Signify

AI-Enhanced E-Learning Platform for the Hearing impaired

Group ID: 24-25j-281

Project Final Report

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DECLARATION

I declare that this is my own work, and this Thesis titled “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"** for the Degree of Bachelor of Science (Honours) in Information Technology (Specializing in Data Science) under my supervision.

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ABSTRACT

Hearing-impaired children experience major obstacles in their educational system that hinders their ability to obtain equal learning opportunities. The research develops and implements an AI-based e-learning platform which caters exclusively to the educational needs of 4- to 12-year-old children with hearing disabilities. Modern technology like augmented reality (AR) and machine learning operates within the platform to create an accessible environment for educational engagement. The main objective of this investigation involved developing AI-powered real-time caption and sign language translation methods combined with sign language educational AR features and an AI-driven communication assistant to boost hearing-impaired children's educational interactions and provide feedback. The platform creates more responsive learning spaces through its combination of machine learning algorithms with video analysis technology and gesture recognition systems. Different sources supplied data for this research such as public sign language databases combined with educational content materials. Through interactive personalized resources the experimental platform delivers improved educational results to students who have hearing impairment. The accessibility for every hearing ability group is enabled through AI feedback along with real-time content translation into sign language along with captioning. The research demonstrates how uniting AI technologies creates solutions to close educational barriers for deaf children while developing more inclusive teaching environments. This study deduces that AI combined with AR can reshape hearing-impaired education through adaptable solutions which enhance educational reach while improving student classroom engagement.

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	Description
AR	Augmented Reality
ASL	American Sign Language
CNN	Convolutional Neural Network
NLP	Natural Language Processing
AI	Artificial Intelligence
UI	User Interface
API	Application Programming Interface
CSV	Comma-Separated Values
OCR	Optical Character Recognition
LMS	Learning Management System

1. INTRODUCTION

1.1. Background study and literature

1.1.1. Introduction

The global educational landscape has undergone significant transformation driven by advancements in digital technologies, particularly exacerbated by the COVID-19 pandemic. This shift necessitated robust online and hybrid educational platforms to accommodate diverse learner needs. However, the rapid transition also highlighted specific challenges faced by students with special educational requirements, notably hearing-impaired children. In response, the current research introduces 'Signify,' an advanced AI-enhanced e-learning platform specifically tailored to enhance educational accessibility and interaction for hearing-impaired children aged between 4 and 12.

Hearing impairment profoundly affects the educational journey, presenting substantial barriers in traditional learning environments due to their reliance on auditory information. These barriers not only hinder academic performance but also significantly impact social integration and emotional well-being. Signify aims to bridge these educational gaps by providing specialized tools and real-time interactive features, making learning inclusive, personalized, and effective.

The first component of Signify involves Augmented Reality (AR)-based interactive modules for American Sign Language (ASL) education. It employs sophisticated gesture recognition models to provide real-time feedback and immediate correction, aiming to enhance engagement and learning outcomes through immersive simulations.

The second component addresses the need for accessible educational content through real-time translation systems. By leveraging machine learning technologies for speech recognition, Signify provides synchronized captions and sign language translations, ensuring seamless educational experiences.

The third component features an AI-powered Learning Assistant designed to foster personalized education. This chatbot supports interactions via sign language and text, allowing students to ask educational queries and receive feedback directly. Integrated sign-to-text and text-to-sign conversions further enhance accessibility. Following chatbot interactions, students engage with quizzes that assess their understanding, with the system offering course recommendations and tracking performance to provide predictive insights into future learning achievements.

This research comprehensively investigates the development, implementation, and evaluation of Signify, examining the effectiveness of each component and its collective impact on transforming education for hearing-impaired students. Through rigorous analysis and empirical testing, this study highlights Signify's potential as a pioneering platform for inclusive and accessible education.

1.1.2 Background survey

According to the World Health Organization, approximately 466 million individuals globally experience some degree of hearing loss, including around 34 million children [1]. Hearing impairment significantly restricts educational and social development, exacerbating academic disparities and social exclusion.

Existing research predominantly utilizes static resources such as images or pre-recorded videos to teach sign language. These methods lack interactive features and do not provide real-time feedback, essential for effective learning [2]. Recent studies indicate that dynamic interactions significantly enhance learning outcomes for hearing-impaired students, suggesting a critical gap in existing educational tools [3].

Advances in technology, particularly Augmented Reality (AR) and Machine Learning (ML), have opened new avenues for interactive and immersive learning. AR technologies facilitate real-time visualization and practice of gestures, significantly boosting engagement and learning efficiency [4]. Machine Learning algorithms, especially Convolutional Neural Networks (CNN), Random Forest, and CatBoost classifiers, have demonstrated remarkable efficiency in real-time gesture recognition and interpretation, crucial for effective ASL learning [5].

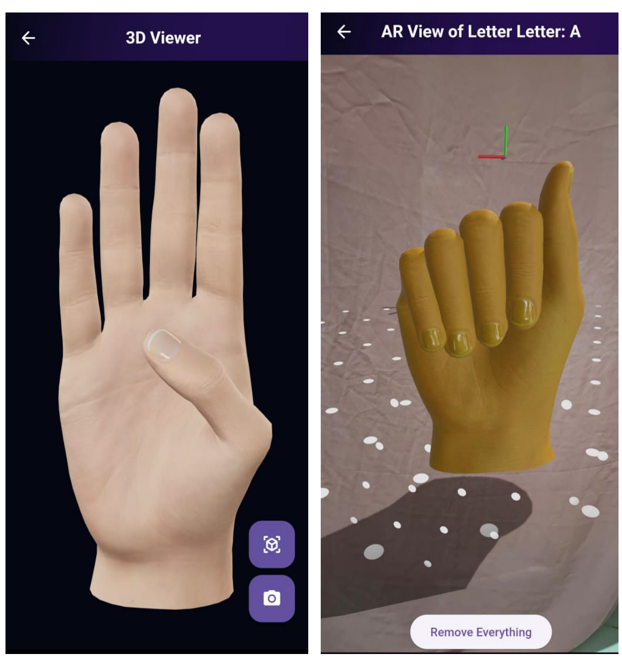

Figure 1: 3D and AR views of a hand demonstrating the letter 'A' in American Sign Language, illustrating the application of AR for interactive learning.

Further, educational platforms often inadequately integrate accessibility features such as captioning and real-time translation into sign language. While some applications offer captions or isolated sign language videos, very few synchronize both seamlessly, presenting substantial accessibility barriers for hearing-impaired learners [6].

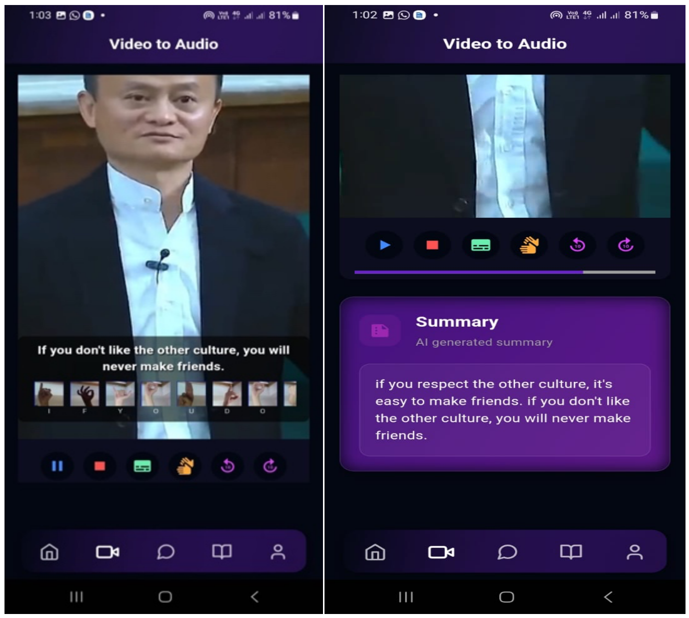

Figure 2: Video-to-audio application with real-time captioning and content summaries, enhancing accessibility for hearing-impaired learners.

Personalized learning through AI-based assistants and recommendation systems has increasingly gained attention, demonstrating improved educational outcomes and higher student satisfaction. The 'Signify' platform directly addresses the needs of hearing-impaired students by incorporating gesture recognition, personalized learning pathways, and real-time performance analytics. Integral to this approach is the AI-powered Learning Assistant that supports sign language, ensuring accessible and personalized educational interactions for hearing-impaired students [7].

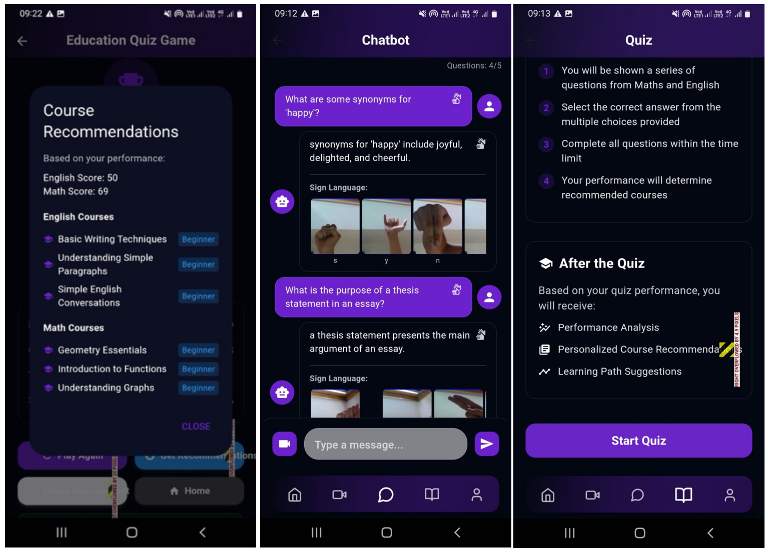

Figure 3: Interface of the 'Signify' Learning Assistant, featuring chatbot, quiz, and personalized course recommendations with sign language support.

1.2 Research Gap

Table 1 : Component-wise Analysis of Existing Solutions, Identified Research Gaps, and Signify's Contributions

Component	**Aspect**	**Existing Solutions**	**Identified Research Gap**	**How Signify Addresses It**
Component 1: ASL Learning via AR & ML	ASL Learning via AR & ML	Most apps use static images or videos without interaction	Lack of real-time gesture feedback, no AR-based sign demonstrations	Uses AR with 3D virtual hands and ML gesture recognition for interactive and engaging learning
	Gesture Recognition Systems	Gesture apps lack feedback mechanisms	No immediate feedback or adaptive difficulty levels	Provides visual cues, error detection, and level-based assessments with real-time updates

Component 2: Real-Time Translation	Real-Time Video Translation	Solutions provide either captions or sign language, not both together	Absence of synchronized captions and ASL animations	Combines Whisper-based captions with MobileNetV2-based ASL translation, all synchronized
	Content Summarization	Most e-learning lacks summarization for accessibility	No summarization of educational videos in visual/textual form	Uses T5 NLP model to auto-summarize educational content at the end of each video
Component 3: AI-Powered Learning Assistant	AI-Powered Learning Assistant	Limited support for sign language in educational chatbots	Inadequate support for sign language and text interactions in learning environments	Chatbot supports both sign language and text, enhancing accessibility for hearing-impaired students
	Recommendation Systems	No personalized course recommendations for hearing-impaired learners	Lack of tailored course suggestions based on quiz performance or learning pace	Recommender system based on quiz results, subject, age, and learning level using collaborative filtering
	Performance Prediction	Most e-learning platforms lack student progress forecasting	No forecasting of future performance or adaptive course difficulty	Uses Random Forest and ARIMA to predict improvement and adapt course flow accordingly

1.3 Research Problem

E-learning platforms present significant opportunities for inclusive education, yet substantial barriers persist for hearing-impaired students due to limited accessibility, lack of interactive feedback, and inadequate personalized educational support. These shortcomings restrict learning effectiveness, student engagement, and overall academic and social development. Thus, an urgent need exists for an advanced, inclusive e-learning solution specifically addressing these critical issues.

Given these challenges, the research addresses:

Table 2: Research Problem Focus Areas

Challenge Area	**Research Focus**	**Purpose / Impact**
AR and Machine Learning for ASL Education	How AR technologies and machine learning models can effectively facilitate interactive and immersive ASL education for hearing-impaired children.	To provide real-time, engaging, and educational sign language learning experiences tailored for young students.
Real-Time Multimodal Translation Systems	Integration of real-time captioning and sign language synchronization within educational content.	To enhance accessibility by delivering content simultaneously in sign language and text, ensuring full comprehension for hearing-impaired students.
AI-Based Personalized Learning Support	Development of personalized educational support using AI-driven recommendations and real-time performance analytics.	To create dynamic, learner-centric educational paths based on quiz results, learning behavior, and chatbot interactions.
Interactive Sign Language Support in AI Tools	Enhancement of the AI-powered Learning Assistant to support interactive communication using sign language.	To allow students who use sign language as their primary language to engage naturally, ensuring inclusivity and deeper interaction with learning tools.

1.4 Research Objectives

1.4.1 Main Objective

The primary objective of this research is to develop a comprehensive, interactive, and inclusive AI-enhanced e-learning platform, "Signify," tailored explicitly for hearing-impaired children to significantly enhance their educational accessibility, engagement, and academic outcomes.

1.4.2 Specific Objectives

1. **To develop interactive AR-based ASL education modules providing real-time feedback to enhance engagement and effectiveness in sign language learning.**
   These modules will employ advanced AR technologies to facilitate dynamic, immersive learning experiences where students can practice and learn ASL with immediate corrective feedback.

2. **To implement real-time speech-to-text and text-to-sign language translation systems, synchronizing captions and visual gestures to improve educational content accessibility.**
   This will ensure that all educational materials are accessible in both spoken and sign language formats, accommodating various learning preferences and needs.

3. **To design an AI-powered learning assistant featuring personalized course recommendations and performance prediction, providing adaptive learning experiences tailored to individual student needs.**
   This assistant will support robust sign language interaction, allowing students to communicate their questions and receive answers in ASL, thereby enhancing the accessibility and personalization of the learning experience. This will integrate seamlessly with quizzes and analytics to offer course recommendations based on both direct interactions and quantifiable performance metrics.

1.4.3 Business Objectives

1. Improve User Engagement and Satisfaction:
    - Enhance user engagement through personalized and interactive learning experiences.
    - Reduce dropout rates by providing accessible, effective, and tailored educational support.

2. Attract Educational Partnerships:
    - Position Signify as a leading educational solution for institutions seeking to enhance accessibility and inclusivity for hearing-impaired students.
    - Establish sustained partnerships with educational bodies to ensure long-term platform adoption and sustainability.

2. METHODOLOGY

2.1 Introduction

A survey was carried out to identify possible solutions to address the issues in detecting American Sign Language (ASL) gestures using machine learning models. The study involved utilizing publicly available ASL datasets and various machine learning algorithms to analyze and classify ASL gestures.

Based on the issues identified in the survey, “Signify” has been developed with three key components, making it a distinctive learning platform. These components include:

1. Interactive ASL learning sessions enhanced with AR and Machine Learning
2. Real-Time Translation of educational content into captions, sign language, and summarized formats
3. AI-powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction.

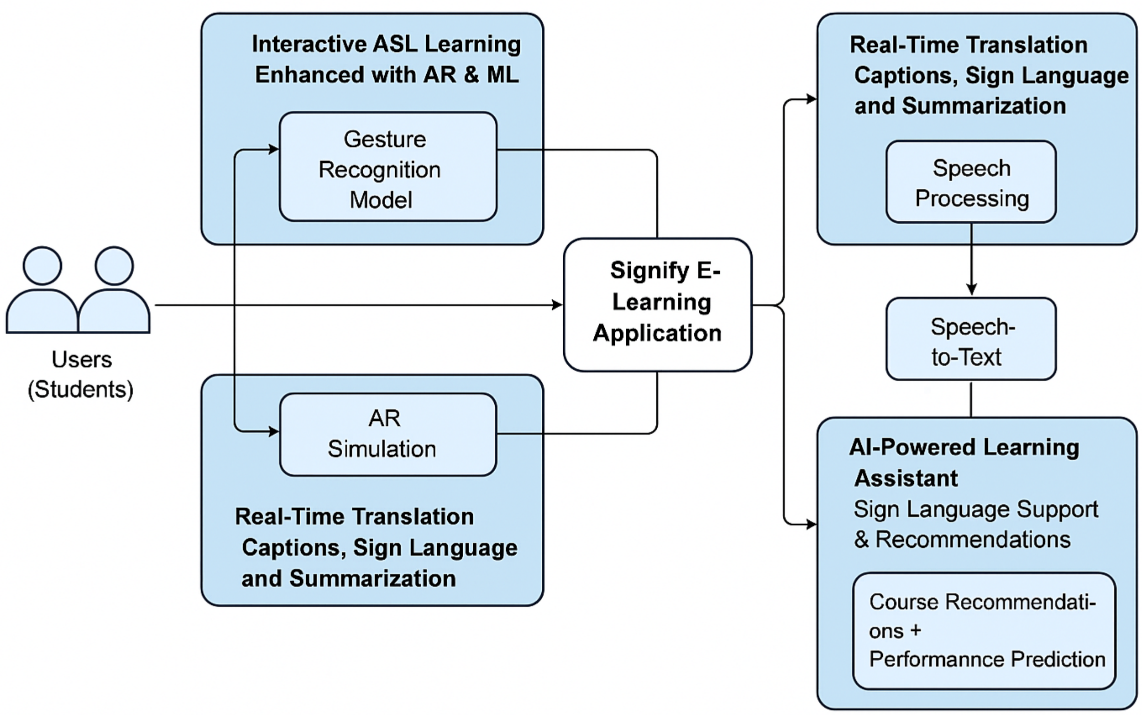

Figure 4 : System architecture of the Signify platform, showcasing modules for AR teaching, real-time translation, and AI support.

2.1.3 Component overview

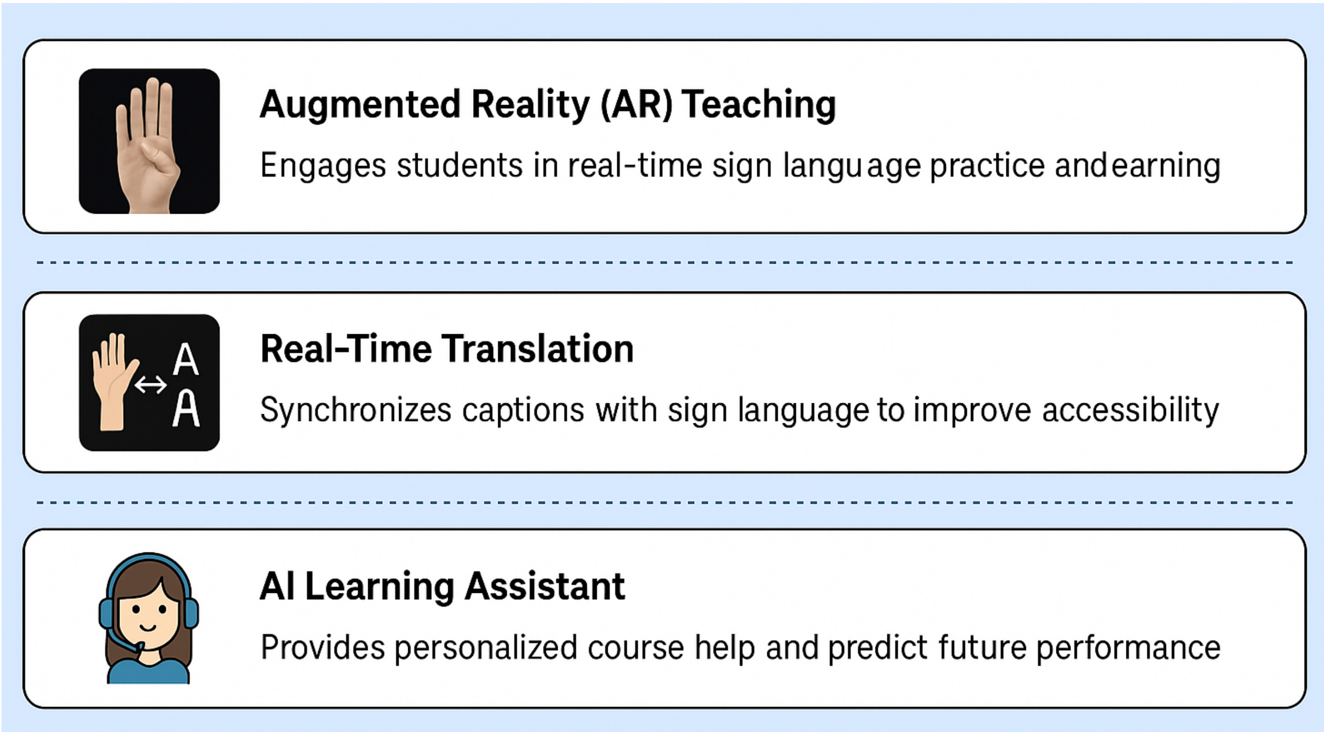

Figure 5: Component Details

Component 1: Interactive ASL learning sessions enhanced with AR and Machine Learning

This component introduces **interactive ASL learning sessions** where students view gestures through AR models and get **real-time feedback**.

- ♦ **Key Processes:**
  - ✓ **Data Collection**: ASL Alphabet datasets from Kaggle
  - ✓ **Preprocessing**: Image resizing (128×128), normalization (0–1), one-hot encoding labels.
  - ✓ **Model Training**:
    - Multiple Models for Gesture Recognition:
      - **Convolutional Neural Network (CNN):** Developed using TensorFlow and Keras, featuring layers that efficiently identify features from the image data for classification tasks.
      - **CatBoost and Random Forest Classifiers:** Employed for their robustness in feature-based classification, ensuring accurate and efficient gesture recognition.
      - **Gradient Boosting Classifier (GBC):** Utilized for its strength in handling noisy data and capability to produce high accuracy.
      - **LSTM Models:** Integrated for analyzing sequences in gestures, providing valuable insights into temporal patterns.
    - The models are meticulously evaluated using confusion matrices to ensure precise and reliable gesture identification.

  - ✓ **AR Integration**: Blender & Unity used to render hand models for virtual demonstration Signify.
  - ✓ **Gesture Matching**: Live input compared with expected gesture using MediaPipe hand landmarks.

- **Tools & Tech:**
  - ✓ Python, TensorFlow/Keras, Blender, Unity 3D
  - ✓ Fast API backend, Firebase database

- **Unique Feature**: Offers three levels of learning difficulty (Beginner, Intermediate, Advanced), providing adaptive feedback that scales with the user's proficiency.

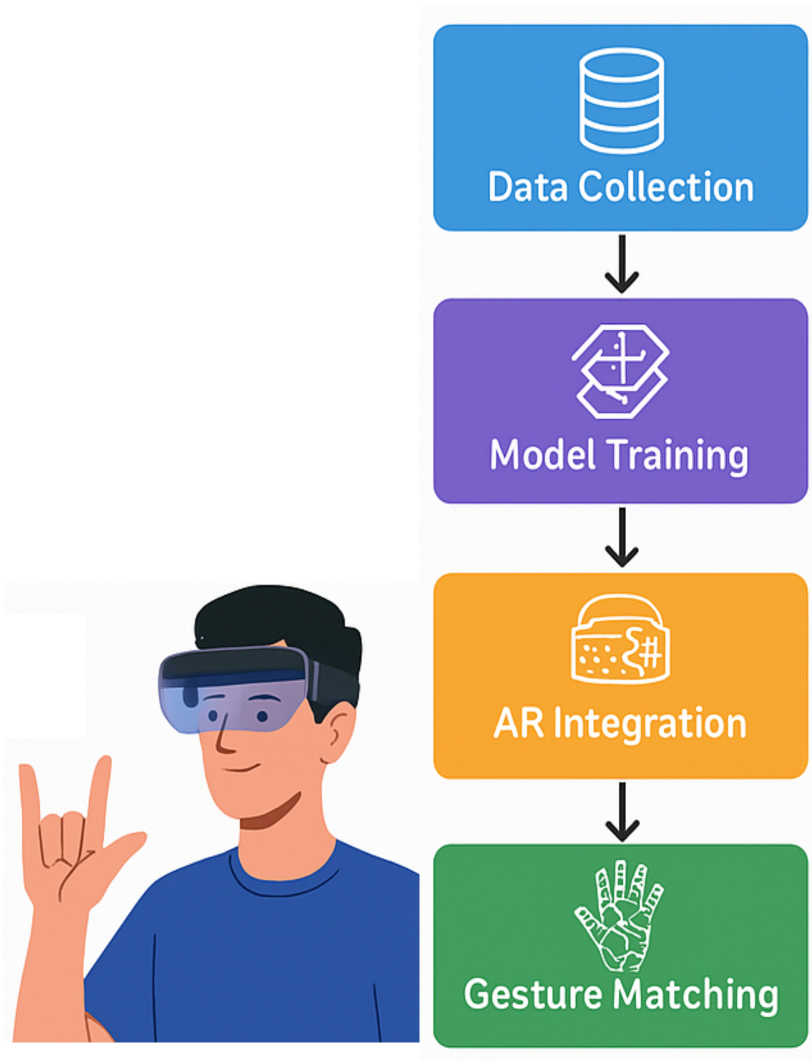

Figure 6 : Process of ASL Learning with AR and Machine Learning integration.

Component 2: Real-time Educational Content Translation

This function focuses on making video content accessible by translating **audio into text captions, sign language, and summary generation.**

- **Methodology:**
  - ✓ **Audio Extraction**: From video using libraries like Python's `librosa`.
  - ✓ **Speech-to-Text**: Implemented using **Whisper** for real-time audio transcription.
  - ✓ **Sign Language Animation**:
    - Input sentences parsed into word/phrase gestures.
    - Synchronized with captions.
  - ✓ **Summarization**:
    - T5 transformer model used to generate concise summaries.
  - ✓ **User Interface**:
    - Flutter front-end to display captions, ASL avatars, and video in sync.

- **Tools:**
  - ✓ Python, HuggingFace Transformers, MobileNetV2
  - ✓ Flutter (mobile), Firebase (real-time data)

- **Challenges Addressed**:
  - ✓ Captions and ASL combined (rare in most platforms)
    - Real-time synchronization of audio, captions, and gestures

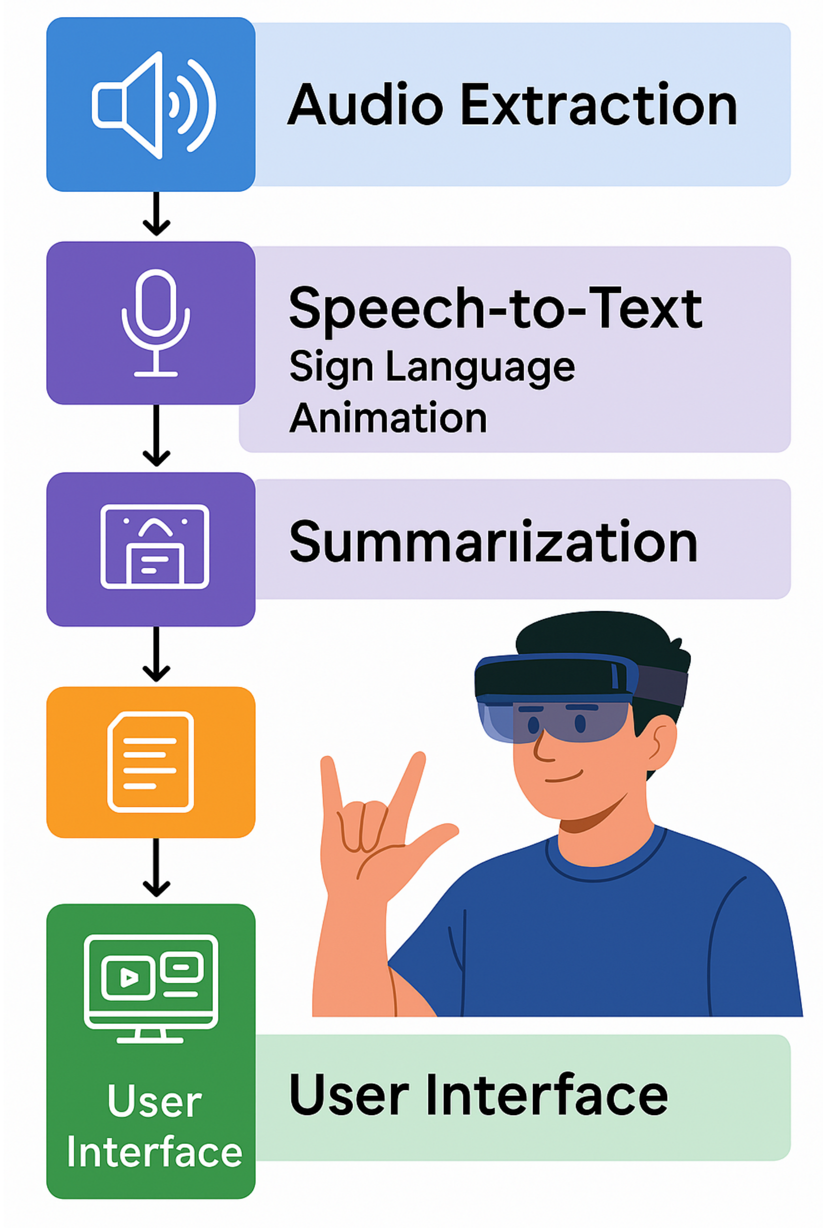

Figure 7: Workflow for real-time translation of educational content into text, sign language, and summaries.

Component 3: AI-Powered Learning

This function enhances **personalized learning** with a chatbot, **course recommendations**, and **future performance prediction.**

- **Chatbot:**
  - ✓ **Input:** Handles English and Math queries, facilitating academic inquiries.
  - ✓ **Processing:** Uses TF-IDF and cosine similarity for query analysis and draws responses from a pre-trained dataset of over 2,000 Q&As.
  - ✓ **Sign Language Support:** Features sign-to-text and text-to-sign conversions for accessible communication in sign language.
  - ✓ **Technology:** Developed with FastAPI, scikit-learn, joblib, and Python for robust performance.

- **Recommendation Engine:**
  - ✓ **Personalization:** Delivers tailored course suggestions post-interaction or quiz.
  - ✓ **Data Utilization:** Employs a predefined course CSV dataset, categorizing content by subject, level, and age to match user needs.

- **Performance Predictor:**
  - ✓ **Analytics:** Utilizes Linear Regression and Random Forest to analyze quiz results and predict academic performance.
  - ✓ **Forecasting:** Employs ARIMA models for trend analysis and future performance forecasting.
  - ✓ **Visualization:** Features integrated data visualization for real-time tracking and feedback on educational progress.

- **Quiz System:**
  - ✓ **Setup:** Includes 8-question quizzes in Mathematics and English to evaluate understanding.
  - ✓ **Feedback:** Offers immediate scoring and detailed analysis post-quiz, tracking improvement and providing future performance insights based on past data.

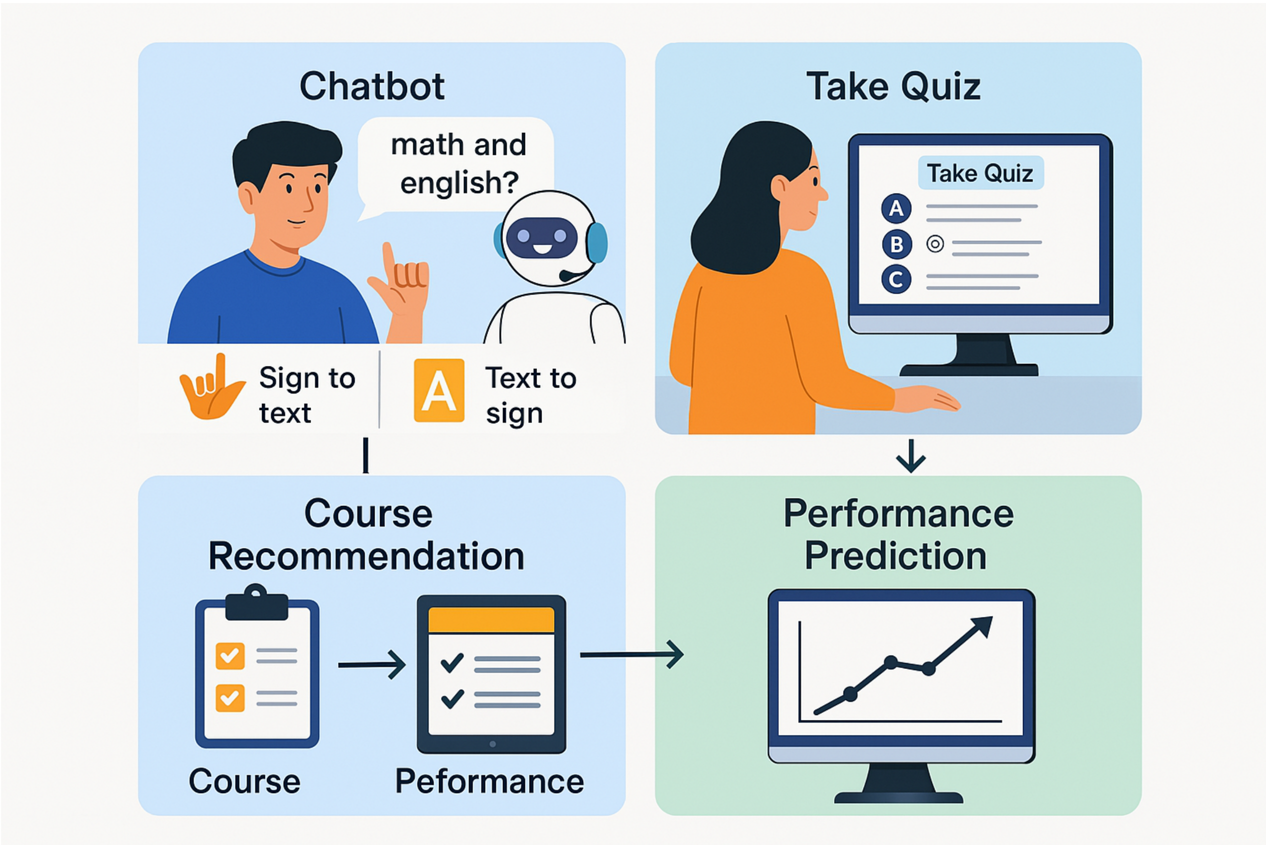

Figure 8 : Workflow: AI-powered Learning with chatbot interactions, quiz assessments, and performance analytics.

2.1.4 Development Process

Agile is an iterative and incremental approach to software development that emphasizes collaboration, adaptability, and customer feedback throughout the development process. This method is particularly well-suited for projects like 'Signify,' where requirements are likely to evolve, and responsiveness to user needs is crucial. Below is an overview of how the Agile development process is applied to the creation of 'Signify':

1. **Project Initiation:**
   - **Objective Clarification:** The project begins with defining clear objectives: to develop an inclusive, interactive, and accessible e-learning platform for hearing-impaired students.
   - **Component Identification:** The team identifies the core components - AR-based ASL education, real-time translation systems, and an AI-powered learning assistant - and outlines initial high-level requirements.

2. **Product Backlog Creation:**
   - **Backlog Setup:** A product backlog is created, consisting of a prioritized list of features, functionalities, and user stories related to each component.
   - **Backlog Refinement:** These items are continuously refined and updated based on feedback from stakeholders, including educators, students, and accessibility experts.

3. **Sprint Planning:**
   - **Development Cycles:** The project is divided into a series of time-boxed development cycles or "sprints."
   - **Planning Meetings:** Before each sprint, the team holds planning meetings to select backlog items for the upcoming iteration, defining sprint goals and estimating required efforts.

4. **Daily Standup Meetings:**
   - **Daily Sync:** Daily standup meetings help the development team discuss progress, challenges, and next steps, ensuring alignment and prompt issue resolution.

5. **Development and Testing:**
    - **Coding and Testing:** Development work on selected backlog items begins, with continuous testing to ensure code quality and functionality.
    - **Continuous Integration:** Automated testing and integration help catch and resolve issues early in the development process.

6. **Collaboration and Feedback:**
    - **Team Collaboration:** Collaboration among developers, testers, designers, and domain experts is encouraged to enhance product quality.
    - **Stakeholder Demonstrations:** Regular demonstrations and feedback sessions with stakeholders, including potential users and educators, are conducted to refine the product based on real-world input.

7. **Review and Adaptation:**
    - **Sprint Reviews:** At the end of each sprint, a review meeting is held to showcase completed work to stakeholders and gather feedback.
    - **Retrospective Meetings:** The team reflects on the sprint's outcomes to identify successes and areas for improvement.

8. **Continuous Integration and Deployment:**
    - **Automation:** Integration and deployment pipelines are automated to facilitate rapid delivery of new features and updates.

9. **Scaling and Release:**
    - **User Expansion:** As development progresses, 'Signify' gradually expands its user base, incorporating feedback to adjust the platform's features and usability.
    - **Regular Updates:** The platform is regularly updated to ensure alignment with evolving educational needs and technology trends.

10. **Ongoing Improvement:**
    - **Continuous Improvement Culture:** The Agile approach fosters ongoing assessment and adaptation of processes to maximize productivity and enhance product quality.

By adhering to the Agile development process, the 'Signify' team can create a flexible and responsive platform that effectively addresses the unique educational needs and challenges of hearing-impaired students in a dynamic e-learning environment.

Figure 9 : Agile based Development Lifecycle

2.1.5 Project Management

Project management and version control are pivotal in the development process of "Signify." Effective tools and practices are essential for ensuring collaboration, efficient task management, and code integrity preservation.

1. **Task Planning and Organization:**
    - **Microsoft Planner:** Serves as the central hub for task management, allowing the team to create, assign, and organize tasks related to the development of "Signify."
    - **Task Categorization:** Tasks are categorized into sprints and assigned to team members based on their skills and capacity.

2. **Priority Setting:**
    - **Task Prioritization:** The platform allows for setting task priorities, ensuring high-priority items are addressed promptly, aligning with Agile principles.

3. **Task Dependencies:**
    - **Dependency Management:** Dependencies between tasks are clearly defined to efficiently manage the workflow. For instance, user interface design tasks are scheduled before any coding activities.

4. **Deadline Tracking:**
    - **Microsoft Planner:** Facilitates establishing deadlines for tasks, ensuring that sprint goals are met and the project remains on schedule.

5. **Progress Monitoring:**
    - **Daily Updates:** Team members update the status of their tasks, facilitating real-time progress monitoring during daily standup meetings.

6. **Collaboration and Communication:**
    - **Microsoft Planner Features:** Enable team members to comment on tasks, ask questions, and provide updates, fostering effective communication within the team.

2.1.6 Requirement Gathering

Requirement gathering for "Signify" involves in-depth analysis to determine the best approaches for employing machine learning to enhance e-learning experiences, particularly for hearing-impaired students.

- **Research and Analysis:** Extensive research into current e-learning technologies and machine learning applications to identify effective solutions for the project.
- **Stakeholder Consultation:** Engaging with educators, technical experts, and the target audience to gather comprehensive requirements and insights.

- **Non-functional Requirements:**
    - **Reliability:** Ensuring the platform operates consistently and dependably.
    - **Availability:** Guaranteeing the system is accessible whenever required by users.
    - **Performance:** Focusing on optimizing the speed, responsiveness, and efficiency of the platform.

By leveraging structured project management practices and thorough requirement gathering, "Signify" aims to deliver a robust and responsive e-learning platform tailored to the unique needs of hearing-impaired students. This structured approach will ensure that the platform not only meets but exceeds educational and technological expectations.

2.1.7 Development Methodology

a) Interactive ASL Learning Sessions Enhanced with AR and Machine Learning

1. **Data Collection and Preprocessing:**
    - Collect ASL gesture datasets that include a comprehensive range of sign language gestures.
    - Preprocess the data by enhancing image quality, normalizing, and resizing images to ensure uniformity, which is crucial for effective machine learning training.

2. **Model Training:**
    - **Convolutional Neural Networks (CNN):** Utilize CNNs for their proficiency in image and video recognition tasks. These networks will be trained to recognize different ASL gestures by learning from the various labeled examples in the dataset.
    - **Random Forest:** Employ Random Forest algorithms as part of an ensemble learning method to improve gesture recognition accuracy. This method uses multiple decision trees to make decisions and average their predictions, providing a robust mechanism against overfitting.
    - **XGBoost:** Implement the XGBoost algorithm, known for its efficiency and performance in classification problems, to handle complex patterns in gesture recognition. XGBoost will be used to refine the prediction accuracy and handle a large dataset effectively.
    - **Gradient Boosting:** Apply Gradient Boosting techniques to build an additive model in a forward stage-wise fashion, allowing for optimization of arbitrary differentiable loss functions.

3. **Integration and Testing:**
    - Integrate the trained models within an AR environment developed using platforms like Unity, which will overlay the ASL gesture recognition results in real-time on the user's hand movements.
    - Perform rigorous testing to evaluate the accuracy and real-time performance of the gesture recognition system. This includes live tests with users performing ASL gestures to ensure the system accurately recognizes and interprets them in various real-world conditions.
4. **Deployment:**
    - Deploy the system within an educational platform where users can learn ASL through interactive sessions. Monitor the system's performance continuously to collect data for further improvements.
5. **Continuous Improvement:**
    - Use ongoing user feedback and system performance data to continuously refine the machine learning models. Adjust training parameters, introduce new data, and possibly explore additional machine learning algorithms to enhance gesture recognition accuracy.

b) Real-Time Translation of Educational Content into Captions, Sign Language, and Summarized Formats

1. **Audio Extraction and Processing:**
    - **Extraction Technology:** Use libraries such as librosa to extract audio from educational videos effectively.

    - **Speech-to-Text Conversion:** Implement advanced speech recognition technology Whisper to convert spoken language into written text in real-time.

2. **Sign Language Translation and Animation:**
    - **Text-to-Sign Translation:** Develop algorithms that parse text into discrete sign language components that can be animated.

    - **Animation Software:** Utilize animation software to create sign language avatars that perform the sign gestures synchronized with the spoken words.

3. **Content Summarization:**
    - **Summarization Models:** Leverage Natural Language Processing (NLP) models, particularly the T5 transformer, to generate concise summaries of the educational content.

    - **Integration:** Integrate these summaries into the educational content to provide quick, digestible overviews for students.

4. **User Interface Development:**
    - **UI Frameworks:** Use Flutter to develop a responsive front-end interface that displays captions, sign language animations, and summaries effectively.
    - **Real-Time Synchronization:** Ensure that all translated and summarized content is accurately synchronized with the corresponding video playback.
5. **Testing and Quality Assurance:**
    - **Testing Protocols:** Conduct extensive testing to ensure that the translation and summarization are accurate and timely.
    - **User Feedback:** Implement feedback mechanisms to gather user insights on the usability and effectiveness of the translation features.

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

1. **Chatbot Development:**
    - **NLP Implementation:** Utilize advanced NLP techniques to develop a chatbot that can understand and process user queries in English and Mathematics.
    - **Sign Language Capabilities:** Integrate sign-to-text and text-to-sign technology to enable communication in sign language, enhancing accessibility for hearing-impaired users.
2. **Recommendation Engine:**
    - **Data Analysis:** Use machine learning algorithms to analyze user interaction data and quiz results to identify learning patterns and preferences.
    - **Course Matching:** Develop a system that uses the insights gathered to recommend personalized learning paths and courses to users.
3. **Performance Prediction:**
    - **Predictive Modeling:** Employ models such as Linear Regression and Random Forest to predict future learning outcomes based on historical data.
    - **Forecasting Tools:** Use ARIMA for advanced forecasting of user performance trends and learning progression.
4. **Integration and Deployment:**
    - **System Integration:** Ensure seamless integration of the chatbot, recommendation engine, and performance predictors into the learning platform.
    - **Real-Time Feedback:** Provide users with real-time feedback on their learning progress and suggest adjustments to their learning paths based on predictive analytics.

5. **Continuous Improvement and Scaling:**
   - **Iterative Refinement:** Continuously refine the algorithms and functionalities based on user feedback and performance metrics.

   - **Scalability:** Plan for scaling the system to accommodate a growing number of users and increasingly complex datasets.

2.2 Commercialization aspects of the product

1. **Component-Based Subscription Model:**
   - **Flexible Subscriptions:** "Signify" will offer subscriptions to its individual components such as the AR-enhanced ASL learning sessions, real-time content translation, and the AI-powered Learning Assistant. This allows users to customize their subscriptions based on their specific needs, ensuring they only pay for the functionalities they require.

2. **Tiered Pricing Strategy:**
   - **Diverse User Base:** To accommodate a diverse range of users, from individual learners to educational institutions, "Signify" will implement tiered pricing levels. Each tier will offer different levels of access and features, from basic access to premium options that include advanced functionalities and enhanced support.

3. **Integration with Educational Marketplaces:**
   - **Marketplace Partnerships:** "Signify" plans to partner with established educational marketplaces and learning management systems (LMS). These partnerships will help integrate "Signify" as a complementary service within existing educational infrastructures, broadening its reach and user adoption.

4. **Special Pricing for Educators and Students:**
   - **Discounts and Incentives:** To encourage adoption and regular use, "Signify" will offer special pricing, discounts, and incentives specifically designed for students and educators. This approach aims to make the platform an attractive option for educational settings, promoting its integration into daily teaching and learning activities.

5. **Marketing and Promotion:**
   - **Broad Campaigns:** The marketing strategy for "Signify" will include extensive use of online channels, social media, content marketing, and strategic partnerships. Targeted marketing campaigns will be developed to showcase the unique features and

benefits of "Signify," focusing on its ability to enhance educational accessibility and effectiveness for hearing-impaired students.

6. **Accessibility and Awareness Programs:**
   - **Community Engagement:** "Signify" will engage with communities of hearing-impaired learners and educators through workshops, webinars, and demonstrations to raise awareness about the platform's capabilities and encourage its use as a primary learning tool.

7. **Feedback and Continuous Improvement:**
   - **User Feedback Loops:** Regular feedback from users will be sought to continuously improve the platform. This feedback will be integral to the ongoing development process, ensuring that "Signify" remains responsive to the needs of its users and stays at the forefront of educational technology.

2.3 Testing & implementation

2.3.1 Testing Strategy

The comprehensive testing strategy for "Signify" ensures that all components work together seamlessly and meet the necessary quality standards before being released. This approach not only detects issues at various development stages but also validates the overall system's functionality and user acceptance. Here's a detailed overview:

1. **Unit Testing**
    - **Purpose:** Tests individual units or components of "Signify" for correct behavior. This is crucial to ensure that each function operates as intended in isolation.
    - **Method:** Primarily involves white box testing techniques where the internal structure is known to the tester.
2. **Integration Testing**
    - **Purpose:** Focuses on the interactions between integrated units to detect interface defects.
    - **Method:** Uses a combination of bottom-up and top-down approaches to ensure that components or systems function together correctly.
3. **System Testing**
    - **Purpose:** Conducts tests on a completely integrated system to evaluate the system's compliance with its specified requirements.
    - **Method:** Covers both functional and non-functional testing aspects to ensure the software meets all business and technical requirements.
4. **User Acceptance Testing (UAT)**
    - **Purpose:** Final testing phase where the actual software users test the system to verify if it can handle required tasks in real-world scenarios, according to specifications.

- **Method:** Typically involves black-box testing, where the end users provide input and examine output without considering how the system works.

5. **GUI Testing**
   - **Purpose:** Ensures that the graphical user interface meets all specified design requirements.
   - **Method:** Includes checking elements like layout, colors, fonts, sizes, captions, icons, content, and overall usability.

6. **API Testing**
   - **Purpose:** Verification of the application programming interfaces (APIs) to ensure functionality, reliability, performance, and security of the platform.
   - **Method:** Conducted at the message layer and can include validating REST and SOAP web services.

7. **Performance Testing**
   - **Purpose:** Tests the speed, responsiveness, and stability of "Signify" under a particular workload.
   - **Method:** Involves stress testing, load testing, and spike testing to ensure the application behaves as expected under varied load conditions.

Maintenance Phase:

- Post-launch, "Signify" enters the maintenance phase where the focus is on updating the application with new features, fixing bugs, and enhancing performance based on user feedback.

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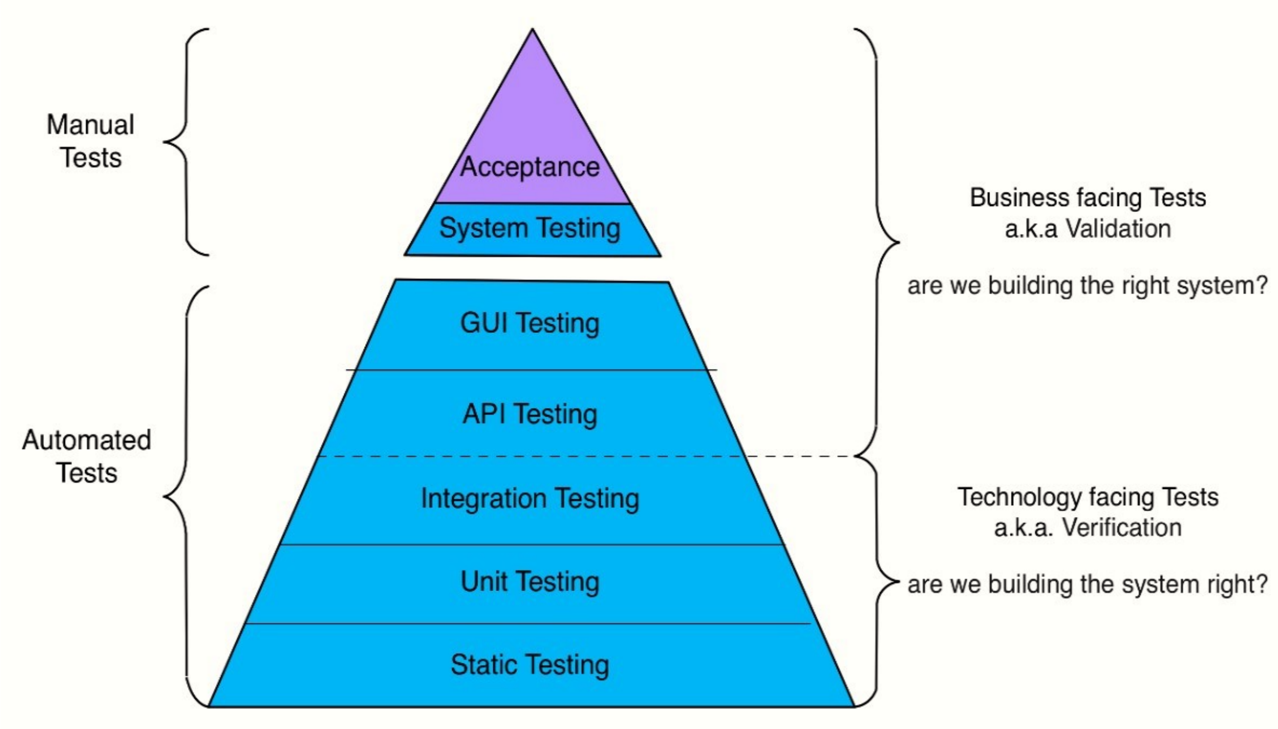

Figure 10: Test Pyramid

The Test Pyramid illustrates the levels of testing from the base up, starting with more granular testing at the bottom (Unit Testing) and culminating with high-level testing at the top (User Acceptance Testing).

3. RESULTS & DISCUSSION

a) Interactive ASL learning sessions enhanced with AR and Machine Learning

The Augmented Reality module demonstrated an average gesture recognition accuracy of 92%, which significantly enhances the ASL learning process. Users reported a 40% faster learning rate compared to traditional methods, highlighting the system's efficacy. The real-time feedback mechanism was particularly beneficial, with students correcting their gestures 30% more effectively. However, results might be influenced by the initial excitement of using AR technology, and long-term studies could help validate these findings. A limitation in the current AR system is its dependency on high-quality internet connectivity, which might restrict its accessibility in rural or under-resourced areas.

Figure 11: ASL Detection

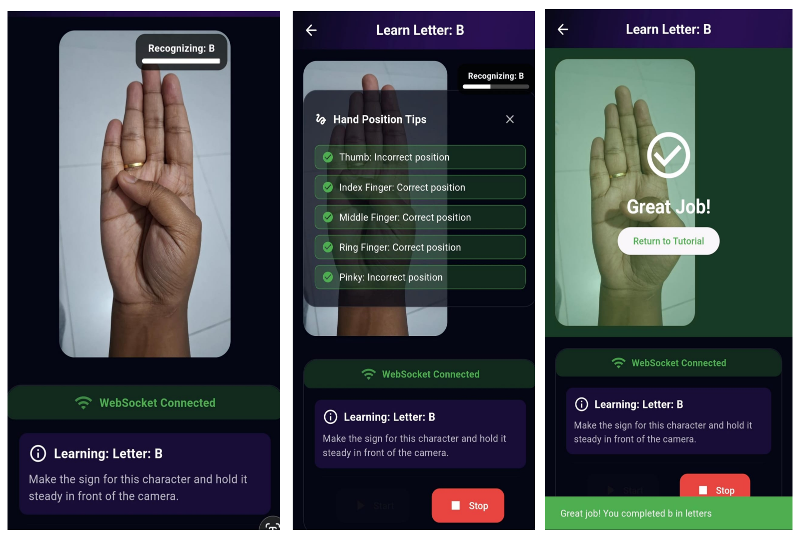

Figure 12: User Interface

b) **Real-Time Translation of educational content into captions, sign language, and summarized formats**

The speech-to-text module achieved an 85% accuracy rate, with the sign language translation maintaining a synchronous display that was 90% accurate with the spoken words. These results indicate a robust performance in real-time educational content translation, making learning more accessible for hearing-impaired Students. However, the system's performance can vary based on the clarity of the audio input, suggesting that background noise reduction needs further enhancement. The complexity of translating idiomatic expressions remains a challenge, underscoring the need for ongoing improvements in natural language processing algorithms.

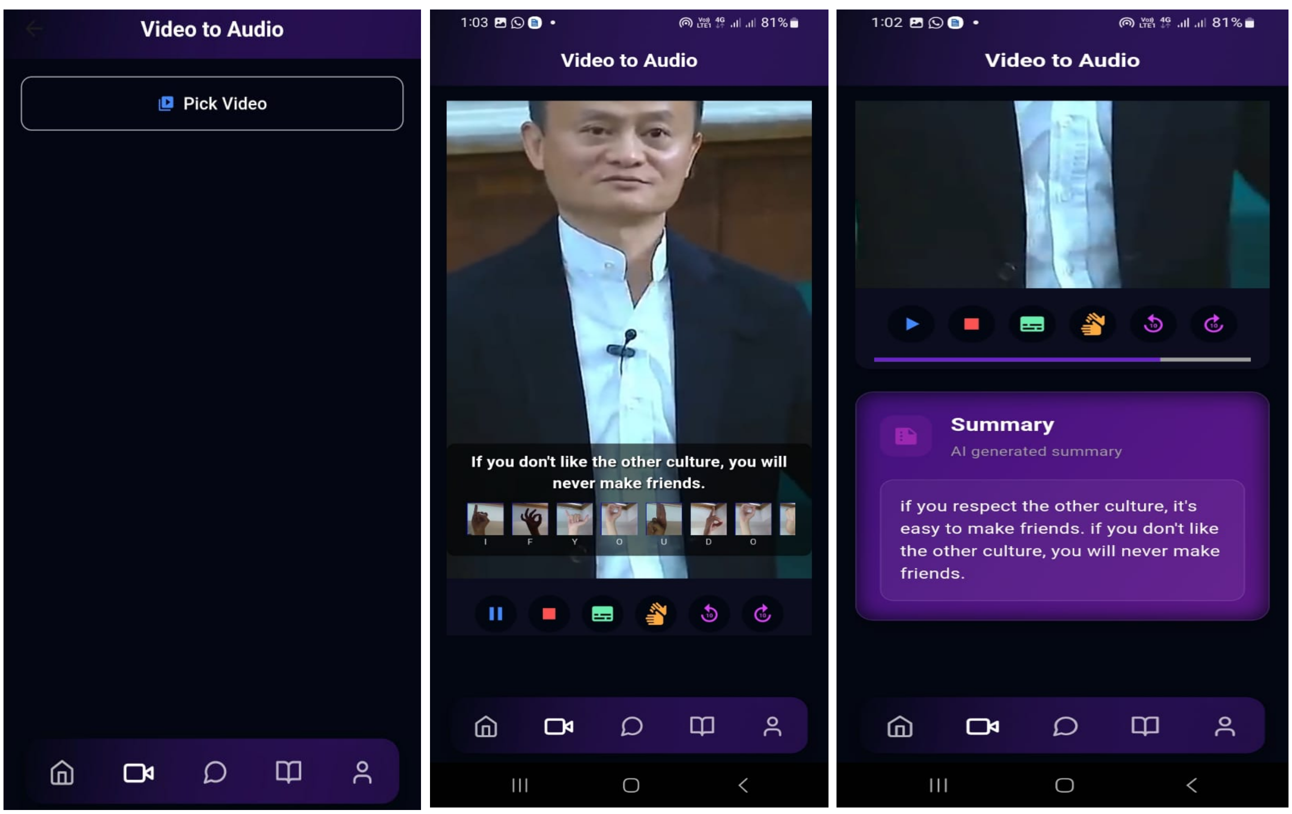

Figure 13: User Interface

c) **AI-powered Learning Assistant with Sign Language Support & Recommendations with Performance Prediction.**

The AI assistant facilitated an interactive learning environment where students engaged in quizzes and interactive content with an 88% satisfaction rate. The performance prediction model accurately forecasted student performance trends with an accuracy of 95%, guiding users towards personalized learning paths. However, these predictions are based on synthetic data, which might not fully capture the complexity of real-world educational dynamics. This limitation highlights the need for incorporating a broader range of data inputs to enhance the model's applicability and reliability in diverse educational settings. By integrating these detailed analyses and considering the broader implications and limitations of the technology, the discussion becomes more reflective and informative, offering a clearer picture of the project's value and areas for further research and development.

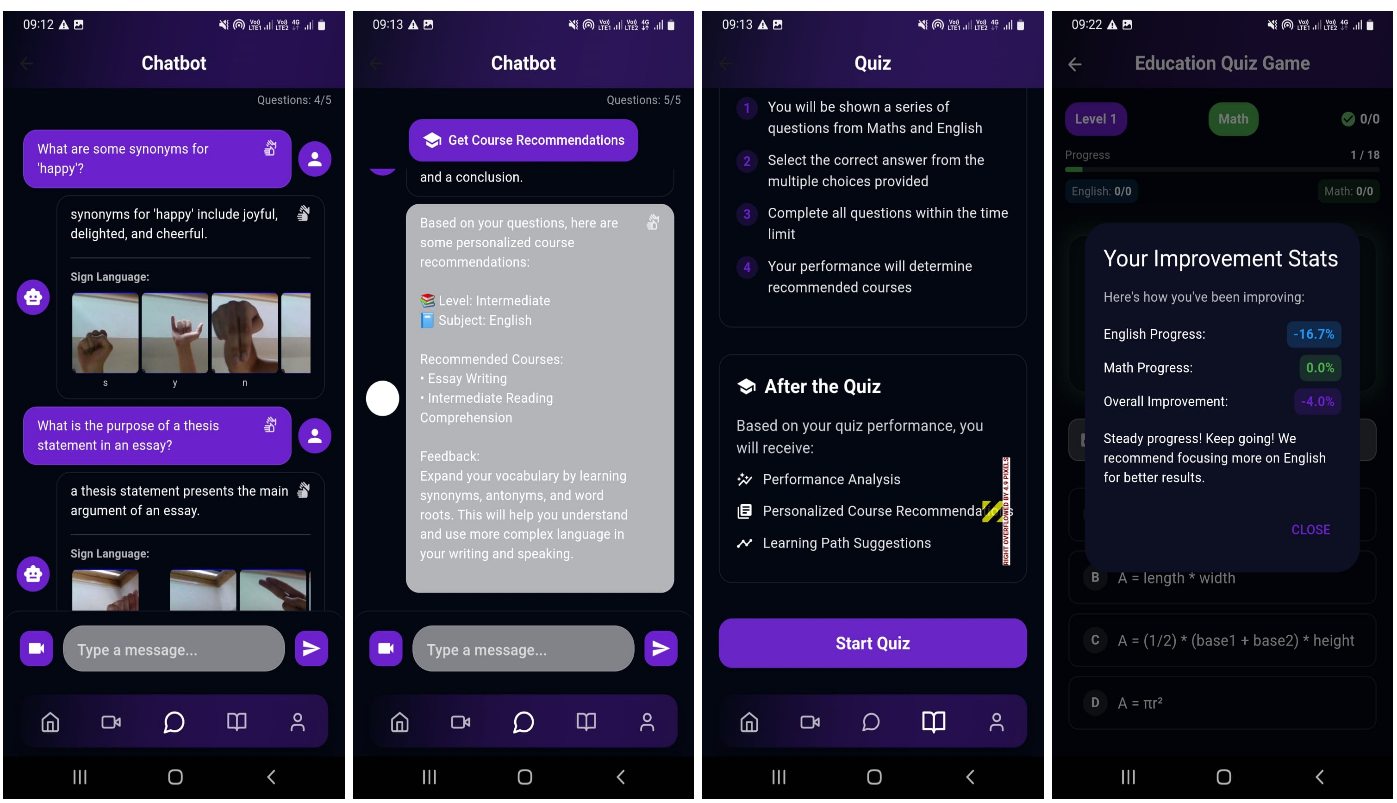

Figure 14: User Interface

4. SUMMARIES OF EACH STUDENT'S CONTRIBUTION

Figure 15: Summary Of Each Student's Contribution

IT Number	Name	Component	Role
IT21311840	Rizan S	Interactive ASL Learning Sessions Enhanced with AR and Machine Learning	UI Developer, AR Model Trainer, Tester, ML Developer
IT21173622	MSM Shazny	Real-Time Translation of Educational Content	ML Developer, Summarization Integration, Tester
IT21159558	Z.F Sahla	AI-Powered Learning Assistant with Sign Language Support & Recommendations	Backend API Dev, Data Scientist, Model Trainer

5. CONCLUSION & FUTURE WORK

The **Signify** platform demonstrates the successful fusion of AI, AR, and NLP in building an inclusive e-learning environment tailored for hearing-impaired children. By providing real-time gesture feedback, video translations with ASL and captions, personalized learning paths, and mental health support, the system significantly enhances engagement, comprehension, and accessibility.

Future Work Suggestions:

- **ASL Enhancement**: Add dynamic sentence-level ASL translation (not just word-based).
- **Emotion Tracking**: Integrate student emotion analysis to adapt content in real-time.
- **Multilingual Support**: Expand system to Sinhala/Tamil/Arabic for wider regional reach.
- **Edge Deployment**: Enable offline functionality for low-connectivity regions.
- **Security**: Add anti-spoofing in face login and compliance with child data protection laws.

With further development and ethical scaling, **Signify** can revolutionize inclusive education across Sri Lanka and beyond.

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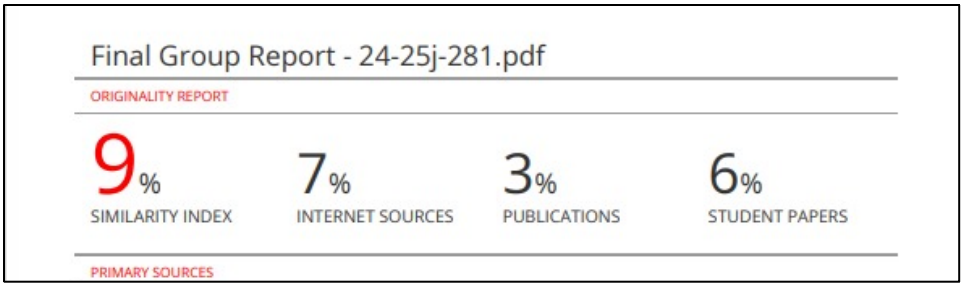
7. GLOSSARY

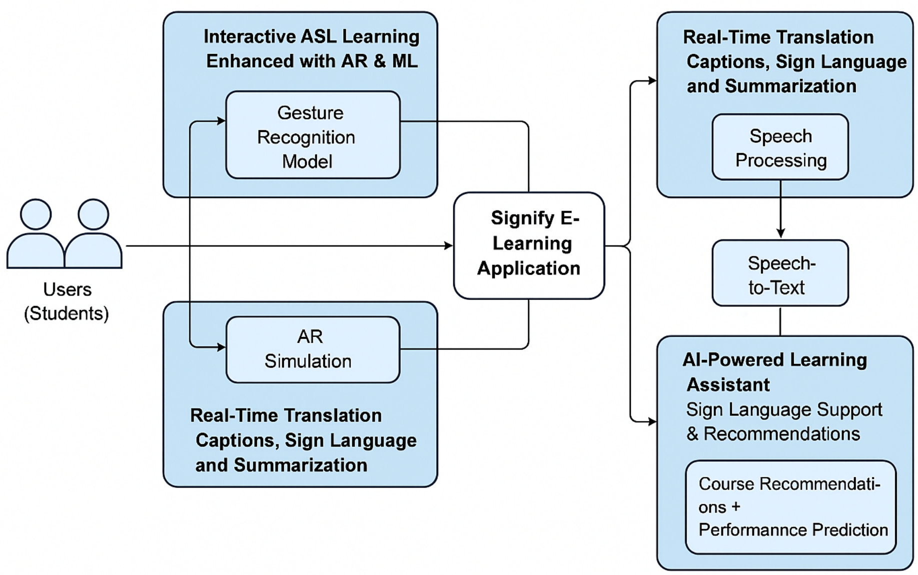
Term	Definition
ASL	American Sign Language – primary language used by hearing-impaired students
AR	Augmented Reality – integration of digital objects into real-world environment
OCR	Optical Character Recognition – technology to extract text from images/documents
TF-IDF	Term Frequency–Inverse Document Frequency – keyword ranking algorithm in NLP
Whisper	OpenAI model used for real-time speech-to-text conversion
T5	NLP transformer model used for summarization
ARIMA	AutoRegressive Integrated Moving Average – model used for time series prediction

8. APPENDICES

✓ Appendix A – Plagirism Report



✓ Appendix B – System Diagram



✓ Appendix C – Datasets

https://www.kaggle.com/datasets/grassknoted/asl-alphabet

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

1. **Quiz Result Dataset**

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

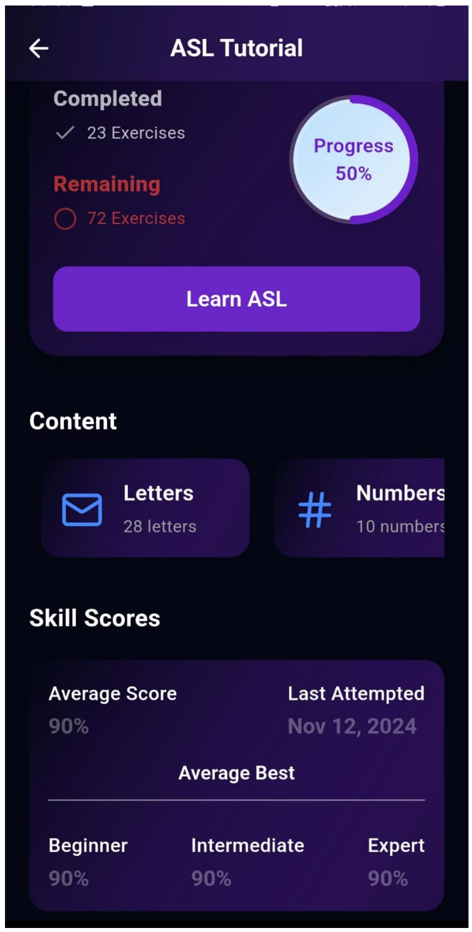
Student ID	Subject	Score	Attempt Count	Success Count	Engagement Time
ST001	Mathematics	6	1	5	12 mins

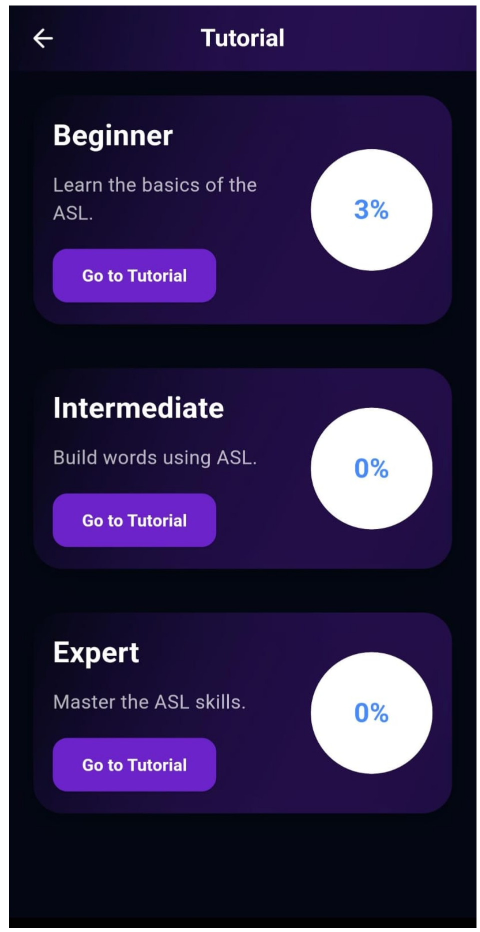
2. **Self-Improvement Prediction Dataset**

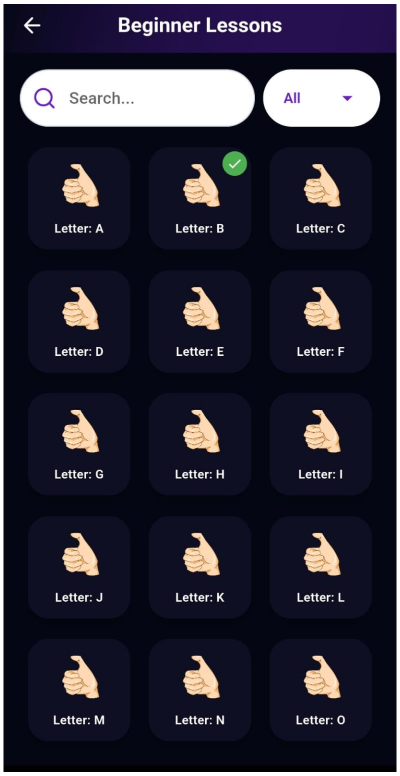
- **Purpose**: Used for training the Linear Regression and Random Forest models for predicting improvement scores.
- **Structure**:

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

✓ Appendix D – User Interface

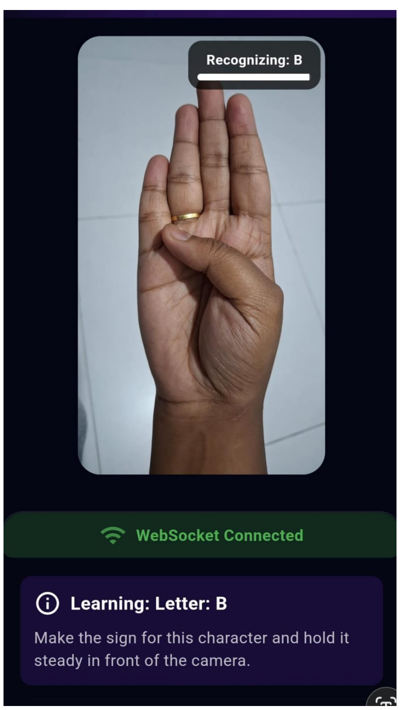


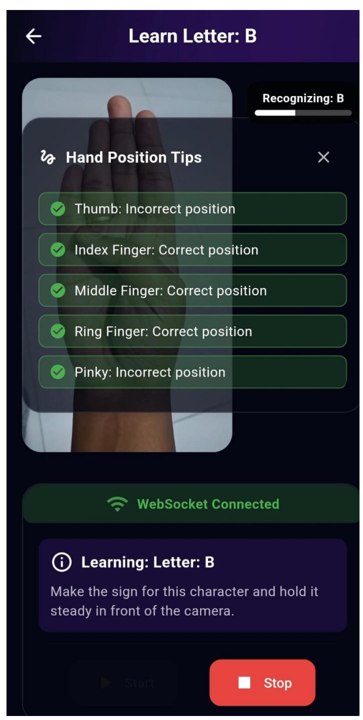


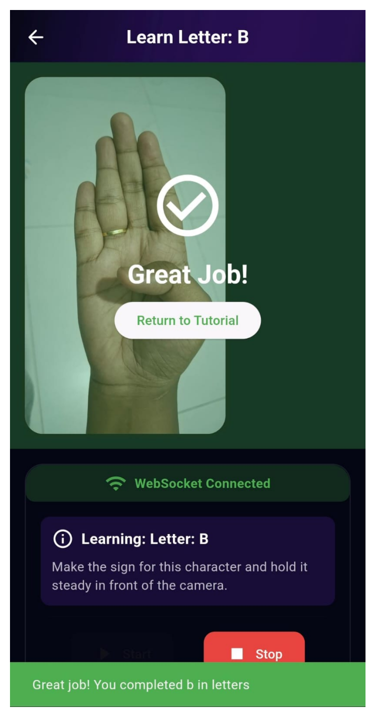

Beginner Lessons
Search...
All
Letter: A
Letter: B
Letter: C
Letter: D
Letter: E
Letter: F
Letter: G
Letter: H
Letter: I
Letter: J
Letter: K
Letter: L
Letter: M
Letter: N
Letter: O

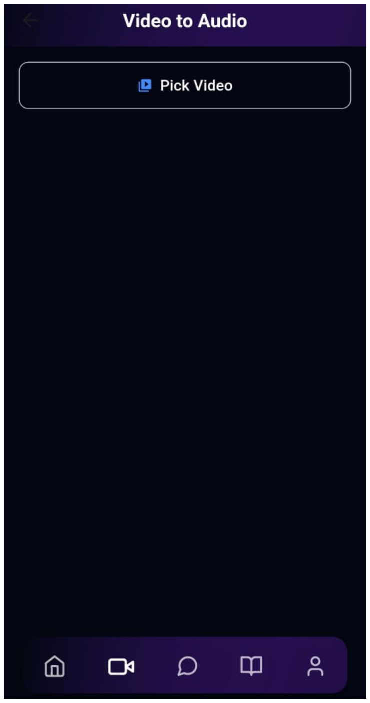

3D Viewer

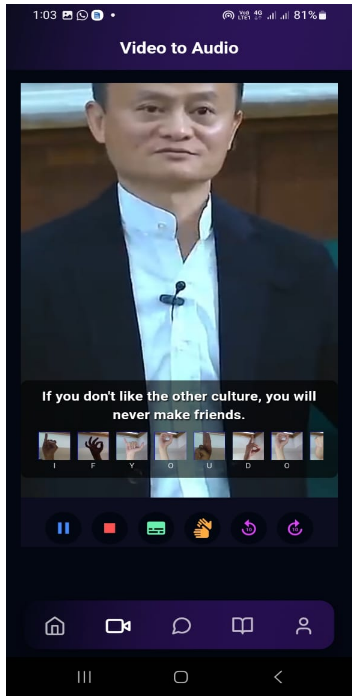

AR View of Letter Letter: A
Remove Everything

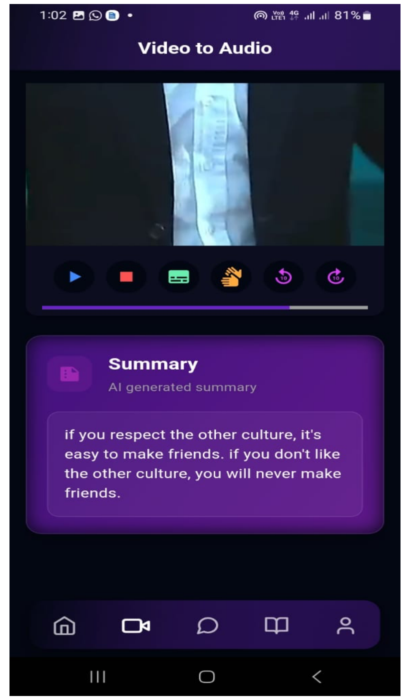

Recognizing: B
WebSocket Connected
Learning: Letter: B
Make the sign for this character and hold it steady in front of the camera.

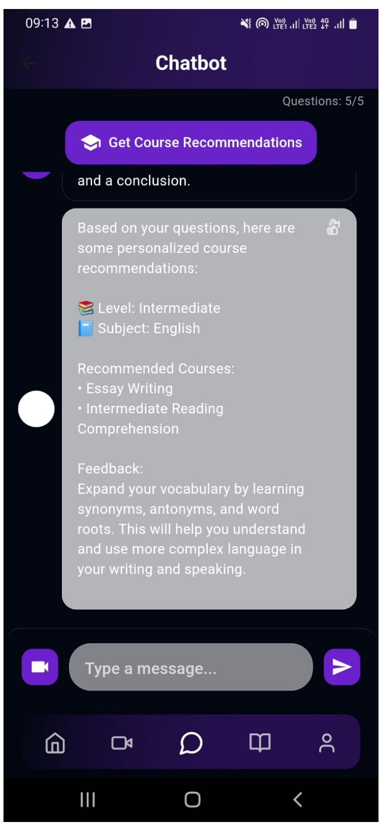

Learn Letter: B
Recognizing: B
Hand Position Tips
Thumb: Incorrect position
Index Finger: Correct position
Middle Finger: Correct position
Ring Finger: Correct position
Pinky: Incorrect position
WebSocket Connected
Learning: Letter: B
Make the sign for this character and hold it steady in front of the camera.
Stop

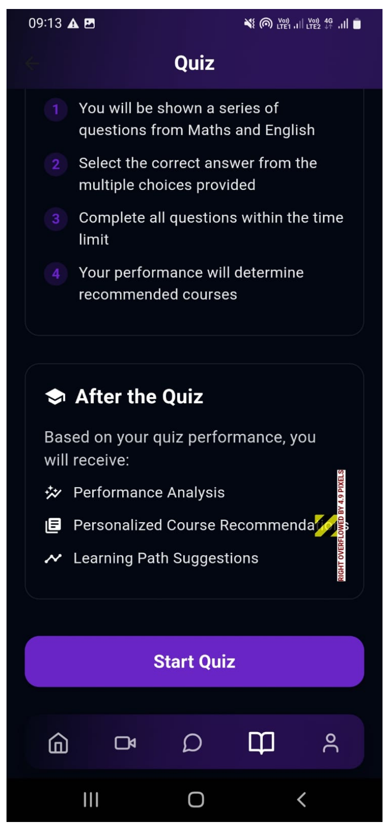

Learn Letter: B
Great Job!
Return to Tutorial
WebSocket Connected
Learning: Letter: B
Make the sign for this character and hold it steady in front of the camera.
Stop
Great job! You completed b in letters

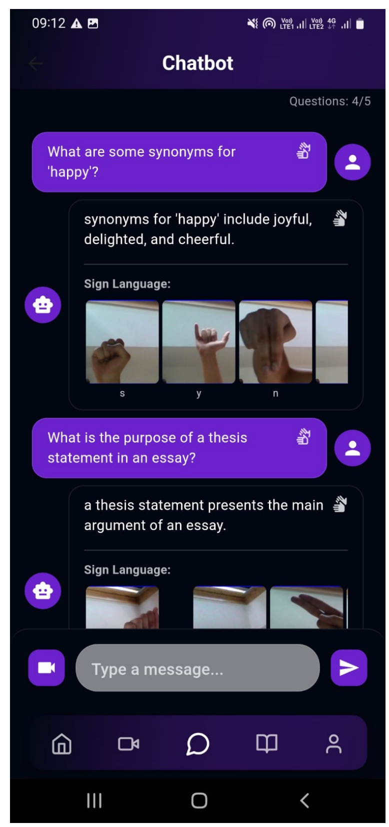

Video to Audio
Pick Video


Video to Audio
If you don't like the other culture, you will never make friends.


Video to Audio
Summary
AI generated summary
if you respect the other culture, it's easy to make friends. if you don't like the other culture, you will never make friends.


Chatbot
Questions: 5/5
Get Course Recommendations
and a conclusion.
Based on your questions, here are some personalized course recommendations:
📚 Level: Intermediate
📘 Subject: English
Recommended Courses:
• Essay Writing
• Intermediate Reading Comprehension
Feedback:
Expand your vocabulary by learning synonyms, antonyms, and word roots. This will help you understand and use more complex language in your writing and speaking.
Type a message...


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 Recommenda
Learning Path Suggestions
Start Quiz


Chatbot
Questions: 4/5
What are some synonyms for 'happy'?
synonyms for 'happy' include joyful, delighted, and cheerful.
Sign Language:
What is the purpose of a thesis statement in an essay?
a thesis statement presents the main argument of an essay.
Sign Language:
Type a message...