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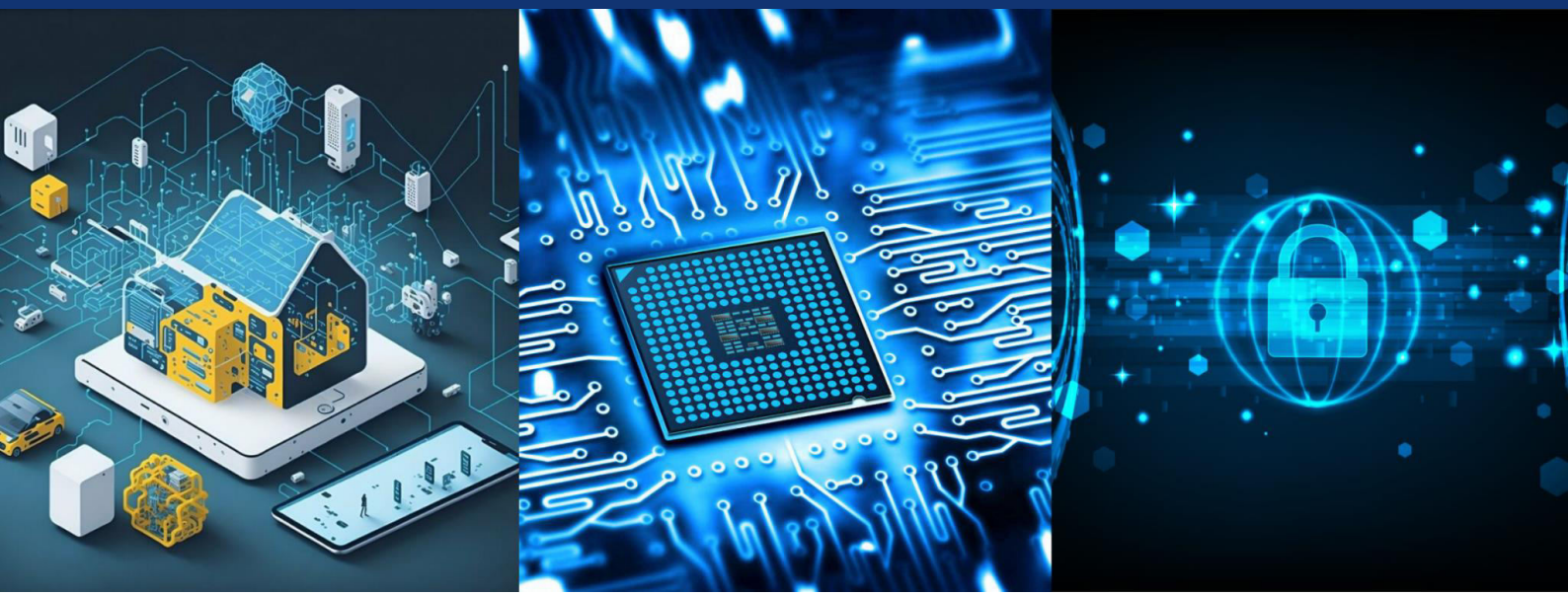

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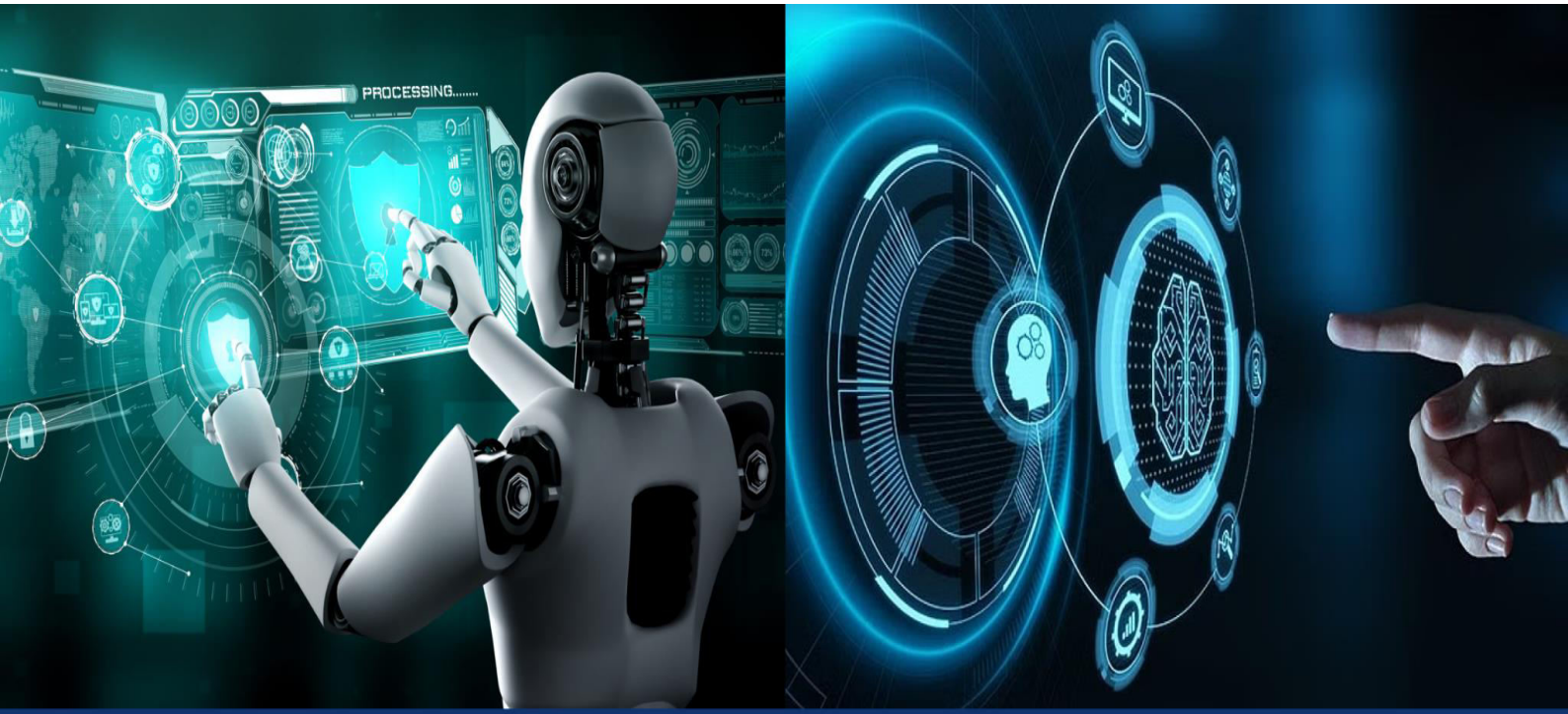


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# Development of an Intelligent Language Learning and Pronunciation Assessment System

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**ABSTRACT:** The increasing demand for foreign language proficiency, particularly for standardized examinations such as JLPT or CEFR-aligned certifications, necessitates intelligent and exam-focused digital learning systems. Existing language learning applications primarily provide generalized vocabulary and grammar practice but lack institutional customization and robust pronunciation evaluation mechanisms. This paper presents the development of an Intelligent Language Learning and Pronunciation Assessment System, a centralized web-based platform designed to support structured, examination-oriented language training.

The proposed system was developed based on user survey insights, which indicated a strong preference for web-based learning and highlighted speaking proficiency as the most critical yet underserved skill area. The platform enables administrators to create customized lessons, flashcards, tests, and reading passages, while students can access learning materials, attempt assessments, and engage in guided speaking practice. A key component of the system is a Python-based machine learning microservice that utilizes the Whisper speech recognition model for pronunciation evaluation. By converting speech to text and comparing it with expected outputs, the system provides reliable accuracy scoring and feedback. The application is implemented using React, Node.js, PostgreSQL, and Python, integrating full-stack development with AI-driven tutoring to deliver a scalable and institution-adaptable language learning solution.

**KEYWORDS**: Language Learning Application, AI-Assisted Education, Pronunciation Evaluation, Speech Recognition, Full-Stack Web Development, Computer-Assisted Language Learning.

## I. INTRODUCTION

The demand for foreign language proficiency has significantly increased in recent years due to globalization, international education, and global employment opportunities. Standardized examinations such as the Japanese-Language Proficiency Test (JLPT) and CEFR-aligned certifications have become essential benchmarks for academic admission and professional advancement. As a result, students increasingly rely on digital learning platforms to supplement classroom instruction and prepare for these examinations. Several widely used applications, such as Duolingo and Anki, provide vocabulary training, flashcards, and gamified exercises. While these platforms are effective for foundational learning, they are primarily generalized systems and often lack institution-specific customization, structured textbook alignment, and examination-oriented content. More importantly, pronunciation and speaking evaluation—critical components of language proficiency—remain inadequately addressed. Many learners' report difficulty in receiving consistent, objective feedback on their fluency, accent, and pronunciation accuracy.

To better understand learner needs, a survey was conducted among foreign language students. The findings indicated a strong preference for a web-based platform, as most learners prepare for examinations using laptops or desktop systems. The survey also revealed that speaking practice and pronunciation evaluation were the most requested features, followed by centralized access to lessons, mock tests, translations, and AI-assisted explanations. These insights highlighted the need for an integrated and institution-adaptable learning environment. In response, this project proposes the development of an Intelligent Language Learning and Pronunciation Assessment System. The system is designed as a centralized web application that enables administrators to create structured lessons, flashcards, assessments, and reading passages aligned with institutional textbooks. Students can access learning materials, attempt evaluations, and engage in guided speaking exercises within a unified interface.

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A key contribution of this work is the integration of a machine learning–based pronunciation assessment module. Unlike traditional audio feature comparison approaches such as MFCC-based analysis, which are sensitive to environmental noise and voice variations, the proposed system employs a Whisper-based speech recognition model to convert spoken input into text and evaluate pronunciation accuracy through transcription comparison. This approach enhances robustness and scalability while providing meaningful feedback to learners. The system is implemented using a full-stack architecture comprising a React-based frontend, a Node.js backend, PostgreSQL database management, and a Python microservice for speech evaluation. By integrating artificial intelligence with structured instructional design, the proposed platform aims to deliver an examination-focused, customizable, and intelligent language learning solution suitable for both institutional deployment and independent learners.

## II. EXISTING SYSTEM

The existing system for language learning primarily relies on traditional classroom-based instruction and standalone digital platforms. In conventional settings, students attend physical classes where learning is guided by a teacher using textbooks, worksheets, and periodic assessments. While this approach ensures structured learning and direct interaction, it often lacks personalization and flexibility. Students are expected to progress at a uniform pace regardless of individual proficiency levels or learning styles.

Furthermore, many existing platforms do not deeply analyze learner behavior, pronunciation accuracy, or contextual language usage. Feedback is generally generic rather than personalized. Peer interaction and real-time conversational practice are also limited, reducing opportunities for practical language application. Another major limitation of the current system is the fragmentation of features. Some platforms focus only on grammar and vocabulary, while others emphasize conversational practice. Rarely do they integrate adaptive assessment, real-time feedback, progress analytics, and user-friendly dashboards into a single, centralized system.

Therefore, while the existing system provides foundational language learning resources, it lacks comprehensive personalization, intelligent feedback mechanisms, and seamless integration of learning, assessment, and progress tracking.

## III. LITERATURE SURVEY

A. C. Graesser et al. [1] examine Intelligent Tutoring Systems (ITS) as computerized learning environments grounded in cognitive science, artificial intelligence, and computational linguistics. Their work highlights the importance of student modeling, where the system continuously tracks learners' psychological states to deliver adaptive feedback. Empirical evaluations indicate that ITS can achieve significant learning gains comparable to human tutoring. However, the complexity of modeling cognitive and affective states presents scalability challenges, particularly when extending ITS across diverse educational domains.

T. Heift and M. Schulze [2] provide a comprehensive overview of Intelligent Computer-Assisted Language Learning (ICALL), integrating second language acquisition theory with computational linguistics and artificial intelligence. Their study emphasizes parser-based error detection and intelligent feedback mechanisms to enhance language instruction. While ICALL demonstrates strong theoretical grounding, the implementation complexity and heavy reliance on linguistic rule encoding limit flexibility and scalability in dynamic learning environments.

A. Neri et al. [3] analyze the pedagogy-technology interface in Computer-Assisted Pronunciation Training (CAPT) systems. Their findings reveal that many commercial CAPT platforms prioritize technological novelty—such as advanced speech processing—over pedagogical soundness. Although CAPT tools provide valuable pronunciation feedback, their limited integration with broader language skills and insufficient adherence to pedagogical frameworks reduce their overall instructional effectiveness.

P. Brusilovsky [4] introduces Adaptive Educational Hypermedia systems that construct individualized user models based on learner goals, preferences, and knowledge levels. These systems dynamically adapt content presentation and navigation structures to enhance personalized learning experiences. While adaptive hypermedia significantly improves learner engagement, its effectiveness depends heavily on accurate and continuously updated user modeling mechanisms.

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J. Hutson et al. [5] discuss the broader disruption of higher education through Artificial Intelligence integration across disciplines. Their study highlights AI's capacity to scale personalized learning, optimize learning outcomes, and increase accessibility. Although AI adoption promises improved retention and reduced costs, institutional resistance and infrastructure readiness remain major barriers to widespread implementation.

C. Piech et al. [6] propose Deep Knowledge Tracing (DKT), employing Recurrent Neural Networks (RNNs) to model student learning trajectories. Unlike traditional knowledge tracing methods that require manual domain encoding, DKT captures complex temporal learning patterns automatically. Experimental results demonstrate substantial improvements in prediction accuracy. Nevertheless, the black-box nature of neural networks limits interpretability, posing challenges for educators seeking transparent decision-making processes.

L. Fryer and R. Carpenter [7] explore the role of chatbots as language learning tools, particularly in Foreign Language Learning (FLL) contexts. Their study shows that students feel more comfortable interacting with conversational bots than with peers or instructors, thereby increasing practice opportunities. However, existing chatbot systems are primarily designed for native speakers, limiting their effectiveness for beginner-level learners and structured curriculum integration.

S. Deterding et al. [8] conceptualize "gamification" as the application of game design elements in non-game contexts to enhance user engagement. Their framework distinguishes gamification from serious games and playful design, providing theoretical clarity. While gamification has demonstrated motivational benefits in educational platforms, its success depends on meaningful integration with learning objectives rather than superficial reward mechanisms.

C. A. Chapelle [9] critically evaluates the pedagogical potential of technology in language learning, emphasizing theory-driven design over technological hype. She argues that effective electronic learning materials must incorporate interaction, authentic tasks, and high-quality feedback aligned with second language acquisition principles. The study highlights that technology alone does not guarantee learning outcomes without pedagogical coherence.

G. Siemens and R. S. J. d. Baker [10] discuss the convergence of Learning Analytics (LAK) and Educational Data Mining (EDM), advocating collaboration between the two research communities. Their work underscores the importance of data-driven insights for improving teaching strategies and student performance prediction. Despite advancements in analytics, challenges remain in translating mined data into actionable pedagogical interventions.

## IV. PROPOSED SYSTEM

The proposed system is an AI-integrated, web-based language learning and pronunciation assessment platform designed to address the limitations of existing generalized language learning applications. Based on the survey conducted among foreign language learners, it was observed that students require a centralized platform that aligns with institutional syllabi and examination patterns. The majority of respondents indicated a preference for a web-based application, as they primarily use laptops or desktop systems for exam preparation. Furthermore, speaking practice and pronunciation evaluation were identified as the most critical yet insufficiently addressed learning components. In response to these findings, the proposed system is developed as a full-stack web application that integrates structured lesson management, assessment tools, and machine learning–based pronunciation evaluation within a unified environment. The platform supports two primary user roles: administrators and students.

The administrator module enables faculty members to create and manage lessons aligned with specific textbooks followed in their institution. Administrators can also design mock tests based on examination formats such as JLPT or CEFR-level certifications, generate flashcards for vocabulary reinforcement, and assign reading passages for speaking practice. This customization ensures that the platform directly supports institutional teaching strategies rather than offering generalized content. The student module allows learners to access uploaded lessons, review flashcards, attempt practice tests, and receive automated scoring. A dedicated speaking practice module enables students to record their pronunciation while reading assigned passages. The recorded audio is processed by a Python-based machine learning microservice utilizing the Whisper speech recognition model. Instead of performing direct audio feature comparison, the system converts speech into text and evaluates pronunciation accuracy by comparing the transcribed output with the expected reference text. This transcription-based approach was adopted after identifying limitations in traditional MFCC-based audio comparison methods, which are highly sensitive to environmental noise, pitch variations, and

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recording inconsistencies. The selected approach provides greater robustness and scalability in real-world learning conditions. In addition to structured learning modules, the system integrates an AI-powered language assistant capable of generating summaries, contextual explanations, example sentences, translations, and mock examination questions. Survey findings indicated that students frequently switch between textbooks, AI tools, and translation platforms during preparation. By centralizing these tools within a single application, the proposed system reduces cognitive load and enhances study efficiency.

The system is implemented using React for the frontend interface, Node.js for backend services and API management, PostgreSQL for data storage, and Python for the speech evaluation microservice. The modular architecture ensures scalability and enables extension to additional languages beyond the current demonstration implementation in Japanese. Overall, the proposed system provides an institution-adaptable, examination-focused, and AI-enhanced language learning platform that directly addresses user-identified gaps in pronunciation feedback, centralized study resources, and structured exam preparation.

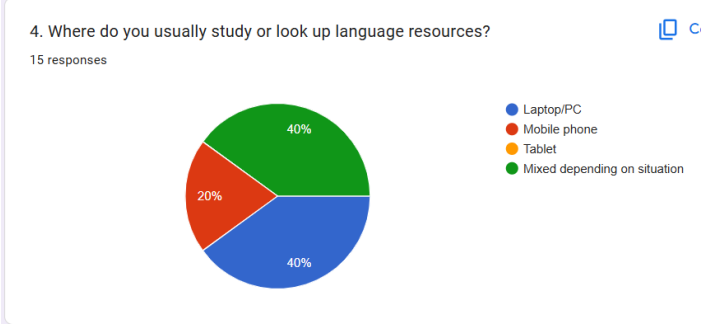


Figure 1: Survey Findings – 1

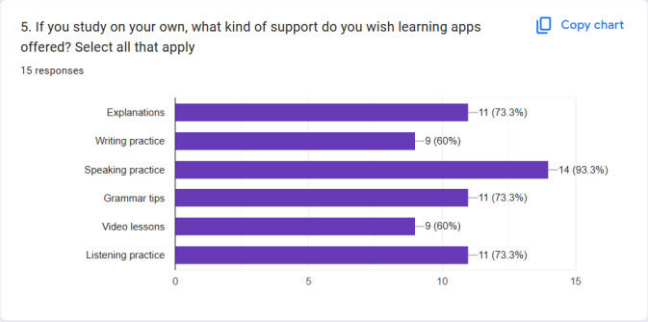


Figure 2: Survey Findings - 2

## V. SYSTEM ARCHITECTURE

The proposed system follows a modular client–server architecture integrated with a dedicated machine learning microservice for pronunciation evaluation. The architecture is designed to ensure scalability, maintainability, and efficient communication between system components. It consists of four primary layers: the front-end interface, backend server, database layer, and a Python-based speech processing module.

The frontend layer is developed using React and serves as the interactive interface for both administrators and students. It manages user authentication, lesson display, flashcard visualization, test attempts, and audio recording for pronunciation practice. All user interactions are processed through RESTful API requests sent to the backend server. The frontend is responsible for presenting structured content and displaying evaluation results in a user-friendly format.

The backend layer, implemented using Node.js, functions as the central control unit of the system. It handles authentication and authorization, lesson and assessment management, score computation, and API routing.

The backend processes incoming requests from the frontend, retrieves or updates data in the database, and coordinates communication with the machine learning microservice when speech evaluation is required. This layer ensures secure data handling and structured business logic implementation.

The database layer uses PostgreSQL for persistent storage of system data. It maintains user credentials, lesson materials, flashcards, test questions, student responses, evaluation scores, and AI interaction history. Centralized storage enables systematic tracking of learner performance and institutional content management.

The pronunciation assessment component is implemented as a dedicated Python-based machine learning microservice to ensure modularity, flexibility, and computational efficiency. Separating the speech processing module from the main backend enables independent scaling and future model upgrades without affecting the core application logic. When a student initiates a speaking exercise, the frontend captures the audio input through the browser's recording interface and transmits the recorded file to the Node.js backend server. The backend temporarily processes the request and forwards the audio data to the Python microservice through an internal API call.

Within the microservice, the audio signal undergoes preprocessing to ensure compatibility with the speech recognition model. The processed audio is then analyzed using the Whisper automatic speech recognition (ASR) model, which converts the spoken input into a textual transcription. Unlike traditional pronunciation evaluation methods that rely on Mel-Frequency Cepstral Coefficients (MFCC) and direct waveform comparison, the adopted approach evaluates pronunciation at the linguistic level rather than the acoustic feature level. MFCC-based comparison methods were experimentally considered during development; however, they were found to be highly sensitive to environmental noise, microphone quality, pitch variations, and speaker-specific vocal characteristics. Since students may record audio in uncontrolled real-world environments, waveform-level comparison produced inconsistent and unreliable results.

To address these limitations, the system employs a transcription-based evaluation strategy. Once the spoken input is transcribed into text, the output is compared with a predefined reference passage assigned by the administrator. Text similarity metrics and word-level matching techniques are applied to determine pronunciation accuracy. This method provides a more stable and scalable assessment mechanism, as it focuses on linguistic correctness rather than raw acoustic similarity. Additionally, this approach enables the system to identify omitted words, substitutions, or mispronunciations that affect intelligibility.

The computed accuracy score and relevant feedback metrics are then returned to the backend server, which stores the evaluation results in the database and forwards them to the frontend interface for display. This architecture ensures a seamless feedback loop in which students can immediately view their pronunciation performance and track improvement over time. The modular design also allows future enhancement, such as incorporating fluency scoring, pause detection, or prosodic feature analysis, thereby expanding the depth of speech evaluation capabilities.

Overall, the architectural design ensures clear separation of concerns, efficient data flow, and scalability. The modular structure allows independent enhancement of the speech evaluation component and supports future extension to additional languages or learning modules without significant structural modifications.

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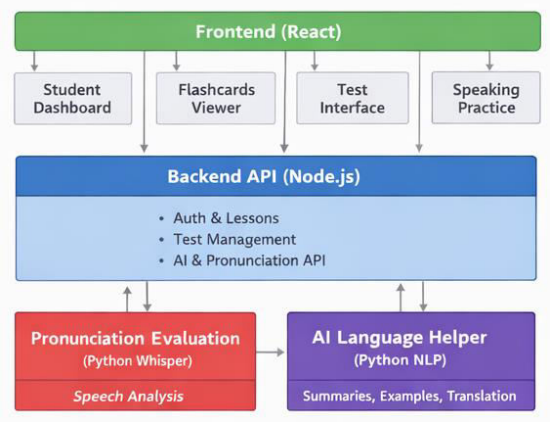


Figure 3: Platform Architecture

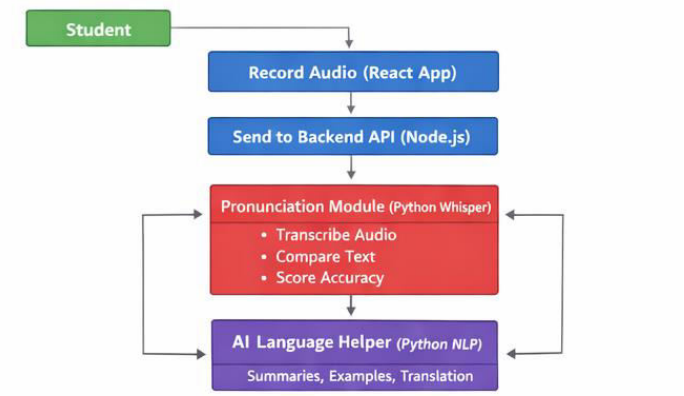


Figure 4: Pronunciation Evaluation Workflow

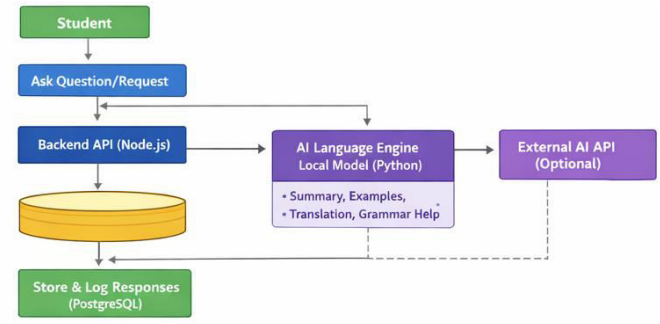


Figure 5: AI-Assisted Learning Workflow

## VI. SYSTEM REQUIREMENTS

The proposed system is developed using a full-stack architecture combined with a machine learning microservice to support pronunciation evaluation and AI-based assistance.

The frontend of the application is built using React.js, which provides a dynamic and responsive user interface for both administrators and students. React enables component-based development, efficient state management, and seamless

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interaction with backend APIs. It is responsible for rendering lessons, flashcards, tests, audio recording interfaces, and AI interaction panels.

The backend is implemented using Node.js, which manages server-side logic, API routing, authentication, session handling, and communication between different system components. The backend acts as an intermediary between the frontend, database, and the machine learning microservice, ensuring secure data transmission and structured request handling.

For data persistence and management, PostgreSQL is used as the relational database management system. It stores user credentials, lesson content, test questions, student responses, pronunciation scores, and AI interaction logs. The relational structure ensures data integrity, scalability, and efficient querying.

The pronunciation evaluation module is developed as a separate Python-based microservice. This microservice utilizes the Whisper speech recognition model for converting recorded speech into text. The transcription output is compared with predefined reference passages to compute pronunciation accuracy scores. The separation of this module enhances modularity and allows independent scaling or future model upgrades.

Together, this technology stack combines modern web development frameworks with machine learning capabilities to deliver a scalable, maintainable, and AI-integrated language learning platform.

## VII. DATABASE DESIGN

The database follows a relational model designed to support structured lesson delivery, assessment management, pronunciation evaluation, and AI-assisted learning. Core entities include Users, Lessons, Vocabulary, and Grammar_Points, which collectively manage instructional content and institutional customization. Assessment-related entities such as Tests, Test_Questions, Test_Attempts, and Test_Answers enable structured examination handling and performance tracking. The Questions table supports lesson-level practice linked to vocabulary or grammar targets through defined constraints. Additional entities for Pronunciation Records and AI Interaction Logs store speaking evaluation results and AI-generated learning history. Referential integrity is maintained using primary and foreign key relationships, as illustrated in the Entity-Relationship diagram below.

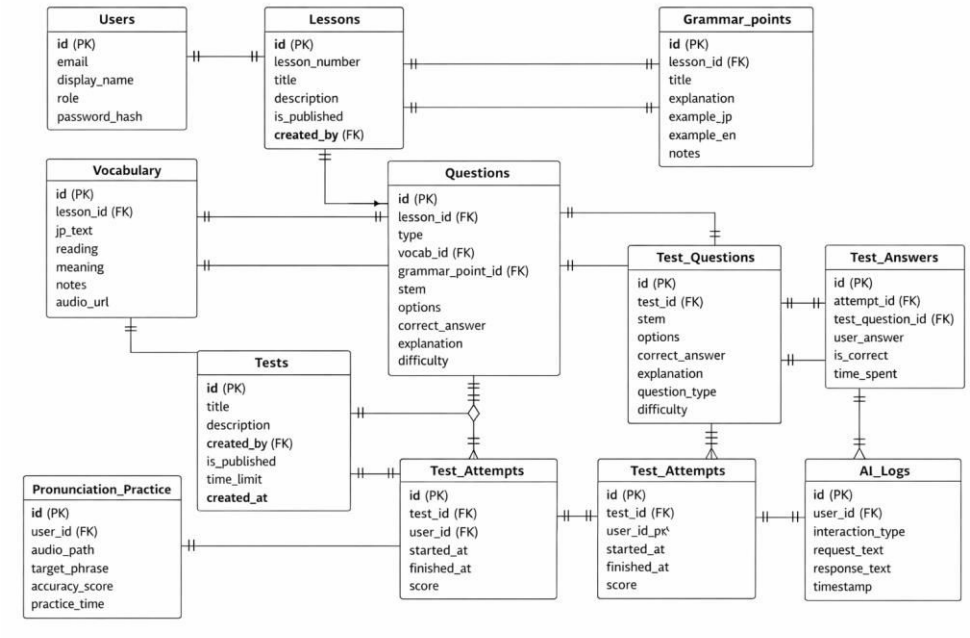


Figure 6: ER Model

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## VIII. WORKFLOW

The development of the proposed Intelligent Language Learning and Pronunciation Assessment System followed a structured, requirement-driven methodology. The initial phase involved conducting a survey among foreign language learners to identify gaps in existing learning platforms. The findings emphasized the need for a web-based centralized system with a strong focus on speaking practice and pronunciation evaluation. These insights guided the architectural and functional design of the platform.

The system workflow begins with user authentication, where administrators and students access role-specific dashboards. Administrators create and publish lessons consisting of vocabulary entries, grammar explanations, and associated practice questions. Mock tests are constructed by defining question sets, difficulty levels, and time constraints. Once published, these learning materials become accessible to students through the frontend interface.

Students engage with the platform by reviewing lessons, practicing vocabulary and grammar questions, and attempting structured tests. During test attempts, user responses are recorded, evaluated, and scored automatically. Performance metrics are stored in the database to allow progress tracking and result analysis.

For pronunciation practice, the workflow involves audio capture through the browser interface, followed by transmission of the recorded file to the backend server. The backend forwards the audio to the Python-based machine learning microservice. The speech input is processed using the Whisper automatic speech recognition model, which converts spoken language into textual transcription. The transcribed output is then compared with the expected reference passage using text similarity evaluation techniques to compute pronunciation accuracy. The resulting score and feedback are returned to the frontend and stored for performance monitoring.

Additionally, the AI language assistant module processes user queries related to lessons, generating summaries, explanations, translations, and mock questions. These interactions are logged to support centralized learning management and historical reference. Overall, the workflow ensures seamless interaction between learning modules, assessment mechanisms, and AI-driven speech evaluation, enabling a structured and examination-oriented language learning experience.

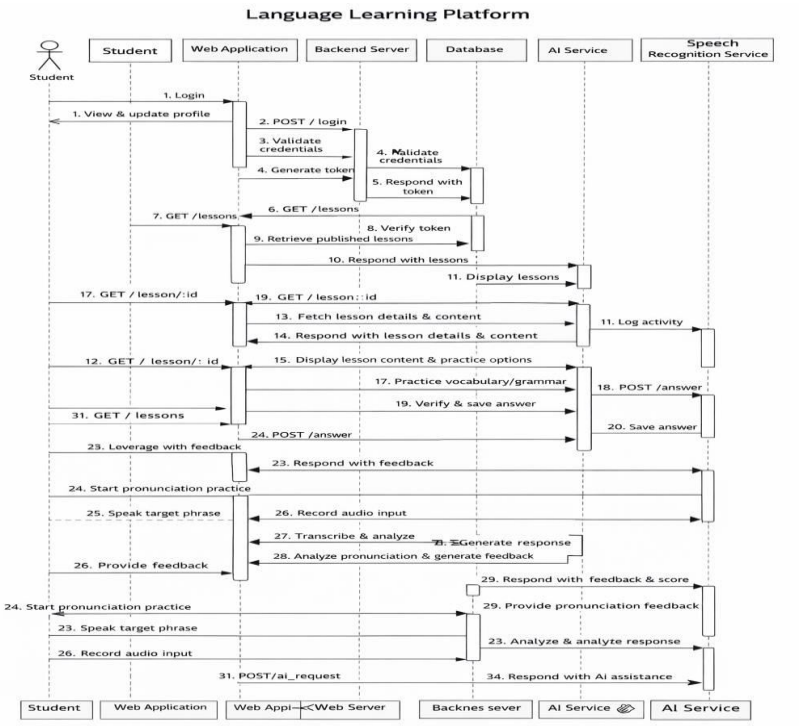


Figure 7: Sequence Diagram

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## IX. SYSTEM IMAGES AND SCREENSHOTS

This section includes screenshots of the web application. The images illustrate the system functionality, providing a clear representation of system performance and user interaction.

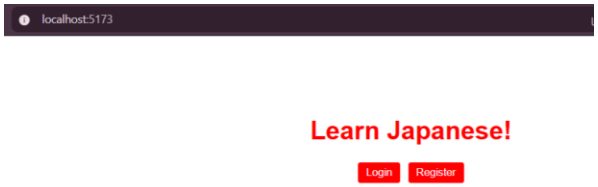


Figure 8: Home Page

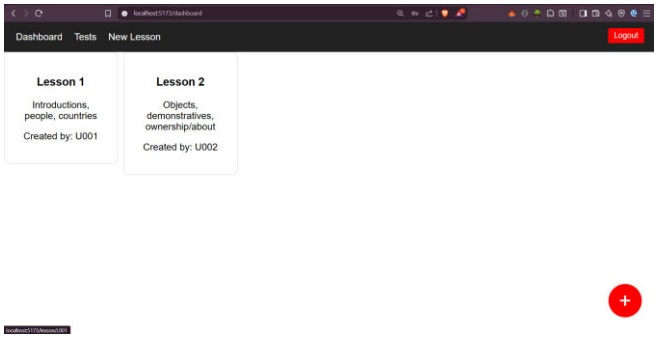


Figure 9: Staff Dashboard

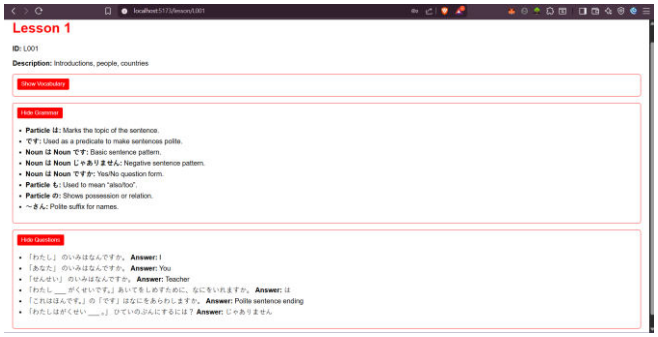


Figure 10: Lesson created by staff

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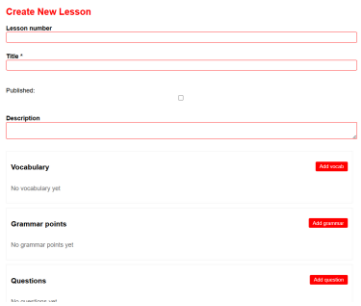


Figure 11: Create new lesson

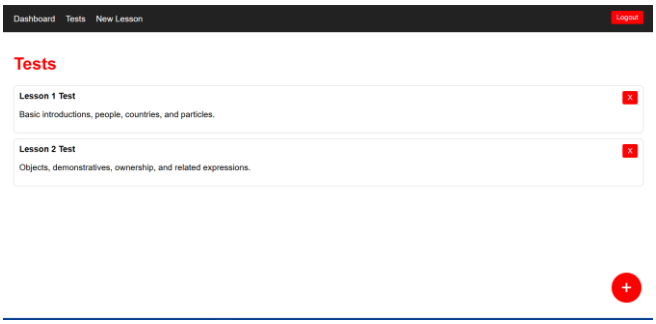


Figure 12: Test Dashboard - Staff

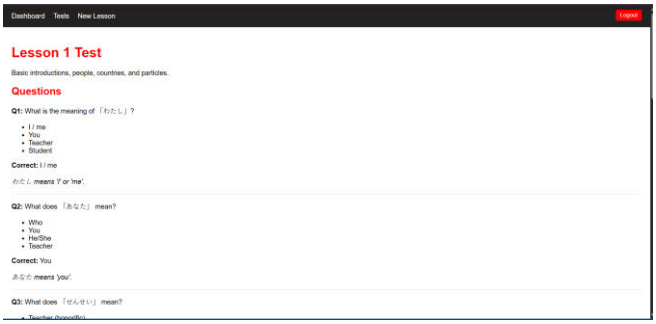


Figure 13: Created Test

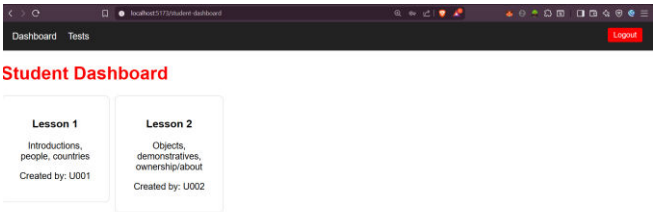


Figure 14: Student Dashboard

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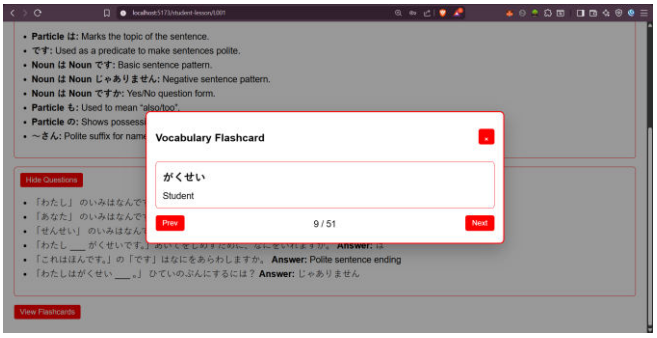


Figure 15: Flashcard

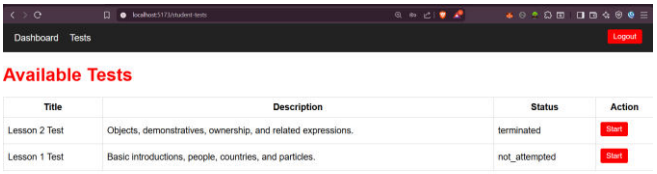


Figure 16: Test Dashboard - Student

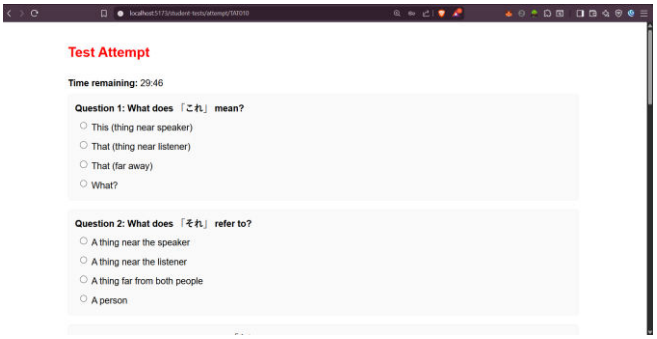


Figure 17: Student Test Attempt

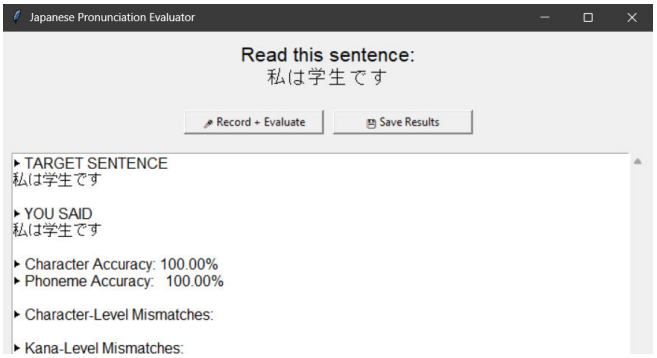


Figure 18: Pronunciation Module - 1

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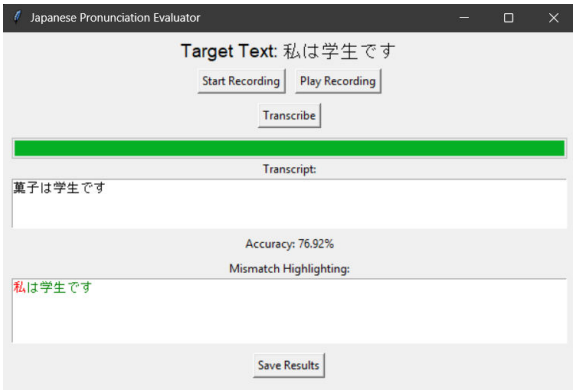


Figure 19: Pronunciation Module – 2

## X. CONCLUSION

This project presented the development of an Intelligent Language Learning and Pronunciation Assessment System designed to address key limitations in existing foreign language learning platforms. Based on survey findings, it was identified that students require a centralized, web-based learning environment with stronger emphasis on speaking practice and structured examination preparation. The proposed system was therefore designed to integrate lesson management, vocabulary training, grammar instruction, assessment modules, and AI-assisted learning tools within a single unified platform. A major contribution of this work is the implementation of a machine learning–based pronunciation evaluation module using a Whisper-based speech recognition approach. By adopting a transcription-based evaluation strategy instead of traditional waveform comparison methods, the system achieves greater robustness and practical applicability in real-world learning environments. This enables learners to receive structured and consistent feedback on pronunciation accuracy.

The platform successfully combines full-stack web development with speech recognition and AI-driven assistance to create a scalable and institution-adaptable solution. Although the current implementation demonstrates Japanese language learning, the modular architecture allows extension to other foreign languages and examination frameworks. Overall, the system provides an intelligent, examination-focused, and centralized learning environment that enhances language acquisition and speaking proficiency.

## XI. FUTURE ENHANCEMENTS

Future enhancements of the system aim to make the platform more immersive, intelligent, and learner-centric. One major planned improvement is the introduction of a realistic testing simulation module. This module will replicate actual examination environments by incorporating timed assessments, randomized question sets, proctoring-like monitoring features, and performance tracking under exam conditions. Such a feature will help students experience real-time pressure scenarios and better prepare for competitive or certification examinations.

Another key enhancement involves implementing advanced analytics for deeper performance insights. By leveraging data analytics and machine learning techniques, the system can generate detailed reports on student progress, learning patterns, strengths, and areas requiring improvement. This module will provide instructors with actionable insights for personalized feedback while enabling students to visualize their academic growth through dashboards and predictive performance indicators.

Additionally, the platform plans to introduce gamification elements to enhance engagement and motivation. Features such as achievement badges, leaderboards, reward points, progress levels, and streak tracking will encourage consistent participation and healthy competition among learners. Gamification will transform the learning experience from a traditional assessment-driven model into a more interactive and rewarding journey.

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Together, these enhancements will elevate the system from a functional learning management solution to an intelligent, adaptive, and engaging educational ecosystem designed to support continuous learning and measurable academic improvement.

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