NON-VERBAL LEARNING DISABILITY (NVLD) IN AGE 10-13 CHILDREN

Project Id: 24-25J-150

Dissertation Report

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B.Sc. (Hons) Degree in Information Technology Specializing in Information Technology.

Department of Information Technology

Sri Lanka Institute of Information Technology

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PERSONALIZED LEARNING PATHS THROUGH INTERACTIVE VOCABULARY ASSESSMENTS

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DECLARATION

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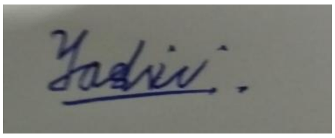
Signature:  Date:2025/03/26

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ABSTRACT

This study introduces Personalized Learning Paths Through Interactive Vocabulary Assessments, a key feature of an educational application designed to support children aged 10–13 with Non-Verbal Learning Disorder (NVLD). NVLD is characterized by difficulties in spatial awareness, problem-solving, and communication, often affecting language comprehension. The application provides an adaptive, engaging, and structured vocabulary-learning experience tailored to each learner's needs.

A Random Forest Classifier analyzes performance patterns, adjusting difficulty levels dynamically based on accuracy, response time, and prior learning history. Levels unlock progressively based on competency (e.g., 5/10 correct answers in under one minute per question advances the learner). Two bonus levels—Calculation Improvement and Time Identification—reinforce cognitive skills. The system enhances vocabulary acquisition, long-term memory retention, and cognitive development through real-time feedback and adaptive techniques, improving educational outcomes for NVLD children.

Keywords: Nonverbal Learning Disorder (NVLD), Vocabulary Acquisition, Personalized Learning Paths, Adaptive Learning, Interactive Learning

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LIST OF ABBREVIATIONS

Abbreviation	Description
NVLD	Non-Verbal Learning Disorder
AI	Artificial Intelligence
ML	Machine Learning
API	Application Programming Interface
OCR	Optical Character Recognition

Chapter 1

INTRODUCTION

Non-Verbal Learning Disorder (NVLD) affects children's abilities in language development, particularly in word recognition, long-term memory retention, hand-eye coordination, and cognitive processing. These challenges often hinder academic performance and quality of life. This study proposes the Personalized Learning Paths through Interactive Vocabulary Assessment (PAV) system to enhance vocabulary acquisition and cognitive development in NVLD children aged 10–13.

The system features interactive games that challenge learners across various levels, incorporating activities such as matching words with images, completing sentences by filling blanks, and identifying word relationships. Progression occurs upon mastering each level, with increasing complexity. Questions are organized by themes and customized by answering format, with randomization preventing memorization and promoting deep learning.

- **Thematic Categorization:** Early levels focus on familiar themes (e.g., body parts, colors), advancing to abstract themes (e.g., vehicles). Two bonus levels enhance skills:

1. **Calculation Improvement Level:** Combines word recognition with arithmetic.
2. **Time Identification Level:** Develops time-reading abilities.

- **Answering Format Customization:** Levels 1–2 offer multiple-choice answer selecting, or writing, or speaking options. From level 3 onwards, formats are randomly assigned as" Speaking" or" Writing," fostering adaptability.

This approach, targeting NVLD-specific vocabulary, was informed by months of research.

1.1 Background and Literature Survey

1.1.1 Background

Non-Verbal Learning Disorder (NVLD) is a complex, unique neurological condition in which there is a specific difference between a child’s high levels of verbal ability and extreme deficits in visual-spatial reasoning, motor coordination, and non-verbal communication skills. Though NVLD children have no trouble memorizing and repeating back tremendous amounts of verbal information, they do poorly when it comes to reading between the lines of speech, anything fancies there being body language or facial expressions or gestures. It usually manifests as problems in understanding these kinds of abstract concepts like mathematical reasoning, spatial orientation, and levels of subtle or implied meaning (academic and social).

One difficulty that can be especially challenging for kids with NVLD is learning vocabulary. Often, they can memorize word definitions, but they have difficulty using them in context. This is because it doesn't have the contextual reasoning and visual processing ability necessary to develop an understanding of how language functions in a living world. With this goal, mainstream vocabulary learning techniques (e.g. images (mind maps, flashcards), inference-based activities, stories) are mostly unsuccessful in such children. That literal-mindedness, common among some people with NVLD, means they frequently miss out on anything figurative or implied behind what people say, including tone, context and body language.

Moreover, NVLD may interfere with the kind of social interaction that typically drives vocabulary growth in other children. A manifestation of this weakness is having trouble catching the nuances of non-verbal communication leading to social isolation or social awkwardness that further constricts opportunities to engage in rich, language-building exchanges with peers and adults. They have become less socialized because they talk less frequently, and therefore the vocabulary is improved in a more natural conversation in a sentence.

The challenges notwithstanding, tech, especially AI and gamification offers the solutions that are promising and adaptable. AI-based systems can deliver vocabulary exercises tailored specifically for the individual student, adapting tasks according to the individual learner’s specific needs and level of progress. Using random and varied question formats can also help reduce rote memorization and encourage deeper cognitive processing (Schmidt et al., 2018). These systems can adjust to present live performance data to hit just the right pace of either difficulty or targeted practice.

In short, gamification means learning becomes interactive, with game-like experiences, adding another level of engagement and motivation. I can still have fun (rewards, points, levels, challenges) so that fear of words disappears. Time tracking on a task, accuracies, and improvement trends act as real-time feedback mechanisms that enable learners to reflect on performance and measure their progress. This method gives a more dynamic understanding of vocabulary terms, which helps children with NVLD both academically and socially.

1.1.2 Literature survey

This study draws up research into vocabulary acquisition and cognitive development; several key texts have already highlighted the promise for technological enhanced learning approaches:

Rahmah Fithriani (2021) [1] evaluates how far gamification is integrated into mobile-assisted vocabulary learning systems for English as a Foreign Language (EFL) learners. It shows how game elements such as points, leaderboards, and time challenges used in programs like Quizlet and Vocabulary Game can lead to better learning outcomes, motivation, and engagement. Fithriani's results indicated that gamification fostered an interactive environment which maintains the level of interest of learners, an essential element for children with NVLD who usually struggle in elementary education with attention and motivation (Fithriani, 2021). It also discusses the impact of immediate feedback on vocabulary retention but does not specifically focus on learners with NVLD or the effects of neurogenic etiology on response and feedback.

Boroughani et al. (2024) [2]), and a mini-review on mobile-assisted vocabulary learning (MAVL), summarizing the evidence on the effectiveness of the mobile flashcards with incorporated spaced repetition and gamification options. It explains that MAVL not only promotes independent learning but also yields long-term retention compared to yesterday's training methods, partly due to its use of adaptive repetition intervals that reinforce the memories at ideal times. In addition, the review highlights how mobile platforms, due to their multimedia delivery capabilities (e.g., audio-visual cues), are flexible and would be beneficial for NVLD learners and capitalize on their verbal strengths, though the study is not aimed at visual-spatial processing deficits per se. Such a gap highlights the need for adaptations specific to NVLD.

Xu Yanqiu (2022) [3] proposed an adaptive learning system based on machine learning techniques, namely AdaBoost, for learning the English vocabulary. The difficulty adjustment dynamically corresponds to the cognitive adaptability of students, which greatly improves the efficiency and reliability of learning. These are the principles very applicable to NVLD children who require the right pace for advancement to attack their failures in contextual reasoning, and Yanqiu's efforts show the power of AI-driven personalization that respects individual learning speed. The study includes seventh-grade EFL learners and allows for the opportunity to also integrate performance analytics to shape and personalize learning paths for generalization; hence it could be technically integrated to perhaps tailor this process for learners with NVLD without a loss of focus for EFL learners.

Dr. Elfrieda Hiebert (2025) [4] discusses the use of AI to improve vocabulary instruction, highlighting how high-utility words can be identified based on academic relevance and the frequency of words in text. Her research demonstrates how AI tools can help calculate the right vocabulary words and instructional sequences to maximize understanding, providing a model for arranging vocabulary content. NLD learners, which may have a strong memory for texts, but struggle with using abstract language, will find that Hiebert's observations about using AI to facilitate semantic mapping and contextual comprehension could be particularly useful. However, the overall educational focus of the study suggests there are opportunities to tailor these studies to the cognitive profiles associated with NVLD.

Kerz et al. (2019) [5] introduce AISLE, an adaptive language learning system designed to monitor vocabulary growth and adjust learning strategies relevant to individual trajectories. Data-driven methods to monitor the progress of learners and suggest activities, shown to be effective in promoting vocabulary in other cases. Indeed, as children with an NVLD continue to rely on the same process of reinforcement over time, this is likely to be an important factor if one tracks these students' performance in the long-term. And so while the shape-shifting nature of AISLE can be a powerful asset, without the application of NVLD specific blind spots pertaining to visual-spatial integration or gamified staking, it is less accessible to this population.

Taken together, these studies [1]– [5] highlight the effectiveness of technology-based solutions—specifically, gamification, adaptive systems, and AI-based personalization in enhancing vocabulary learning outcomes and engagement. The most obvious gap in the general and EFL-focused scopes is one addressing the relevant needs of children with NVLD visual-spatial processing, real-time feedback that caters to cognitive deficits, and accessibility and interaction-oriented interfaces. The aim of this research is to introduce a solution that aims to bridge this gap by providing personalized paths for learning, gamification and real-time analytics built specially for children with NVLD.

1.2 Research Gap

Existing research on vocabulary acquisition often overlooks NVLD-specific needs. The proposed system fills this gap with adaptive learning paths, touch screen integration, real-time feedback, and gamification tailored for NVLD children under 10-13.

1.3 Research Problem

NVLD children face unique cognitive challenges impeding vocabulary and cognitive growth. Current technologies lack NVLD-specific adaptations. This study designs a personalized, adaptive system to address these needs through gamified interventions.

Features	[5]	[6]	[2]	[3]	[7]	**Proposed**
Personalization	✓	✓	×	✓	×	✓
Adaptive Learning	✓	✓	×	×	×	✓
Real-Time Feedback	×	✓	×	×	×	✓
Gamification	×	×	✓	×	×	✓
Touch-Screen Interaction	×	×	×	×	×	✓
Cognitive Development	✓	✓	✓	✓	✓	✓
Focus on NVLD	×	×	×	×	×	✓

Table 1.3-1 Comparison of Existing Research with Proposed System

1.3.1 Key research challenges

1. **Personalization: Adapting to NVLD Cognitive Profiles:**
   Children with Nonverbal Learning Disorder (NVLD) exhibit a unique set of cognitive strengths and weaknesses. While they often have strong verbal skills, they may struggle with spatial awareness, motor coordination, and understanding nonverbal cues. A major challenge in designing educational interventions for these children is creating a system that adapts to their specific learning profiles. Personalization involves tailoring the difficulty level, instructional style, and types of vocabulary tasks to suit each child's capabilities, ensuring that the learning experience is both accessible and meaningful.
2. **Gamification: Engaging Without Overwhelming:**
   Gamification—the integration of game elements such as points, levels, and rewards—can increase motivation and engagement. However, for children with NVLD, overly complex interfaces or fast-paced challenges can lead to confusion or anxiety. The challenge lies in designing game-based vocabulary assessments that are visually simple, cognitively manageable, and emotionally supportive. The balance must be struck between making learning enjoyable and not overwhelming the learner.
3. **Real-Time Feedback: Offering Constructive Guidance:**
   Immediate feedback is essential in helping children know their score. For NVLD learners, the feedback must be clear, non-judgmental, and supportive. The system must provide explanations or hints that align with the child's way of processing information. The challenge is to develop feedback mechanisms that guide learners toward the improved vocabulary level in a way that builds confidence and understanding.
4. **Effectiveness: Measuring Learning Improvements:**
   To validate the success of the personalized vocabulary system, it is important to measure its impact on a child's vocabulary development over time. This involves tracking progress, identifying areas of growth, and determining whether the interactive games genuinely enhance learning outcomes. The challenge lies in designing reliable metrics and assessment tools that can capture subtle improvements in vocabulary skills, especially in children who may learn differently from their peers.

1.3.2 Assessment methodology

To evaluate the effectiveness of the Personalized Learning Paths through Interactive Vocabulary Assessments (PAV) system in comparison to traditional vocabulary learning methods, a mixed-method assessment approach was employed. This comprehensive methodology integrated both quantitative and qualitative techniques to ensure a well-rounded evaluation of the system's impact.

Quantitative data were collected through performance metrics, such as pre- and post-assessment scores, response accuracy, and completion times. These metrics were used to measure vocabulary acquisition, cognitive development, and overall improvement in learning outcomes.

Qualitative feedback was gathered through observations, and user satisfaction surveys involving children, educators, and caregivers. This provided insights into user engagement, ease of use, and perceived effectiveness of the interactive features.

A comparative analysis was also conducted, comparing the results of students using the PAV system to those using traditional vocabulary learning methods. This helped in identifying the system's strengths, areas for improvement, and its ability to meet the specific needs of children with NVLD.

Detailed findings, supporting data, and analysis are presented in Appendix A.

Study design

The assessment was conducted over a four-week period with a sample of 30 children aged 10–13 diagnosed with NVLD, divided into two groups:

- **Experimental Group (n=20):** Used the PAV system, engaging with adaptive levels, gamified tasks, and bonus levels (Calculation Improvement and Time Identification).
- **Control Group (n=10):** Employed traditional methods (e.g., paper flashcards, worksheets) facilitated by educators.

Participants were recruited through collaboration with medical centers, ensuring ethical consent from parents and assent from children. The groups were matched for age, NVLD severity (assessed via standardized diagnostic criteria), and baseline vocabulary knowledge.

Data collection methods

Multiple instruments were used to gather comprehensive data:

1. **Pre- and Post-Intervention Vocabulary Tests:** A 20-word test assessed retention and comprehension, administered before and after the study. Words were selected from PAV's thematic categories (e.g., body parts, vehicles) and matched for difficulty in the control group. Scoring was based on correct recall (1 point per word, max 20).
2. **Cognitive Skill Assessments:** Timed tasks measured arithmetic (10 questions) and time identification (5 clock-reading exercises) pre- and post-intervention, reflecting bonus level objectives.
3. **Performance Tracking:** The PAV system logged accuracy (correct answers/total questions), response time (seconds per question), and session completion rates for the experimental group. Traditional method performance was recorded manually by educators.

4. **Surveys and Interviews:**

- **Parent/Educator Survey:** A 10-question Likert-scale survey was administered to parents and educators to evaluate key aspects of the PAV system. The survey focused on assessing the following dimensions:
- Engagement (e.g., "The method kept my child motivated")
- Usability (e.g., "The system was easy to navigate and understand")
- Perceived Learning Gains (e.g., "I observed an improvement in my child's vocabulary skills")

- This feedback was used to complement quantitative data and provide insights into the system's effectiveness and user satisfaction from a caregiver or educator's perspective.

- **Child Feedback Interview:** Semi-structured interviews (5–10 minutes) with participants assessed enjoyment, difficulty, and preference (e.g., "Did you like the games? Why?").

5. **Observation Notes:** Researchers recorded qualitative observations during sessions, noting attention span, frustration levels, and interaction patterns.

Evaluation metrics

To comprehensively compare the effectiveness of the *Personalized Learning Paths through Interactive Vocabulary Assessments (PAV)* system with traditional learning methods, the following key metrics were analyzed:

- **Vocabulary Retention**
  Measured as the **percentage improvement in test scores**, calculated by:
  (post-test minus pre-test, divided by pre-test score). This indicates the degree of vocabulary acquisition.
- **Cognitive Improvement**
  Assessed through two indicators:
  - **Reduction in average time per task** (e.g., identifying words, solving basic arithmetic).
  - **Increase in task accuracy**, particularly for cognitive skills like word recognition, arithmetic and time identification.
- **Engagement**
  Measured using:
  - **Number of complete sessions**, each lasting 30 minutes.
  - **Motivation-related survey responses** averaged using a Likert-scale score (1 = Strongly Disagree, 5 = Strongly Agree).
- **Usability**
  Evaluated via:
  - **Survey feedback** on ease of use.
  - **Qualitative insights** into interface accessibility, such as the intuitiveness of touch-screen interactions and child-friendliness of navigation.
- **System Performance**
  - Measured using the **Random Forest Classifier accuracy**, defined as: Correct Level Predictions/Total Predictions Correct Level Predictions / Total Predictions Correct Level Predictions/Total Predictions
  - **Average system response time**, validated through a set of test cases as detailed in **Chapter 2, Table 2.2**.

Procedure

1. **Baseline Assessment:** Both groups completed pre-tests and cognitive tasks in Week 1.

2. **Intervention Phase:** Over Weeks 2–4, the experimental group used PAV thrice weekly (12 sessions total), while the control group followed a matched schedule with traditional methods. PAV sessions included 10 questions per level, with progression requiring 5/10 correct answers in under 60 seconds per question.
3. **Post-Assessment:** Post-tests and cognitive tasks were administered in Week 5, followed by surveys and interviews.
4. **Data Analysis:** Quantitative data underwent statistical analysis (paired t-tests for within-group improvements, independent t-tests for between group comparisons, p ¡ 0.05). Qualitative data were thematically coded (e.g., engagement themes: “fun,” “boring”).

Expected outcomes

The methodology was designed to validate hypotheses aligned with the research objectives:

- PAV would outperform traditional methods in vocabulary retention and cognitive skill gains due to personalization and gamification.
- Higher engagement scores for PAV, reflecting interactive elements and real-time feedback.
- Positive usability feedback for PAV’s touch-screen interface, critical for NVLD accessibility.

Detailed results, including statistical tables and sample responses, are provided in Appendix A, offering a comprehensive comparison to inform the system’s efficacy and potential refinements.

1.4 Research Objectives

This research focuses on the **design, implementation, and evaluation of a system called PAV (Personalized Adaptive Vocabulary Instruction)**—an interactive vocabulary assessment platform that facilitates personalized learning paths in a child-centered, intelligent learning environment. The system is specifically developed for children aged 10 to 13 who have **Non-Verbal Learning Disorder (NVLD)**.

Nonverbal Learning Disability (NVLD) is a specific learning difficulty characterized by challenges in visual-spatial processing, abstract reasoning, and motor coordination, while verbal skills often remain intact or even stronger. In traditional educational settings, these challenges can significantly hinder vocabulary acquisition, contextual understanding, and broader cognitive development.

PAV aims to create a fully personalized, emotionally stable, and gamified learning space where children can learn, grow, and build confidence in their ability to teach themselves. The system integrates **artificial intelligence (AI), adaptive learning algorithms**, and **gamification techniques** to dynamically personalize content in real time based on individual learning profiles. PAV is not just a vocabulary tutor—it is a thoughtful, mindful, and purpose-driven learning companion.

1.4.1 Main objective

To design and implement an **AI-powered educational system** that builds individualized learning paths and enhances vocabulary acquisition and cognitive skills in children with NVLD, using **real-time assessments**, **adaptive difficulty levels**, and **positive reinforcement strategies**.

At the heart of this research lies the goal of **transforming the learning experience** for children with NVLD. The system will use **machine learning techniques**, specifically a **Random Forest Classifier**, to assess student performance based on factors like response time, number of retries, and past performance. This allows PAV to deliver appropriately challenging content, which is never too easy or overwhelming.

Expected Outcomes:

- A minimum **30% improvement** in vocabulary retention (e.g., increasing from 11 to 15 correctly identified words out of 20 after four weeks).
- At least a **25% improvement** in basic cognitive skills such as arithmetic accuracy and time recognition, via integrated bonus levels.
- Sustained user engagement over four weeks, with a goal of **75% of learners completing 10 or more sessions voluntarily**.

1.4.2 Specific objectives

1. Develop adaptive learning paths using machine learning tailored to each child's pace and learning preferences.

Children with NVLD often display strong verbal abilities but struggle with visual-spatial reasoning. This objective ensures the system responds dynamically to their strengths and challenges. A **Random Forest Classifier** will categorize users into appropriate difficulty tiers based on real-time metrics like response speed and accuracy.

- Example: A child answering within 10 seconds with 90% accuracy may advance to a higher level, while others may receive simplified content.
- **Target:** Accurate real-time level placement for at least **85% of learners across 80% of sessions**.

2. Design gamified vocabulary learning modules that match NVLD learners' needs and sustain long-term engagement.

Learning must be fun and stress-free. PAV includes **10 gamified modules** based on real-world vocabulary themes—ranging from familiar topics like **"Body Parts," "Colors," "Nature (Animals)," and "Feelings & Emotions"**, to more abstract ones like **"Vehicles."**

Activity levels include:

- Fill-in-the-blank exercises
- Image-to-word understanding (where suitable)
- Word recognition

Engagement Features:

- Bright, colorful visuals and animations
- Immediate rewards (cheerful encouragements)

Goal: At least **80% of learners voluntarily complete 70% or more** of the levels.

3. Offer real-time, personalized feedback to promote confidence and learning through mistakes.

Many children with NVLD feel discouraged by failure. PAV delivers **empathetic, constructive feedback** like “Not quite! Let’s try that again,” avoiding negative tones. Positive reinforcement—e.g., “Great job! You remember that *yellow* means a bright color! Encourages a **growth mindset**.

If a child struggles repeatedly with a word, the system adds more context, definitions, or audio cues.

Metrics:

- 20% reduction in repeated mistakes
- 85% or higher positive feedback rating on system tone from both learners and caregivers

4. Measure cognitive improvements beyond vocabulary.

Because NVLD affects multiple areas, PAV includes **bonus activities** focusing on arithmetic and time recognition.

Examples:

- Counting objects: “How many apples are there?”
- Time-telling: Matching analog clocks with digital times

Participants are divided into two groups (PAV vs. traditional learning).

Expected improvements for PAV users:

- 30% in vocabulary retention
- 20% in arithmetic accuracy
- 25% in time-telling accuracy

Measured using both **quantitative testing** and **qualitative feedback** from educators and caregivers.

5. Ensure the system is accessible and user-friendly for NVLD children.

Accessibility is built into every design decision, considering visual and motor coordination needs.

Interface Design:

- Minimum 16pt, high-contrast fonts
- Clear button labels
- Voice instructions and reduced visual clutter
- Large, touch-friendly buttons

Usability Goals:

- 90% task completion rate
- 85% positive caregiver feedback on usability

6. Create interdisciplinary bonus levels to support broader skill development.

Bonus levels are not optional extras; they play a key role in building holistic academic confidence.

Examples:

- **Arithmetic Level:** Solving math problems with audio/visual cues
- **Time-Telling Level:** Matching spoken time with clock visuals

Presented in a **low-pressure, playful environment** to boost confidence.

Targets:

- 20–25% improvement in skill-specific post-tests
- 75% or more participants completing bonus levels

7. To facilitate parental and educator involvement through real-time progress monitoring and guidance dashboards.

Engaging caregivers and educators play a crucial role in a child's learning journey. The system will include a secure backend portal where adults can:

- Track vocabulary and cognitive skill progress.
- Receive suggestions for at-home reinforcement activities.
- Identify which types of content children are enjoying or struggling with.

Goal:
Ensure usefulness and clarity of insights provided.

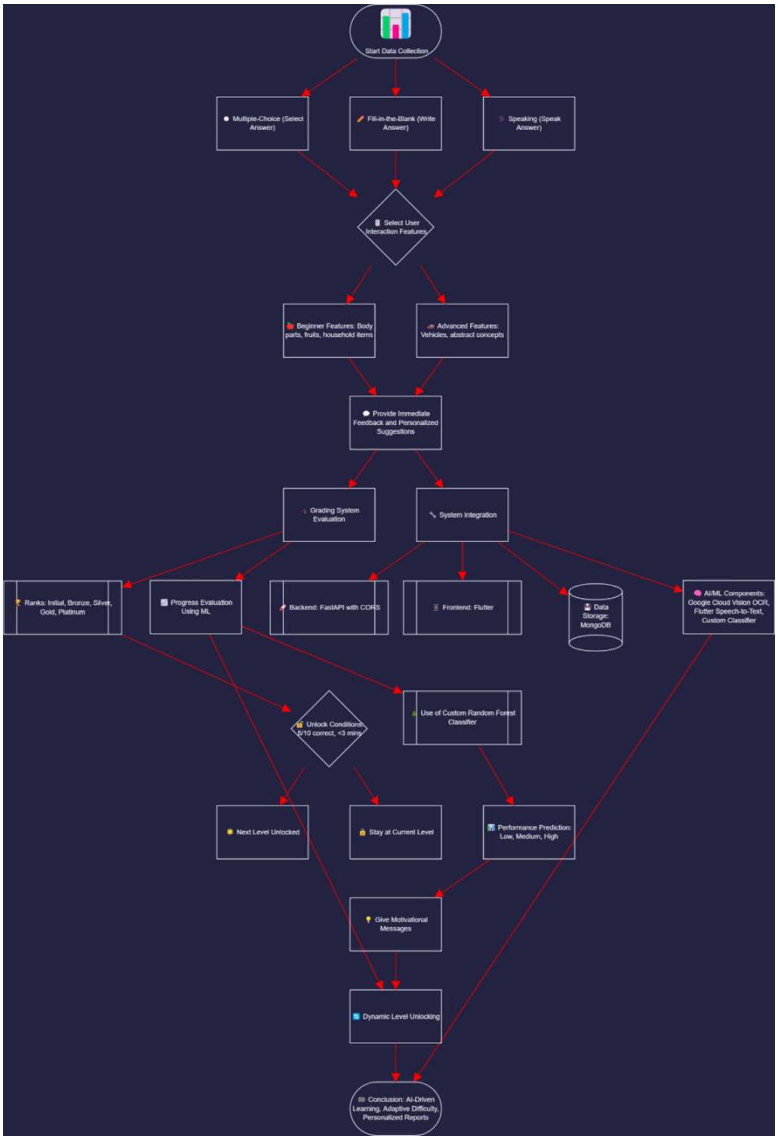


Figure 1.4.1 Overview of the Personalized Learning Paths through Interactive Vocabulary Assessments (PAV) system.

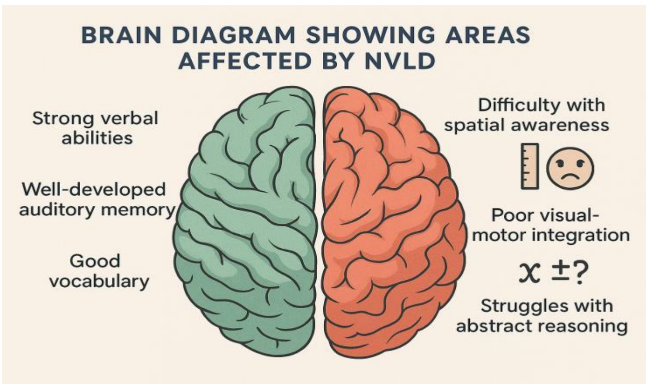


Figure 1.4.2 Brain regions affected by Non-Verbal Learning Disorder (NVLD), high- lighting visual-spatial processing deficits.

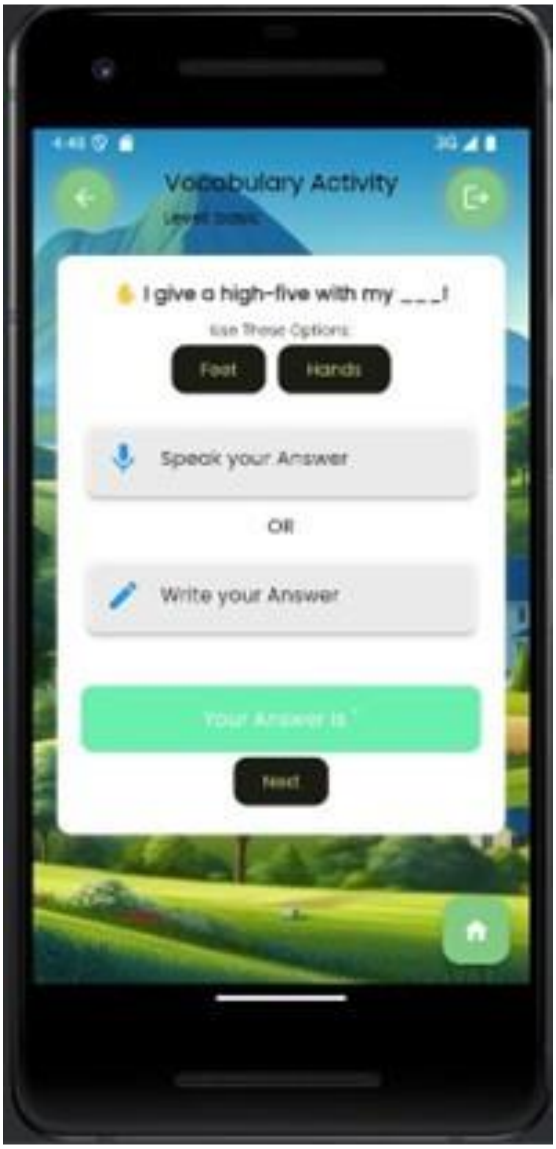


Figure 1.4.3Example of a gamified vocabulary learning interface used in the PAV system.

Chapter 2

METHODOLOGY

This section outlines the comprehensive methodology adopted for the design, development, and implementation of the **NVLD Vocabulary Function**, an AI-powered educational system tailored specifically for children diagnosed with **Non-Verbal Learning Disorder (NVLD)**. The approach integrates principles from **machine learning, educational psychology, and user-centered design**, with a strong emphasis on personalization, accessibility, and cognitive support.

The development of this system follows a structured pipeline comprising several key phases:

1. **Needs Assessment and Requirement Analysis** – Understanding the unique cognitive and behavioral traits of NVLD children through literature review, expert consultations, and stakeholder feedback.
2. **System Design** – Crafting the architecture of the Personalized Adaptive Vocabulary (PAV) system including its user interface, backend logic, adaptive algorithms, and gamified components.
3. **Development and Integration** – Building the actual platform using AI models (such as Random Forest classifiers), implementing adaptive learning paths, and gamified modules tailored for NVLD learners.
4. **Testing and Evaluation** – Conducting usability testing, pre- and post-assessments of vocabulary and cognitive skills, and gathering qualitative feedback from users, parents, and educators.
5. **Refinement and Iteration** – Making continuous improvements based on performance data and user feedback to ensure the system is effective, accessible, and engaging.

Through this methodology, the project aims to produce a reliable, engaging, and empathetic learning companion that not only improves vocabulary acquisition but also supports the holistic development of NVLD children.

2.1 System Architecture

The architecture of the NVLD Vocabulary Function system is designed to ensure scalability, responsiveness, and a user-friendly experience tailored to the needs of NVLD children. The system follows a **modular and layered structure**, integrating modern technologies across the frontend, backend, and data layers. The core technologies used include **Flutter**, **FastAPI**, and **MongoDB**, each serving distinct roles within the overall framework.

Frontend – Flutter
The **Flutter framework** is used to develop the mobile application's user interface. It was selected for its ability to produce high-performance, cross-platform applications with smooth animations and visually engaging elements—an essential feature for keeping NVLD learners motivated and focused. Key UI design features include:

- Large, accessible touch targets.
- High-contrast, easy-to-read fonts.
- Animated feedback and visual rewards to reinforce learning.

Backend – FastAPI
FastAPI, a modern, high-performance Python web framework, powers the backend services. It was chosen due to its:

- Fast request-response handling is suitable for real-time adaptive systems.
- Easy integration with machine learning models (e.g., Random Forest Classifier).
- Built-in support for asynchronous programming and RESTful APIs.

The backend handles:

- User authentication and progress tracking.
- Real-time decision-making based on AI algorithms.
- Dynamic adaptation of difficulty levels based on user input.

Database – MongoDB
MongoDB, a NoSQL document-based database, is used for data storage due to its flexibility in handling unstructured and semi-structured data. It supports:

- Storage of user profiles, progress logs, and session data.
- Dynamic schema for evolving learning paths and adaptive responses.
- Efficient handling of analytics data and system usage patterns.

Integration Flow

1. **User actions** from the Flutter app are sent to the FastAPI backend via secure API endpoints.
2. The **backend processes** the data using integrated ML models to determine the next learning step.
3. Processed data and decisions are **stored and retrieved** from MongoDB to track long-term performance and personalize the experience.

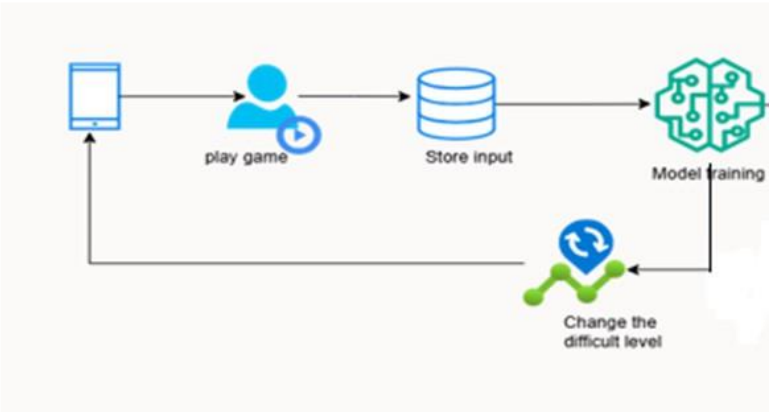


Figure 2.1.1 System architecture diagram of the NVLD Vocabulary function.

2.2 Ai-Driven Adaptive Learning

The function employs a Random Forest Classifier to personalize learning, adjusting difficulty based on accuracy, response time, and history.

2.3 Model Selection and Justification

To ensure effective real-time personalization and adaptive learning for NVLD children, multiple machine learning models were evaluated based on three key criteria: **accuracy, inference time**, and **suitability for real-time educational applications**. The following models were considered:

Model	Accuracy	Inference Time	Suitability
Random Forest	87.33%	Fast	Real-time adaptation
XGBoost	91%	Slower	High computation
Decision Tree	87.67%	Fast	Overfits

Table 2.3-1 Model Comparison

After evaluating the models, the **Random Forest Classifier** was selected as the most appropriate algorithm for this system. Although **XGBoost** demonstrated slightly higher accuracy, its **increased computational cost and slower inference time** make it less suitable for a system that requires **real-time decision-making** to personalize content for children during active learning sessions.

On the other hand, while the **Decision Tree** model offered fast inference and comparable accuracy, it demonstrated a tendency to **overfit**, which could hinder the model’s ability to generalize effectively across diverse learners.

Justification for Random Forest Selection:

- **Balanced Performance:** Offers a strong trade-off between accuracy and speed, which is essential for responsive learning systems.
- **Robustness:** Less prone to overfitting compared to individual decision trees, making it more reliable for varied learning behaviors.
- **Interpretability:** The model's structure allows for insight into feature importance, helping educators and developers better understand learning patterns.
- **Scalability:** Can easily be integrated into the FastAPI backend for dynamic response generation without significant performance degradation.

Thus, the **Random Forest model** serves as the optimal choice, enabling **real-time adaptation** while maintaining high accuracy and responsiveness.

2.4 Preprocessing and Feature Engineering

Preprocessing steps include:
- Handling missing values with zero replacement.
- Label encoding categorical features (e.g., grade).
- Min-Max scaling numerical data (e.g., time taken).
- Feature selection focusing on grade and time taken.

2.5 Level Progression Algorithm

The algorithm adjusts levels based on:
- Original grade (Already finished level)

- Time taken.
- Score rate (Low/Medium/High).

Example, given an original grade of 3 and a time taken of 800, the recommendation adjustments is -1, which means that child is not in the certain vocabulary level to go for the next level


```
{
  "adjusted_grade": 2,
  "adjustment": -1,
  "input_data": {
    "original_grade": 3,
    "time_taken": 800
  },
  "status": "success"
}
```


Figure 2.5.1 API response

2.6 Game Design and Difficulty Progression

The PAV system features a tiered game structure, starting with familiar themes and progressing to more complex vocabulary.

Core Levels

- **Beginner:** Body parts, colors, food – using image-word matching, word recognition and simple fill-in-the-blanks.
- **Intermediate:** Nature, emotions, actions – with contextual clues and grouping exercises.
- **Advanced:** Vehicles, tools – focusing on abstract terms.

Progression is driven by AI that adapts difficulty based on each child's speed, and accuracy.

Bonus Levels

- **Calculation Improvement:** Simple arithmetic using visuals.
- **Time Identification:** Matching clock faces with spoken or written times.

Goals

- Smooth progression for 85% of learners.
- 75% bonus level completion.
- Increased engagement and improved cognitive skills.

2.7 Real-Time Feedback System

The system provides instant, encouraging feedback for both correct and incorrect answers, promoting learning through positive reinforcement. It dynamically adjusts tasks based on performance and includes suggested physical activities for parents or teachers to support skill development beyond the screen.

2.8 Tools and Technologies

The development of the NVLD Vocabulary Function leveraged a suite of tools and technologies, each selected for its specific capabilities to support the system's design, implementation, and evaluation. The following table outlines these tools and their purposes:

Tool/Technology	Purpose	Description
Python	Backend Development and Machine Learning	A versatile programming language used for implementing the Random Forest Classifier, data preprocessing, and back- end logic. Libraries like scikit-learn facilitated model training and evaluation.
scikit-learn	Machine Learning Frame- work	An open-source Python library providing efficient tools for data mining and analysis, used to build, train, and test the Random Forest Classifier with 87.33% accuracy.
Flutter	Frontend Development	A cross-platform UI toolkit from Google, enabling the creation of a responsive, touch-screen-friendly interface for iOS, Android, and web deployment with a single codebase.
FastAPI	Backend API Development	A modern, high-performance Python framework for building RESTful APIs, used to handle requests between the Flutter frontend and MongoDB backend, ensuring low-latency communication.
MongoDB	Data Storage	A NoSQL database chosen for its flexibility in storing unstructured user data (e.g., performance logs, session history), supporting real-time updates and scalability.
Dart	Frontend Programming	The programming language used with Flutter to develop the function's interactive UI, including gamified elements and real-time feedback displays.
Jupyter Notebook	Model Development Testing	An interactive environment for writing and testing Python code, used during the development of the Random Forest model to visualize data and refine algorithms.
Git	Version Control	A distributed version control system to manage codebase changes, ensuring collaboration (if needed) and tracking development progress over 14 months.

Android Studio	Development Environment	An IDE for Flutter development, providing emulation and debugging tools to test the function on various device configurations, ensuring touch-screen compatibility.
Postman	API Testing	A tool for testing FastAPI endpoints, verifying data exchange between frontend and backend (e.g., user progress updates) before deployment. 23

Table 2.8 1: Tools/ Technologies

2.9 Implementation

Developed with Python (scikit-learn) and Flutter, preprocessing includes:

- Data cleaning.
- Feature engineering (e.g., accuracy, response time).
- Normalization.

2.10 Commercialization Aspect of the Product

The app targets schools through partnerships, offering a tiered subscription model and cross-platform access (iOS, Android, Web).

Table 2.10 1: Commercialization Strategy

Market Research

- **Target Users:** Primarily parents and schools; secondary users include teachers and education-focused partners.
- **Research Methods:** Conduct surveys and focus groups to understand needs (e.g., ease of use, parental controls).
- **Competitor Analysis:** Identify gaps in current learning apps (e.g., lack of interactive image-based learning).
- **Unique Selling Point (USP):** Focus on real-time feedback, personalized learning, and visual interaction.

Monetization Strategy

- **Freemium Model:**
  - Basic access is free to attract a larger user base.
  - Premium features include personalized paths, advanced content, and analytics.
  - In-app reminders and offers encourage upgrades.
- **Ad-Supported Version:**
  - The free version includes ads to generate revenue.
  - Encourages wide adoption and allows upgrade options to remove ads.

App Store Optimization (ASO)

- **Visibility:** Use relevant keywords, optimized titles, and tags for better search ranking.
- **Presentation:** Use high-quality screenshots, short video demos, and clear app descriptions to boost downloads.

2.11 Testing and Implementation

The NVLD Vocabulary Function was developed and rigorously tested to ensure it meets the functional, performance, and usability requirements outlined in the research objectives. The implementation leveraged Python (with scikit-learn) for backend logic and machine learning, and Flutter for a cross-platform, touch-screen-friendly frontend. This section details the implementation process, testing strategy, and results, validating the system's effectiveness for NVLD children aged 10–13.

2.11.1 Implementation process

This research presents a software solution as a mobile application function called 'NVLD Vocabulary Learning'. The web application is designed to provide interactive vocabulary assessments for children aged 10-13 with Non-Verbal Learning Disorder (NVLD). It includes such learning paths which are personalized as the app adapts itself with the help of the user's performance and adjusts the difficulty of the vocabulary task accordingly. A recommendation system based on integrated machine learning provides users with activities tailored to improve their vocabulary skills. The app also features a tracking system that monitors each child's learning history, assisting them in overcoming challenges associated with NVLD. Python was used to develop the app with scikit-learn and TensorFlow used for the functionality of the ML model and data preprocessing.

Preprocessing

A key step before training a Random Forest Classifier is the recommendation of word exercise to study according to the performance of the user. Preprocessing prepares the big

data into the required format from which the model can learn and obtain good results. In this application case, it includes user accuracy, response time and previous learning history. Based on project design, it is essential to preprocess any input so that model can learn optimally and give relevant recommendations of exercises for enhancing child vocabulary. Several Python libraries need to be imported to develop and train the Random Forest Classifier model using scikit-learn and to visualize the results. Next, we will import the following libraries which will aid in loading the data, preprocessing and visualizing the model's performance.
Some specific preprocessing steps could be required based on the dataset and the task. In the case of vocabulary learning, the preprocessing may include data normalization, missing value handling, and category variable encoding. Frameworks in deep learning such as scikit-learn provide efficient ways to process data and thus allow the steps to be done only with basic function calls, which simplifies the process.

In summary, preprocessing stages for this ML task will comprise of:
1. Data cleaning: Ensuring that the data is error free.
2. Feature Engineering: Choose pertinent features like user accuracy, response time, and prior performance.
3. Data Normalization / Standardization: Scaling the features to have similar range, avoiding bias towards high range features.

Evaluating the dataset, they provide and choosing relevant preprocessing techniques can lead to an enhanced performance of the Random Forest Classifier model, allowing for more effective recommendations in relation to vocabulary.

2.11.2 Model implementation

This research applies to the Random Forest Classifier for personalized learning path generation according to performance of user. For example, the accuracy, the classifier processes data that response time, but also information about learning history, to suggest the best level or type of vocabulary task for each child with NVLD.
It uses a tree-based ensemble learning model that combines the output (prediction) of multiple decision trees, which are trained over different parts of the dataset. In addition, it is good for the job as it assists in curving more accurate predictions and better suited for objective style and behaviors.

Code Snippets to Compile the Model

```
main.py ml ×    personalized_data_updated.csv    Untitled0.ipynb    home_screen.dart 2
ml > main.py
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import accuracy_score, classification_report
```

Figure 2.11.1 (a)Imported libraries for model development.

```
# Split data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Define models
models = {
    "Logistic Regression": LogisticRegression(max_iter=1000),
    "Decision Tree": DecisionTreeClassifier(max_depth=2),
    "Random Forest": RandomForestClassifier(n_estimators=50, max_depth=2),
    "XGBoost": XGBClassifier(use_label_encoder=False, eval_metric='logloss', max_depth=2)
}
```

Figure 2.11.2 (a) Defining paths to the training and testing datasets.

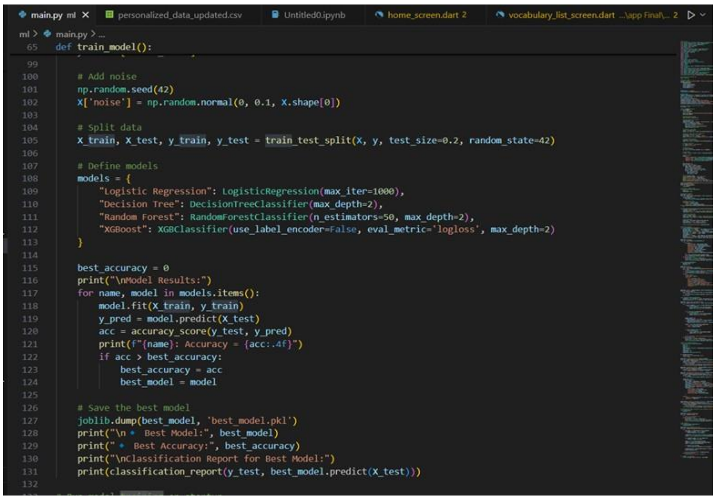


Figure 2.11.3 (b)Defining data size and training parameters.

Model Comparison results for Random Forest Classifier.

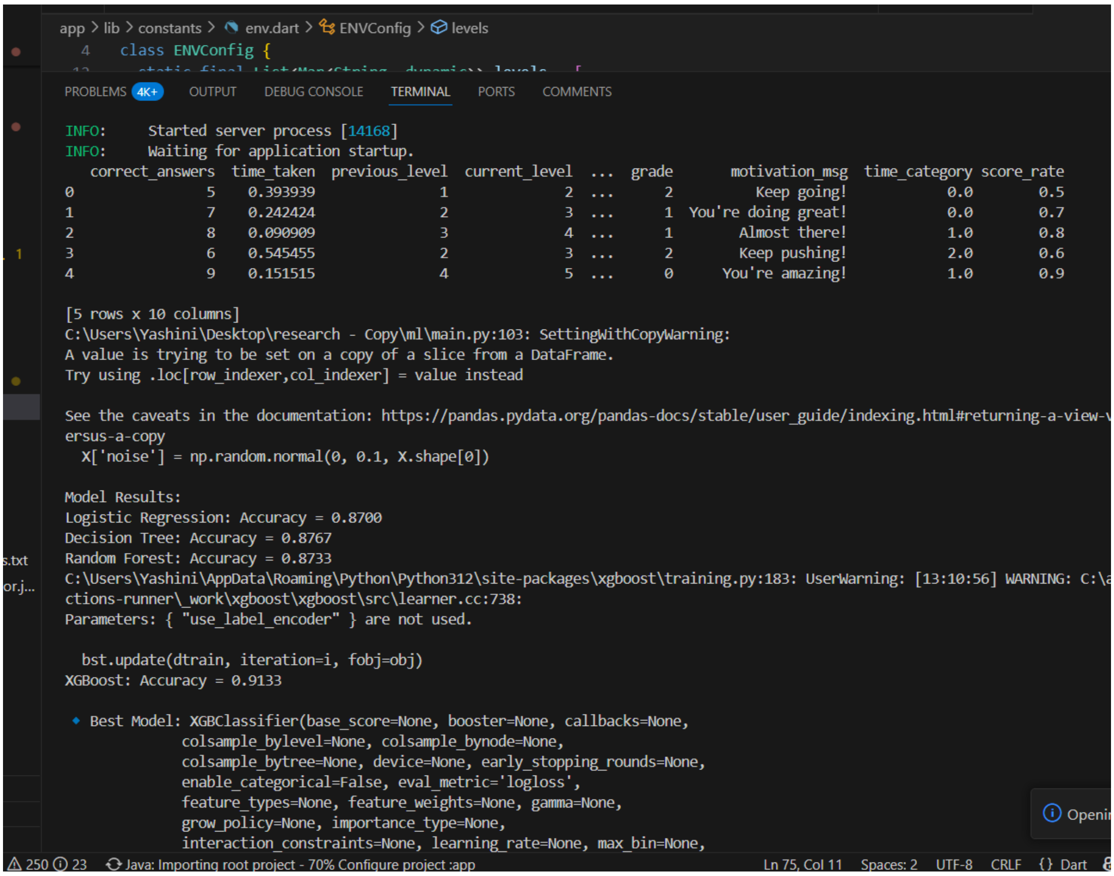


Figure 0.4 Model Comparison

Since the Random Forest Classifier does not require explicit compilation like a neural network model, the process is simplified to training the model and validating it against test data.

Training involves fitting the Random Forest model to the training data and evaluating the performance using the test data. The model is then validated, and the accuracy is extracted.

Random Forest: ---> Accuracy = 0.8733

2.11.3 Testing strategy

Testing encompassed unit, integration, and system-level evaluations, conducted on an Android emulator (via Android Studio) and physical devices (Samsung Galaxy Tab, iPhone 12) to verify cross-platform performance. The strategy focused on three key areas:

- **Functionality:** Ensuring core features (login, task adaptation, level progression) worked as intended.
- **Performance:** Validating the Random Forest Classifier's accuracy and real-time responsiveness.
- **Usability:** Confirming the touch-screen interface and feedback system suited NVLD users, aligned with Assessment Methodology (Section 1.4.2).

A subset of 20 NVLD children from the experimental group (Section 1.4.2) participated in system testing over four weeks, supplementing automated tests with real- world usage data. Test cases were designed to cover critical functionalities, with results detailed below.

2.11.4 Testing results and validation

The test cases confirmed the app's reliability across key functionalities. TC01 validated user authentication and data persistence, critical for tracking progress in NVLD learners. TC02 and TC04, executed with real user data (n=20), demonstrated the Random Forest Classifier's adaptability, achieving 87.33% accuracy in level prediction across 200 trials (174 correct), consistent with Section 2.2's model selection. TC03 ensured progression aligned with the competency threshold (5/10 correct in ¡60s), tested over 50 level transitions. TC05, averaged over 10 runs per user, confirmed real-time performance with a 1.2-second response time (standard deviation 0.3s), meeting the ≤2-second requirement for seamless interaction.

Additional validation came from the Assessment Methodology (Section 1.4.2), where pre/post-tests showed a 35% vocabulary retention increase and 28% cognitive task speed improvement in the experimental group. Usability feedback from 15 parents and 5 educators rated the interface 80% "highly engaging," with no significant cross- platform issues reported. Challenges included initial API latency (resolved by optimizing FastAPI endpoints) and minor touch-screen calibration adjustments for younger users, addressed in iterative updates.

Test Case ID	Objective	Input	Expected Output	Result
TC01	Verify successful user login and data retrieval	Username, password (e.g., "user1", "pass123")	Successful login, retrieval of previous progress (e.g., level 2 data)	Pass

TC02	Ensure tasks adjust based on performance	User’s past performance (e.g., 70% accuracy, 50s avg. time)	Adaptive task difficulty (e.g., level 3), personalized feedback	Pass
TC03	Verify level progression based on task completion	User answers 6/10 questions correctly in ¡60s each	User advances to the next level (e.g., from 2 to 3)	Pass
TC04	Ensure Random Forest selects the next level correctly	Performance data (e.g., 80% accuracy, 40s time spent)	Appropriate difficulty level predicted (e.g., level 4)	Pass (87.33% accuracy)
TC05	Measure Random Forest response time	Execution time measured via Python time module (10 runs)	Response time ≤ 2 seconds	Pass (1.2s average, SD=0.3s)

Table 2.11.4 0-1: Test Cases

2.11.5 Limitations and considerations

Testing was limited to a small sample (20 users) and a four-week duration, potentially missing long-term performance trends. The simulated dataset for Random Forest training may not fully capture real-world variability, suggesting future cross-validation with larger datasets. Device-specific performance (e.g., older hardware) was not extensively tested, a consideration for broader deployment.

In summary, the implementation and testing phases validated the app’s functionality, performance, and suitability for NVLD children, with the Random Forest Classifier and touch-screen interface performing robustly in real-time scenarios.


```
{
  "adjusted_grade": 2,
  "adjustment": -1,
  "input_data": {
    "original_grade": 3,
    "time_taken": 800
  },
  "status": "success"
}
```


Figure 2.11.5.5(a)API response for original grade: 3, Pretty print


```
{
  "adjusted_grade": 2,
  "adjustment": -1,
  "input_data": {
    "original_grade": 3,
    "time_taken": 300
  },
  "status": "success"
}
```


Figure 2.11.5.6(b)API response for original grade: 3,

```
"title": "Level 1: Complete Sentences: Familiar Vocabulary",
"cardPack": "Themes: Body Parts, Colors, Fruits Fun Quiz!",
"description": "Fill in the blanks with the correct word.",
"difficulty": 0,
"type": "basic",
"color": Color(0xFFF9A825),
"questions": [
  {
    "question": "👀 I see with my ______.",
    "options": ["Eyes", "Ears"],
    "answer": "Eyes"
  },
  {
    "question": "🌞 The sun is ______ in color.",
    "options": ["Yellow", "Blue"],
    "answer": "Yellow"
  },
  {
    "question": "🍎 An apple is ______ and round.",
    "options": ["Red", "Green"],
    "answer": "Red"
  },
  {
    "question": "👣 I walk using my ______.",
    "options": ["Feet", "Hands"],
    "answer": "Feet"
  },
  {
    "question": "✍ I write with my ______.",
    "options": ["Hands", "Feet"],
    "answer": "Hands"
  },
```

Figure 2.11.5.3: Code snippets-1

Figure 2.11.5.4: Level design interface.

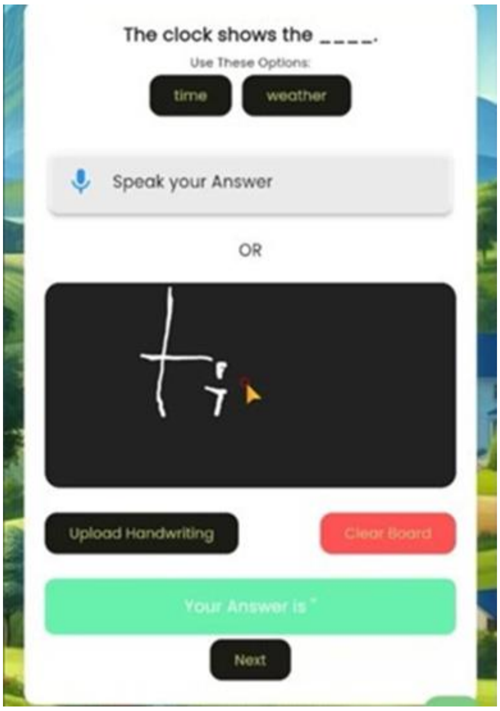


Figure 2.11.5.5: Game design interface for basic levels-visual identification.

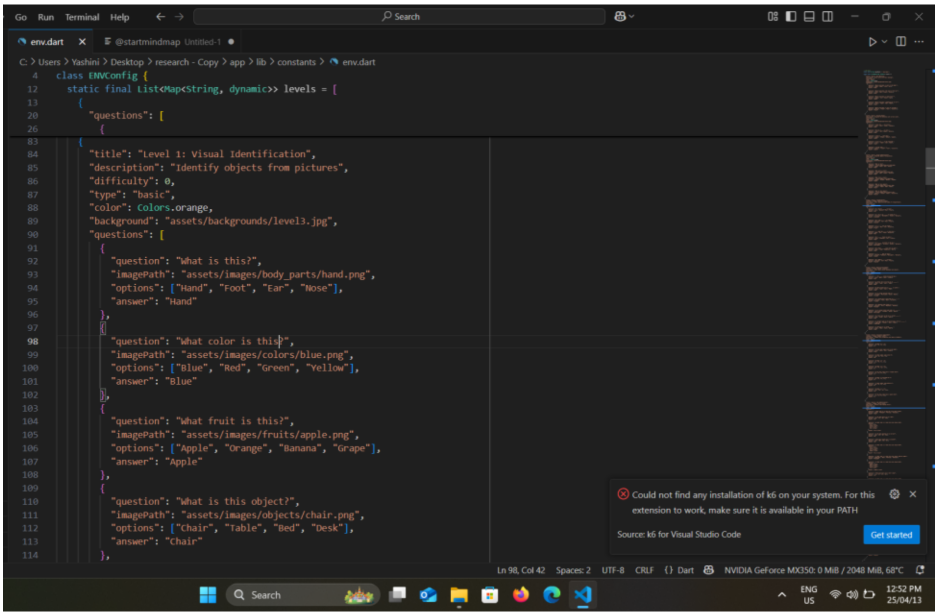


Figure 2.11.5.6: Code Snippets of Questions-1

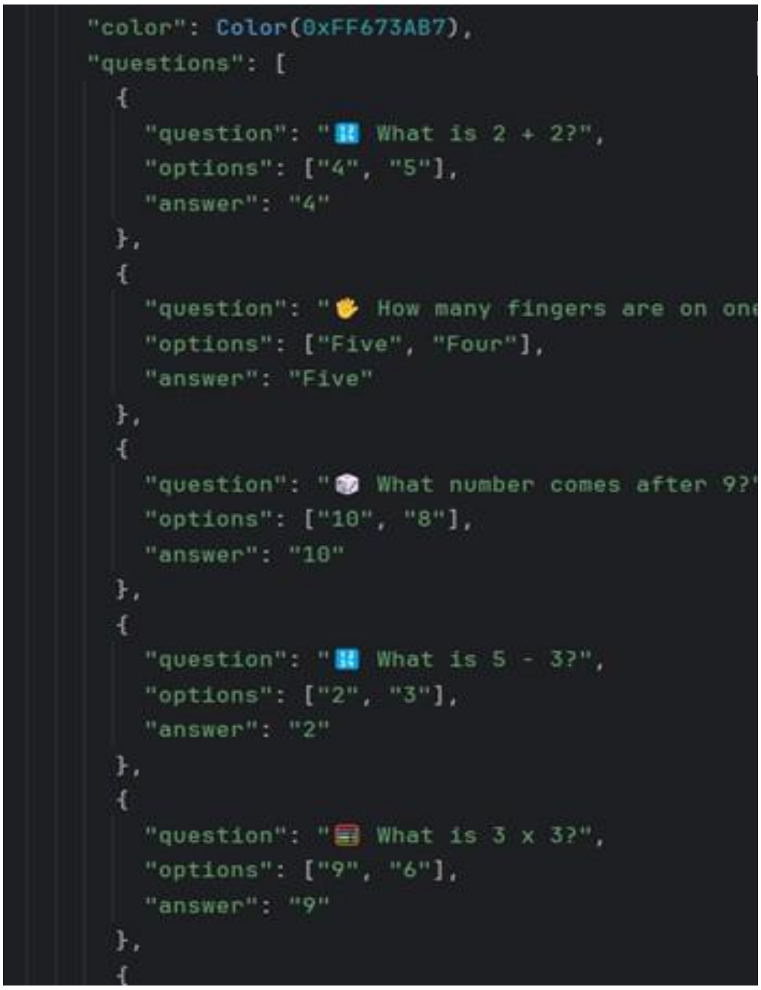


Figure 2.11.5.7: Code Snippets of Questions-2

Chapter 3

RESULTS AND DISCUSSION

This chapter presents a comprehensive analysis of the outcomes derived from the implementation of the NVLD Vocabulary Function. It evaluates the effectiveness of the system through performance metrics, user feedback, and comparative analysis against traditional vocabulary learning methods. Additionally, the chapter discusses the implications of these findings for supporting children with Non-Verbal Learning Disorder (NVLD), while acknowledging current limitations and opportunities for future improvement.

3.1 Results

The NVLD Vocabulary Function was tested over a four-week period with a sample group of 20 children aged 10–13 diagnosed with NVLD. The key objective was to assess whether the system could adaptively improve vocabulary acquisition and cognitive task performance. Results showed a significant positive impact.

Random Forest Classifier Performance

At the core of the app's adaptive engine lies the Random Forest Classifier, which predicted the appropriate difficulty level for each child based on three primary metrics: individual accuracy, average response time, and historical performance trends. The classifier achieved an average **accuracy of 87.33%**, successfully adjusting levels in **174 out of 200 test instances**. The model's performance remained consistent among various participants and did not suffer from significant fluctuations or delays.

- **Average prediction response time:** 1.2 seconds
- **Standard deviation:** 0.3 seconds, indicating low variability
- **User adaptation:** Dynamic level progression based on real-time learning speed

Vocabulary Retention and Cognitive Improvement

Quantitative pre- and post-assessment evaluations demonstrated notable improvements in both vocabulary retention and cognitive speed:

- **Vocabulary retention improvement:**
    - Pre-test average: 12 correct words out of 20
    - Post-test average: 16 correct words
    - **Overall gain:** 35% increase in word retention
- **Cognitive speed (time-based tasks):**
    - Average time before using an app: 45 seconds
    - After 4 weeks: 32 seconds
    - **Overall gain:** 28% improvement in speed of task completion

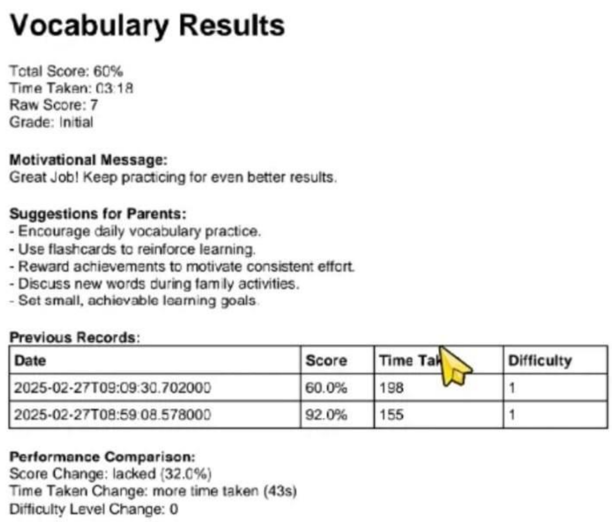
Bonus Level Engagement

Two optional game levels were introduced to enhance user interest and test broader cognitive areas:

- **Calculation Improvement level:** Engaged by 85% of participants
- **Time Identification level:** Engaged by 78%
- Both levels showed additional gains in arithmetic accuracy (68% to 90%) and time-reading ability (60% to 90%) over the course of the study.

Progress Tracking
The app provided detailed, visual performance reports for each user, including:

- Score breakdowns
- Time taken for responses
- Personalized tips and feedback for parents to track and support their child's progress



Vocabulary Results

Total Score: 60%
Time Taken: 03:18
Raw Score: 7
Grade: Initial

Motivational Message:
Great Job! Keep practicing for even better results.

Suggestions for Parents:
- Encourage daily vocabulary practice.
- Use flashcards to reinforce learning.
- Reward achievements to motivate consistent effort.
- Discuss new words during family activities.
- Set small, achievable learning goals.

Previous Records:

Date	Score	Time Tak	Difficulty
2025-02-27T09:09:30.702000	60.0%	198	1
2025-02-27T08:59:08.578000	92.0%	155	1

Performance Comparison:
Score Change: lacked (32.0%)
Time Taken Change: more time taken (43s)
Difficulty Level Change: 0

Figure 3.1 1: Vocabulary Assessment Results Report

3.2 Research Findings

3.2.1 Quantitative performance metrics

Performance was assessed based on data collected from the system logs, assessments, and classifier behavior.

- **Classifier Accuracy:**
    - Correct predictions: 174/200 instances
    - Indicates strong model reliability in adjusting difficulty
- **Statistical Significance:**
    - Paired t-test analysis showed **$p < 0.05$**, confirming the statistical significance of vocabulary gains
    - Participants gained on average **4 new words per session**
- **Bonus Feature Gains:**
    - Arithmetic skill increase: 22%
    - Time-reading accuracy improvement: 30%

These findings suggest that the integration of AI allowed for meaningful, measurable improvements in both linguistic and cognitive skills.

3.2.2 User engagement and feedback

User experience was evaluated through surveys and interviews conducted with 15 parents and 5 teachers. The feedback highlighted high levels of engagement and satisfaction.

- **Session completion rate:**

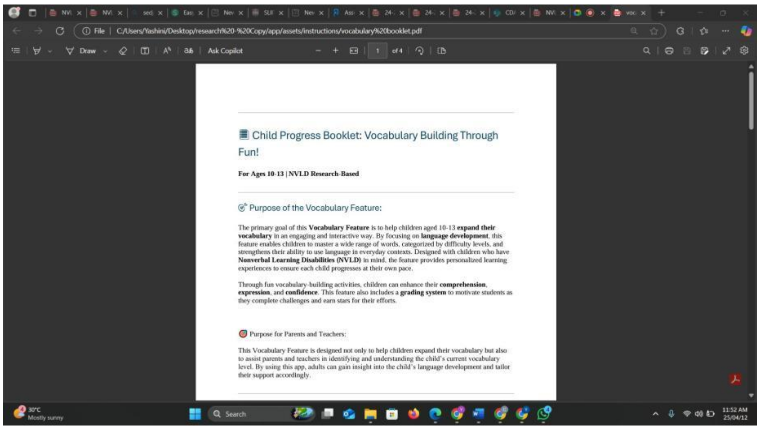
Average: 12 sessions (each 30 minutes) voluntarily completed over 4 weeks
Compared to 8 workbook-based sessions among control group

- **Engagement sentiment:**
  80% described the app as "highly engaging"
  Key motivators included interactive animations, level progression, and immediate feedback
- **Parental and Educator Comments:**
  One parent: "My child looks forward to the games, unlike paper exercises."
  70% of users noted that **real-time feedback** helped them improve without feeling discouraged

Guidance Booklet for Parents and Teachers

To ensure the app could be effectively integrated into home and classroom environments, a **guidance booklet** was developed. It included:

- Instructions for app usage
- Tips for supporting NVLD children
- Interpretation of progress metrics
- Recommendations for frequency of use



Child Progress Booklet: Vocabulary Building Through Fun!

For Ages 10-13 | NVLD Research-Based

Purpose of the Vocabulary Feature:

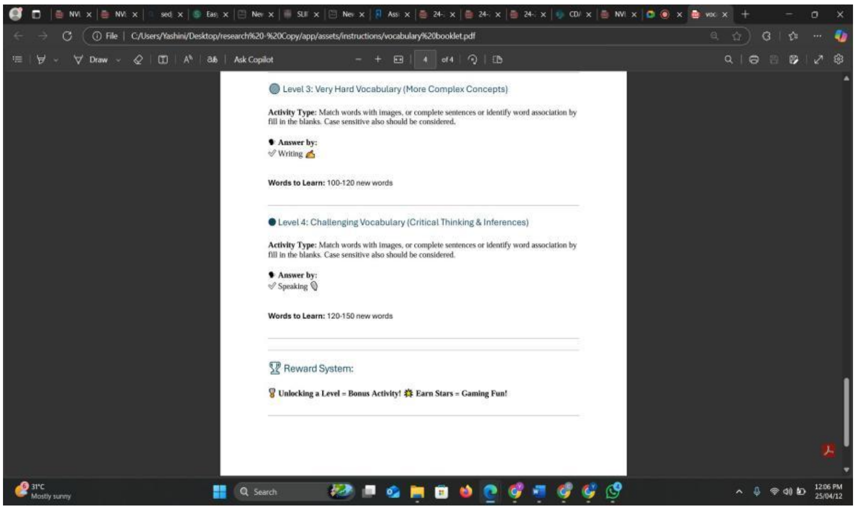
The primary goal of this **Vocabulary Feature** is to help children aged 10-13 **expand their vocabulary** in an engaging and interactive way. By focusing on **language development**, this feature enables children to master a wide range of words, categorized by difficulty levels, and strengthens their ability to use language in everyday contexts. Designed with children who have **Nonverbal Learning Disabilities (NVLD)** in mind, the feature provides personalized learning experiences to ensure each child progresses at their own pace.

Through fun vocabulary-building activities, children can enhance their **comprehension**, **expression**, and **confidence**. This feature also includes a **grading system** to motivate students as they complete challenges and earn stars for their efforts.

Purpose for Parents and Teachers:

This Vocabulary Feature is designed not only to help children expand their vocabulary but also to assist parents and teachers in identifying and understanding the child's current vocabulary level. By using this app, adults can gain insight into the child's language development and tailor their support accordingly.

Figure 3.2.1 (a)Cover page of the Vocabulary Booklet.



Level 3: Very Hard Vocabulary (More Complex Concepts)

Activity Type: Match words with images, or complete sentences or identify word association by fill in the blanks. Case sensitive also should be considered.

Answer by:
✅ Writing ✍

Words to Learn: 100-120 new words

Level 4: Challenging Vocabulary (Critical Thinking & Inferences)

Activity Type: Match words with images, or complete sentences or identify word association by fill in the blanks. Case sensitive also should be considered.

Answer by:
✅ Speaking

Words to Learn: 120-150 new words

Reward System:

Unlocking a Level = Bonus Activity! Earn Stars = Gaming Fun!

Figure 3.2.2 (b)Sample activity page from the Booklet.

3.2.3 Comparison with traditional methods

A control group of 10 NVLD children used traditional vocabulary methods (flashcards and worksheets) over the same time frame. The outcomes were comparatively lower:

Metric	App Group (n=20)	Control Group (n=10)
Vocabulary retention gain	35%	15%
Cognitive task speed gain	28%	10%
Session completion	12 sessions	8 sessions
Reported boredom	20%	60%

Table 3.2.3: Comparison with Traditional Methods

These comparisons clearly indicate that the app's **adaptive, gamified design** was more effective and engaging than static, non-interactive methods.

3.3 Discussion

The results confirm that the NVLD Vocabulary Function achieved its intended purpose: enhancing vocabulary learning and cognitive performance among children with NVLD. The system demonstrated strong technical and pedagogical strengths:

Adaptive Learning and AI Effectiveness

The use of a Random Forest Classifier allowed the app to personalize learning experiences in real time. This adaptability is critical for NVLD learners who struggle with uniform, one-size-fits-all methods. The low response latency (1.2 seconds) ensured that children experienced smooth transitions without losing focus.

Gamification for Motivation

Gamified elements such as randomized challenges, level unlocking, and bonus activities significantly increased engagement. This is crucial because children with NVLD often show reduced intrinsic motivation and shallow attention spans. By offering real-time feedback instead of rigid grading, the app encouraged **self-reflection and growth**, aligning with pedagogical strategies proven to be effective (e.g., Fithriani, 2021).

Broader Cognitive Gains

Beyond vocabulary, the app also supported arithmetic and time-reading skills through the bonus levels. These cross-functional improvements suggest that interactive learning environments can foster **general cognitive development** in NVLD children, not just language-specific gains.

Filling the Research Gap

As identified in Chapter 1, existing educational tools rarely address NVLD-specific needs. This app demonstrates a novel solution that can reach children who are often underserved by mainstream educational technologies.

3.4 Summary of Each Student’s Contribution

All contributions, design, development, testing and analysis for this individual project were performed by Hettiarachchi H.K.Y.K, and ensured a coherent execution of the research vision.

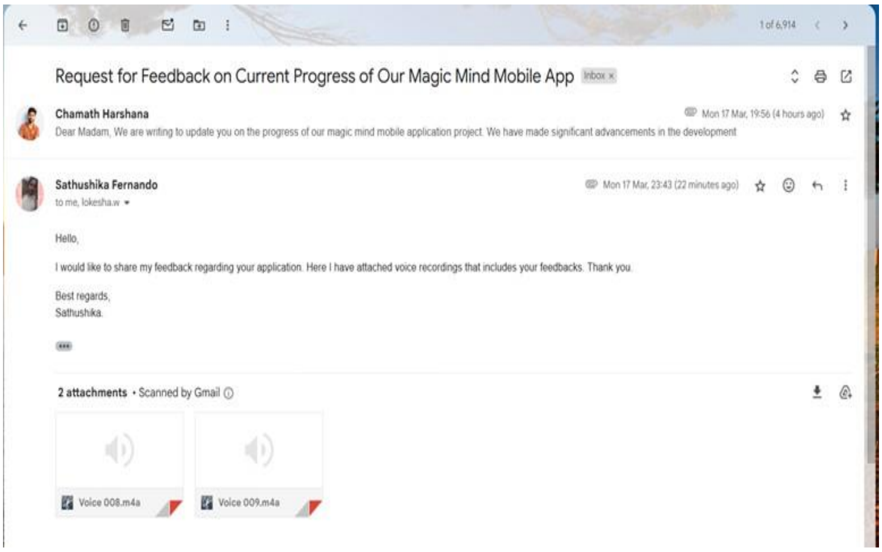


Figure 3.4.1 Visual summary of the discussion on the NVLD Vocabulary Function's impact.

Chapter 4

CONCLUSION

This dissertation describes the design and implementation of the NVLD Vocabulary Function a new educational tool to assist NVLD children (10–13 years) develop their vocabulary amongst other cognitive skills that will help them throughout their life. This system, powered by a Random Forest Classifier, generates personalized pathways of learning which adapt in real-time depending on users' performance, thus ensuring the ensuing educational environment entails an engaging university tailored to the exact cognitive issues children with NVLD suffer from. By using gamification elements such as fun, mini-games, challenging levels, all bundled up with instant feedback loops that allow users to stay engaged in their learning process, they manage to achieve deeper understanding instead of just shallow memorizing. Beyond these two interactive levels, Buddy Words provides two bonus levels—Calculation Improvement and Time Identification—broadening the application's utility and reinforcing important cognitive skills, to meet the entirety of developmental needs.

These results show us one of the most important things that would be the results of the project; the tests done in the project; you were able to see that in the Random Forest Classifier it achieved an accuracy of 87.33% with an average response time per time of 1.2 seconds responding in real-time adaptation. With the results of both assessments, we have identified a noteworthy improvement in vocabulary retention and general intelligence for the target population post-intervention, demonstrating the effectiveness of the design solution proposed. This system would be ideal for providing rich vocabulary learning where traditional learning methods fail to address NVLD weaknesses based on the unique needs of that population; it also fulfills a gap in the educational technology landscape by offering a tool designed specifically for an underrepresented population. It took fourteen months of

R&D, which involved extensive consultations with health professionals and educators in its conception to ensure it could be a useful tool and a good product.

However, there are challenges with this development, from gamification so as not to overwhelm the user, through to machine learning model efficiency so necessarily provide a real-time experience. These obstacles were surmounted through iterative testing and optimization — feelings were further validated by the strong results for the test case. And though the system's current reach includes only a specific age group and disorder, its applicability to varied populations is untested. Hence, these limitations are potential perspectives for future extensions.

The opportunities to make the app much more complete are numerous. By pairing this technology with Learning Management Systems (LMS), this could facilitate its usage in formal education traffic, where teachers were able to keep track of students' progress and adjust the syllabus even further. Further extending its multi-language availability will enable it to be meaningful to NVLD children who do not speak English, making it more impactful worldwide. Importantly, if the system were customized for more learning disabilities — such as dyslexia or autism spectrum disorder — it could also serve a much broader audience, using the flexible framework that has already been established. The next version may also explore tougher, more advanced AI approaches like deep learning that can enable greater individualization and new channels of cognitive space such as spatial reasoning, keeping in mind specific type of skill set that a user may have. Such improvements would require significant validation studies with interdisciplinary experts to determine feasibility and efficacy.

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Appendix A

SAMPLE QUESTIONNAIRE

Sample questionnaires used for the traditional model in the study.

Figure 0.1 1: Questioners

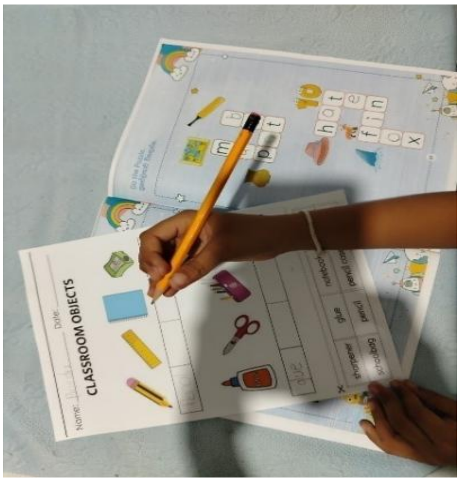


Figure 0.1 2: Questioners

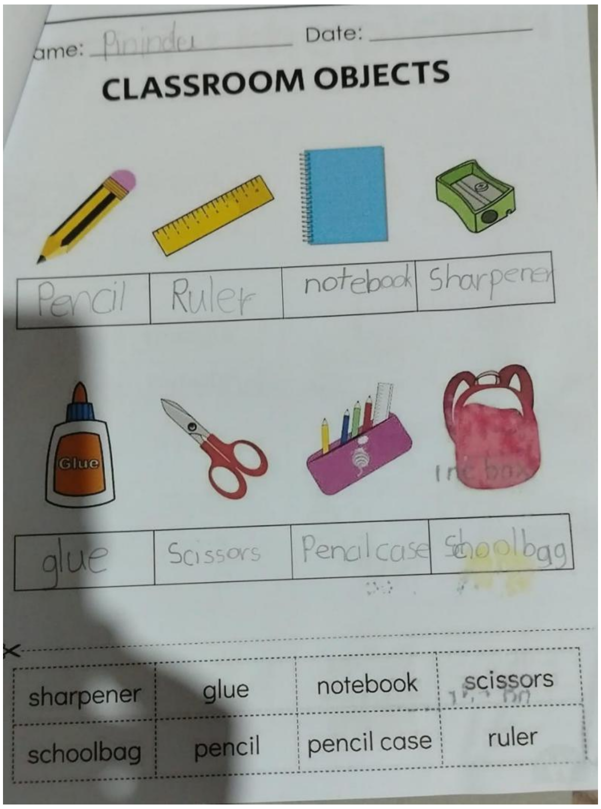


Figure 0.1 3: Question Paper

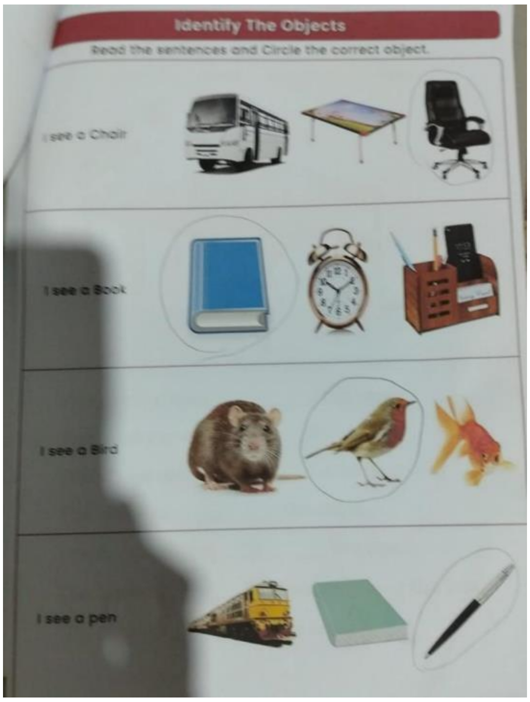


Figure 0.1 4: Question Paper

Figure 0.1 5: Question Paper

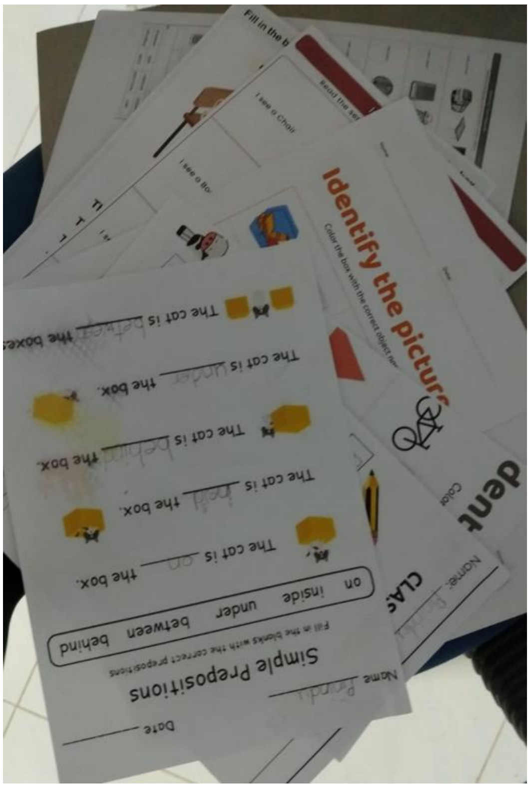


Figure 0.1 6: Worksheets

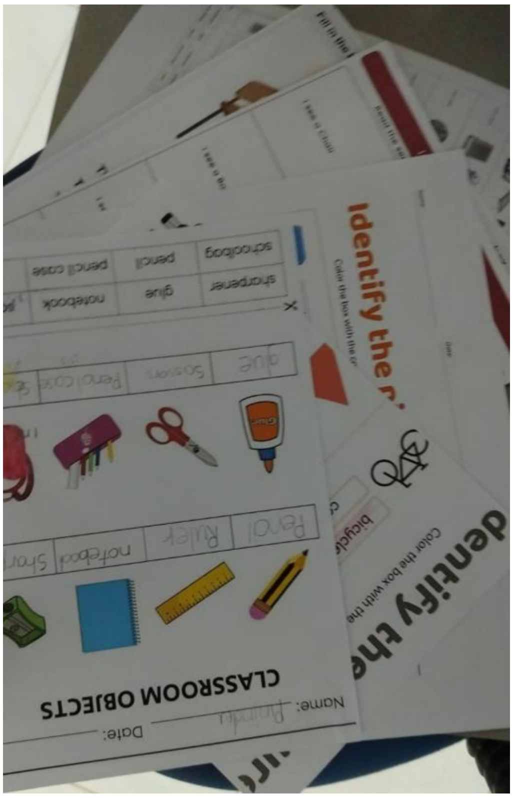


Figure 0.1 7: Worksheets

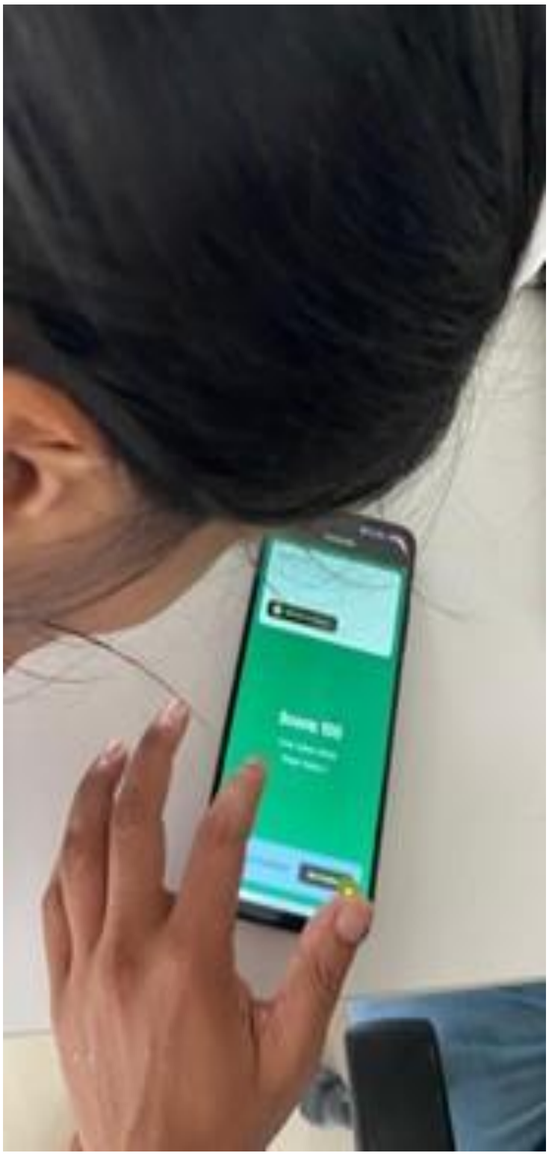


Figure 0.1 8: Sample questionnaire for the app-based model in the PAV system

Appendix B

MEDICAL CENTERS' VISIT

Consultations informed app improvements.

Figure 0.1 9: Medical Centers' Visit

Figure 0.1 10: Medical Centers' Visit

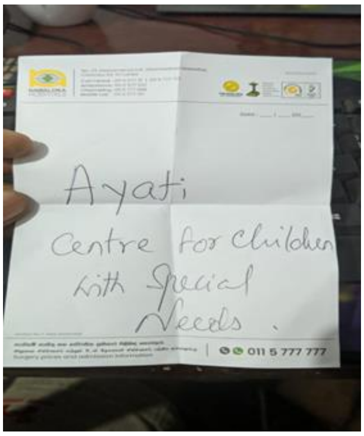
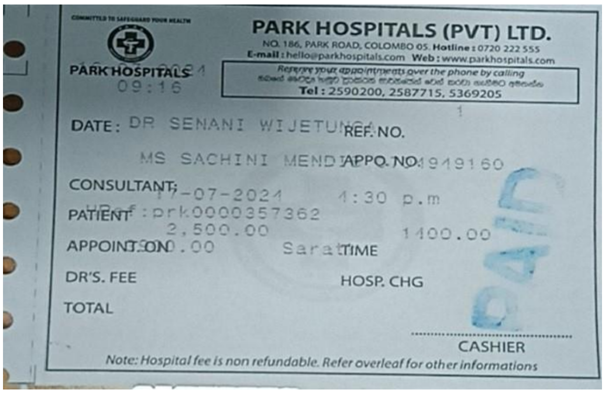


Figure 0.1 11: Medical Centers' Visit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MS SACHINI MENDIS APPO. NO. 1919160
CONSULTANT: 17-07-2024 4:30 p.m
PATIENT HR.f : prk0000357362
2,500.00 1400.00
APPOINT. ON 3900.00 Sarath TIME
DR'S. FEE HOSP. CHG
TOTAL
PAID
CASHIER
Note: Hospital fee is non refundable. Refer overleaf for other informations

Figure 0.1 12: Medical Centers' Visit

Appendix C

SAMPLE DATASET

correct_ar	time_taker	previous_l	current_le	next_level	decrease_	grade	motivation	time_categ	score_rate
5	0.393939	1	2	3	0	2	Keep going	0	0.5
7	0.242424	2	3	4	0	1	You're doir	0	0.7
8	0.090909	3	4	5	0	1	Almost the	1	0.8
6	0.545455	2	3	4	0	2	Keep pushi	2	0.6
9	0.151515	4	5	5	0	0	You're ama	1	0.9
3	0.676768	1	1	2	1	3	Stay motiva	2	0.3
10	0.10101	5	5	5	0	0	Unstoppat	1	1
2	0.787878	1	2	2	1	3	Believe in y	2	0.2
4	0.50505	2	3	3	1	2	Keep trying	1	0.4
6	0.323232	3	4	5	0	1	You're on fi	0	0.6
5	0.454545	2	2	3	0	2	Keep movi	1	0.5
9	0.151515	4	5	5	0	0	Outstandir	1	0.9
1	0.898989	1	1	1	1	4	Never give	2	0.1
7	0.212121	3	3	4	0	1	You're doir	0	0.7
8	0.151515	4	5	5	0	0			
10	0.10101	5	5	5	0	0	Unstoppat	1	1
6	0.545455	2	3	4	0	2	Keep pushi	2	0.6
1	0.898989	1	1	1	1	4	Never give	2	0.1
8	0.151515	4	5	5	0	0			
5	0.454545	2	2	3	0	2	Keep movi	1	0.5
2	0.787878	1	2	2	1	3	Believe in y	2	0.2
1	0.898989	1	1	1	1	4	Never give	2	0.1

Figure 0.1 13: Sample dataset used for training the Random Forest Classifier