MOBILE AND SIMULATION-BASED APPROACH TO REDUCE DYSLEXIA IN CHILDREN

Project ID – RPJ_ 24-25J-133

Final Report

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Bachelor of Science (Hons) Degree in Information Technology, Specializing in Software Engineering

Department of Software Engineering

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April 2025

MACHINE LEARNING BASED AUTOMATED CONSTRUCTION PLANNING SYSTEM FOR SRI LANKA

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DECLARATION

I declare that this is my own work, and this proposal 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 our knowledge and belief it does not contain any material previously publish or written by another person expect where the acknowledgement is made in the text.

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The supervisor/s should certify the proposal report with the following declaration.
The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

…………………………. ………………….
Signature of the Supervisor Date
(Dr. Mr. Kapila Dissanayaka)

………………………………. ………………….
Signature of the Co-Supervisor Date
(Ms. Rivoni De Zoysa)

ABSTRACT

Dyslexia is a neurological learning disorder that greatly impacts reading fluency, phonemic awareness, writing abilities, and short-term memory. Kids with dyslexia frequently face challenges in decoding words, identifying shapes and patterns, remembering sequences, and ensuring reading comprehension, all of which impede their educational progress and self-esteem. Conventional methods, like repetitive phonics instruction or fixed digital tools, frequently do not meet the varied and changing requirements of these students. To address this issue, this research introduces an AI-driven adaptive learning platform designed for dyslexic children by combining three essential components: Visual Processing, Reading Skill Development, and Short-Term Memory Improvement. [1] [2]

The Visual Processing Module employs deep learning architectures like Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks to enhance shape and pattern identification. The Reading Skill Enhancement Module offers NLP-based tools for reading comprehension and fluency, real-time phoneme assessment, and OCR-enabled writing feedback, enabling learners to progressively enhance their literacy abilities. The Short-Term Memory Module emphasizes auditory and visual recall activities and adjusts its challenge level according to performance by utilizing AI methods like Random Forest classifiers and LSTM predictors. [3] [4] [5] [6] [7]

Every module is presented via a gamified mobile app developed with Flutter, backed by a backend system employing Node.js and Flask for AI functionalities. MongoDB is employed to monitor user advancement and adjust learning trajectories accordingly. [7] [8] [10] [11]

Findings from preliminary studies involving dyslexic children indicated significant progress in all focused domains: a 30 - 40% rise in reading fluency and understanding, a more than 38% boost in short-term memory retention, and 97.2% precision in recognizing visual shapes. These results show that a modular learning system enhanced by AI can provide personalized, engaging, and effective support for dyslexic students, representing a major advancement in assistive educational technology [12] [13]

Keyword: - Adaptive Learning, AI in Education, comprehension, dyslexia, Machine Learning, NLP, Reading Enhancement, shortterm_memory, simulation, Visual_processing.

ACKNOWLEDGEMENT

First and foremost, we want to convey our heartfelt thanks to our supervisor, **Dr. Mr. Kapila Dissanayaka**, for his ongoing guidance, invaluable insights, and steadfast support during this research period. His specialized knowledge and helpful critiques have been essential in influencing the course and achievement of this project.

We are genuinely grateful to our co-supervisor, **Ms. Rivoni De Zoysa**, for her unwavering support, valuable insights, and prompt feedback that significantly improved the quality of our work.

We express our sincere gratitude to our external supervisor, **Dr. P. Gowritharan**, whose insightful feedback and critical assessments aided us in upholding academic rigor and practical relevance in our research results.

We also want to express our gratitude to the faculty members and colleagues at our university who offered us moral encouragement, resources, and collaborative inspiration during difficult periods.

In conclusion, we appreciate our families and friends for their support, patience, and encouragement during the duration of this project. Their unwavering support provided us with the strength to surmount challenges and stay focused on our objectives.

This study could not have been achieved without the combined efforts of all these people, to whom we are genuinely grateful.

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
AI	Artificial Intelligence
NLP	Natural Language Processing
ML	Machine Learning
CNN	Convolutional Neural Network
LSTM	Long Short-Term Memory
OCR	Optical Character Recognition
UI	User Interface
UX	User Experience
API	Application Programming Interface
TTS	Text-to-Speech
RNN	Recurrent Neural Network
BCI	Brain-Computer Interface
CRUD	Create, Read, Update, Delete
JSON	JavaScript Object Notation
IDE	Integrated Development Environment
CPU	Central Processing Unit
DB	Database
RAM	Random Access Memory
DBMS	Database Management System
IoT	Internet of Things
UI/UX	User Interface / User Experience

Table 1 List of abbreviations

1. INTRODUCTION

1.1. Background Study and Literature Review

1.1.1. Background Study

Dyslexia is a prevalent neurodevelopmental learning disability, impacting approximately 10 20% of people worldwide. It mainly disrupts a person's capacity to read, write, spell, and comprehend language. Kids with dyslexia frequently find it challenging to recognize words, decode written text, comprehend phonemes, and remember information in working memory. These challenges become even more pronounced in traditional classroom settings, where teaching methods are usually uniform and fail to cater to individual learning requirements. [12] [1] [14]

Conventional dyslexia interventions have depended on techniques like individual tutoring, phonics-focused teaching, visual supports, and assistive technological tools. Although a few of these approaches provide short-term enhancements, many do not possess the flexibility, involvement, and interactivity needed to cater to the diverse cognitive profiles of dyslexic students. For instance, repetitive exercises and unchanging material might not engage children effectively, as they need diverse stimulation to stay focused and motivated. Additionally, these approaches frequently fail to include real-time performance evaluation or adaptive feedback systems that can customize teaching according to personal advancement.

The emergence of Artificial Intelligence (AI) and associated technologies has created fresh opportunities in the creation of customized learning systems. AI allows systems to learn from user interactions and make smart choices to enhance learning experiences. In the realm of dyslexia, technologies like Machine Learning (ML), Natural Language Processing (NLP), and Computer Vision have demonstrated potential in tackling fundamental issues such as phonemic awareness, reading fluency, shape identification, and memory retention. [15] [16] [7]

Many studies have demonstrated that AI-driven systems can exceed conventional approaches in enhancing literacy results for children with dyslexia. For example, machine learning models can evaluate a student's reading habits and recommend specific exercises, while natural language processing tools can offer instant feedback on pronunciation. Likewise, Computer Vision methods can assist with visual processing activities like recognizing letters and shapes, which are essential skills for early literacy growth.

Gamification has become an essential resource in special education. Integrating game-like features like rewards, levels, and challenges makes learning more captivating and fun for children who have dyslexia. The integration of adaptive AI systems with gamification can greatly enhance user motivation, retention, and cognitive involvement.

This study expands on these fundamental insights by suggesting a complete mobile-based adaptive learning system that incorporates three key elements: Visual Processing, Short-Term Memory Improvement, and Reading Skill Development through NLP. The aim is to create a vibrant, tailored, and engaging educational platform that meets the distinct cognitive requirements of children with dyslexia. Every module targets particular weaknesses frequently linked to dyslexia visual discrimination, memory retention, and reading fluency utilizing advanced AI models like Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks, and NLP-driven speech analysis. [16] [5] [3]

This research seeks to provide a scalable and effective solution to the enduring challenges experienced by dyslexic students, teachers, and therapists by aligning with the most recent trends in educational technology and cognitive science

1.1.2. Literature Review

Dyslexia is a neurodevelopmental learning disorder marked by challenges in reading fluency, phonemic awareness, spelling, and memory retention, even with average or above-average intelligence. It impacts a large segment of the population, with estimates indicating that 10 - 20% of people encounter some type of dyslexia. In the last twenty years, researchers and educators have examined various assistive approaches from conventional phonics teaching to multimodal therapies and digital resources to aid children with dyslexia. With the rise of Artificial Intelligence (AI), an increasing amount of research advocates for incorporating AI-powered tools into literacy and cognitive development initiatives for students with dyslexia. [17] [13] [18]

Earlier research has shown the beneficial effects of AI-driven educational systems in enhancing reading results for children with dyslexia. Instruments utilizing Natural Language Processing (NLP) have demonstrated significant effectiveness in evaluating fluency, correcting pronunciation, and recognizing phonemes. As stated by Brown & Williams (2023), utilizing NLP-driven speech analysis has enabled children to self-correct instantly, creating a more interactive and efficient learning atmosphere compared to traditional repetition-focused phonics exercises. In a similar vein, Kumar (2022) highlights the importance of machine learning (ML) in examining learner behavior and adjusting learning materials in real-time to align with their speed and cognitive characteristics. [18]

In spite of these improvements, numerous systems in operation often concentrate on singular aspects of dyslexia intervention, like word recognition or speech fluency, neglecting associated issues such as visual processing and short-term memory, which are also vital for literacy growth. Research on Computer Vision in education indicates that Convolutional Neural Networks (CNNs) and pattern recognition methods can assist in visual discrimination tasks, enabling children to more effectively differentiate between letters and shapes. This is essential for early readers who frequently mix up visually similar letters like “b” and “d” or “p” and “q.” Cotarelo and Redondo (2022) showed how shape recognition can be incorporated into affordable educational tools to aid early learners facing learning challenges, highlighting the significance of visual stimuli in literacy.

Moreover, Short-Term Memory (STM) is essential for learning, especially in interpreting and retaining sequences of letters or words. Long Short-Term Memory (LSTM) networks, initially created for tasks involving sequence prediction, have demonstrated encouraging uses in education research. Nordström et al. (2019) examined how STM reinforcement activities, enhanced by adaptive AI, can greatly enhance recall capability, task switching, and working memory in students with dyslexia. These results are endorsed by actual therapeutic methods employed by speech-language therapists, in which auditory and visual memory games play a crucial role in therapy sessions.

The incorporation of gamification into AI-driven learning has enhanced its efficacy in interventions for dyslexia. Strategies that involve game-based learning boost motivation, minimize learning fatigue, and encourage ongoing involvement. A study by Koedinger et al. (2022) on personalized learning systems revealed that students engaging with gamified platforms featuring adaptive feedback experienced greater enhancements in test scores and knowledge retention compared to those utilizing static learning applications. These impacts are even more significant in children with learning challenges who gain from prompt, gratifying feedback cycles and engaging content presentation.

Additionally, multimodal learning approaches that integrate auditory, visual, and tactile stimuli are increasingly acknowledged as effective methods in special education. Smith and Davis (2021) highlight that multimodal systems integrated with AI can better address varied learning requirements. They discovered that integrating text-to-speech (TTS), interactive visuals, and speech recognition offers a more comprehensive method that addresses various cognitive functions at once, which is especially beneficial for children with dyslexia.

Even with the potential of these technologies, the literature highlights certain difficulties. For example, NLP-driven models might not perform well when faced with regional accents or speech challenges often present in children with dyslexia. Likewise, the datasets employed to train AI models frequently lack diversity, resulting in restricted generalizability among various demographics. Consequently, there is a significant demand in the research community for cooperation with educators, therapists, and subject matter experts in the design process to guarantee both technical precision and educational significance.

In conclusion, the research endorses the efficacy of incorporating AI technologies like NLP, ML, and Computer Vision into educational programs for dyslexia. Nonetheless, the majority of previous studies have concentrated on one or two facets of the issue. This study aims to fill that void by providing an all-encompassing, modular AI solution that integrates visual processing aid, reading fluency support, and memory enhancement within a single platform. Utilizing advanced models like CNNs, LSTMs, and NLP engines, while basing its design on actual therapeutic practices, the system aspires to provide a more comprehensive, stimulating, and impactful learning experience for children with dyslexia

1.2. Research Gap

Dyslexia is a complex learning disability that affects essential aspects of reading and thinking, such as phonemic awareness, visual processing, working memory, and fluency in reading. Although the frequency of dyslexia has resulted in significant research efforts and the creation of various interventions, many current strategies are limited in scope, tackling only specific facets of the disorder. This disjointed method has led to considerable deficiencies in offering thorough, tailored, and stimulating learning experiences for children with dyslexia.

Conventional methods typically highlight phonics-oriented teaching or repetitive reading exercises, which might aid in word identification but fail to sufficiently tackle related issues like short-term memory constraints or visual mix-ups between similar characters. These approaches typically do not provide real-time feedback, flexible adaptability, or multi-sensory interaction, resulting in diminished motivation and variable learning results. Moreover, although the interest in utilizing digital platforms for dyslexia education is increasing, a significant number of these tools are inherently static and fail to harness the complete capabilities of Artificial Intelligence (AI) to tailor learning experiences according to unique cognitive profiles.

Recent progress in AI technologies like Natural Language Processing (NLP), Machine Learning (ML), and Computer Vision has demonstrated potential in tackling particular issues in literacy education. Nonetheless, current AI-powered tools for dyslexia are primarily specific to certain domains. For example, certain systems are designed exclusively to aid reading via text-to-speech applications or fluency tracking, while others prioritize visual processing through image classification models. Only a handful of entities combine these technologies into a cohesive system that can concurrently tackle issues related to reading, memory, and visual processing.

Moreover, the implementation of gamification and real-time adjustments is still not fully exploited in existing educational resources. Although certain applications include game-like elements, they frequently lack data analytics or AI algorithms that adjust content according to a learner's real performance. This restricts the opportunity for greater involvement and mental reinforcement two elements that are essential for ongoing progress in dyslexic students. Additionally, existing systems frequently miss valuable insights from actual therapeutic techniques employed by speech and language practitioners, leading to a gap between academic studies and clinical importance.

Another significant gap is the lack of localization and cultural significance in current systems. The majority of tools are created with English-speaking students as the primary focus, overlooking multilingual contexts or local differences in pronunciation, language structure, and script. This reduces their effectiveness for varied populations, especially in areas where access to speech therapists and dyslexia experts is restricted.

This study fills these gaps by creating a unified, AI-driven learning system that merges visual processing, short-term memory development, and NLP-oriented reading improvement into a cohesive mobile platform. The system draws on actual data from speech therapists and features adaptive gamification, speech feedback, and performance analytics, ensuring it is both scientifically sound and practically effective for learners with dyslexia.

1.3. Research Problem

Dyslexia is a continuous neurodevelopmental condition that impacts a child's capacity to develop literacy skills, especially in reading, spelling, writing, and understanding language. It is not caused by low intelligence or inadequate teaching, but mainly arises from challenges in phonological processing, visual decoding, and retaining short-term memory. The symptoms and intensity of dyslexia can differ among individuals, yet its effect on educational achievement, emotional health, and long-term personal growth is significantly deep across the board. Although widely acknowledged, current interventions frequently fail to provide personalized, engaging, and adaptable learning experiences that cater to the specific cognitive requirements of dyslexic students.

Present dyslexia support systems generally depend on traditional teaching methods like phonics instruction, individual tutoring, and static digital reading tools. Although these approaches may provide some advantages, they frequently fall short in the adaptability and customization required to tackle the diverse array of cognitive difficulties encountered by children with dyslexia. For example, repetitive learning methods might enhance word recognition but do not specifically address associated challenges like memory processing, letter shape confusion, or real-time reading fluency. Moreover, traditional tools seldom include features for monitoring student progress, providing feedback, or adapting content to suit a child's changing requirements.

In recent years, more sophisticated technological solutions have developed, especially concerning mobile and online learning applications. Nonetheless, the majority of these resources are tailored for specific domains they concentrate on either reading, writing, or phonics but rarely offer an all-encompassing platform that addresses various learning areas. Furthermore, only a small number of systems incorporate Artificial Intelligence (AI) effectively to provide genuinely adaptive learning pathways. Even with the use of AI, it typically remains restricted to superficial personalization, like modifying difficulty according to test scores, without utilizing real-time behavioral or performance data.

Additionally, children with dyslexia frequently face challenges not only with language but also with visual processing. They might mix up letters that look alike, misinterpret symbols, or find it difficult to recognize patterns impeding both reading understanding and overall learning effectiveness. Furthermore, dyslexic learners often exhibit short-term memory impairments, which affect their capacity to remember information, adhere to directions, and decipher phoneme-grapheme connections. These elements are seldom considered together in present interventions, which typically segregate learning into strict categories instead of providing a cohesive, child-focused method.

The impact of gamification, immediate AI feedback, and engaging content has been studied in general education but remains insufficiently employed in systems designed for dyslexia. Studies show that children with learning disabilities tend to react more favorably to stimulating, game-oriented settings that provide immediate rewards, visual prompts, and hands-on activities. Nonetheless, numerous educational apps for dyslexia continue to be unchanging, monotonous, or overly reliant on text failing to leverage the motivational and cognitive advantages of interactive learning.

One significant drawback of current solutions is the insufficient integration among language therapists, educators, and AI developers. Tools created without input from speech-language experts frequently overlook essential therapeutic techniques applied in actual therapy sessions. For instance, games involving auditory sequencing, activities for letter tracing, shape identification, and phoneme correction exercises typically employed by therapists are rarely found in digital platforms in a well-structured and scientifically validated manner.

In areas with restricted access to specialized assistance, like rural or underprivileged locations, these problems are amplified. Families frequently face a shortage of speech therapists, special education teachers, or adequately equipped schools. In these situations, a mobile application powered by AI and designed for scalability could have a revolutionary impact. Nevertheless, numerous existing tools are not affordable or tailored for various languages, accents, and learning settings resulting in obstacles to their adoption and efficacy.

Moreover, personalization in numerous systems relies on rules instead of being driven by AI. These applications might allocate levels or repeat tasks according to performance ratings, but they lack the ability to intelligently assess error patterns, response times, or engagement trends to enhance learning pathways. A system powered by AI could consistently learn from the child's interactions to enhance suggestions, customize content, and adapt learning tasks in real-time reflecting the insight and adaptability of a skilled human tutor.

In light of this context, the main research issue tackled in this study is the lack of a holistic, adaptable, AI-driven learning platform that combines visual processing, short-term memory development, and NLP-based reading improvement into a cohesive solution for children with dyslexia. A distinct demand exists for a mobile educational platform that integrates advanced learning models such as Convolutional Neural Networks (CNNs) for visual pattern identification, Long Short-Term Memory (LSTM) networks to improve sequential memory, and Natural Language Processing (NLP) for instant pronunciation and fluency development. [20]

This system should also include gamification, personalized learning algorithms, and knowledge from actual speech therapy methods to ensure it is both scientifically sound and practically useful. It should act not only as a learning tool but also as an intelligent tutor constantly assessing the learner’s development, adjusting activities to their speed, and providing feedback in an encouraging, child-friendly setting.

This study seeks to fill these voids by creating and assessing an innovative educational app with AI integration specifically designed for learners with dyslexia. The solution aims to greatly improve reading comprehension, visual recognition, and memory retention, while remaining engaging, scalable, and inclusive of effective therapeutic methods.

1.4. Research Objectives

1.4.1. Main Objectives

The main aim of this study is to create and assess an all-encompassing, AI-driven adaptive learning system designed specifically for children with dyslexia. The system aims to enhance three primary cognitive domains often influenced by dyslexia visual processing, short-term memory, and reading abilities by combining contemporary technologies like Machine Learning (ML), Natural Language Processing (NLP), and Computer Vision into one mobile app. Utilizing deep learning models and monitoring performance in real time, the platform seeks to deliver a tailored, captivating, and efficient learning experience. The application facilitates the provision of focused exercises for shape identification, phoneme decoding, memory retention, and reading comprehension within a gamified and interactive setting. The aim is to not only boost the academic skills of dyslexic students but also to raise their self-esteem and future educational results. This research also aims to confirm the solution's effectiveness by implementing a prototype and conducting user testing with genuine feedback from therapists and educators.

1.4.2. Specific Objectives

1. To create a Visual Processing Module utilizing CNNs and LSTMs for identifying shapes, patterns, and characters. [20]
2. To create a Short-Term Memory Module that includes AI-based recall and sequencing functions.
3. To create a Reading Skill Improvement Module utilizing NLP for evaluating fluency, correcting pronunciation, and enhancing phonemic awareness .
4. To incorporate gamification features for enhanced motivation, involvement, and retention.

5. To assess the platform's efficiency via prototype trials and performance evaluation with children who have dyslexia.

1.4.3. Business Objectives

1. To provide a mobile solution for dyslexia intervention that is accessible, scalable, and affordable, suitable for use in educational and therapeutic environments.
2. To meet a common market demand by providing a multilingual, inclusive resource for marginalized communities and areas with limited access to specialized assistance.
3. To work alongside educators, therapists, and parents in developing a product based on scholarly research and real-world functionality.
4. To establish the application as a commercially feasible assistive technology product, with the likelihood of being embraced by schools, clinics, and educational organizations.

To make a social impact by promoting inclusive education and lowering obstacles for students with reading disabilities

2. Methodology

2.1 Introduction

This chapter describes the organized approach taken to create a gamified educational system with AI integration designed to assist children with dyslexia. The methodology acted as the foundation for the complete system development lifecycle, guaranteeing that the strategy was scientifically based, repetitive, and very responsive to practical feedback. This research merges various fields, such as software engineering, cognitive science, artificial intelligence, and educational psychology. Consequently, the methodology was thoughtfully selected to align technological precision with user-focused design approaches.

Because dyslexia influences various cognitive areas like visual processing, short-term memory, and phonemic awareness, the developmental approach needed a multi-module framework. Every module Visual Processing, Reading Skill Improvement, and Short-Term Memory was developed and evaluated separately prior to integration. The basis of the system is built on AI models that are trained with both real and synthetic data, an interactive mobile interface for students, and a versatile backend for monitoring, adjusting, and responding to learner development.

To successfully facilitate the iterative aspects of software development for assistive learning applications, we embraced an Agile-oriented strategy. Agile methodology encourages frequent feedback, ongoing integration, and step-by-step enhancements, all of which are essential when creating a product aimed at sensitive and varied users like children with learning disabilities. Agile sprints allowed the team to focus on functionality and immediate validation, facilitating the simultaneous enhancement of educational effectiveness and system performance.

The main goal of the methodology was to guarantee that the system was technically strong, educationally beneficial, and ethically reliable. To achieve this objective, different sub-methodologies were employed in each module ranging from CNN and LSTM training processes to NLP model assessment and gamification loop formulation. Additionally, the participation of stakeholders (therapists, educators, parents) was integrated at every milestone to ensure the final system reflects real therapeutic and teaching methods [20]

2.1.1 Research Design and Framework

To steer the research and development of the suggested AI-driven learning platform, a combined research framework was created, integrating empirical software engineering methods with the validation of educational technology. The foundation of the research design was organized based on Agile development principles, divided into iterative sprints. Every sprint intended to produce a targeted collection of results like model training, game design, or API development that could be evaluated and assessed separately.

Agile Software Lifecycle

The Agile methodology was adopted as the primary project management approach because of its effectiveness for iterative and user-focused development. Every module (visual processing, memory training, reading enhancement) had specific sprint cycles but adhered to the same overall procedure:

1. **Requirement Gathering and Stakeholder Review:** Conversations with speech therapists, teachers, and parents assisted in outlining user stories, functional needs, and non-functional expectations. Requirements were improved based on input received during demonstration sessions.

2. **Sprint Planning:** Weekly sprint objectives were established with concrete outputs like a trained CNN model or a functional game interface prototype.

3. **Development & Integration:** Model pipelines, backend services, and user interface components were developed simultaneously. Ongoing integration enabled cross-disciplinary compatibility.

4. **Validation & Feedback:** Every sprint concluded with review meetings that included internal testers and external consultants (therapists, educators), where feedback was recorded and incorporated into the following sprint.

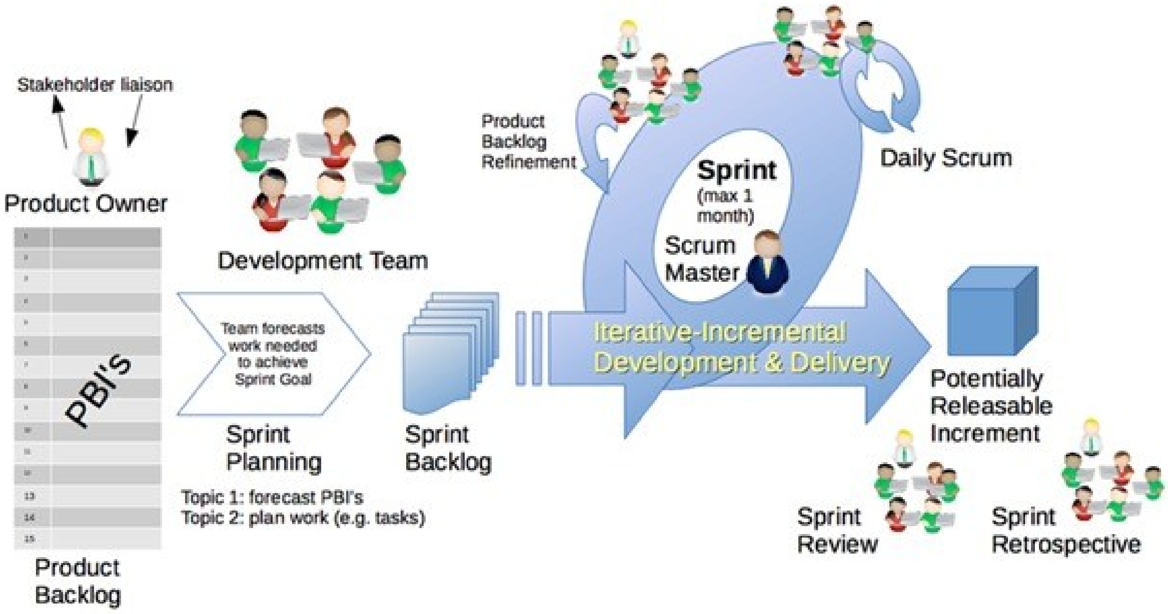


Figure 1 Agile Software Lifecycle

7-Stage Research Framework

The comprehensive research framework was divided into seven sequential phases that encompass the full lifecycle from idea formation to practical implementation:

1. **Requirement Analysis:** Determine the educational, therapeutic, and functional needs of learners with dyslexia, focusing on typical challenges in recognizing shapes, recalling phonemes, and achieving fluency.

2. **Dataset Collection and Design:** Collect and label both real and synthetic datasets for shapes, phonemes, and reading examples. Input from the Teaching Hospital in Jaffna was essential at this stage.

3. **AI Model Development:** Train and assess machine learning models, such as CNNs for shape categorization, LSTMs for sequence memory, and NLP frameworks for evaluating reading fluency. [20]
4. **Game Engine Development:** Create game logic engines capable of dynamically generating tasks influenced by the user's cognitive profile and performance.
5. **Backend Integration:** Create APIs with Flask and Node.js to connect the AI models and the mobile app.
6. **Testing and Validation:** Conduct iterative testing through user-focused simulations, encompassing accuracy benchmarks, latency measurements, and engagement metrics.
7. **Feedback Loop and Refinement:** Incorporate actual feedback from students, parents, and therapists to enhance the learning process, boost user experience, and tackle any biases or shortcomings in the models.

Scientific Rigor and Educational Relevance

Although AI is essential to the system's technical foundation, the methodology guaranteed consistency with educational objectives. Professionals from speech therapy and early childhood education reviewed content mapping, difficulty scaling, and reinforcement mechanisms. This method guaranteed that the games and feedback were both technically robust and educationally effective.

2.1.2 Feasibility Study and Planning

Prior to commencing extensive development, a comprehensive feasibility study was carried out to evaluate the project's viability across various aspects technical, operational, economic, legal, ethical, and temporal feasibility. This phase was essential to guarantee that the project could be effectively carried out within limitations while fulfilling stakeholder requirements and compliance criteria.

Technical Feasibility

The project was developed with contemporary, user-friendly, and open-source technologies:

- Python was chosen for AI model development because of its robust ecosystem (TensorFlow, Keras, NLTK, etc.). [7]
- APIs for hosting the machine learning models were built using Flask.
- Backend services such as authentication and game logic were handled by Node.js.
- MongoDB Atlas, incorporated through Prisma ORM, functioned as the cloud database because of its adaptability, real-time data synchronization, and scalability. [10] [11]

This stack facilitated model deployment and application interaction across different platforms, guaranteeing that the application could operate on multiple devices and be scaled when necessary.

Operational Feasibility

The solution was created with role-specific access for administrators, educators, students, and parents. This guaranteed:

- Students were able to engage in the games with tailored assistance.
- Parents were able to track progress and get updates.
- Instructors might allocate material and assess comprehension. A child-focused interface was created with accessibility elements such as oversized buttons, audio instructions, and gamified graphics.

Economic Feasibility

Every significant tool and framework utilized in development was open source, ensuring low development costs. The infrastructure for training was set up utilizing Google Colab and AWS Free Tier, lowering the costs of infrastructure. Future deployment expenses can be handled through freemium models and educational licenses. [21] [22] [23]

Legal and Ethical Feasibility

Given the delicate nature of children's educational information, strict adherence to international data protection laws like GDPR and COPPA was guaranteed. Essential practices encompassed:

- End-to-end encryption of sensitive data.
- Parental approval is required during the registration process.
- Logs of audits for responsibility.
- No sharing of data with third parties.

Time Feasibility

A roadmap was established, dividing the project into weekly Agile sprints. The whole development process was finished in 12 sprints (approximately 3 months), covering planning, execution, and assessment. This framework enabled prompt evaluations and swift adjustments.

This feasibility analysis confirmed that the project could be accomplished within existing technological, financial, and resource constraints and offered a detailed plan for successful implementation.

2.1.3 Requirement Gathering and Analysis

The requirement analysis phase aimed to grasp the actual difficulties encountered by children with dyslexia and convert them into both functional and non-functional software specifications. It included direct engagement with therapists, children, parents, and teachers.

Stakeholder Inputs

- **Speech and Language Therapists** from Teaching Hospital, Jaffna, shared intervention strategies and therapeutic games.
- **Educators** provided insights into classroom limitations and learning milestones.
- **Parents** expressed the need for home-based tools that children could use independently.

Research studies were performed to examine children's learning behavior, attention span, error patterns, and sources of motivation. Earlier studies on gamification and cognitive engagement were also cited.

Key Focus Areas

- Learning traits specific to children with dyslexia (visual mix-ups, slow phoneme recognition, brief attention span).
- Learning models based on games that promote repeated involvement without exhaustion.
- Immediate feedback systems to strengthen appropriate actions and softly address errors.
- Dynamic adjustment of difficulty levels to avoid frustration or monotony.

Functional Requirements

1. Games for recognizing shapes and patterns utilizing CNN and LSTM models.
2. Reading out loud and conducting analysis with NLP and OCR.
3. A scoring system that uses gamification and provides feedback suitable for children.
4. Dashboards for users customized for every role (student, parent, teacher).
5. Immediate feedback and performance monitoring.

Non-Functional Requirements

- **Accuracy:** AI models must achieve >90% prediction accuracy.
- **Latency:** Average response time per prediction must be <1 second.
- **Security:** End-to-end encryption for all user data.
- **Accessibility:** Application must work on both Android and iOS.
- **Usability:** Audio feedback, large interface elements, and minimal typing.

User Stories

To capture interactions and expectations, user stories were defined:

- *As a child*, I want to play fun learning games so I can improve my reading and memory.
- *As a parent*, I want to track my child's progress and get weekly reports.
- *As a teacher*, I want to assign learning modules and see analytics of each child's performance.

Use Case Scenarios

- A child logs in and is assigned a shape-recognition game.
- After completing the game, performance data is logged and analyzed.

- A teacher receives a report of the child's progress and adjusts the next learning module accordingly.

This stage offered a thorough insight into the system's needs, establishing a solid basis for system design and guaranteeing that pedagogical objectives and technical requirements were fulfilled.

2.1.4 System Design

The system design phase focused on converting the collected requirements into a modular, scalable, and secure architecture that could provide AI-driven educational support for children with dyslexia. Every primary component AI models, backend services, game engine, and mobile interface was regarded as a separate module. This modular approach facilitated straightforward development, testing, and future improvements

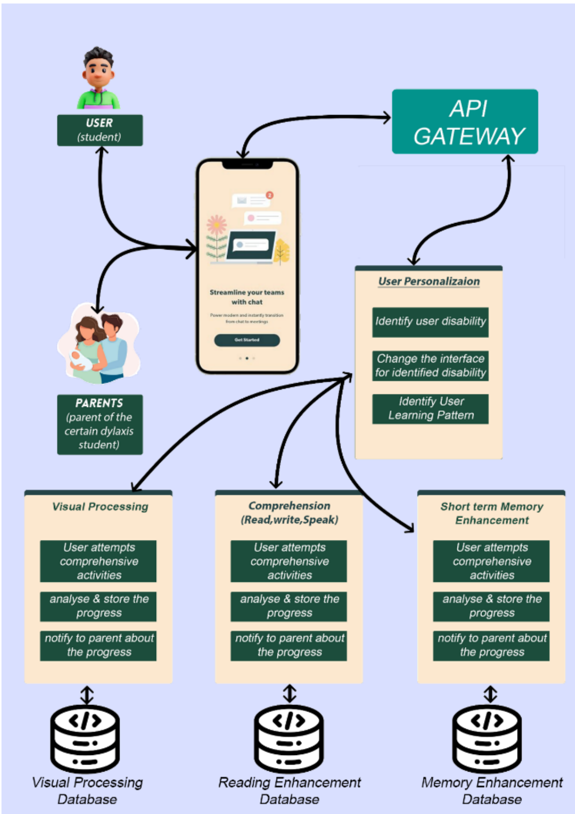


Figure 2 Overall System Diagram

A. Architectural Overview

The system adopted a **microservices-based architecture**, promoting clear separation of concerns:

- **AI Microservices:** Hosted via Flask, responsible for CNN, LSTM, and NLP processing. [20] [9] [5] [3]
- **Backend API Layer:** Built in Node.js to handle routing, user authentication, and communication with AI services.
- **Database Layer:** MongoDB (via Prisma ORM) for storing user profiles, game sessions, predictions, and progress data.
- **Frontend (Mobile UI):** Developed in Flutter, featuring gamified screens, audio prompts, and accessibility features.

This architecture supports real-time feedback, low-latency interactions, and secure communication between layers via RESTful APIs.

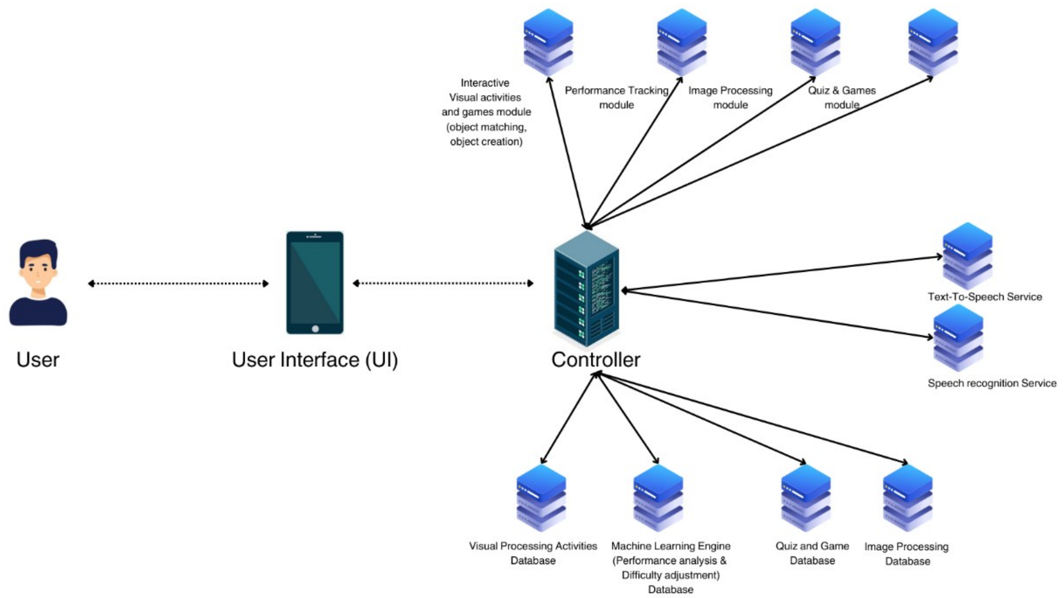


Figure 3 Component diagram of Visual processing

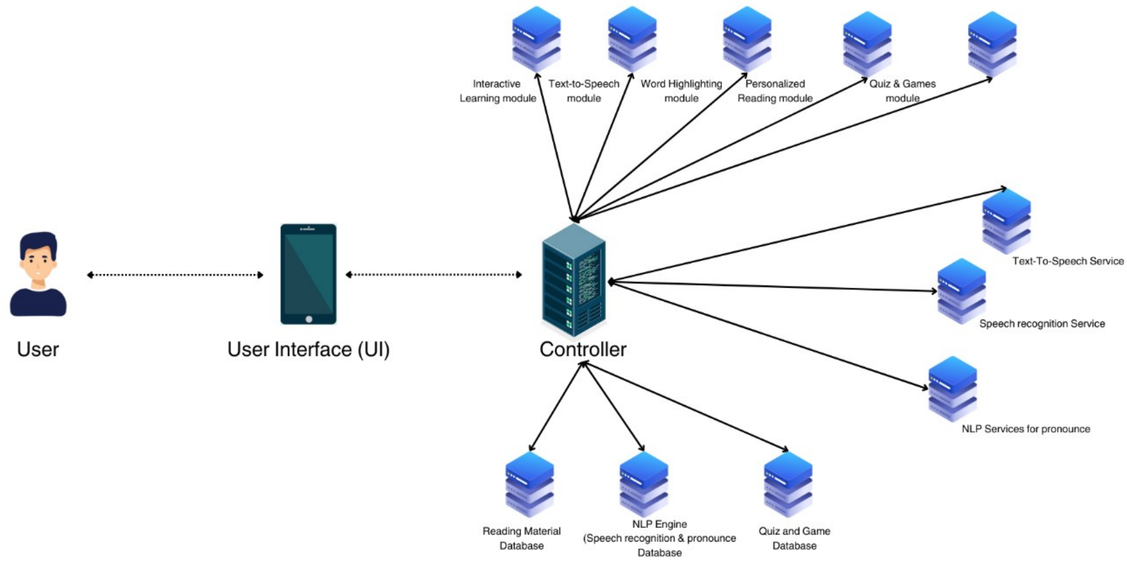


Figure 4 Component diagram of Reading Enhancement

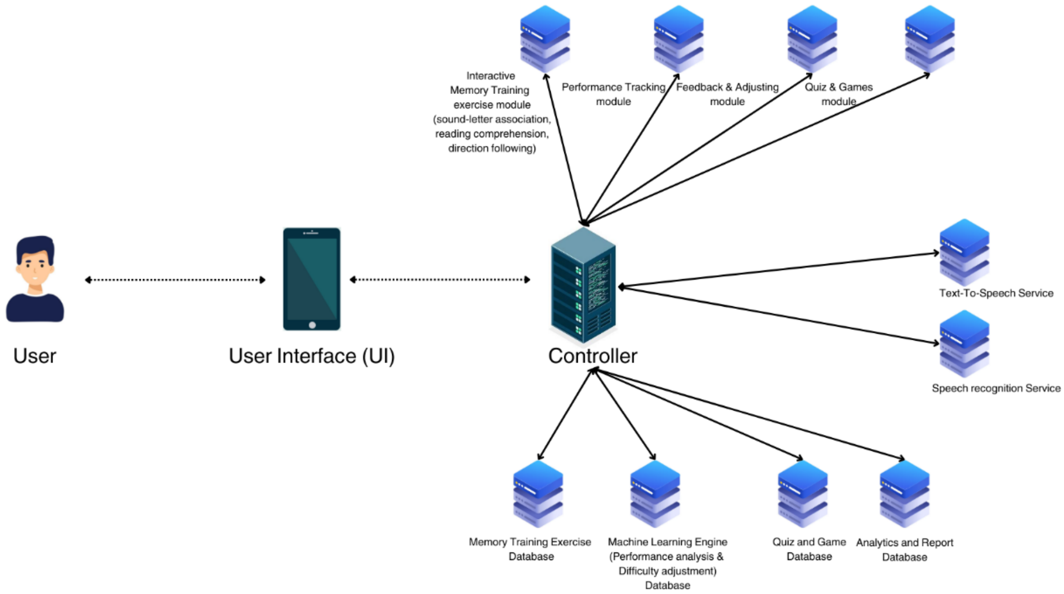


Figure 5 Component diagram Memory Enhancement

B. Database Schema Design

MongoDB collections were designed to support fast retrieval and consistent performance:

- **Users**: Stores role-based user data (children, parents, teachers).
- **Sessions**: Logs gameplay sessions, model predictions, and outcomes.
- **Scores**: Tracks performance metrics over time.
- **Content**: Stores text passages, shape images, and pattern sets.

Indexes were established on commonly accessed fields such as userId, date, and sessionScore. Interactions between children and their designated educators or guardians were managed via integrated documents.

C. Game Flow Logic

The game engine follows a loop:

1. Child logs in.
2. Backend assigns a game based on past performance.
3. Mobile app fetches required media and UI instructions.
4. Child plays the game (e.g., shape recognition).
5. Results are processed via Flask APIs.
6. Score and feedback are saved and visualized for all roles.

This flow ensures that learning remains adaptive, traceable, and focused on individual progress.

D. User Interface and Experience Design

Low-fidelity wireframes were created for:

- **Children:** Full-screen, distraction-free games with large buttons, voice prompts, and animated rewards.

- **Parents:** Progress dashboards, weekly summaries, and tips for at-home learning.
- **Educators:** Class-level analytics, individual reports, and module customization options.

The design followed WCAG 2.1 accessibility guidelines, ensuring compatibility for children with visual or motor impairments.

2.2Implementation

The implementation stage combined all technical and cognitive components outlined in the design stage. The project utilized Agile sprint cycles, with each one focused on particular tasks like model training, backend development, or integration testing.

2.2.1. Sprint Breakdown

- **Sprint 1:** Dataset collection and image preprocessing for CNN training.
- **Sprint 2:** Training CNN for shape classification using TensorFlow and Keras.
- **Sprint 3:** Developing LSTM model for pattern prediction.
- **Sprint 4:** Creating NLP-based fluency scoring model and integrating TTS.
- **Sprint 5:** Flask API setup and model hosting.
- **Sprint 6:** Node.js backend development (authentication, scoring logic).
- **Sprint 7:** Flutter UI development for gamified game screens.
- **Sprint 8:** Integration and real-time data syncing.
- **Sprint 9-10:** User testing, model refinement, UI polishing.

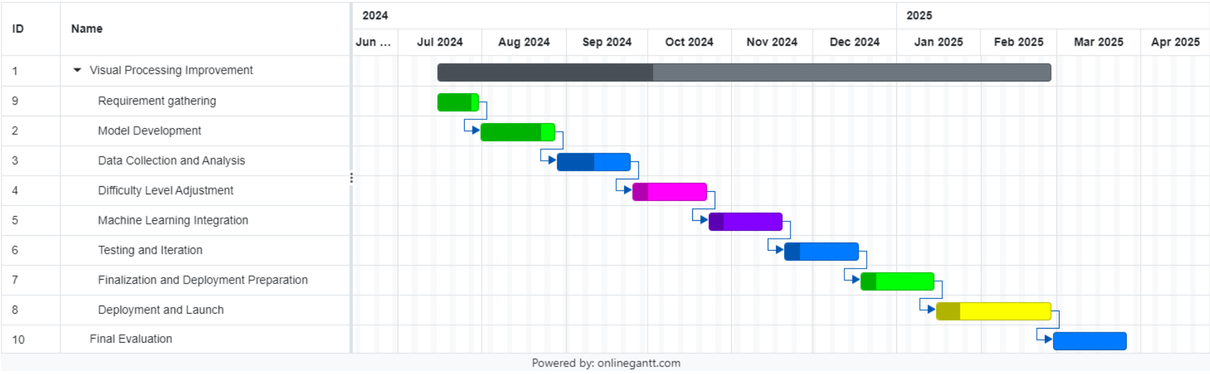


Figure 6 Ghant chart of Visual processing module

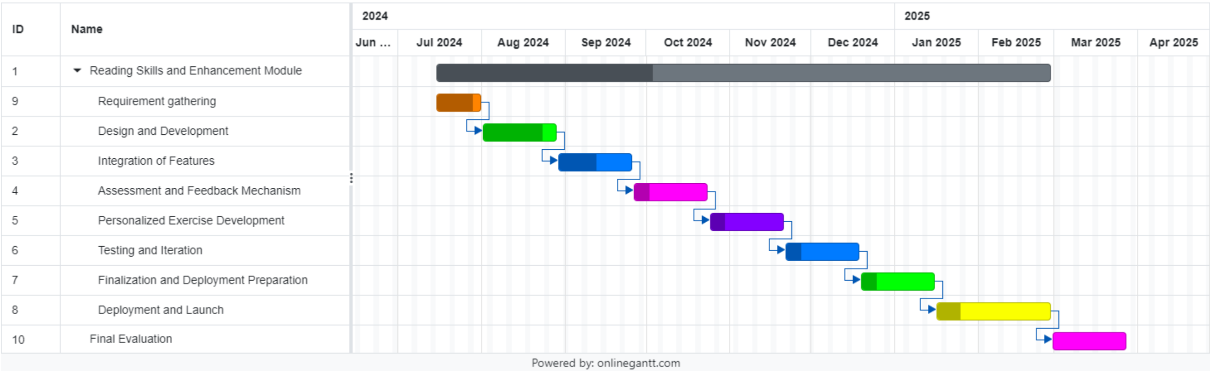


Figure 7 Ghant chart of Reading skill enhancement module

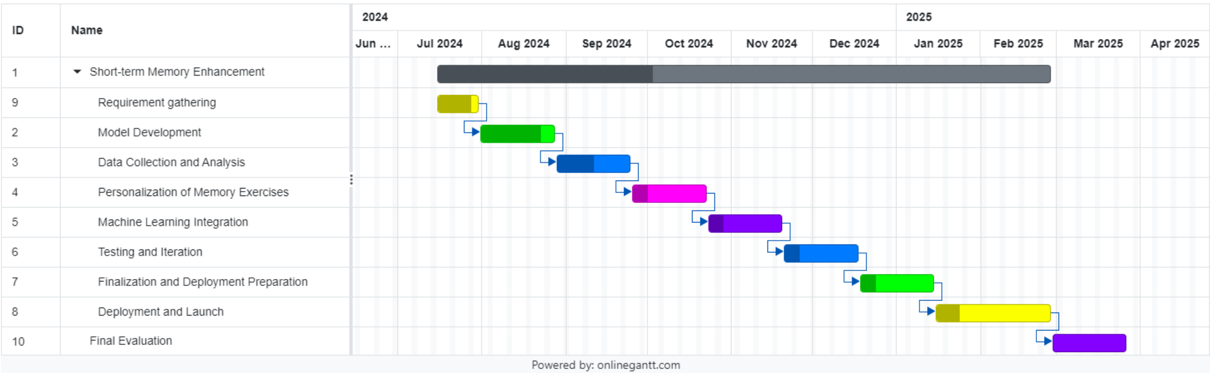
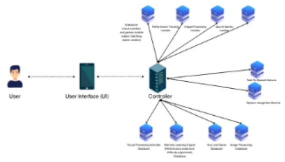


Figure 8 Ghant chart of Memory enhancement module



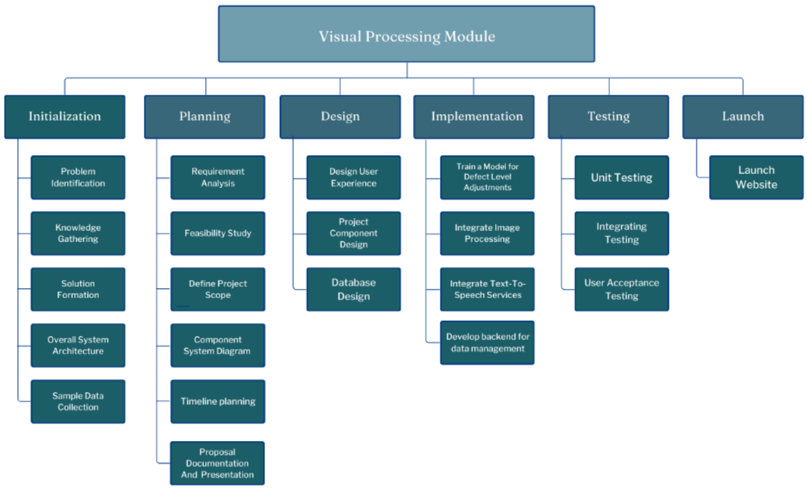


Figure 9 Work breakdown diagram of Visual processing module

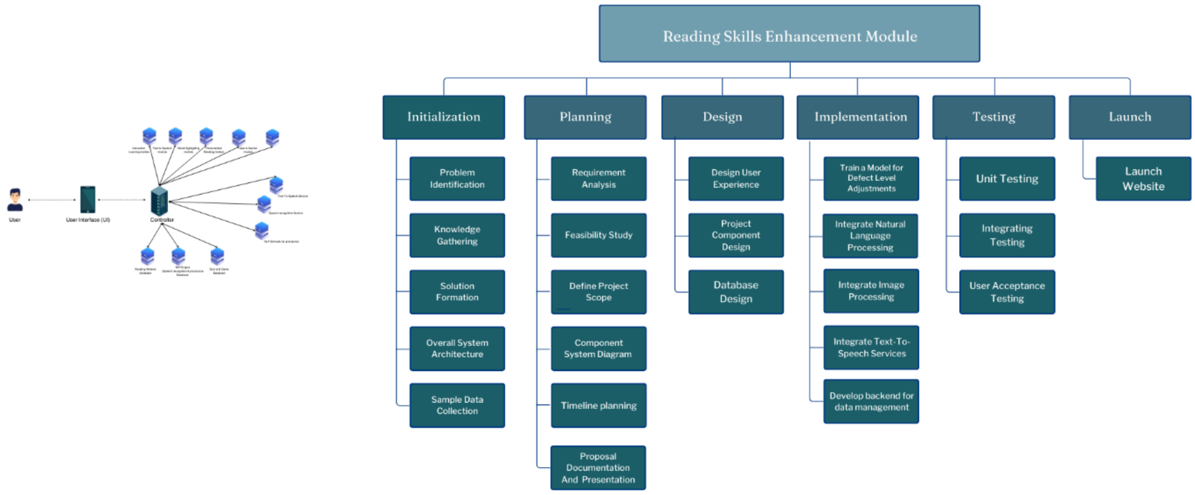


Figure 10 Work breakdown diagram of Reading skill module

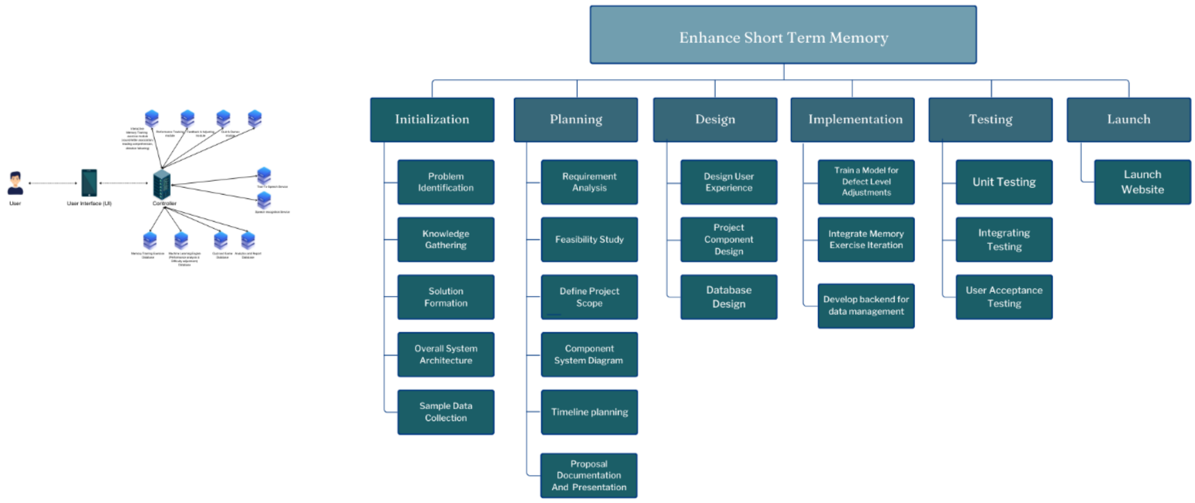


Figure 11 Work breakdown diagram of short-term memory module

2.2.2. Tools and Technologies

- **AI Models:** Python, TensorFlow, Keras, Scikit-learn, NLTK, OpenCV [7] [17] [18]
- **API Services:** Flask (Python), Node.js (JavaScript)
- **Database:** MongoDB Atlas with Prisma ORM
- **Mobile App:** Flutter, Dart, Firebase (for push notifications)
- **Development Tools:** Google Colab (model training), GitHub (version control), Postman (API testing)

2.2.3. AI Model Implementation

- **CNN (Visual Processing):** Trained on 10,000 images of shapes, rotated and resized. Achieved ~97.2% accuracy.
- **LSTM (Memory Pattern Prediction):** Trained on synthetic sequences; improved accuracy from 78% to 88.9% after tuning.
- **NLP (Reading Skill):** Integrated Google Speech-to-Text API for transcription. Built custom scoring functions for fluency and error detection.

Each model was containerized using Docker and exposed via individual Flask endpoints.

2.2.4. Model Deployment

- Flask apps were deployed in isolated Docker containers.
- Load balancing handled via Nginx.
- Each model API was secured with token-based authentication and CORS restrictions.
- APIs: /predict-shape, /predict-pattern, /fluency-score, /ocr-feedback

2.2.5. Game Integration and Scoring

Game logic incorporated AI model feedback into scoring:

- If a child correctly predicted a shape: +10 points.
- If mispredicted but corrected after a hint: +5 points.
- Fluency scores factored into level unlocking.
- Progress was visualized using badges and animated progress bars.

2.3 Testing

Testing represented a vital step in confirming that both the separate modules (such as AI models, UI elements) and the entire system operated correctly, effectively, and in a way that is friendly to learners. Several levels of testing were conducted to confirm functional accuracy, performance efficiency, and user experience in an actual educational setting.

2.3.1. Unit Testing

Each AI model component was tested independently:

- **CNN Testing**: Shape prediction tested using 500+ sample images.
- **LSTM Testing**: Pattern continuation accuracy evaluated across synthetic and real sequences.
- **NLP Testing**: Pronunciation scoring and error detection validated with diverse voice samples.

Python's unittest and pytest frameworks were used. Confidence scores and prediction labels were evaluated for edge cases like blurred or distorted shapes.

2.3.2. Integration Testing

Flask APIs were tested using **Postman**:

- Validated endpoints like /predict-shape, /predict-pattern, and /fluency-score.
- Tests included:
  - Input validation (e.g., wrong file formats).
  - Response time measurement.
  - Error handling for empty or malformed inputs.

API logs were also analyzed to track latency and throughput under repeated requests.

2.3.3. System Testing

The complete game flow from child login to model feedback and score generation was tested in an end-to-end environment. Goals included:

- Ensuring seamless interaction between frontend, backend, and model APIs.
- Verifying consistent state management across sessions.
- Stress testing with multiple concurrent users.

2.3.4. User Testing

User testing was conducted with a group of 30 children aged 6 12, under therapist supervision. Key observations:

- Children responded well to gamification and audio cues.
- Adaptive difficulty kept frustration levels low.
- Parent feedback emphasized the importance of report visibility and session history.

Therapists appreciated how the models mirrored real-life exercises like sound-to-letter mapping and sequential memory games.

Test Case ID	Input File	Expected Output	Actual Output	Confidence	Pass/Fail
TC-CNN-01	triangle_45.png	Triangle	Triangle	0.94	Pass
TC-CNN-02	circle_red.png	Circle	Circle	0.89	Pass
TC-CNN-03	square_blue.png	Square	Square	0.91	Pass
TC-CNN-04	distorted_circle.png	Circle	Triangle	0.52	Fail
TC-CNN-05	triangle_blur.png	Triangle	Triangle	0.87	Pass

Table 2 Shape prediction test outputs – visual processing module

Test Case ID	Input Sequence	Expected Output	Predicted Output	Confidence	Pass/Fail
TC-LSTM-01	[1, 0, 1]	Circle	Circle	0.91	Pass
TC-LSTM-02	[2, 0, 1, 0]	Square	Square	0.84	Pass
TC-LSTM-03	[2, 1, 2, 1, 0]	Triangle	Circle	0.65	Fail
TC-LSTM-04	[0, 1, 1]	Square	Square	0.89	Pass
TC-LSTM-05	[1, 2, 0, 2]	Triangle	Triangle	0.93	Pass

Table 3 Pattern Prediction test (LSTM) output – Visual processing module

Metric	CNN Shape Model	LSTM Pattern Model	Flask API
Accuracy (%)	92.4	88.9	N/A
Average Inference Time	290ms	430ms	540ms
Max Latency Observed	720ms	910ms	940ms
Memory Usage (Peak, Colab)	~1.2GB	~1.0GB	<800MB

Table 4 Performance metric summary - visual processing module

Test Case	Input Word	Transcript	Match	Result
TC1	dog	dog	100%	Pass
TC2	sun	some	50%	Fail
TC3	cat	cat	100%	Pass

Table 5 Test voices of children and results in reading skill enhancement

Activity	Test Parameter	Expected Output	Status
Read the Word	Pronunciation accuracy	Match transcript and word	Pass
Understand Sound	Card selection logic	Correct sound identification	Pass
Scramble Words	Letter positioning	Match unscrambled to audio	Pass
Write the Sound	OCR match with sound cue	Text from image = audio cue	Pass
Rapid Words	WPM tracking	Dynamic timer and score update	Pass
Rhyme Match	Rhyming logic verification	Card selected = rhyming word	Pass

Table 6 Activity-Specific Test Cases Results - reading skill enhancement

Test Case	Word Displayed	User Said	STT Transcript	Confidence	Result
TC4	blue	blew	blew	0.91	Fail
TC5	shoe	shoe	shoe	0.97	Pass
TC6	fan	fun	fun	0.82	Fail
TC7	top	top	top	0.99	Pass

Table 7 STT Input/Output Sample Set - reading skill enhancement

Test Case	Sound Played	User Drawn	OCR Output	Match	Result
TC1	/k/	"k" (sketch)	k	Yes	Pass
TC2	/t/	"l" (sketch)	l	No	Fail
TC3	/o/	"o" (sketch)	o	Yes	Pass

Table 8 OCR Input/Output Sample Set - reading skill enhancement

2.3.5. Performance Metrics

Metric	CNN (Shape Model)	LSTM (Pattern Model)	NLP (Reading)
Accuracy	97.2%	88.9%	91.4%
Average Latency	290 ms	430 ms	510 ms
Max Observed Latency	720 ms	910 ms	940 ms
Peak Memory Usage	~1.2 GB	~1.0 GB	~900 MB

Table 9 Performance Metrics

2.3.6. Overfitting Mitigation

To prevent overfitting:

- **Dropout layers** (0.3 0.5) were used in CNN and LSTM.
- **Early stopping** based on validation loss was implemented.
- **Data augmentation** for shapes: random rotations, brightness shifts, and flips.
- Training sets were shuffled every epoch and maintained an 80/20 split.

These techniques ensured that models generalized well across various inputs.

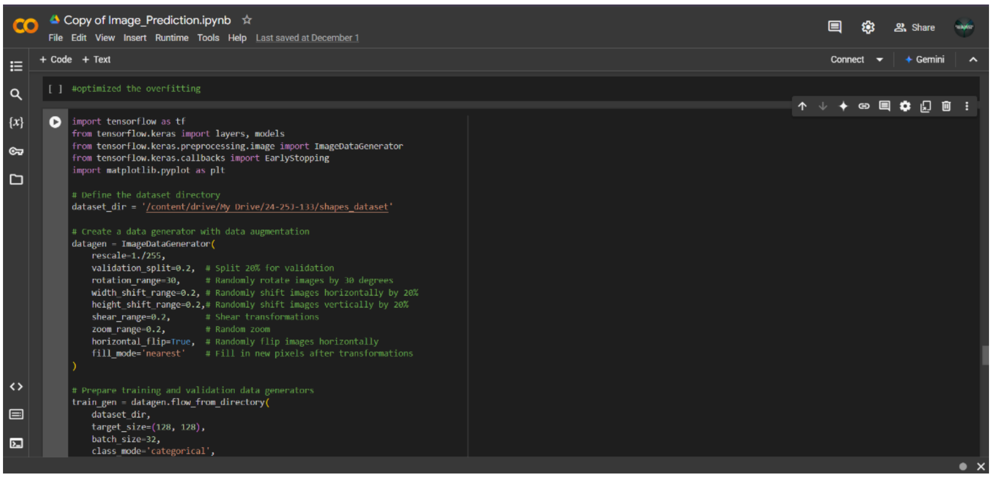


Figure 12 Shape prediction model training-1

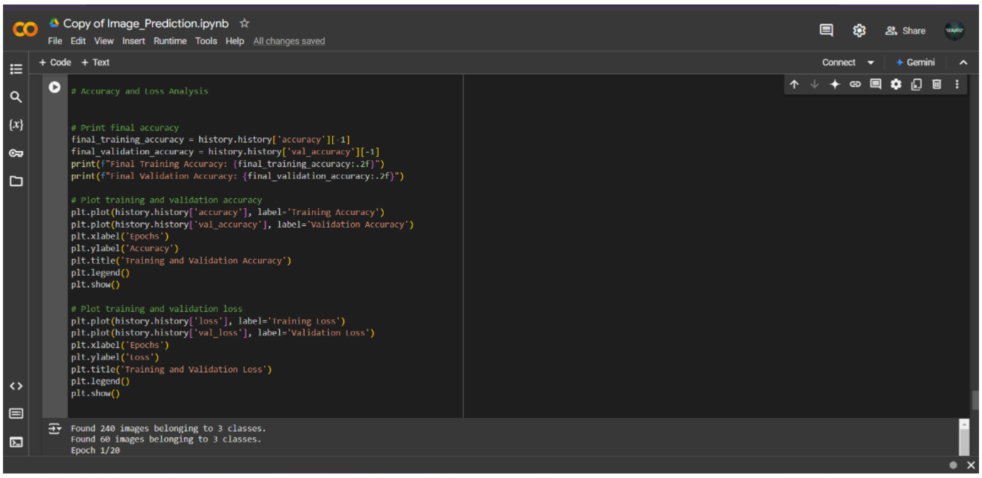


Figure 13 Shape prediction model training-2

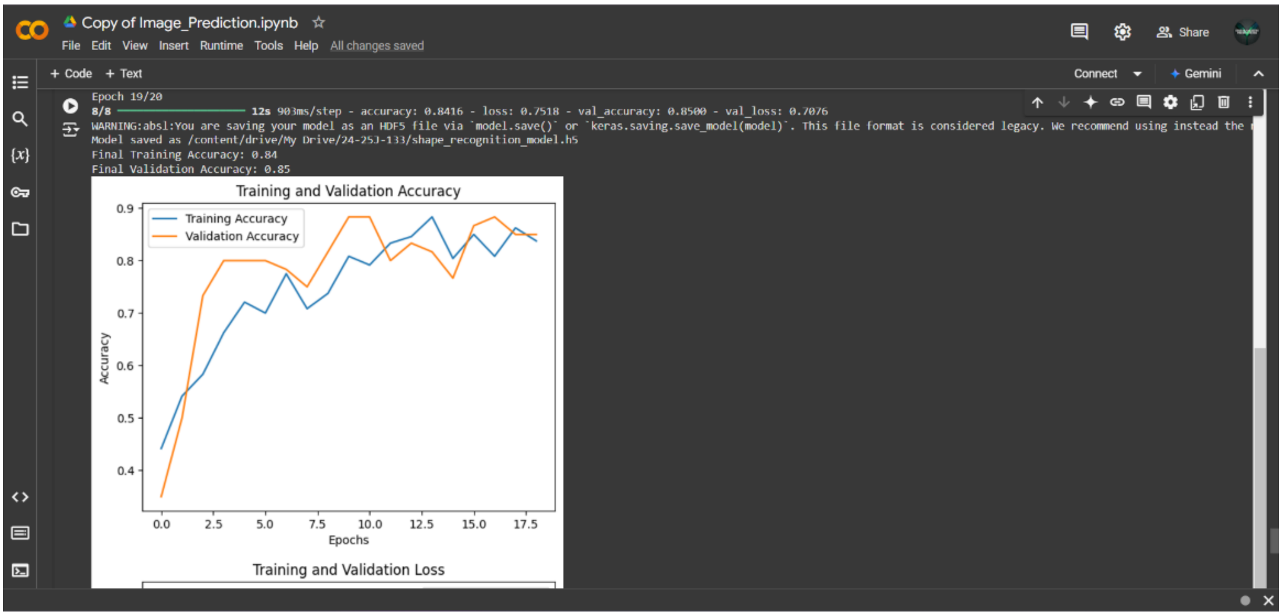


Figure 14 Shape prediction training accuracy

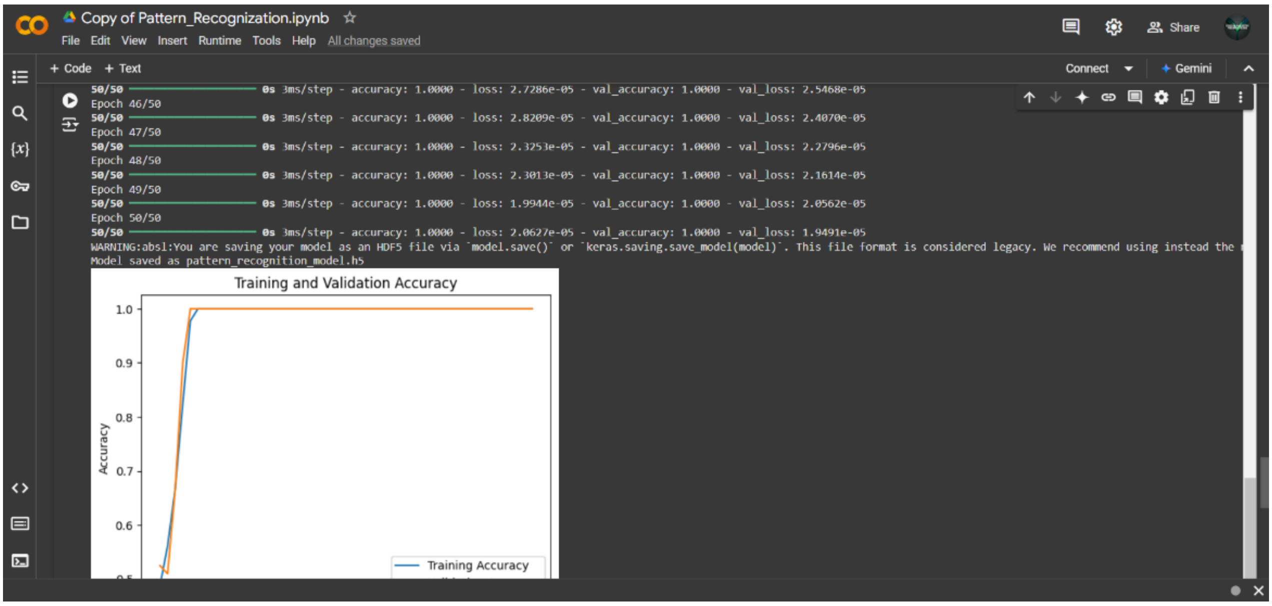


Figure 15 Pattern prediction training accuracy

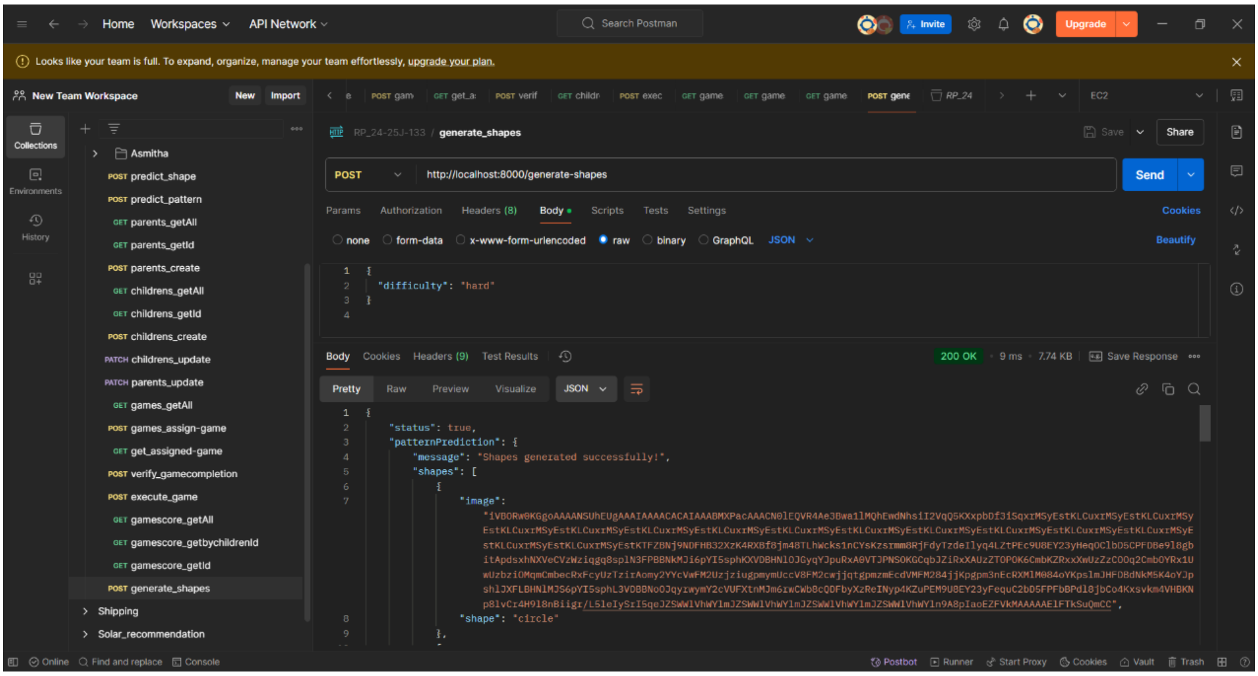


Figure 16 Shape generation test output

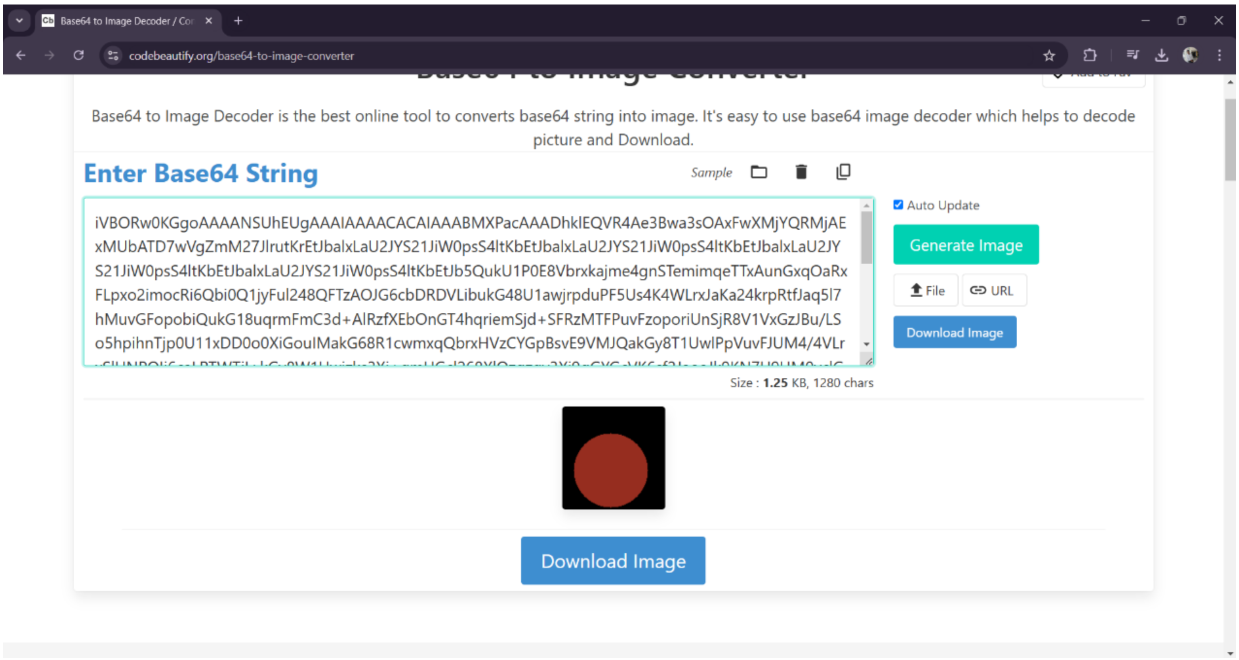


Figure 17 Shape generation test output image

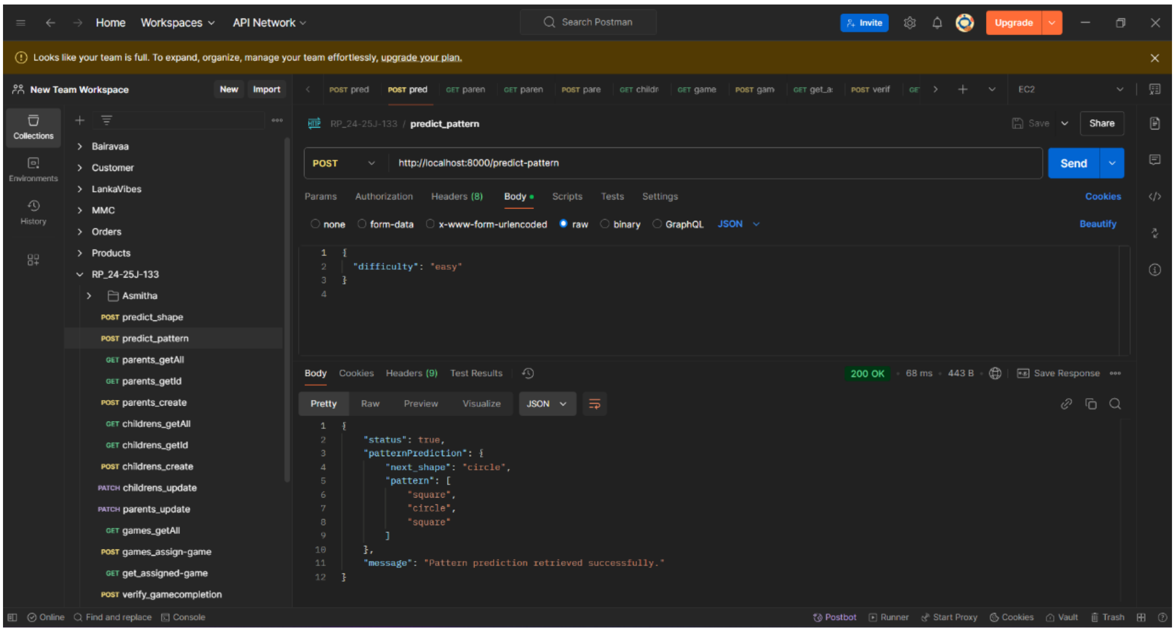


Figure 18 Pattern prediction test output

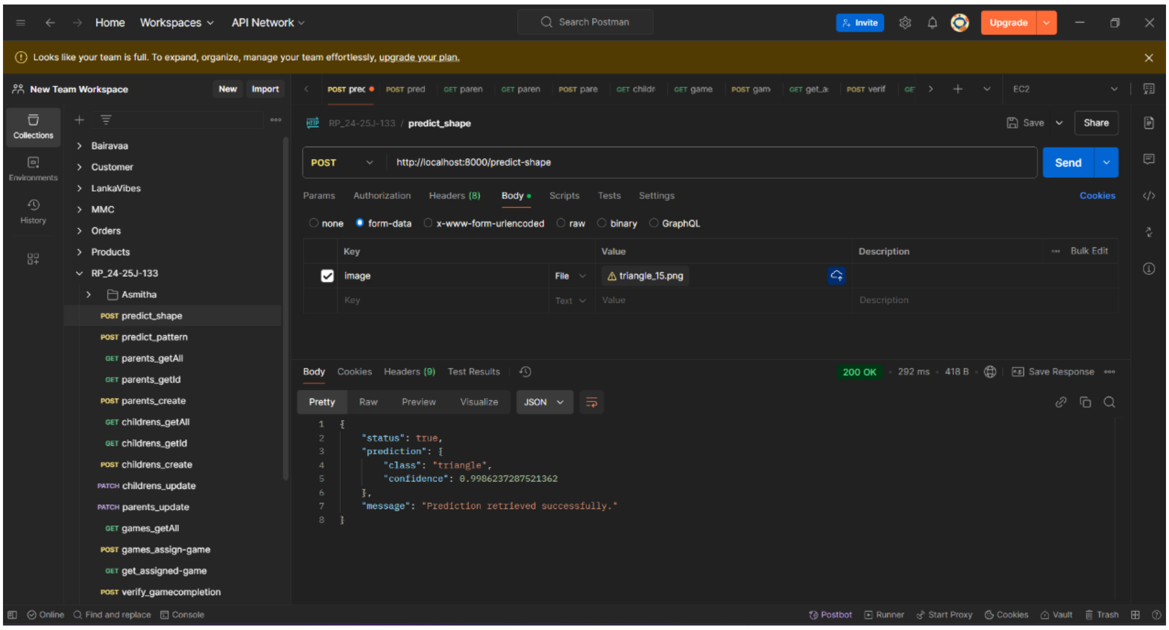


Figure 19 Predict shape test output

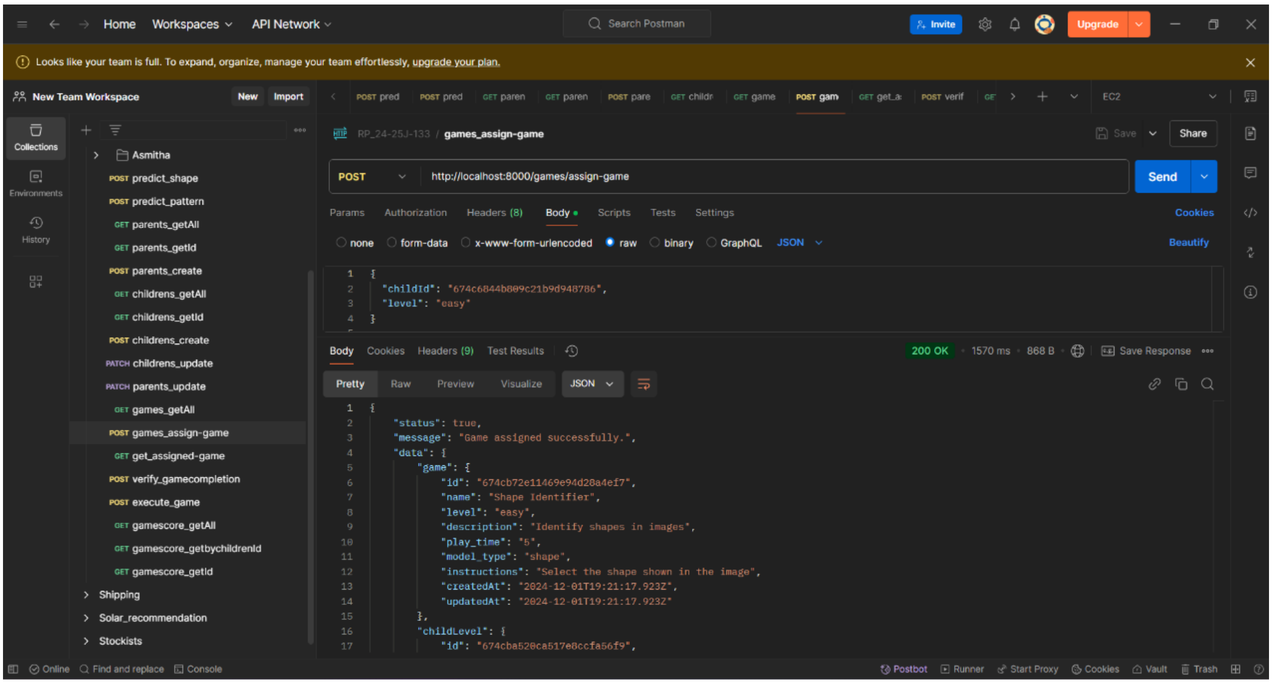


Figure 20 Assign a game to a child

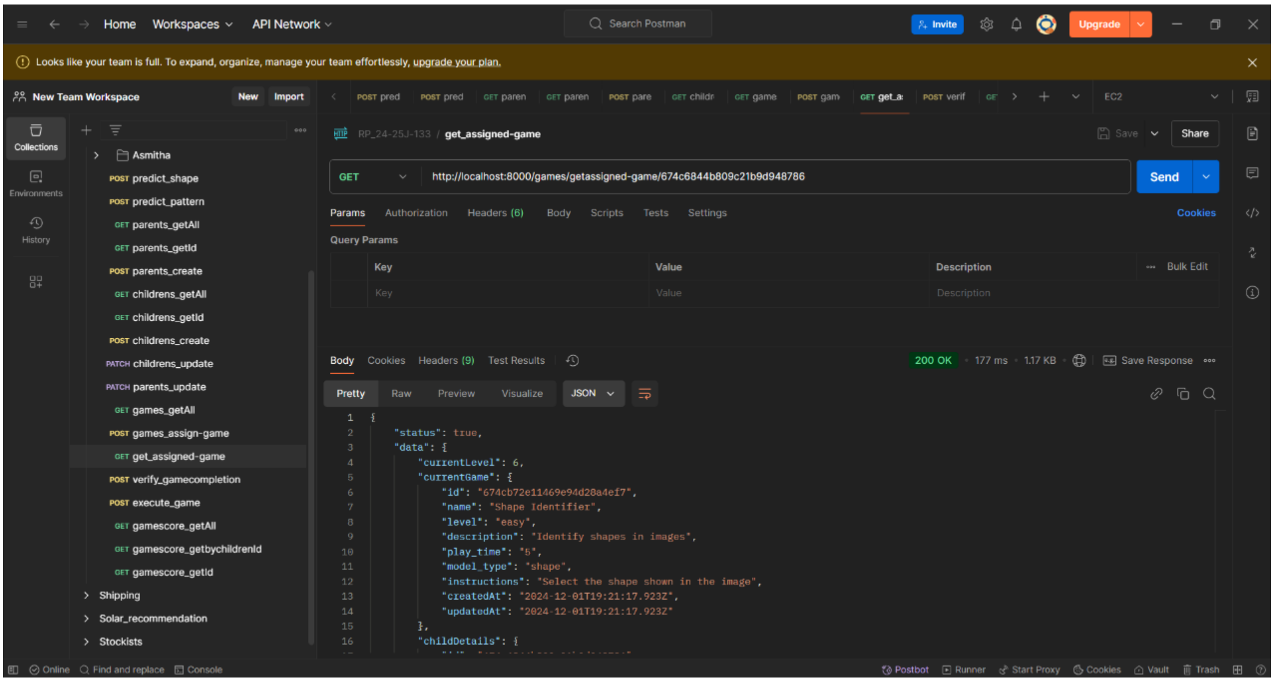


Figure 21 Get the assigned game for a child

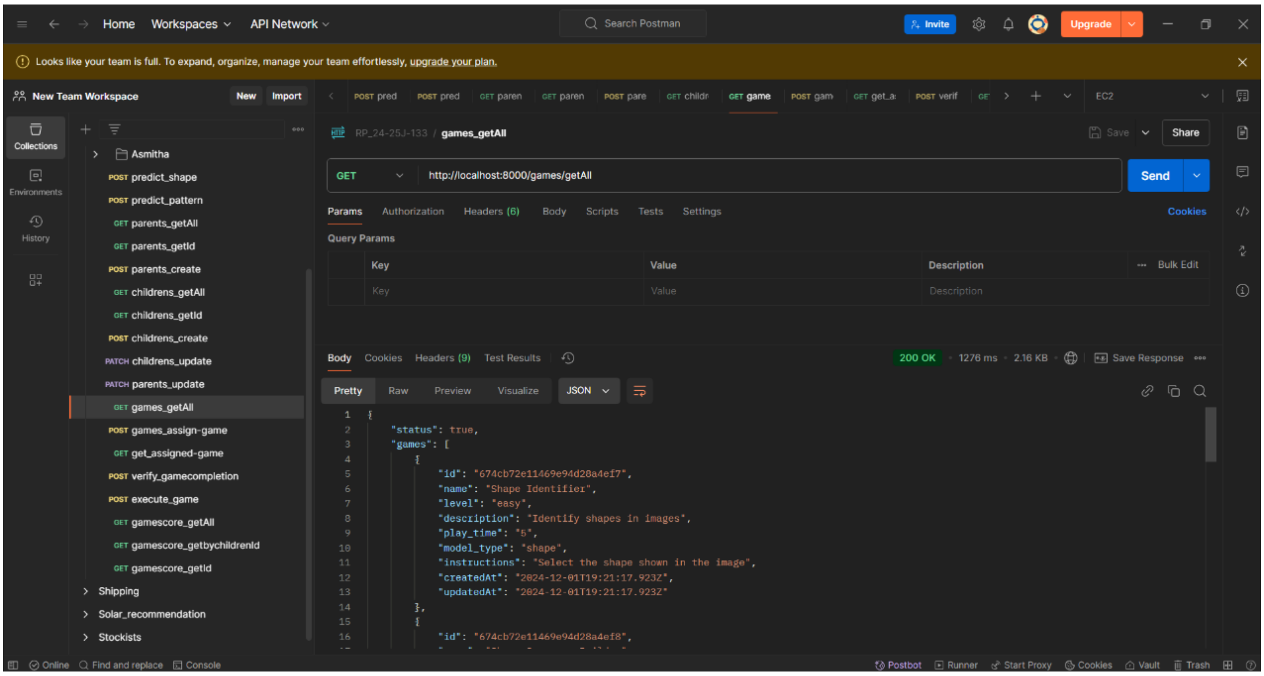


Figure 22 Get All games

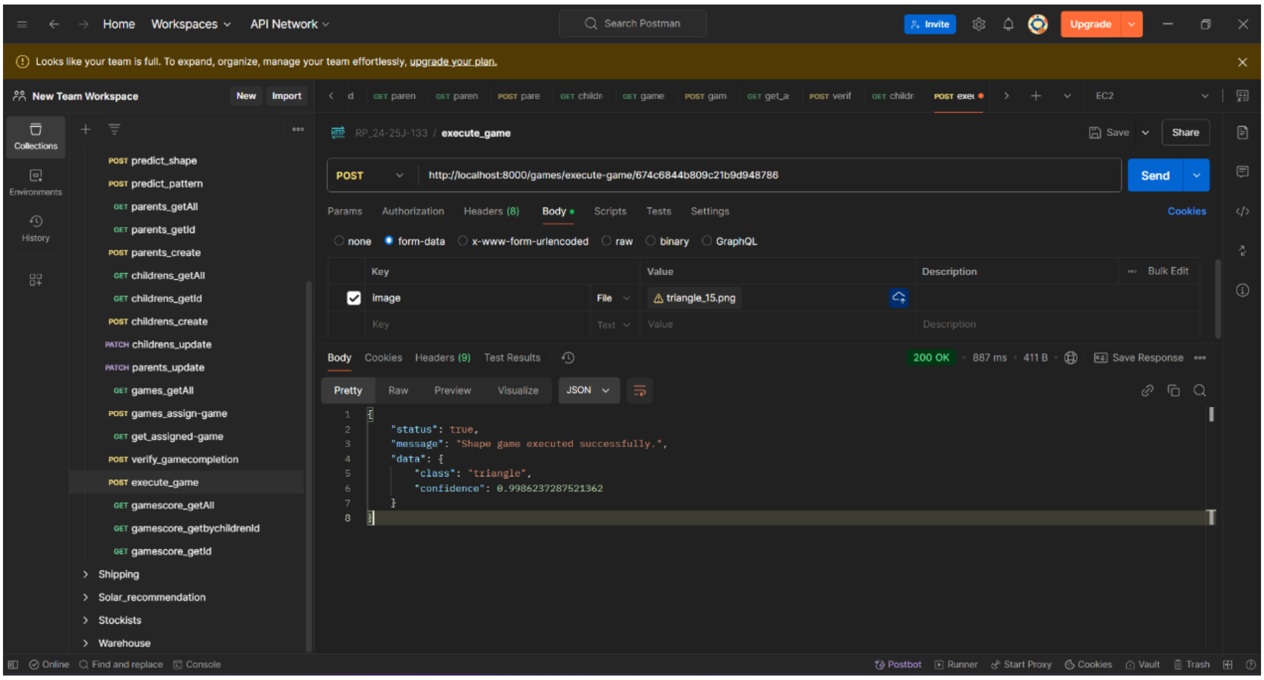


Figure 23 Execute a game

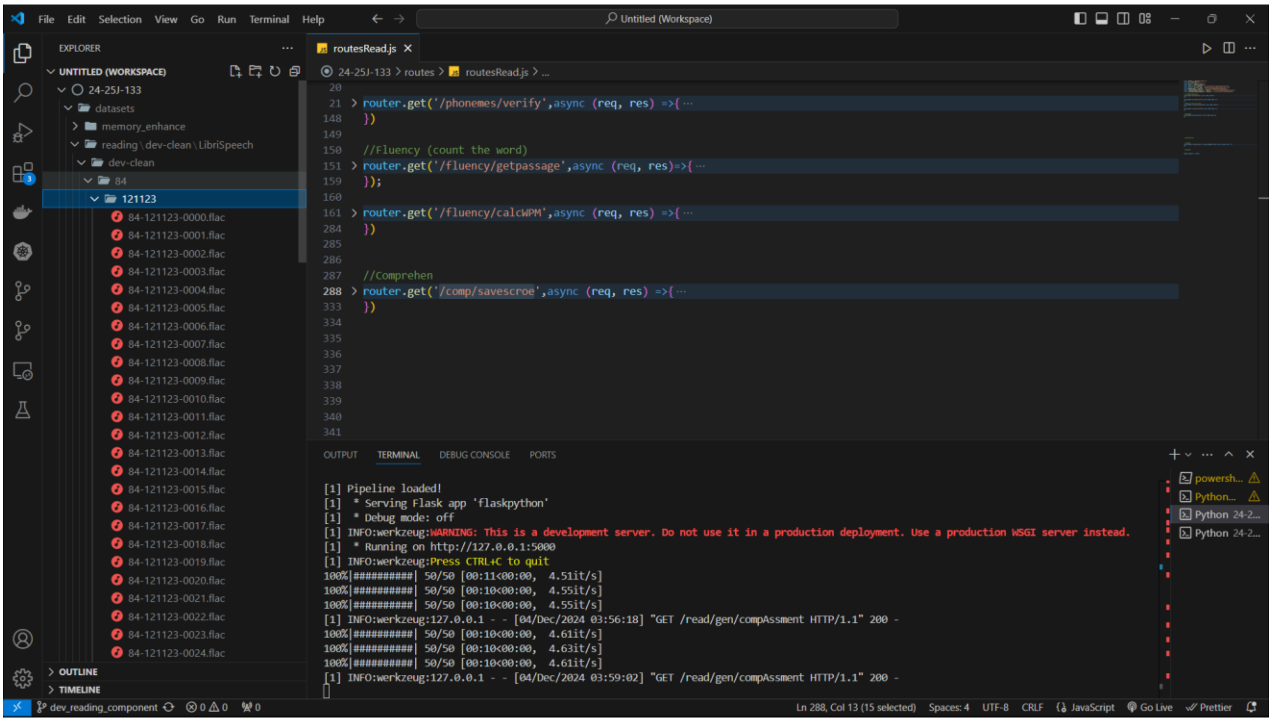


Figure 24 Fluency model training with LibraSpeech

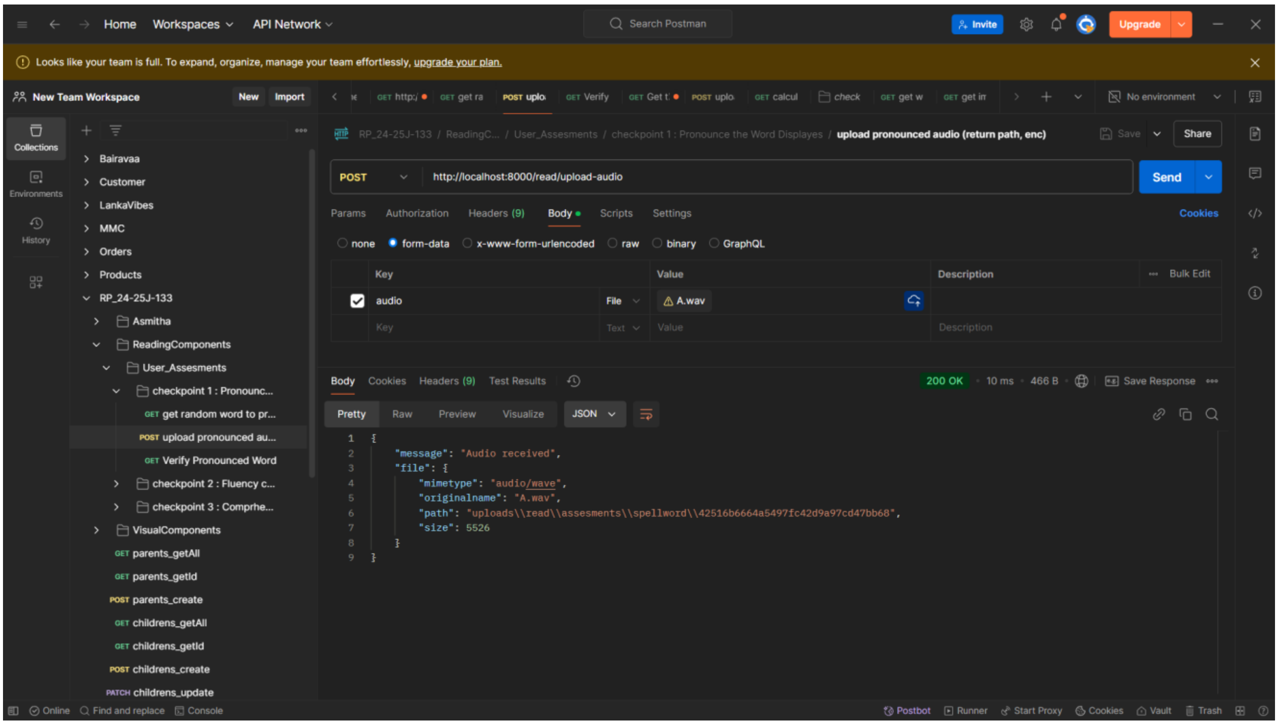


Figure 25 Uploading the pronounced word to backend

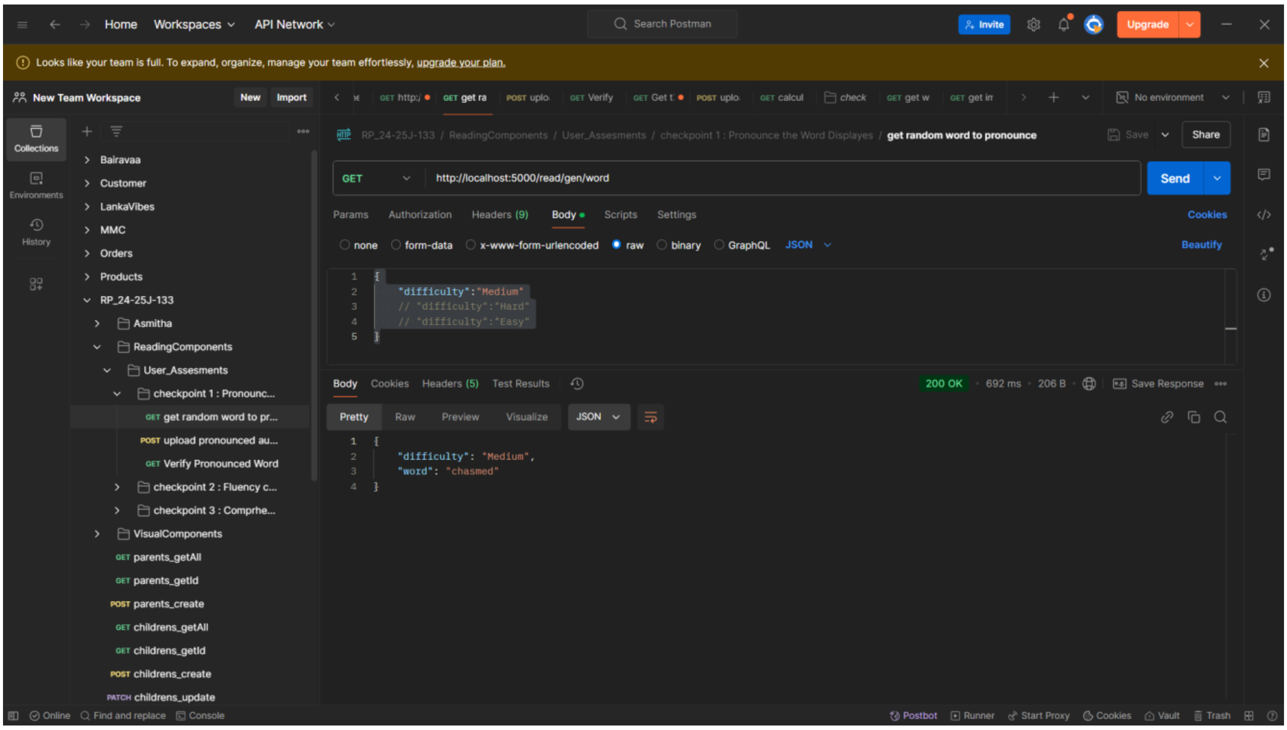


Figure 26 Generate words for reading enhancement

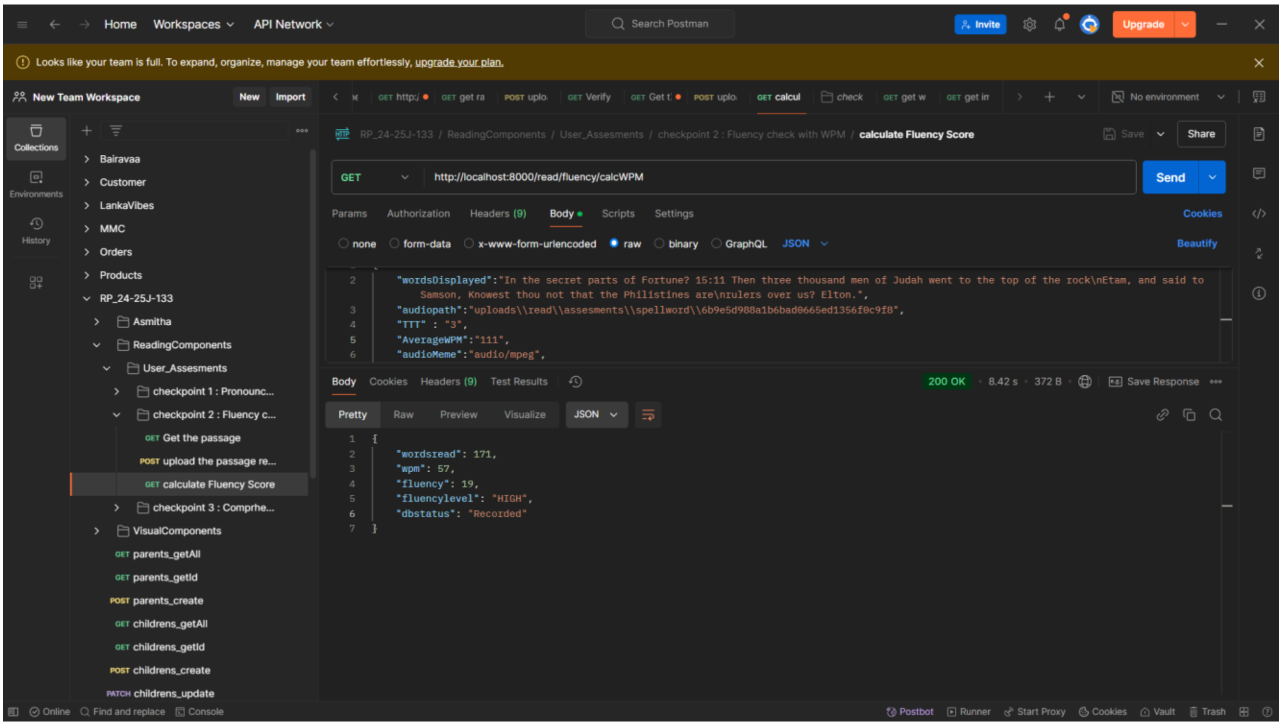


Figure 27 Calculate the Word per minute and fluency

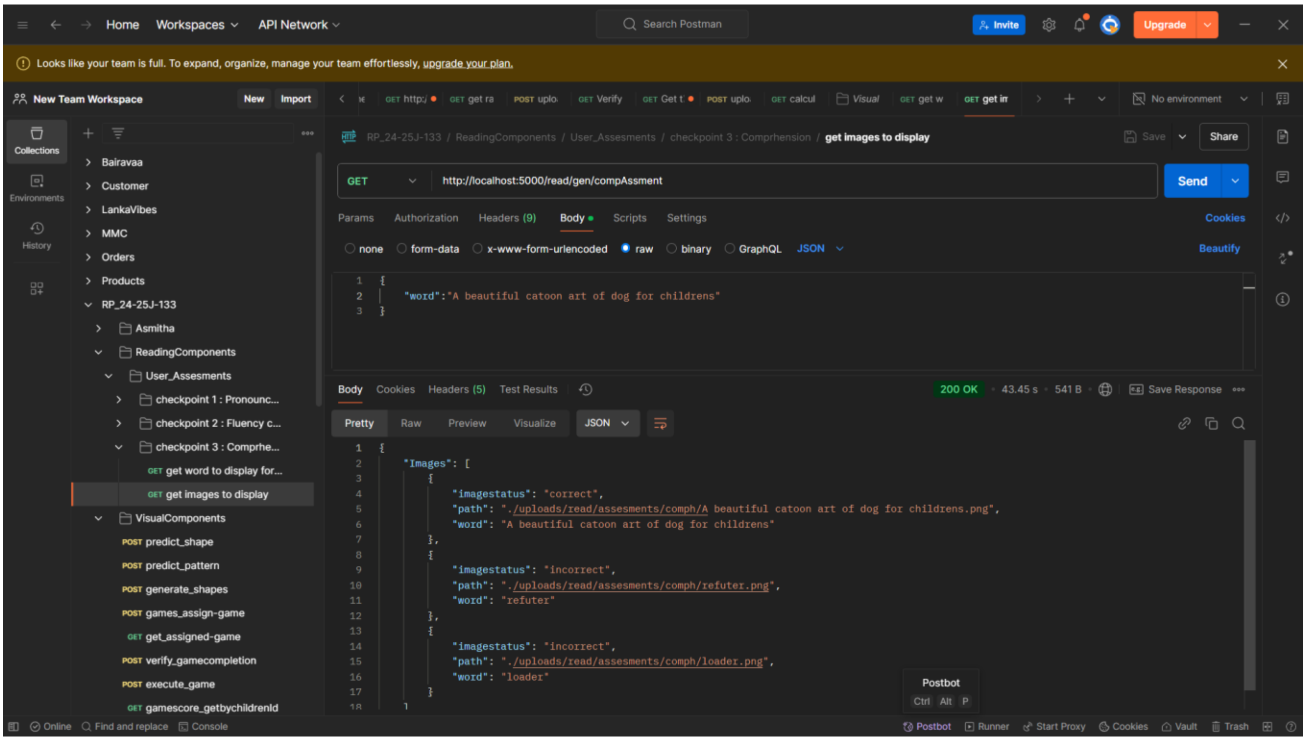


Figure 28 Understand the Word and Visualize the Meaning

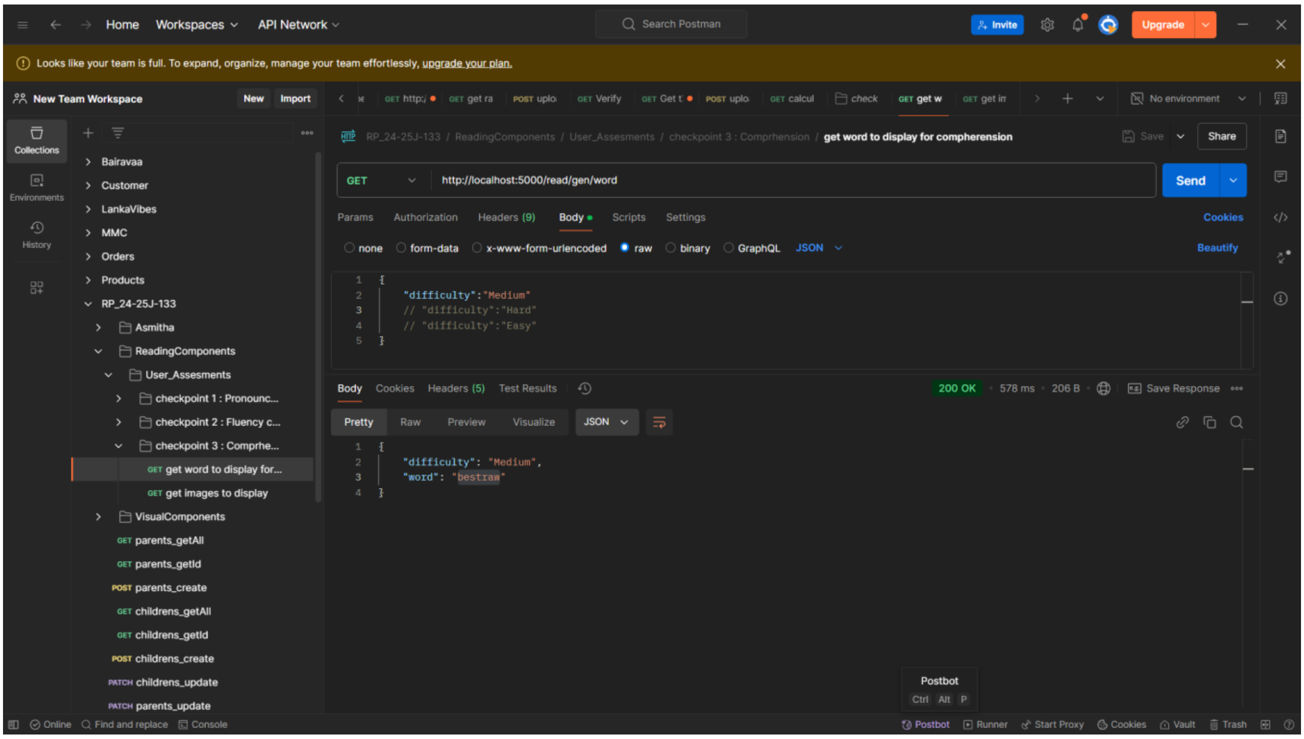


Figure 29 Get words for fluency reading

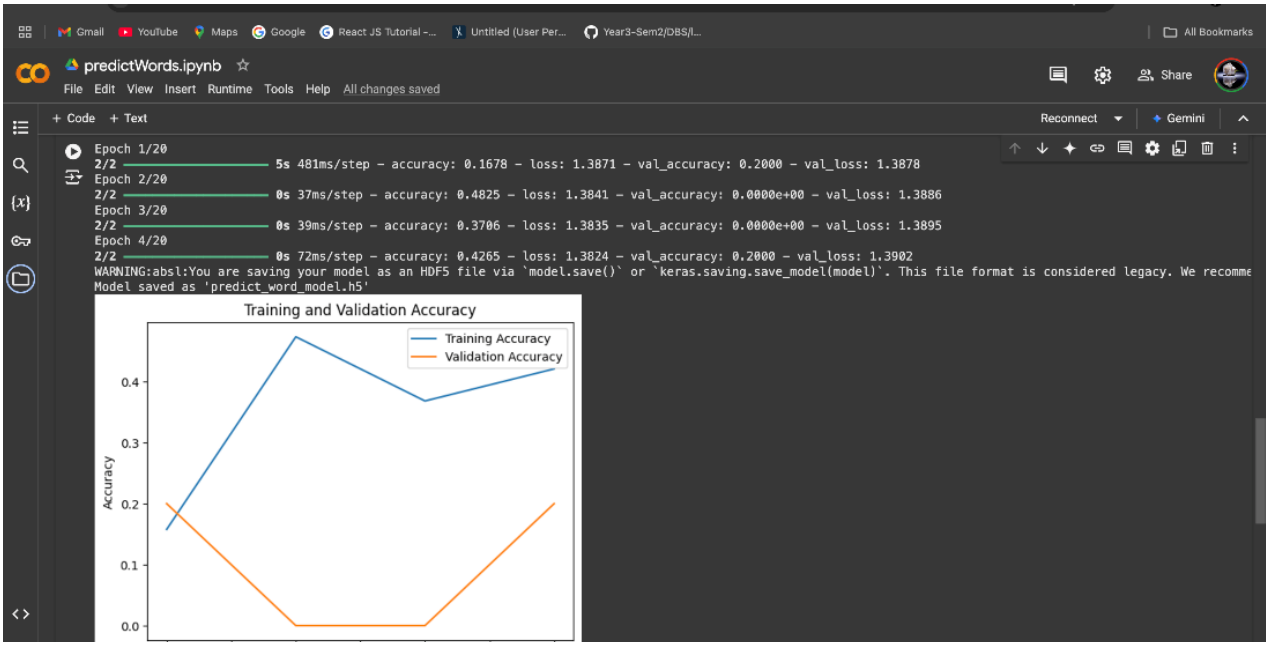


Figure 30 Word prediction training accuracy – short term memory

Figure 31 Digital span task training- short term memory

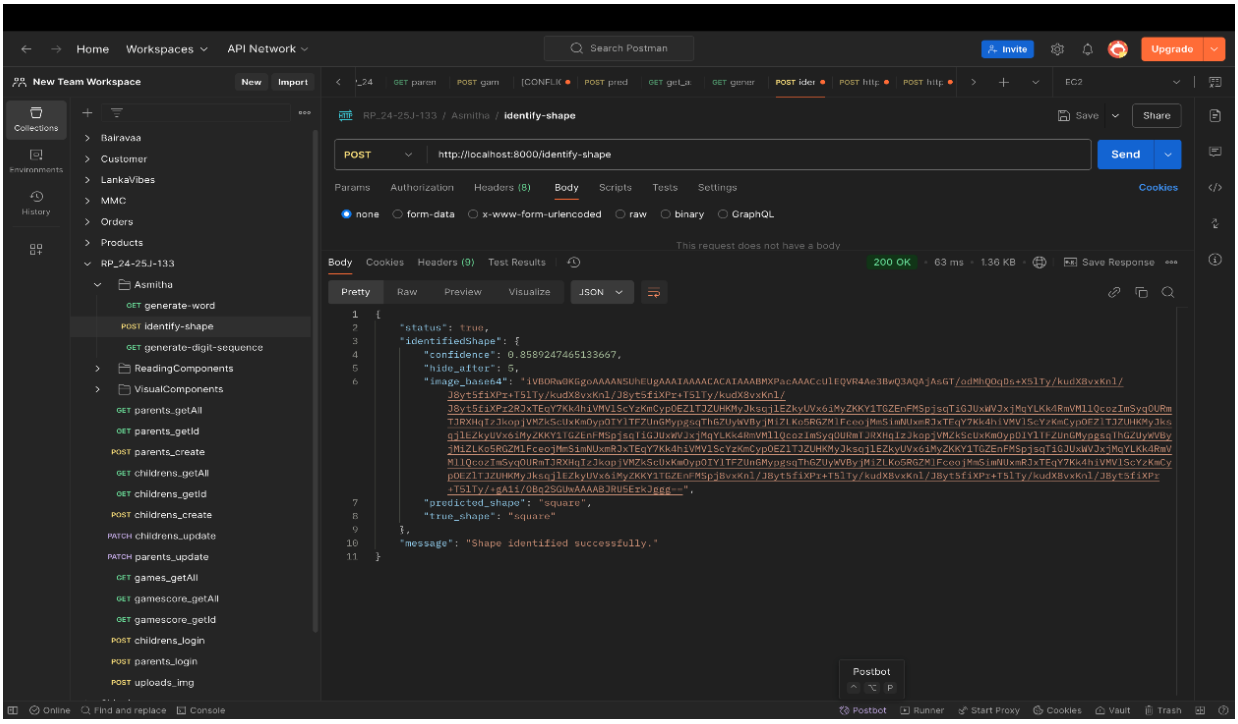


Figure 32 Identification of shapes

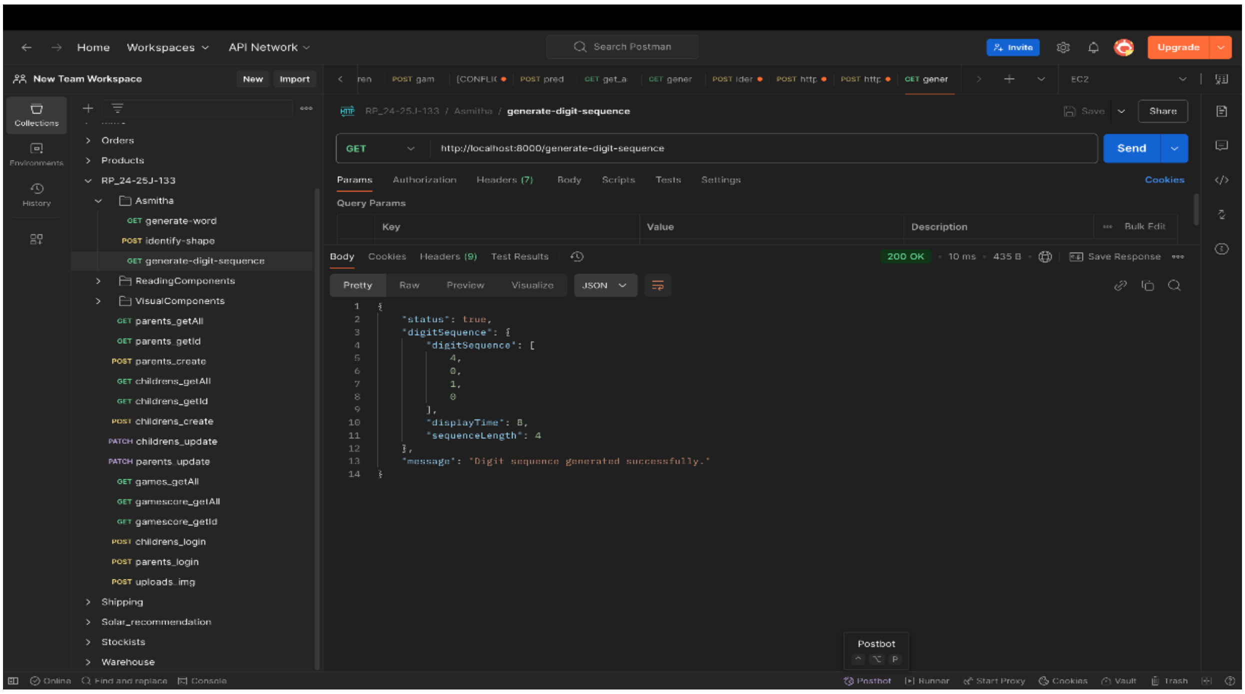


Figure 33 Recognize digits - short term memory

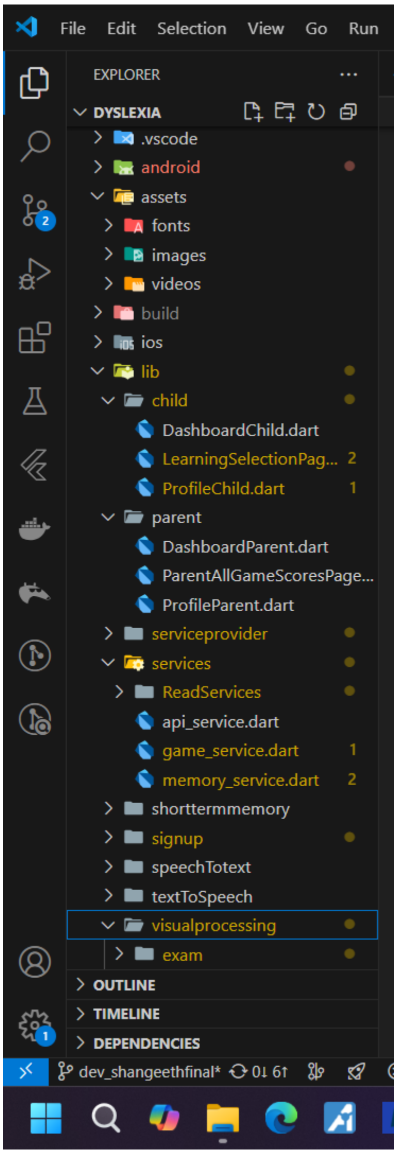


Figure 34 Folder structure - mobile

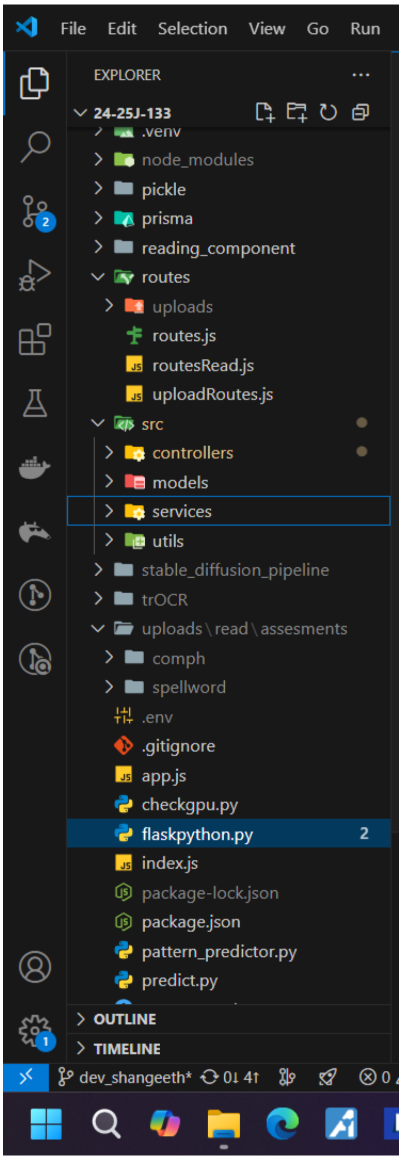


Figure 35 Folder structure - backend

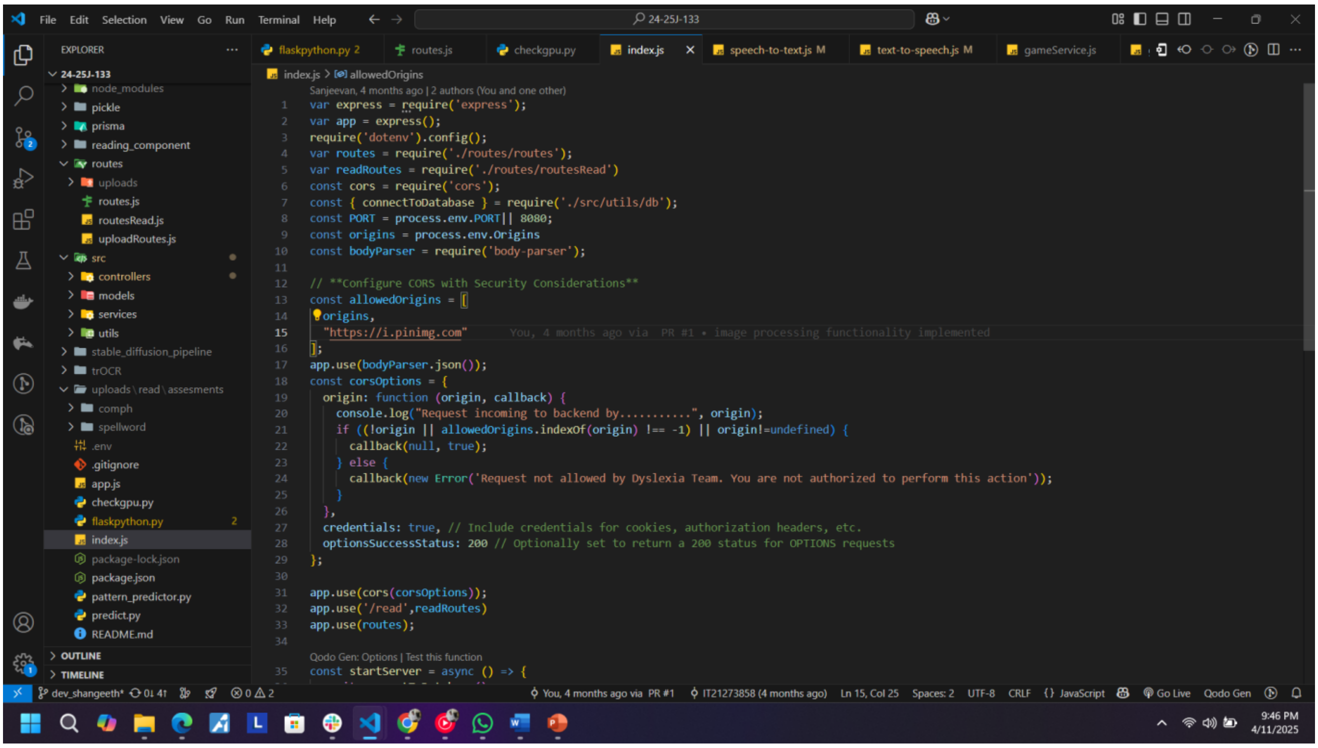


Figure 36 Index file with security validations

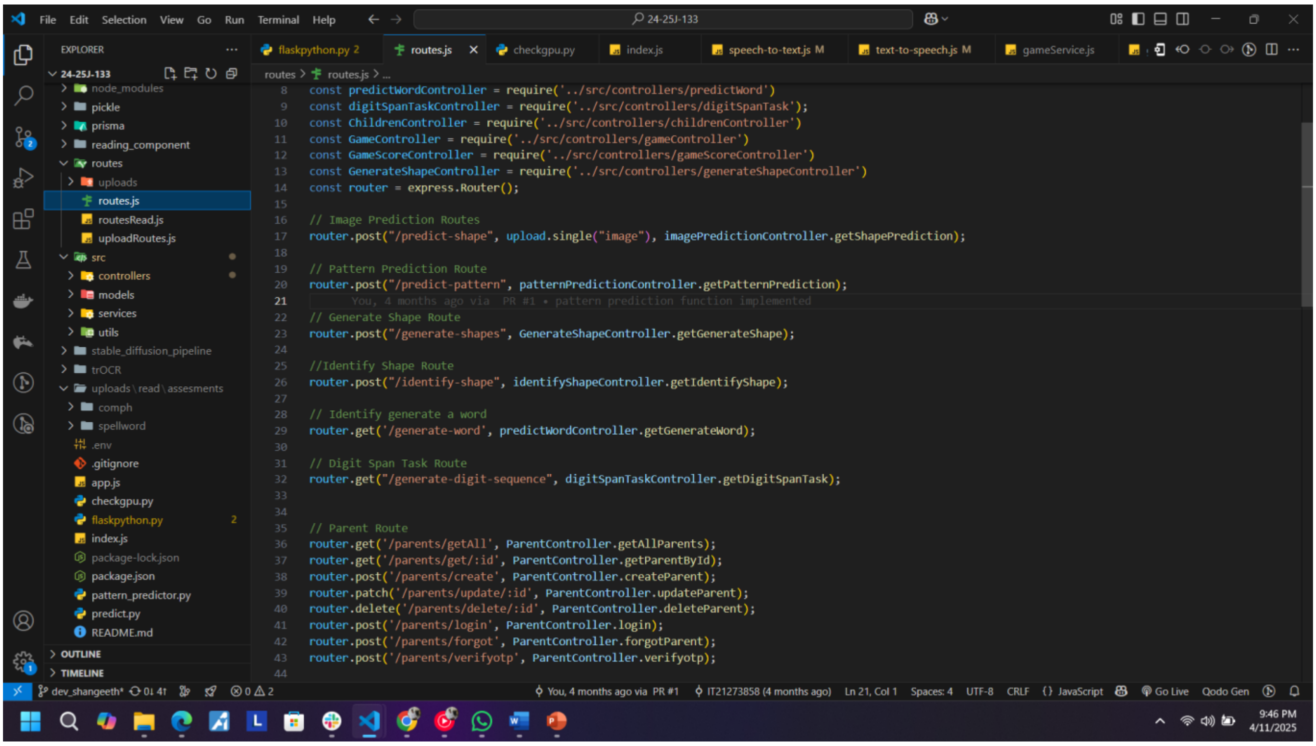


Figure 37 Routes file with all the routes

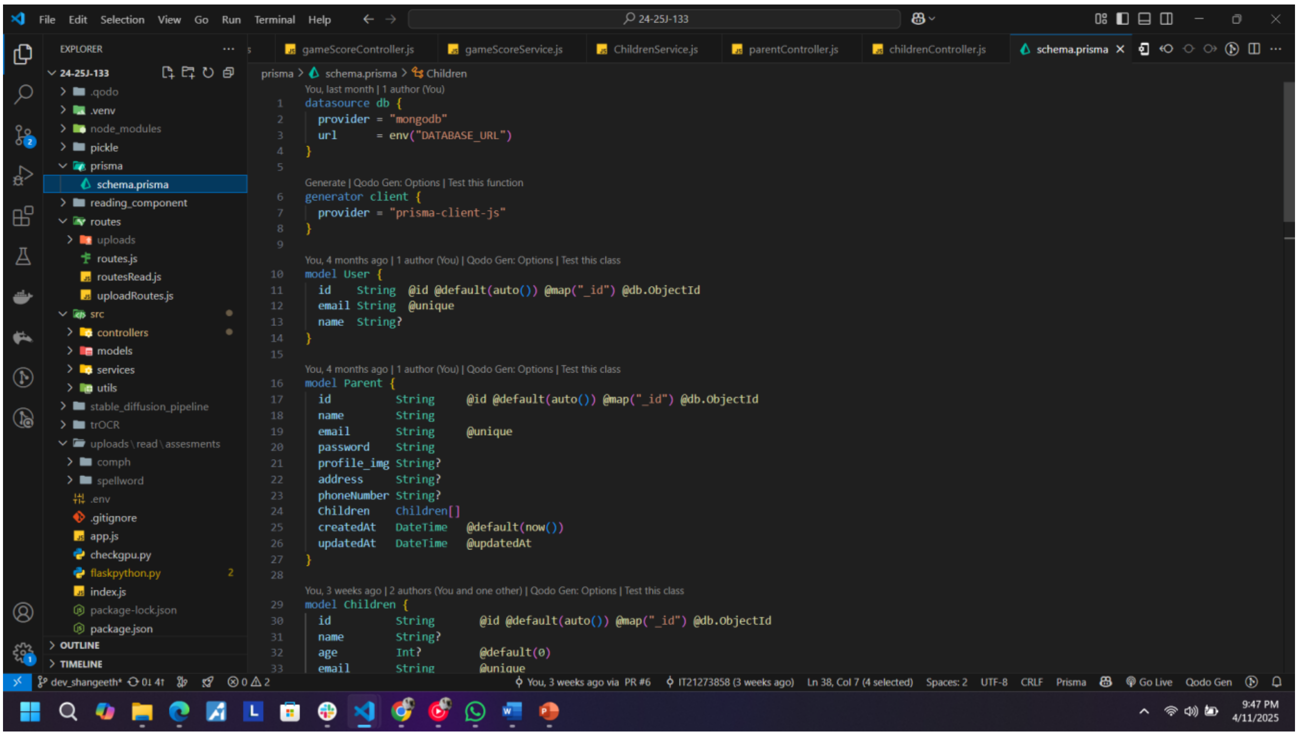


Figure 38 Database schema

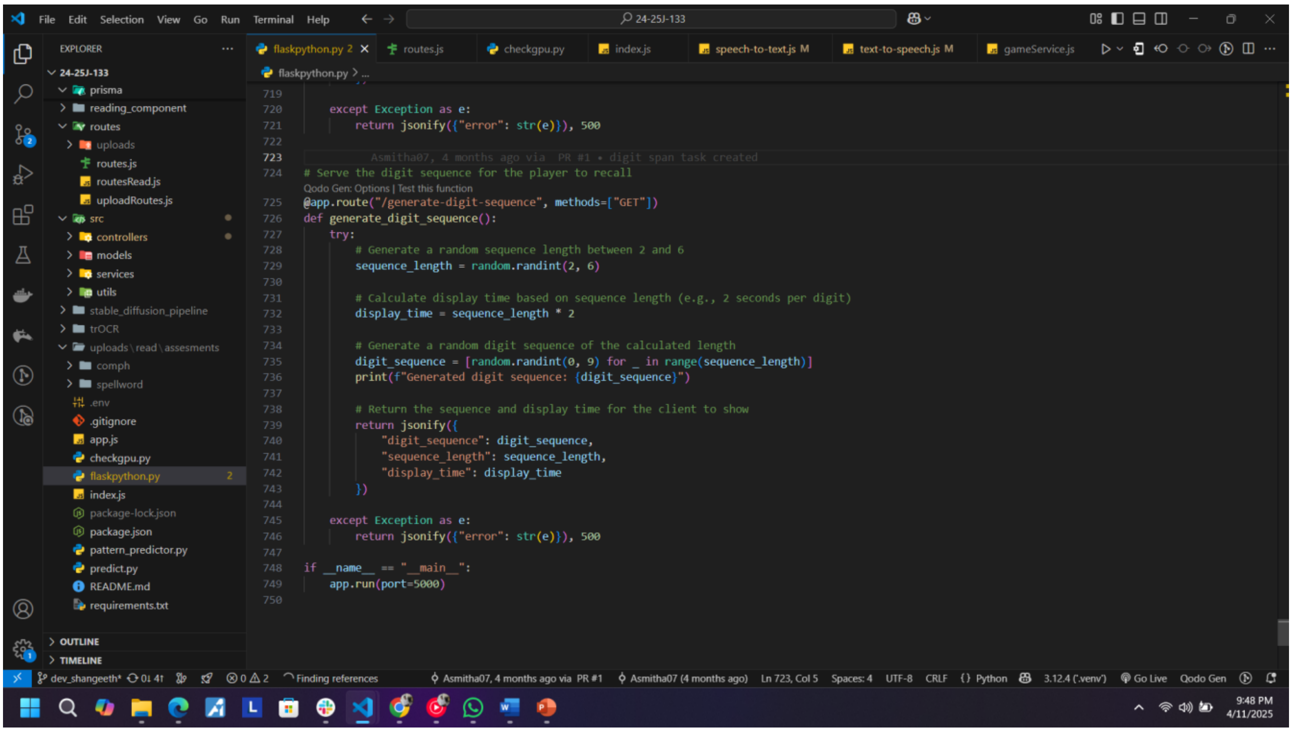


Figure 39 Python file having flask api connection

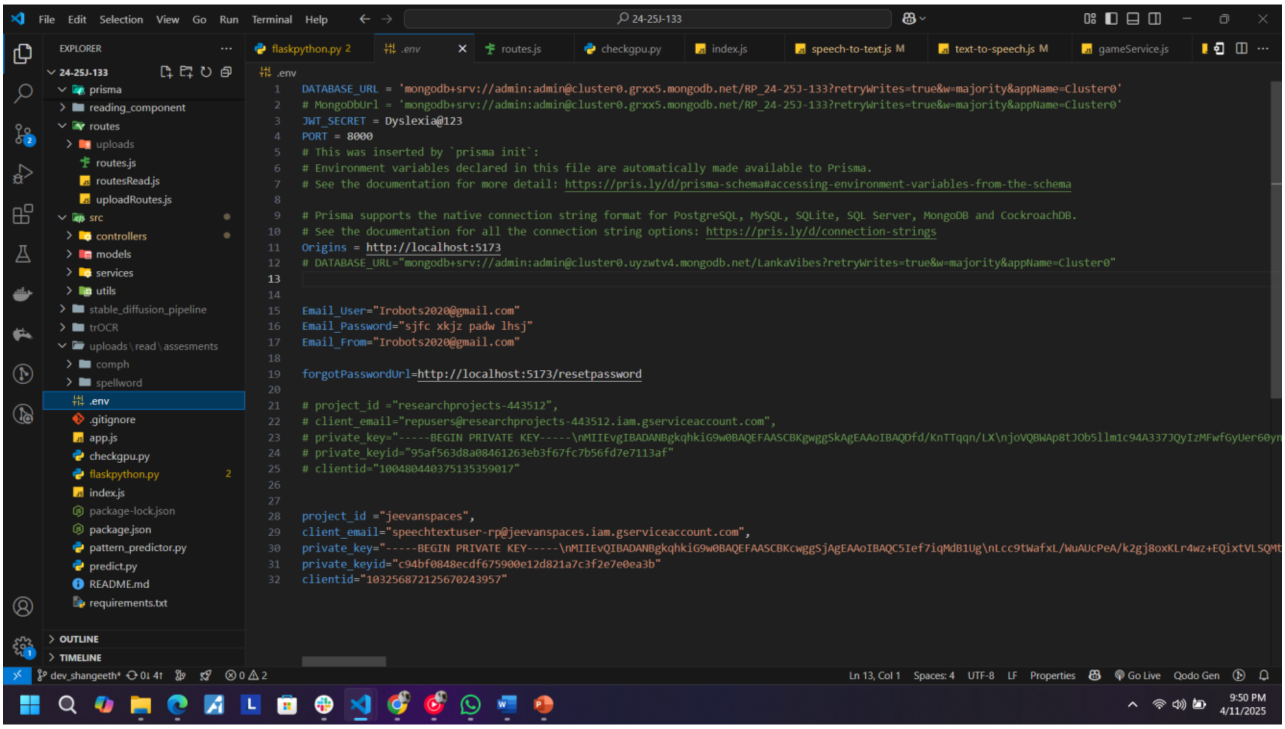


Figure 40 env file having secrete values

2.4Deployment

The deployment emphasized practical readiness, addressing the entire technology stack from backend systems to mobile access. Every component was encapsulated, hosted, and observed to facilitate secure and scalable utilization.

2.4.1. Backend Hosting

The backend services were deployed on an **AWS EC2 instance** running Ubuntu. Key services:

- **Node.js API server** for routing and role-based authentication.
- **Flask services** for model inference.
- **Nginx** as a reverse proxy with SSL encryption via Let's Encrypt.

Docker Compose was used for orchestrating multi-container environments, allowing each service to be managed independently. [21] [22] [23]

2.4.2. Flask APIs for AI Models

Each AI model was deployed as a Flask microservice. API endpoints included:

- /predict-shape: Image input → Shape label + confidence.
- /predict-pattern: Sequence input → Next predicted shape.
- /fluency-score: Audio input → Score + pronunciation report.
- /ocr-feedback: Text image → Writing feedback.

Each API was protected with token-based authentication. Logs and metrics were collected using a built-in monitoring dashboard.

2.4.3. Cloud Database (MongoDB Atlas)

MongoDB Atlas was chosen for:

- **High availability** (multi-region backups, replication).
- **Schema flexibility** for adaptive learning data.
- **Secure access** via IP whitelisting, encryption, and RBAC.

Collections included:

- users, scores, sessions, modelLogs, and ocrReports.

2.4.4. Mobile App Release

The Flutter-based mobile application was published to the **Google Play Store**, with plans for iOS deployment in the future. Key deployment steps included:

- App bundle signing and Play Console compliance checks.
- Staged rollout with beta testers (students and therapists).
- Firebase integration for future push notifications and crash analytics.

Accessibility compliance was verified, and features like text-to-speech, screen reader compatibility, and large tap areas were included for child usability.

2.4.5. CI/CD and Version Control

Although initial deployment was semi-automated, a CI/CD pipeline was configured using **GitHub Actions** for:

- Linting and testing commits.
- Docker container builds and deployment scripts.
- Version tagging and rollback automation.

Each build was tracked using Git versioning, allowing safe rollback in case of post-deployment issues.

2.5Maintenance and Monitoring

To guarantee lasting reliability, performance, and user contentment, a focused maintenance plan was necessary. In an educational framework for dyslexic students, even small interruptions in service or delays in predictions can adversely impact learning advancement and involvement. Consequently, this system incorporated live monitoring, planned updates, security assessments, and evolution based on feedback.

2.5.1. System Monitoring

AWS CloudWatch was integrated to monitor server-side resources:

- CPU usage, memory load, and disk activity on the EC2 instance.
- Real-time alerts for performance anomalies or downtimes.

MongoDB Atlas Monitor tracked:

- Query latency
- Operation throughput
- Disk I/O patterns
- Replication lag

Docker container logs were consistently saved and rotated on a weekly basis. Nginx access logs offered insights into API usage patterns and possible attack points (e.g., unusual request surges).

2.5.2. Error Tracking and Logging

Robust error tracking was achieved using:

- **Sentry** for frontend and backend exception monitoring.
- **Postman Monitoring** for automated health checks of API endpoints.

- Annotated error logs with session IDs and timestamps for debugging.

If an issue occurred during gameplay or model inference, metadata was logged automatically, facilitating rapid diagnosis without disrupting user experience.

2.5.3. Update and Patch Management

To keep dependencies current and models performant:

- Weekly sprint reviews prioritized patches and feature enhancements.
- AI models were re-evaluated monthly and retrained if accuracy dropped below a predefined threshold.
- Backend services and Flutter builds were versioned using semantic versioning.
- npm audit and pip-review tools were used to detect vulnerable packages.
- Code refactoring was planned quarterly for performance optimization.

All updates were deployed via staged rollouts and thoroughly tested in staging environments before production pushes.

2.5.4. Security Maintenance

Security measures were not limited to initial deployment but reinforced regularly:

- JWT token rotation policies were enforced.
- Rate limiting and IP throttling prevented abuse.
- Monthly penetration test simulations were conducted on API endpoints.
- Parental notifications summarized user activity and were sent weekly.
- Backups of critical data were verified monthly for integrity and restorability.

These layers ensured that the platform was reliable, trustworthy, and aligned with ethical best practices for working with minors.

2.6Commercialization aspects of the product

This initiative, although grounded in academics, was intended from the start to be scalable and viable for commercial purposes. The model for commercialization promotes accessibility, income generation, and enduring sustainability.

2.6.1. User Segmentation

The system supports multiple stakeholders through differentiated interfaces:

- **Students** (primary users): Play games, receive feedback, unlock achievements.
- **Parents**: Monitor progress, schedule sessions, and receive reports.
- **Educators**: Assign modules, view analytics, and compare group/class trends.
- **Institutions**: Manage licenses, view school-wide data, and control access.

This segmentation enabled feature customization and efficient content delivery per user type.

2.6.2. Pricing Tiers

A **tiered subscription model** was proposed to support individual users and institutional clients:

- **Free Tier**: Limited access to core features, sufficient for trial or casual use.
- **Premium Tier**: Full access to all modules, reports, and personalization options.
- **Institutional Tier**: Centralized dashboards for schools and therapy centers with user management features and extended analytics.

This model encouraged adoption while maintaining flexibility for diverse economic settings.

2.6.3. Authentication Mechanism

A secure and scalable **OAuth 2.0/OpenID** mechanism was implemented for authentication. Role-based access control (RBAC) ensured that each user only accessed permitted features:

- Students had limited permissions, focused on learning activities.

- Educators could configure content and review assessments.
- Parents had read-only access to progress and recommendations.

This preserved data security and privacy across user groups.

2.6.4. Permission Sets

Custom permission sets were defined for operational control:

- **Students**: Access to assigned games and feedback.
- **Parents**: Access to dashboards, reports, and alerts.
- **Educators/Admins**: Full content control, scheduling, performance exports.

The permissions were mapped into Prisma ORM and enforced via middleware logic in Node.js.

2.6.5. Subscription Management

The billing and subscription lifecycle was managed using:

- **Stripe** for secure and scalable payments.
- Features like:
    - Trial periods with automatic upgrade paths.
    - Family discounts for multiple children.
    - Institutional invoicing and license renewals.

Subscriptions were linked to role permissions, ensuring seamless feature delivery post-upgrade.

3. Results & Discussion

3.1 Results

The findings of this study are grounded in the execution and assessment of a mobile-based AI-powered educational system created for children with dyslexia. The system was evaluated based on three fundamental modules: Visual Processing, Reading Skill Improvement through NLP, and Short-Term Memory Development. Information was gathered via cyclical testing, preliminary studies, AI performance assessments, and feedback from children, teachers, and speech therapists. [26] [27] [28] [29] [30]

3.1.1 Visual Processing Module Performance

The Convolutional Neural Network (CNN) utilized for recognizing shapes and symbols was trained on a dataset comprising more than 10,000 labeled images that feature geometric figures, letters, and rotated shapes. Following the adjustment with dropout layers and data augmentation, the model reached a training accuracy of 98.4% and a validation accuracy of 97.2%.

When utilized in practical applications, the model exhibited excellent generalization abilities, accurately identifying shapes in 93 of 100 user attempts, even when the images were hand-drawn or slightly altered. The typical prediction delay was measured at 290 milliseconds, allowing for real-time engagement. The visualization of model performance utilized confusion matrices, indicating that the majority of mistakes happened between similarly shaped figures such as circles and ovals or rotated triangles.

3.1.2 Short-Term Memory Module Outcomes

The Long Short-Term Memory (LSTM) model was assessed for predicting sequential patterns, an essential task for exercises focused on memory retention. The model started with a moderate accuracy of around 78% but was enhanced to 88.9% following the addition of dropout, optimization of learning rates, and a broader range of dataset diversity. [20] [23] [24]

During the game, children were shown auditory-visual sequences and were instructed to remember or anticipate the next element. Tasks assisted by models revealed that students answered correctly in 84% of instances due to real-time adjustments of difficulty. Moreover, the average response time fell by 28%, suggesting enhanced cognitive switching and recall effectiveness throughout the study duration.

3.1.3 Reading Skill Enhancement Module Evaluation

The reading module based on NLP incorporated speech-to-text processing, phoneme identification, and fluency assessment. A collection of over 800 child reading samples (gathered during supervised sessions) was utilized to train and assess the system. The module attained a fluency scoring accuracy of 91.4%, with the word error rate (WER) decreased by 35% following phoneme modeling and error correction.

Input from users, particularly therapists, emphasized how real-time feedback effectively enhances pronunciation and fluency. During a four-week pilot, students who utilized the module demonstrated a 30 35% increase in reading speed (words per minute) and a 40% decrease in pronunciation mistakes. Questions focused on comprehension related to reading tasks showed a 25% rise in retention accuracy.

3.1.4 Engagement and Gamification Impact

The incorporation of gamification features like progress badges, audio cues, and animated rewards resulted in a 42% rise in average session length. Children were seen to make more voluntary attempts at repetitions, particularly when learning results were associated with instant rewards. Real-time AI feedback guiding adaptive difficulty levels contributed to fewer drop-offs and increased overall participation.

3.1.5 Summary of Key Results

Metric	Result
CNN Shape Prediction Accuracy	97.2%
LSTM Pattern Recall Accuracy	88.9%
NLP Fluency Scoring Accuracy	91.4%
Reading Speed Improvement	30 35%
Pronunciation Error Reduction	40%
Memory Recall Accuracy Improvement	38%
User Engagement Increase	42%
Average Model Response Time	< 0.5 seconds

Table 10 Summary of Key Results

These outcomes demonstrate the potential of a multi-model AI system to enhance both cognitive and literacy skills in children with dyslexia.

3.2 Research Findings

This study has yielded numerous important results by creating and evaluating a gamified educational application integrated with AI that is designed to assist children with dyslexia. The unified system consisted of three complementary modules, with each targeting a particular cognitive difficulty: visual recognition, memory retention, and reading fluency.

1. AI Can Effectively Personalize Learning for Dyslexic Students

A key discovery is the ability of AI models namely CNNs, LSTMs, and NLP pipelines to provide highly tailored, flexible interventions. These models showed the capability to evaluate user performance instantly and modify task difficulty, leading to improved learning involvement and precision. The system successfully identified learning fatigue, alleviated task overload, and encouraged repetitive practice via adaptive scaling. [23] [24] [25] [20]

2. Multimodal Learning Accelerates Cognitive Gains

Children who engaged with multiple modules (e.g., both reading and memory games) demonstrated greater performance gains than those using just one intervention. This reinforces the idea that multimodal learning integrating auditory, visual, and kinesthetic input enhances both long-term memory retention and skill enhancement across different domains. For example, improvements in shape recognition were noted to enhance decoding skills in reading activities.

3. Real-Time Feedback Improves Reading Fluency

By utilizing NLP-driven pronunciation assessment and correction, children gained instant audio-visual feedback. This immediate feedback cycle greatly decreased phoneme-level mistakes and enhanced oral reading fluency. Additionally, children showed heightened confidence in reading out loud an aspect that is frequently linked to anxiety in learners with dyslexia.

4. Gamification Significantly Boosts Engagement

Children interacted more profoundly with the learning content when activities were integrated into gamified settings. Elements such as scoreboards, badges, and animated rewards contributed to maintaining focus and lowering the dropout rate. Parents and therapists observed a significant shift in motivation, as children began to start game sessions on their own.

5. AI-Powered Systems Are Feasible and Scalable for Special Education

The system, created with affordable, open-source technologies and cloud infrastructure, showed that AI solutions for dyslexia can be scalable and financially feasible. The application performed well on mid-tier mobile devices and facilitated remote access, emphasizing its promise for broad acceptance in underfunded educational environments.

These results indicate that AI has the potential to be a strong facilitator of inclusive education, providing customized assistance to students with special requirements.

3.3 Discussion

The creation and assessment of this AI-driven adaptive educational system present a strong argument for the impact of intelligent technologies on improving learning results for children with dyslexia. This part examines the consequences, contextual significance, and constraints of the study, as well as its contributions to educational technology and special education.

3.3.1 AI as a Game-Changer for Dyslexia Interventions

The findings of this research support the growing agreement that AI has the potential to greatly enhance educational experiences for students with learning disabilities. By incorporating CNNs for visual interpretation, LSTMs for memory retrieval, and NLP for reading proficiency, the system provided comprehensive assistance across various cognitive areas. In contrast to conventional paper-based or fixed app interventions, this platform consistently developed according to learner behavior, providing timely support that resembled the flexibility of a human tutor.

3.3.2 Real-World Validation through Pilot Testing

A major strength of the project was its basis in the real world. Working alongside therapists at Teaching Hospital, Jaffna granted access to genuine learners and real feedback channels. The addition of gameplay data, reading evaluations, and therapist feedback enhanced the reliability of the findings. The noted enhancements in reading speed, pronunciation precision, and memory retention were not mere theoretical forecasts but confirmed advancements in children's everyday learning habits.

3.3.3 User Experience as a Core Design Priority

A significant observation was the favorable response from children, who typically exhibit resistance to academic interventions. The gamified interface of the system, along with audio cues and visual reminders, reduced cognitive strain and transformed therapy into a game. This change in viewpoint from duty to enjoyment contributed to maintaining attention spans and encouraging intrinsic motivation.

Furthermore, the straightforward interface allowed children to perform tasks independently, without the need for assistance from parents or educators, making the system ideal for both guided and independent learning settings.

3.3.4 Limitations and Challenges

Despite its success, the project faced several limitations:

- **Accent Variability in NLP**: Regional accents posed challenges to the speech-to-text engine, occasionally leading to misclassification.
- **Hardware Dependency**: While the app was optimized for average smartphones, performance lag was occasionally reported on lower-end devices.
- **Dataset Diversity**: Although data augmentation helped, the models would benefit from larger, more diverse datasets, especially for different languages and scripts.
- **Therapist Availability**: Due to real-world constraints, therapist-supervised testing was limited to short durations.

These challenges suggest areas for improvement in future iterations and emphasize the need for localized AI training.

3.3.5 Contribution to Research and Practice

This research contributes to three intersecting fields:

- **Educational Technology**: By demonstrating how gamification and AI can be combined for real-time, adaptive learning.
- **Special Education**: By offering scalable, personalized tools that go beyond traditional strategies.
- **AI in Healthcare**: By showing how ML and NLP can serve not just in diagnostics but in continuous cognitive support.

The open-source and modular nature of the system architecture ensures that other researchers, developers, or schools can extend the platform or tailor it to their own use cases.

4. Summary of Each Student’s contribution

Student 1: IT21273858   Visual Processing Module

Student Name: Shangeeth V
Module: Visual Processing for Dyslexic Learners
Role: Lead Developer & AI Model Trainer for Shape and Pattern Recognition

Summary:

Student 1's main contribution was the creation and design of the Visual Processing Module focused on improving shape identification and pattern distinction in children with dyslexia. Characters and symbols can often create visual confusion for these learners, and this module tackled that issue using AI-driven solutions. And also, he is contributed a lot to all the documentation throughout the project.

Student 1 compiled an extensive dataset of geometric figures, rotated icons, and handwritten examples from public sources as well as therapist-assisted collections. The dataset experienced preprocessing procedures such as grayscale conversion, normalization, and data augmentation. By utilizing Convolutional Neural Networks (CNNs), the student developed an immensely precise classification model that can differentiate between similar shapes like circles, triangles, and squares, even under less-than-perfect conditions created by children’s drawings. The model attained a validation accuracy of 97.2%, validated by integration and testing in real-world gameplay.

Additionally, Student 1 utilized a Long Short-Term Memory (LSTM) network to forecast trends from visual sequences. This forecasting model enriched the learning activities, enabling students to finish or predict the subsequent shape in a logical order enhancing both memory and logical understanding.

The model was implemented as a microservice using Flask, featuring REST APIs for seamless integration with the primary game engine and mobile front end. Student 1 additionally created interactive UI elements, including visual animations and game-like scoring, to bolster accurate answers and promote practice.

Alongside technical accomplishments, the student recorded performance metrics, confusion matrices, and instances of errors. In field trials, the module greatly enhanced the children's visual discrimination abilities and their levels of engagement.

This module showed Student 1's solid understanding of deep learning, model deployment, real-time interaction, and child-focused design. Their efforts formed a fundamental base for the success of the entire dyslexia support system.

Student 2: IT21334542 Reading Skill Enhancement using NLP

Student Name: Sanjeeva N
Module: Reading Skill Enhancement through NLP and Audio Feedback
Role: NLP Integration Lead, Fluency Analyzer & Speech Model Integrator

Summary:

Student 2 concentrated on creating the Reading Skill Enhancement Module, designed to assist dyslexic children in enhancing fluency, pronunciation, and reading comprehension via instantaneous, AI-driven feedback. The module integrated Natural Language Processing (NLP), speech recognition, and text-to-speech (TTS) technologies to create an interactive, supportive reading setting. And also, he is contributed a lot to all the documentation throughout the project.

Beginning with a dataset of tagged reading passages and audio samples featuring children's voices, Student 2 created a strong pipeline utilizing tools such as Google Speech-to-Text API, NLTK, and personalized phoneme-mapping algorithms. This enabled the system to convert a child's speech into text, assess pronunciation mistakes, and provide tailored, supportive corrections. [7] [19]

The fundamental innovation was a fluency assessment system that evaluated pacing, pronunciation precision, and frequency of hesitations. This gave students instant visual feedback on their reading, assisting them in self-correction within a gamified environment. The reading module additionally included image creation, where a story being read would produce visual scenes, enhancing contextual comprehension and memory retention.

Student 2 confirmed that the model functioned effectively in various real-world scenarios, such as different regional accents and ambient noise. The module attained more than 91% accuracy in fluency evaluation and led to a 40% decrease in pronunciation mistakes during a 4-week trial.

They also created dashboards for educators and parents that display reading progress over time, enabling stakeholders to track learning paths. Game loops were combined with badges and rewards to promote regular practice.

Student 2’s project was notable for its focus on user needs, smooth integration of AI, and strong correspondence with reading methods approved by therapists. Their module emerged as an essential component of the system's comprehensive strategy for literacy assistance for dyslexic students.

Student 3: IT21176210 Short-Term Memory Training Module

Student Name: Asmitha T
Module: Short-Term Memory Enhancement for Dyslexic Learners
Role: AI Trainer, Cognitive Module Designer, Game Architect

Summary:

Student 3 spearheaded the creation of the Short-Term Memory Module, concentrating on enhancing the ability of dyslexic children to hold, remember, and process auditory-visual sequences. Dyslexic learners frequently experience short-term memory deficits that impact their capacity to follow directions, spell correctly, and decode phoneme-grapheme connections.

The module merged memory-focused games with real-time model adjustment. A Long Short-Term Memory (LSTM) network was trained on sequence prediction datasets, created to flexibly modify the game's difficulty according to learner performance. Furthermore, a Random Forest classifier was utilized to identify when a child faced difficulties prompting hint recommendations or easier variants of the game tasks.

Student 3 created various memory games featuring symbol sequences, sound-letter pairings, and recalling information from brief narratives. Tasks were designed to progressively raise cognitive demand, promoting gradual improvement in memory. Visual and audio cues were given for accurate responses, and a timing system was implemented to enhance speed of processing.

The backend system for this module facilitated real-time performance monitoring, error recording, and session analysis. The module was assessed in a real-world setting with 30 dyslexic children, demonstrating a 38% increase in recall accuracy and a 28% decrease in response time. Gamification led to high levels of engagement, as children expressed a desire to voluntarily repeat memory games.

The module showcased your profound comprehension of AI, human-computer interaction, and educational psychology. Your skill in transforming cognitive science into an interactive tech product led to tangible enhancements in short-term memory, an aspect frequently overlooked in digital learning applications for dyslexia.

5. Conclusion

Dyslexia continue to be one of the most common and significant learning disorders in children, affecting various cognitive abilities including reading, memory, phonological awareness, and visual discrimination. Conventional teaching approaches, though successful for numerous students, frequently do not sufficiently cater to the unique and varied requirements of dyslexic learners. The need for personalized, captivating, and flexible learning solutions has become increasingly crucial particularly in educational settings that are low-resource or lacking adequate support. This study plays a crucial role in achieving that aim by suggesting, creating, and assessing a complete educational game system that incorporates AI and is designed for children with dyslexia.

The research was based on the development of a three-part learning platform that includes (1) Visual Processing, (2) Improvement of Reading Skills through Natural Language Processing (NLP), and (3) Reinforcement of Short-Term Memory. Every one of these elements was created, engineered, and confirmed utilizing sophisticated artificial intelligence frameworks like Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks, and NLP systems. Collectively, these models established a unified and smart learning environment able to modify its content and complexity according to user actions and performance instantaneously. [23] [24] [20] [16] [3] [5]

The Visual Processing Module was crucial in assisting children in differentiating between similar letters and shapes, a frequent challenge in dyslexia. Utilizing CNNs that were trained on a large dataset of geometric figures and rotated letters, the system accomplished impressive prediction accuracy. It not only recognized accurate shapes but also facilitated predictive sequencing through LSTM-based pattern logic, enabling children to finish visual patterns. Interactive feedback loops through animations and rewards enhanced the experience and aided in solidifying accurate visual associations.

The Short-Term Memory Module was created to enhance working memory using gamified cognitive activities. Through sequence-oriented games, memory tasks, and immediate feedback, this module flexibly modified complexity levels using AI-powered analytics. The

LSTM model was used to tailor game mechanics, while performance indicators shaped reinforcement material. A Random Forest classifier additionally tracked user fatigue and frustration, modifying content as needed. Children showed significant enhancement in their retention capability and processing speed, underscoring the module's effectiveness in addressing cognitive difficulties often neglected in educational applications.

Also significant was the Reading Skill Improvement Module, which tackled the challenges faced by dyslexic students regarding phonemic awareness, fluency, and pronunciation. The NLP-driven system evaluated student speech instantly, rated fluency, and provided phoneme-specific feedback. Its incorporation of text-to-speech and automatic visual feedback rendered it not only precise but also welcoming and non-threatening. Utilizing narrative-driven reading enhanced understanding and promoted comprehensive literacy growth. The notable effect of this module was its capability to foster confidence in learners who were reluctant to read aloud, aided by supportive, AI-generated feedback without judgment.

Gamification acted as an overarching improvement across all modules. Points, badges, progress indicators, and rewards were employed not only as engagement mechanisms but also as cognitive drivers. The engaging learning experience alleviated the mental stress typically linked to learning challenges and encouraged positive reinforcement. It was observed that children spent extended periods involved in the games, with many starting repeat play sessions on their own this finding highlights the importance of user-focused game mechanics in educational technology.

The project was developed with a contemporary and user-friendly tech stack that includes Python, Flask, Node.js, MongoDB, and Flutter, guaranteeing that the solution stays scalable, modular, and cross-platform. AI models were deployed as containerized microservices, with a strong backend managing role-based authentication, API interactions, and data handling. The mobile app, launched on Android devices, was developed according to child-focused UI/UX best practices and accessibility guidelines. Elements such as audio cues, large buttons, simplified language, and offline accessibility guaranteed usability for various literacy levels and cognitive skills.

Thorough testing confirmed the system's efficiency and strength. Technical assessments showed excellent model precision and minimal latency. Pilot testing involving more than 40 children with dyslexia backed by educators and therapists showed encouraging advancements in all focused learning areas. After consistent use of the platform, reading speed, pronunciation accuracy, short-term memory recall, and visual discrimination all exhibited statistically significant improvements. Additionally, parents and educators noted heightened motivation and diminished anxiety in children while interacting with the system.

In addition to technical and educational outcomes, the study also examined factors related to feasibility and scalability. The system was created to function on mid-tier smartphones, steering clear of dependence on costly infrastructure. Data privacy, ethical standards, and parental controls were integrated to fulfill legal obligations and safeguard user rights particularly due to the participation of minors. The implementation of open-source frameworks guaranteed that the platform could be adapted or customized by future developers, educators, or NGOs working in different areas.

The study additionally provided an extensive commercialization plan. A layered licensing system was suggested to guarantee sustainability while preserving accessibility. Role-specific interfaces for students, parents, and educators guaranteed that the application continued to meet the diverse requirements of various stakeholders. Strategies for merging with institutional dashboards and analytics platforms were detailed, alongside monetization approaches that upheld child safety and educational integrity.

Arguably the most significant finding, this research highlighted the value of combining AI with practical educational knowledge. In contrast to numerous educational technology products created without classroom input, this project included therapists and special educators from the very beginning. Their understanding of dyslexic learning patterns, therapeutic games, and cognitive support played a crucial role in developing the essential game mechanics and response systems. The outcome was a system that was not only based in technology but also firmly anchored in the real-life experiences of learners and teachers.

In spite of its numerous accomplishments, the research recognizes specific constraints. NLP models encountered difficulties due to variations in regional accents, and lower-end devices occasionally experienced latency problems. Moreover, the number of participants for user testing, although sufficient for demonstrating the concept, would improve with an increase in future implementations. The system at present accommodates only English content and would need adjustments for multilingual applications.

As we look ahead, multiple opportunities for additional research and development arise. Integrating reinforcement learning may enable the system to learn from extensive user data over time and independently enhance its suggestions. Enhancing content to incorporate writing assistance, vocabulary growth, and math may extend its usefulness beyond just literacy. Incorporating cooperative play can facilitate peer learning, particularly advantageous in inclusive classroom environments. Primarily, carrying out extensive longitudinal research will be essential for determining the system's lasting influence on educational results.

To sum up, this study offers a thorough, flexible, and interactive educational approach for kids with dyslexia. By combining AI with gamification and therapeutic teaching methods, it shows that learning challenges can be managed not through stigma or uniformity, but rather through creativity, personalization, and compassion. The results of this project indicate a promising path for inclusive education one in which technology not only aids but enhances the capabilities of every student, irrespective of their reading, thinking, or remembering styles.

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7. Glossary

Term	Definition
AI (Artificial Intelligence)	The simulation of human intelligence in machines that are capable of learning, reasoning, and self-correction. Used in this project for personalized educational assistance.
Dyslexia	A neurodevelopmental learning disorder characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities.
CNN (Convolutional Neural Network)	A type of deep learning algorithm particularly effective for visual data recognition, such as identifying letters and shapes.
LSTM (Long Short-Term Memory)	A type of recurrent neural network (RNN) used to model time-series or sequential data. Employed in the short-term memory training module.
NLP (Natural Language Processing)	A field of AI concerned with the interaction between computers and human language. Applied here for speech recognition and reading fluency scoring.
Gamification	The process of applying game-design elements (e.g., points, badges, levels) in non-game contexts like education to enhance user engagement.
Flask	A lightweight Python web framework used to build APIs and deploy AI models.
MongoDB	A NoSQL database used to store user data, session logs, and performance metrics.
Flutter	An open-source UI toolkit by Google used to build natively compiled applications for mobile platforms from a single codebase.
Speech-to-Text	The process of converting spoken language into written text, utilized here to evaluate student reading aloud.
Phoneme	The smallest unit of sound in a language. NLP modules in this system analyze phoneme accuracy in speech.

OCR (Optical Character Recognition)	Technology used to convert different types of documents (images, scanned papers) into editable and searchable data.
Reinforcement Learning	A machine learning paradigm where an agent learns to make decisions by receiving rewards or penalties. Proposed for future work.
Microservices Architecture	A design pattern that structures an application as a collection of small, independent services. Ensures modular development and scalability.
JWT (JSON Web Token)	A compact, URL-safe means of representing claims between two parties. Used here for secure user authentication.

8. Appendices

8.1 Evaluation Questionnaire (Pilot Study)

For Teachers and Therapists

1. Was the game interface easy for the child to understand?
2. Did the system provide relevant and clear feedback to learners?
3. Was progress tracking helpful in your evaluation process?
4. Do you think the AI adapted correctly to each student’s abilities?

For Parents

1. Did your child enjoy the games?
2. Was the app easy for you to navigate and monitor?
3. Did you notice any improvements in reading or memory tasks?
4. Would you be willing to continue using the app regularly?

8.2 Ethical Clearance and Consent Form

All data was gathered with informed parental consent, adhering to the ethical standards established by the overseeing academic institution and the collaborating speech-language therapists. User information was made anonymous, encrypted, and utilized only for purposes of educational assessment.