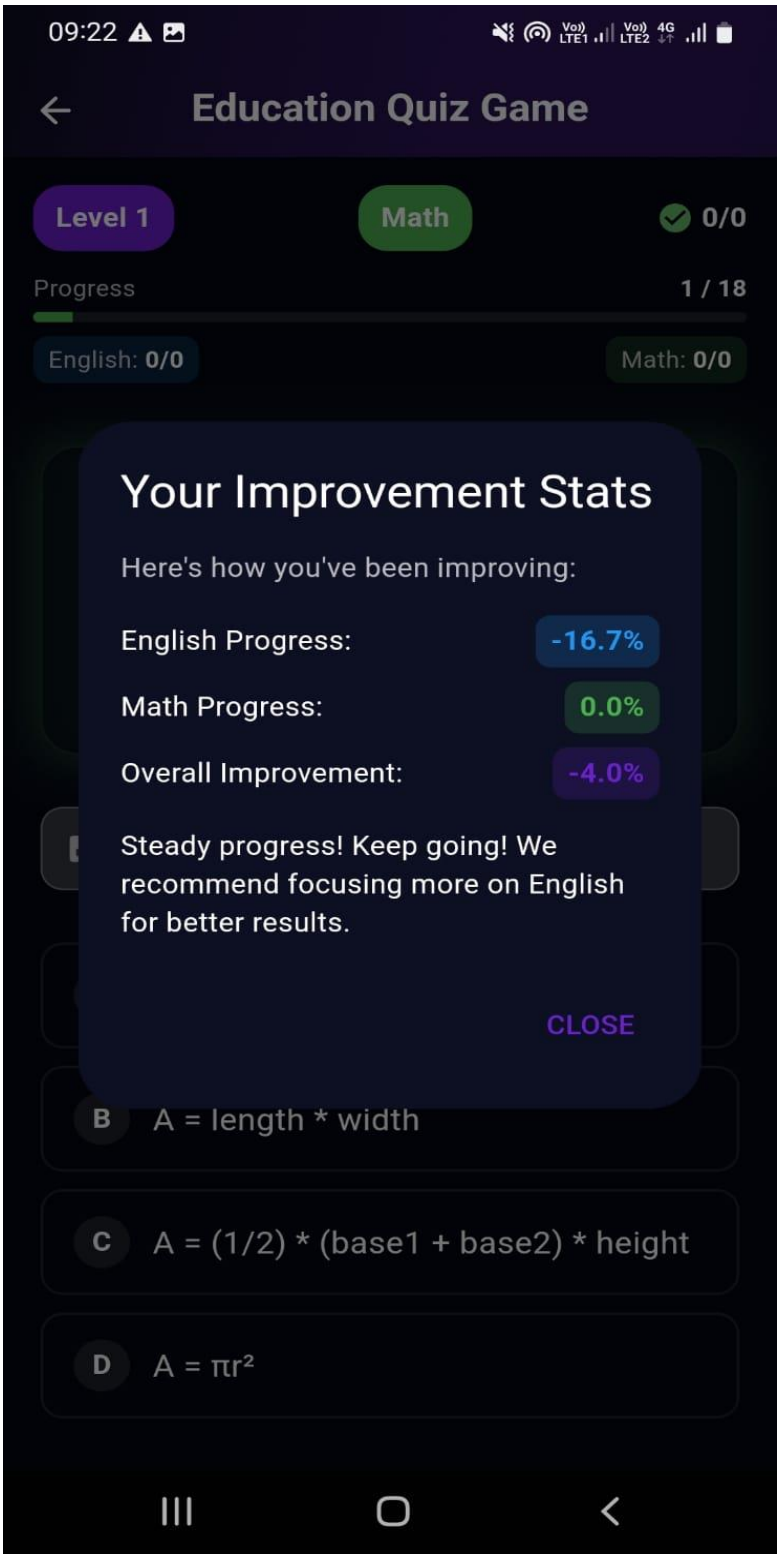



09:13
Quiz
1 You will be shown a series of questions from Maths and English
2 Select the correct answer from the multiple choices provided
3 Complete all questions within the time limit
4 Your performance will determine recommended courses
After the Quiz
Based on your quiz performance, you will receive:
Performance Analysis
Personalized Course Recommendations
Learning Path Suggestions
RIGHT OVERFLOWED BY 4.9 PIXELS
Start Quiz


09:16
Education Quiz Game
Level 11
Math
10/20
Progress
11 / 18
English: 5/12
Math: 5/8
Question
Math
What is a prime number?
User appears to have good Math skills
A Any even number
B A number divisible by both 2 and 3
C A prime number is a natural number greater than 1 that has no divisors other than 1 and itself
D A number with decimal places


09:21
Education Quiz Game
Your Score
96
English
50
9/18
Math
69
9/13
Levels Completed 19
Correct Answers 18
Total Attempts 31
Success Rate 58%
Play Again
Get Recommen ations
Check Improvement
Home
IT OVERFLOWED BY 20 PIXELS
OVERFLOWED BY 39 PIXELS


09:22
Education Quiz Game
Course Recommendations
Based on your performance:
English Score: 50
Math Score: 69
English Courses
Basic Writing Techniques Beginner
Understanding Simple Paragraphs Beginner
Simple English Conversations Beginner
Math Courses
Geometry Essentials Beginner
Introduction to Functions Beginner
Understanding Graphs Beginner
CLOSE
Home


09:22
Education Quiz Game
Level 1
Math
0/0
Progress
1 / 18
English: 0/0
Math: 0/0
Your Improvement Stats
Here's how you've been improving:
English Progress:
-16.7%
Math Progress:
0.0%
Overall Improvement:
-4.0%
Steady progress! Keep going! We recommend focusing more on English for better results.
CLOSE
B
A = length * width
C
A = (1/2) * (base1 + base2) * height
D
A = πr²