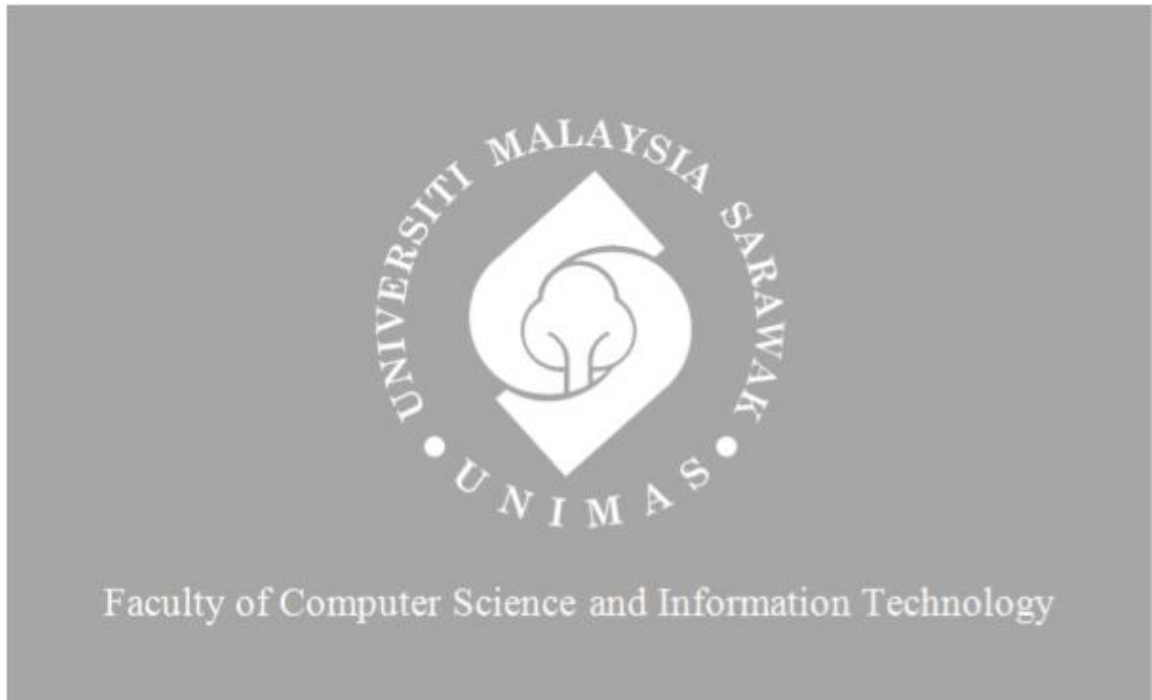




Doodle Recognition for Early Language Learning in Young Children

HOO DY LLEN

(81785)

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ABSTRACT

This project presents a Doodle Recognition system designed to enhance English vocabulary retention issues among young children aged 3 to 6. The project aims to study the strategies to address vocabulary retention as well as implementing a doodle drawing recognition web app to create an interactive and engaging educational tool. The Rapid Application Development (RAD) methodology proposes a user-centric design with iterative feedback to refine functionality throughout the Software Development Life Cycle (SDLC). Key features include a responsive drawing canvas, AI-driven doodle recognition, pre- and post-tests for assessment, and real-time feedback to improve learning outcomes. The proposed solution focuses on developing fine motor skills alongside cognitive abilities, aligning with play-based learning principles. The study reviews existing applications, identifies gaps in their design, and demonstrates the potential of combining doodling with vocabulary learning to create a holistic educational experience. By aligning with the Malaysian preschool curriculum, this innovative approach contributes to early childhood education, fostering vocabulary acquisition through hands-on, creative activities.

ABSTRAK

Projek ini membentangkan satu Sistem *Doodle Recognition* dengan fokus untuk meningkatkan penguasaan kosa kata Bahasa Inggeris dalam kalangan kanak-kanak berusia 3 hingga 6 tahun. Tujuan projek ini adalah untuk mengkaji strategi untuk menangani masalah *retention* kosa kata serta membina aplikasi web *Doodle Recognition* untuk mewujudkan alat pendidikan yang interaktif dan menarik. Metodologi *Rapid Application Development (RAD)* mencadangkan kaedah yang berpusat kepada pengguna dengan maklum balas berulang untuk memastikan fungsi sistem berfungsi dengan sempurna sepanjang *Software Development Life Cycle (SDLC)*. Ciri-ciri utama system termasuk kanvas lukisan responsif, *doodle recognition*, ujian pra and pasca untuk penilaian, dan maklum balas yang pantas untuk meningkatkan hasil pembelajaran. Penyelesaian yang dicadangkan memberi tumpuan kepada pembangunan kemahiran motor halus (*fine motor skill*) serta kebolehan pemikiran kognitif, dengan prinsip pembelajaran berasaskan permainan. Kajian ini mengkaji aplikasi sedia ada, mengenal pasti jurang dalam reka bentuknya, dan menunjukkan potensi menggabungkan lukisan *doodle* dengan pembelajaran kosa kata untuk mewujudkan pengalaman pendidikan yang holistik. Pendekatan inovatif ini menyumbang kepada pendidikan awal kanak-kanak, memupuk pemerolehan kosa kata melalui aktiviti kreatif dan *hands-on*.

Chapter 1: Introduction

1.1 Background

According to Suwanto and Rahman (2022), preschool vocabulary growth and enrichment in English is an essential component of early childhood education, with far-reaching implications for prospects in a globalized society, cognitive development, and academic achievement. Malaysia education teaches students from preschoolers up until secondary school as a second language (English as Second Language, ESL). Preschoolers are regarded as the golden age to master language acquisition (Abu Bakar et al., 2021). As a result, the significance of learning English at a young age became apparent.

Vocabulary is a group of words that are divided into two groups: lexical words that provide information and functional words that serve grammatical purposes. Learning grammar and syntax is linked to, but distinct from, expanding one's mental vocabulary (Pascual et al., 2022). Vocabulary retention among young children is a significant concern, particularly as many children enter school with limited vocabulary knowledge, which can hinder their academic success (Kelley et al., 2020). According to Strong (2023), the research found that retrieval practice methods that encourages active recall and metacognition, including Flashcards and Low-Stakes Quizzes, and The Brain Dump, can improve long-term vocabulary memory.

Based on study done by Winter et al. (2024), young children can improve their language skills through the development of fine motor skill (FMS) with play-based activities. The study demonstrated the significance of motor development in language acquisition, particularly in vocabulary retention, by finding that FMS substantially predicted both receptive and expressive vocabulary as well as oral narrative skills.

Drawing helps children improve their fine motor skills and hand-eye coordination because it requires children to hold and manipulate writing utensils. It gives them opportunity to form connections between what they see and do. Drawing also gives immediate, visual feedback that allows children to improve their technique to get their desired results (Team, 2022). Doodle recognition is known to play a role in significantly influencing young children's fine motor skills and hand-eye coordination, which are critical for their future academic performance. Research demonstrating notable improvements in

motor abilities through such interventions suggests that drawing and colouring can help with fine motor development (Putri et al., 2023).

Examples and Limitations of Existing Solutions:

Several applications aim to tackle vocabulary retention for learners, though many are better suited for older children and lack the hands-on interaction beneficial for young children. For example, *Anki* is a popular flashcard-based program that uses spaced repetition to improve vocabulary retention by practicing and memorizing words over time. However, while effective for older students preparing for exams, *Anki* lacks interactive or motor-skill-engaging elements that support long-term memory for younger children. Without a tactile component, young children may find it challenging to retain vocabulary in a meaningful way.

ChatterStars (Figure 1) is another application designed to make vocabulary study engaging for children between the ages of 6 and 16. Using active recall and visual learning strategies, *ChatterStars* helps users strengthen their vocabulary through interactive games. However, it does not address the needs of younger children or integrate sketching activities that could promote fine motor skills and assist with vocabulary retention.



Figure 1: ChatterStars

Vocabulary.com (Figure 2) also serves as a vocabulary-building tool, utilizing engaging activities and quizzes that adapt to a user's level. While helpful in reinforcing language through visual aids and gamified learning, its focus on text-based learning limits its effectiveness for young children who benefit more from hands-on activities.

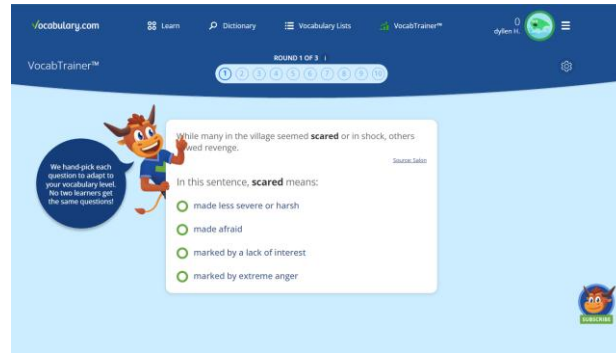


Figure 2: Vocabulary.com VocabTrainer

These applications highlight the importance of vocabulary retention techniques; however, they often lack components that engage younger children's fine motor skills and active drawing practices. By introducing doodle recognition into vocabulary learning, this project aims to fill this gap, providing an engaging, interactive approach to help young children build vocabulary through hands-on, creative activities.

Drawing activities offer a unique opportunity to improve vocabulary retention by engaging young children in interactive, play-based learning. This method encourages active recall and metacognition, similar to retrieval practices such as flashcards and quizzes. However, current applications designed to support language learning in young children, like simple flashcard apps or animated stories, often lack the interactive, motor-skill-engaging features that could truly aid retention through active involvement.

1.2 Problem Statement

Vocabulary retention is a common challenge among young children due to limited exposure and engagement when learning the English vocabulary. Vocabulary refers to the collection of words that a person knows and uses, that are essential for clear communicate and comprehension in any languages. Vocabulary acquisition refers to the process where individuals learn and internalize new words. It is often supported by direct instruction and number of techniques such as contextual learning, and spaced repetition, which have shown improvement in both acquisition and retention of vocabulary in language learners (Kriama, 2023) (Shohsanam & Dildoraxon, 2023). Contrarily, vocabulary retention refers to the capacity to remember and apply newly acquired words over time; this is a problem that many students encounter because of cognitive issues like forgetting and interference (Allanazarova, 2020).

According to Nurmala & Zulfahmi (2024), early interventions and play-based activities significantly enhance the development of fine motor skills in young children since their fine motor skills progress significantly around the age of 3. Essential abilities like dexterity and hand-eye coordination are fostered by participating in activities like cooking, colouring, pottery making, and educational games. For example, working with clay in pottery exercises fosters creativity and sensory experiences in addition to fine motor abilities. Since vocab retention is critical at this early stage, as it supports not only language acquisition but also broader academic success in later years.

Winter et al. (2024) found that incorporating doodle recognition technology into learning techniques dramatically improves vocabulary memory. By using doodle recognition technology, young children will be able to draw since it promotes the development of fine motor abilities, which improves knowledge retention. As a result, this study will seek to address the difficulty of vocabulary retention among young children by incorporating doodle recognition technology into the English vocabulary learning process.

1.3 Scope

- **Target users:** Young children in preschools, between the age of 3 to 6 years old.
- **Dataset:** Dataset that will be used for training and testing will be in form of doodle drawings with categories within the syllabus of young children such as Food, Animals, and Objects.

1.4 Aims and Objectives

1. To study the strategies used to improve their English vocabulary retention.
2. To implement a doodle drawing recognition web app to improve their English vocabulary retention.
3. To evaluate young children's vocabulary retention skills through pre-test and post-tests after using the doodle recognition system.

1.5 Significance of Project

This project addresses the critical challenge of vocabulary retention among young children by combining English language learning with interactive drawing recognition. Vocabulary retention at an early age is foundational not only for language acquisition but also for long-term academic success. Drawing activities naturally improve hand-eye

coordination and fine motor skills, fostering connections between actions and language concepts. This interactive approach supports cognitive and motor skill growth in tandem, providing a comprehensive and enjoyable way for children to learn and remember vocabulary. Furthermore, by aligning with the Malaysian preschool curriculum and focusing on familiar vocabulary categories such as animals, food, and objects, which are curated to the preschooler level of education. This innovative approach contributes to early education practices by offering a novel tool that combines language learning with developmental benefits, supporting Malaysia's educational goals and helping to prepare children for future academic success in a globalized society. Therefore, by integrating doodle recognition with English vocabulary learning, the proposed system engages children in active, play-based learning, helping them to recall vocabulary through their own creative drawings.

1.6 Expected Outcome

The project aims to improve vocabulary retention among young children by implementing an interactive web app that uses doodle recognition. Children will freely draw figures on a canvas, with the system recognizing their drawings accurately using machine learning. To reinforce correct vocabulary association, the app provides real-time feedback on the accuracy of the doodle, helping children adjust and refine their drawings to better match the target word. This interactive approach engages children's fine motor skills while promoting better vocabulary recall, as they repeatedly encounter and correctly identify everyday words through hands-on, playful drawing activities.

1.7 Summary

The introduction outlines the importance of English vocabulary development among young children, as early language acquisition significantly impacts cognitive development and future academic success. English, taught as a second language in Malaysian schools, is especially crucial for preparing young children for a globalized society. Research highlights that vocabulary retention remains a major challenge for young children, particularly due to limited exposure and engagement with the language. Traditional methods like flashcards and low-stakes quizzes improve retention through retrieval practice, but they lack the tactile and motor engagement that could benefit younger children. Additionally, studies suggest that fine motor skills (FMS), developed through

activities like drawing, play a vital role in vocabulary acquisition, as they support hand-eye coordination, dexterity, and overall cognitive development.

Current language-learning applications, such as Anki, ChatterStars, and Vocabulary.com, provide vocabulary-building tools but often target older children and rely on text-based or flashcard learning, which lacks motor-skill engagement and interactivity. While these programs are effective for older learners, they don't address the unique needs of young children, who benefit more from hands-on, interactive experiences.

The scope of the project focuses on Malaysian preschoolers aged 3 to 6, with a dataset of doodle drawings categorized by themes relevant to their syllabus, including animals, food, nature, and objects. The project objectives are to investigate the challenges of embedding drawing into English learning, implement a doodle recognition web app to aid vocabulary retention, and *evaluate the app's performance through unit testing and usability assessments*.

The significance section underscores the project's contribution to early education by combining language learning with developmental benefits, aligning with Malaysia's educational goals and addressing the need for effective vocabulary retention strategies. By engaging children in drawing activities, the app promotes fine motor skill development and facilitates vocabulary recall through interactive learning.

The expected outcome of the project is a web app that uses machine learning for doodle recognition, allowing young children to draw on a canvas and receive real-time feedback on the accuracy of their drawings. This feedback reinforces correct vocabulary association, helping children retain new words more effectively through active, play-based learning.

Chapter 2: Literature Review

2.1 Introduction

Vocabulary retention during early childhood is essential for cognitive and social development, as it serves as a cornerstone for effective communication and literacy. In this crucial stage, children learn, retain, and apply new words in meaningful contexts, laying the foundation for their future language skills and overall development. Research consistently underscores the importance of early interventions that integrate engaging and interactive methods to enhance vocabulary retention, particularly for young children who benefit from tactile and creative learning activities (Winter et al., 2024).

The formative years of a child's life are marked by rapid development in cognitive, motor, and social skills. Early exposure to language-rich environments and interactive learning strategies can significantly influence their ability to acquire and retain new vocabulary. Vocabulary is a critical aspect of language acquisition, forming the basis for other skills such as reading, writing, speaking, and listening. As noted by Dionisio et al. (2022), the lack of robust vocabulary knowledge is a primary obstacle for learners in both understanding and expressing themselves effectively. This is especially relevant in the context of learning a second language, where vocabulary is considered an indispensable element of communication.

Traditional teaching methods, such as rote memorization, often result in passive learning habits and limited long-term retention (Phung, 2021). Furthermore, studies suggest that students tend to forget vocabulary quickly due to a lack of engaging and innovative teaching strategies (Carranza et al., 2015). To address these challenges, integrating technology with play-based, creative activities such as drawing can offer a more dynamic and engaging approach to vocabulary learning, fostering better retention and comprehension (Nguyen, 2021).

One promising approach is the integration of drawing and doodling activities into vocabulary learning. Drawing not only enhances fine motor skills and hand-eye coordination but also creates a visual and physical representation of words, which reinforces memory and understanding. By engaging multiple senses, drawing can bridge

the gap between abstract concepts and tangible learning experiences, making it a powerful tool for vocabulary acquisition (Putri et al., 2023).

Doodle recognition systems further amplify this potential by leveraging advancements in artificial intelligence to provide real-time feedback and interactive experiences. Such systems can identify children's drawings, associate them with corresponding vocabulary, and deliver immediate auditory and visual reinforcement. This dynamic interaction fosters active participation and sustained interest, aligning with the principles of play-based learning, which is widely regarded as an effective strategy for early education (Team, 2022).

This project seeks to explore and implement a doodle recognition system tailored to the needs of young children. By combining the developmental benefits of drawing with the cognitive advantages of interactive language learning, the proposed solution aims to address the challenges of vocabulary retention and support holistic child development. In the following sections, the literature review will delve deeper into related works, existing tools, and applications to identify gaps and opportunities that the project aims to address.

2.2 Review of Vocabulary Retention Strategies

- ***Flashcards***

Flashcards are one of the known effective methods in improving vocabulary retention among young children. It incorporates visual elements such as images, alphabets, symbols, and colours, which capture children's attention and facilitate easier retention of new words. The visual stimulation is crucial for young learners, as it enhances their ability to recognize letter shapes and sounds, thereby improving listening skills and promoting verbal expression (Riadoh & Larasati, 2024).

A study conducted at Apple Tree Pre-school demonstrated that kindergarten students showed significant vocabulary development when taught using flashcards, which were organized by themes and included colourful images that captured the children's attention (Rachmita, 2016). Similarly, research at Little Elephant Kindergarten School found a substantial improvement in students' vocabulary achievement, with mean scores increasing from 12.7 in the pre-test to 75.0 in the post-test after the introduction of flashcards (Risdanti, 2016). Despite these positive findings, some challenges remain, such

as the potential for traditional memorization techniques to become monotonous, which can lead to decreased engagement and retention over time (Bahrudin, 2015).

- ***Picture Dictionary***

Picture dictionaries are effective in improving vocabulary retention among young children in kindergarten because young children are inherently more receptive to visual learning, using pictures to teach vocabulary is consistent with their cognitive development. By grabbing and holding their attention, this visual engagement makes learning more effective and pleasurable. (Nawaz et al., 2021). Additionally, pictures serve as a mnemonic device, aiding in the retention of new words by creating strong visual associations that are easier for children to recall (Othman et al., 2022).

For instance, research done by Othman et al. (2022), indicates that associating words with images helps children remember vocabulary for longer periods, as demonstrated in a study involving Malaysian pupils where the use of pictures significantly enhanced vocabulary retention. Similarly, a study on kindergarten students using a matching picture game reported an increase in vocabulary mastery, with mean scores improving from 2.71 to 3.62 after the intervention (Sari et al., 2022).

- ***Drawing and Doodling***

The integration of drawing into vocabulary learning allows children to create visual representations of words, which aids in the retention and recall of vocabulary by linking visual and verbal information in the brain. This multimodal approach is particularly beneficial for young learners who are still developing their fine motor skills and cognitive abilities, as it provides a more holistic learning experience (Steffani & Selvester, 2009) (Randoha, 2015).

A study on the use of drawing as a memory aid found that children who participated in interactive drawing activities recalled more correct information, suggesting that drawing can serve as an effective tool for reinforcing vocabulary learning (Barlow et al., 2010b). Moreover, the integration of drawing into language learning activities aligns with the natural developmental processes of young children, who often use drawing to explore and communicate their understanding of the world around them (Dyson, 1986).

2.3 Review of Existing Applications

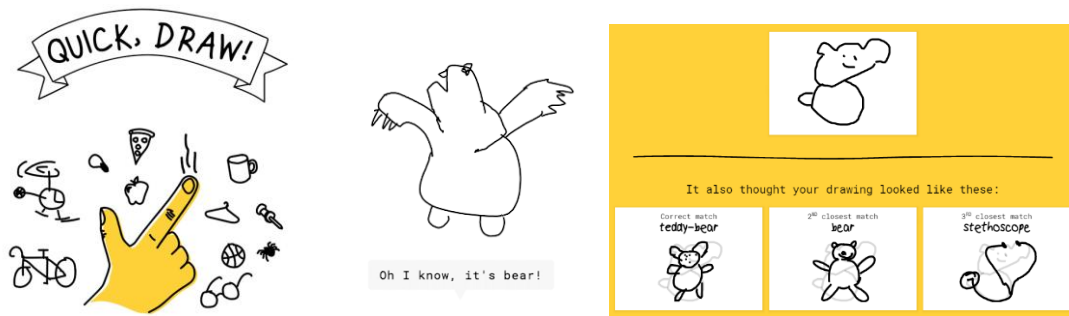


Figure 3: Sample of Google Quick, Draw!

Quick, Draw! (Figure 3) is an interactive game developed by Google, which also gathers user-generated doodling and created a huge dataset of more than 50 million drawings in 345 categories. According to Fernandez-Fernandez et al. (2019), users will draw a given object within 20 seconds and an AI attempt to recognize the drawing through a classification Neural Network. This is due to the dataset recording drawings as time series of pencil positions rather than static images, with offers a dynamic perspective on sketch recognition. The second image shows that the application recognised the drawing accurately as a bear, while the third image shows the possible answers that were recognised by the application with your drawing.

The target users for Quick, Draw! by Google primarily include children and young learners who are in the early stages of language acquisition. This interactive game not only engages them in a fun and creative activity but also aids in developing their cognitive and motor skills through doodling. Additionally, educators and parents can utilize the application as a tool for teaching vocabulary and enhancing visual recognition skills in a playful manner. The game's design encourages collaboration and social interaction, making it suitable for group settings, such as classrooms or family gatherings. By appealing to a broad audience that includes both children and adults, Quick, Draw! serves as an educational resource while also providing entertainment (Fernandez-Fernandez et al., 2019).

While Quick, Draw! by Google offers numerous benefits for early language learning and engagement through doodling, there are several limitations and gaps that can be identified in its design and functionality.

Limited Vocabulary Range: The application primarily focuses on a predefined set of 345 categories, which may restrict the breadth of vocabulary exposure for young learners. As noted by Fernandez-Fernandez et al. (2019), this limited vocabulary could hinder comprehensive language development, as children may not encounter words outside the specified categories, potentially leading to gaps in their linguistic knowledge.

AI Recognition Accuracy: While the AI recognition system is designed to provide immediate feedback, its accuracy can vary based on the quality of the drawings made by children. Young learners may struggle with fine motor skills, resulting in drawings that do not conform to the AI's expectations. This could lead to frustration and disengagement if their efforts are not recognized correctly (Fernandez-Fernandez et al., 2019).

Lack of Personalized Learning: The application does not currently offer personalized learning paths or adaptive feedback tailored to individual users' progress and learning styles. This one-size-fits-all approach may not adequately address the diverse needs of children, as some may require more support or different types of engagement to thrive in their language learning journey (Fernandez-Fernandez et al., 2019).

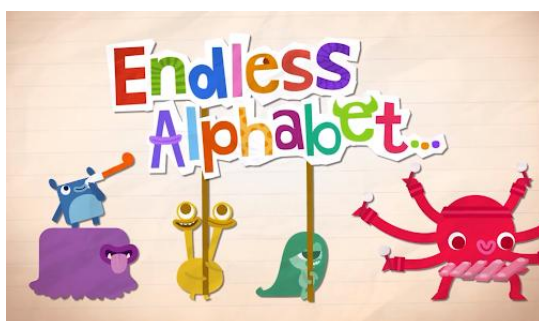


Figure 4: Endless Alphabet by Originator Inc.



Figure 5: Interactive exercise in Endless Alphabet

Endless Alphabet (Figure 4 & Figure 5) is an interactive educational application specifically designed for young children, with a primary focus on enhancing vocabulary acquisition and retention in the English language. The app features a playful and engaging interface that allows young children to explore a vast array of vocabulary words through animated illustrations and interactive puzzles (Xu, 2024).

Each word in the application is accompanied by a whimsical character that represents its meaning, which aids children in visualizing concepts and creating stronger associations between the words and their definitions (Berk, 2016). This visual representation is crucial for memory retention, as children are more likely to remember words that are connected to engaging images and stories (Miller & Sussman, 2021; Xu, 2024). The interactive elements of the app, such as puzzles and animations, further enhance engagement, making the learning process enjoyable and effective.

The design of Endless Alphabet encourages active participation from young children, allowing them to learn at their own pace while exploring new vocabulary in a fun and creative way. By transforming vocabulary learning into an interactive experience, the app supports better retention of information, as children are more inclined to remember words that they have visualized and interacted with (Miller & Sussman, 2021).

While Endless Alphabet is an engaging application designed to enhance vocabulary acquisition in young children, it does have several limitations and gaps that can be addressed to improve its effectiveness.

One significant limitation of Endless Alphabet is the lack of personalized feedback. The current design does not cater to individual learning styles or progress, which can be particularly important for young children who have varying levels of language acquisition (Berk, 2016). A one-size-fits-all approach may not adequately support children who require more tailored guidance. To address this limitation, the application could incorporate adaptive learning mechanisms that assess a child's progress and provide personalized feedback or suggestions for further practice. This could involve adjusting the difficulty of vocabulary words based on the child's performance, thereby ensuring that each user receives an experience suited to their unique learning journey.

Another limitation of Endless Alphabet is its lack of drawing activities, which could enhance vocabulary retention through creative expression. While the application

effectively employs animated illustrations and interactive puzzles to engage young learners, it does not incorporate doodling or drawing tasks that allow children to visually represent the words they are learning. Research indicates that engaging in drawing activities can significantly bolster memory retention by fostering a deeper connection between visual representations and vocabulary (Fernandez-Fernandez et al., 2019).



Figure 6: ABC Mouse Learning Academy



Figure 7: Main menu of ABCmouse

ABCMouse (Figure 6 and Figure 7) is an interactive online learning platform designed for children aged 2 to 8 years. It offers a comprehensive curriculum that encompasses various subjects, including reading, math, science, art, and music, aimed at fostering early childhood education. The platform features a wide range of activities, including games, books, songs, and puzzles, which are designed to engage young learners and make the educational experience enjoyable (ABCMouse, n.d.).

One of the key elements of ABCmouse is its structured learning path, which guides children through different levels of difficulty as they progress. This personalized learning experience adapts to each child's individual pace, allowing them to master concepts before moving on to more advanced topics. The platform employs a multi-sensory approach, incorporating visual, auditory, and kinaesthetic learning strategies, which have been

shown to enhance retention and engagement among young learners (Berk, 2016; (Xu, 2024).

ABCmouse also includes features that allow parents and educators to track a child's progress, enabling them to provide support and encouragement as needed. This aspect of the platform fosters a collaborative learning environment, where parents can be actively involved in their child's education (Johnson, 2022). Furthermore, the platform's content is designed to align with early childhood education standards, ensuring that children are receiving a high-quality educational experience that prepares them for future academic success (Miller & Sussman, 2021).

While ABCmouse is a valuable educational tool for young children, it does have several limitations and gaps when it comes to improving vocabulary retention:

Lack of Drawing Activities: ABCmouse does not incorporate drawing or doodling activities, which can significantly enhance vocabulary retention through creative expression. Research indicates that engaging in drawing can foster a deeper connection between visual representations and vocabulary (Fernandez-Fernandez et al., 2019). By omitting this interactive element, ABCmouse may miss opportunities to further enrich the learning experience.

Generic Feedback Mechanisms: ABCmouse lacks personalized feedback tailored to individual learning progress. This one-size-fits-all approach may not adequately address the diverse needs of children, as some may require more targeted support or different engagement strategies to effectively learn vocabulary (Johnson, 2022).

2.4 Discussion

Table 1: Comparison Table of Vocabulary Retention Strategies

Strategy	Target Audience	Key Features	Limitations	Relevance to Project
Flashcards	All ages	Visual aids such as images, symbols, and colours to capture attention and improve retention	Monotonous repetition can reduce engagement over time	Highlights the need for engaging alternatives like drawing activities
Picture Dictionary	Preschoolers and early primary schoolers	Visual-mnemonic associations to aid recall, consistent with cognitive development	May not engage motor skills or provide tactile interaction	Emphasizes the importance of visual aids but lacks motor-skill integration

Drawing and Doodling	Preschoolers	Multisensory approach linking visual and verbal information for better retention	Requires guided instruction for effective vocabulary association	Directly supports integrating doodle recognition for vocabulary learning
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Table 1 above compares three strategies for improving vocabulary retention, highlighting their target audience, key features, limitations, and relevance to the project.

Flashcards, widely used among preschoolers and primary schoolers, rely on visual aids like images and colours to facilitate learning. While effective in drawing children's attention, the repetitive nature of flashcards can lead to disengagement over time. This points to the need for more interactive alternatives, such as drawing.

Picture dictionaries engage preschoolers through visual-mnemonic associations, making learning enjoyable and easier to recall. However, they do not incorporate tactile or motor-skill activities, which are critical for young children's holistic development. This underscores the value of combining visual and motor skills in vocabulary learning tools.

Drawing and doodling provide a multimodal approach, integrating visual and verbal cues to enhance memory retention. This strategy aligns well with young children's natural development, as it improves fine motor skills and engages multiple senses. Its benefits directly support the implementation of a doodle recognition system, making it a core feature of the project.

Table 2: Comparison Table of Similar Application

Application	Target Audience	Key Features	Focus on Fine Motor Skills	Limitations	Relevance to Project
Google Quick, Draw! (Google, n.d.)	All ages	Real-time sketch recognition, feedback	Strong	Not designed for language learning	Inspiration for doodle recognition features
AutoDraw (Google, n.d.)	General users	AI-assisted drawing, predictive suggestions	Strong	Limited to predefined prompts, lacks educational context	Inspiration for creative and interactive features
Endless Alphabet (Originator Inc, 2013)	Preschoolers	Interactive word puzzles and animations	None	No integration of motor-skill activities	Reinforces interactive content design
ABCmouse (Age of Learning Inc., 2010)	Preschoolers	Comprehensive activities, including songs and puzzles	Moderate	Lacks AI-based interactive doodle recognition	Illustrates preschool-centric content and learning paths

Table 2 is a comparative analysis of existing doodle recognition tools and educational applications highlights key areas of potential for the proposed system. *Google Quick, Draw!* and *AutoDraw* demonstrate the effectiveness of AI-driven sketch recognition in creating engaging user experiences. However, these tools lack the educational context necessary for supporting vocabulary retention among preschoolers. While *Quick, Draw!* offers robust interactivity, its limited focus on general-purpose doodling and predefined categories restricts its ability to cater to the specific learning needs of young children. *AutoDraw*'s predictive features showcase creative possibilities but fail to integrate a tailored educational content essential for early language development.

Conversely, applications like *Endless Alphabet* and *ABCmouse* effectively incorporate interactive and visual elements to support vocabulary learning in preschoolers. *Endless Alphabet* uses animations and puzzles to make learning enjoyable, while *ABCMouse* offers a structured curriculum designed for young learners. Despite these strengths, both tools overlook the benefits of integrating doodling activities, which research has shown to significantly enhance vocabulary retention and fine motor skill development. The absence of drawing-based interactivity limits their ability to fully engage children in multisensory learning experiences.

The proposed doodle recognition system addresses these gaps by combining the strengths of existing tools while introducing features specifically designed for preschoolers. By linking doodle recognition to vocabulary learning, the system will enable children to associate their drawings with corresponding words, thereby fostering active recall and long-term memory retention. Additionally, the system's design will accommodate the motor skill development stage of preschoolers, provide visual prompts and forgive recognition thresholds to create a supportive and enjoyable learning environment.

This approach aligns with the problem statement by addressing the challenges of limited engagement and vocabulary retention in preschoolers. The integration of doodling into vocabulary acquisition not only enhances cognitive and motor skill development but also provides an innovative, play-based solution to early language learning. By leveraging the interactive potential of doodle recognition and tailoring it to the needs of young learners, the proposed system advances the objectives of creating a meaningful and

engaging educational tool. This project represents a significant step toward bridging the gaps identified in current tools, ensuring preschoolers benefit from a holistic and interactive approach to language acquisition.

2.5 Summary

The literature review explores vocabulary retention and its significance in early childhood education, particularly for preschoolers. It highlights the challenges of traditional teaching methods, such as rote memorization, which often result in passive learning and poor long-term retention. Research supports the integration of interactive and tactile methods, such as drawing, into vocabulary learning to enhance retention and comprehension.

Drawing activities, combined with advances in doodle recognition technology, offer a promising approach to address these challenges. Studies show that interactive tools utilizing drawing can engage young learners, support fine motor skill development, and create strong associations between visual and verbal information. Doodle recognition systems leverage artificial intelligence to provide real-time feedback, fostering active learning and long-term memory.

Existing tools like Google's Quick, Draw!, Endless Alphabet, and ABCmouse demonstrate various levels of interactivity and educational value. However, they often lack integration of motor-skill-enhancing activities like drawing or the tailored feedback necessary for preschool-aged users. Technologies such as Convolutional Neural Networks (CNNs), MobileNet, and ResNet are evaluated for doodle recognition tasks, with MobileNet emerging as the most suitable for this project due to its efficiency on resource-constrained devices.

The chapter concludes by identifying gaps in current systems and proposing a doodle recognition-based learning application to support vocabulary retention for young children. This solution aims to combine the cognitive benefits of drawing with interactive, play-based learning to foster both vocabulary retention and motor skill development.

Chapter 3: Requirement Analysis and Design

3.1 Introduction

This chapter will interpret the design requirements and specifications of the suggested system. Solutions are created to satisfy the system's requirements while they are being gathered and documented. This chapter's objective is to generate an understandable and thorough set of requirements that will direct the system's design and development in the next stages. Apart from that extra information and thorough explanation are provided on the technique of the suggested system. According to Patel & Patel (2019), methodology is the systematic, theoretical analysis of the methods applied to a field of study. Since Rapid Application Development (RAD) has been chosen as the technique for the proposed system, all its stages, from Requirement Planning and Analysis, Prototype Cycle, Development, to Transition will be discussed in this chapter.

To recap this project aims to 1) to study the strategies used to improve their English vocabulary retention; 2) implement a doodle recognition web app that helps young children improve their English vocabulary retention; 3) evaluate young children's vocabulary retention skills through pre-test and post-test after using the doodle recognition system.

3.2 Architecture

The system architecture diagram in Figure 8, illustrates the design of a Doodle Recognition System for English Vocabulary Learning, aimed at young children to improve their vocabulary through interactive drawing. The system comprises several key components. Users are divided into two categories: students, who use the system for doodling, and vocabulary tests, while the teachers or admins, monitors results, and handles user management. The system is accessible across multiple devices, including desktops, tablets, and mobile phones, with a focus on touch-screen functionality for drawing.

Frontend Infrastructure

The frontend implementation uses Next.js, a React-based framework that provides both client-side and server-side rendering capabilities. This enables optimized

performance through features such as automatic code splitting, prefetching and built-in optimization mechanisms. The React foundation facilitates the creation of interactive components, which is essential for drawing interface and real-time feedback. Tailwind CSS serves as the primary styling framework, offering utility-first CSS classes that ensure consistent design patterns while maintaining flexibility for responsive layouts across different device types.

The integration of ml5.js will handle machine learning operations directly within the browser environment. This Javascript library, built upon TensorFlow.js, enables the implementation of DoodleNet models for real-time doodle recognition without requiring server-side processing. By executing machine learning inference locally, the system reduces latency, decreases server load, and provides immediate feedback to users, which is particularly important for maintaining young learners' engagement and attention spans.

Backend Instructure and Database

The backend architecture revolves around Supabase, a comprehensive Backend-as-a-Service platform built on PostgreSQL. This provides several architectural advantages, including robust relational database capabilities, built-in authentication systems, and real-time data synchronization features. Supabase's PostgreSQL foundation ensures data integrity and supports complex queries necessary for tracking student progress and managing user relationships between students and teachers.

The authentication system integrated within Supabase handles user registration, login process and session management, providing secure access control mechanisms appropriate for educational environments. Row-level security policies can be implemented to ensure that students can only access their own data while allowing teachers to view information for their assigned students. The real-time capabilities enable immediate updates to progress dashboards and facilitate collaborative learning environments where teachers can monitor student activities as they occur.

Communication Protocols and Data Flow

The system architecture implements a streamlined communication pattern where the Next.js frontend communicates directly with Supabase through RESTful API calls and

real-time subscriptions. This direct communication eliminates the need for intermediate API layers, reducing complexity and potential points of failure. Authentication tokens are managed automatically by Supabase client libraries, ensuring secure data transmission and proper access control enforcement.

The machine learning workflow operates independently of backend communications, with DoodleNet models loaded directly into the browser environment through ml5.js. When a student completes a drawing, the frontend processes the canvas data locally, generates predictions using the loaded model, and then transmits only the results. This hybrid approach optimizes both performance and resource utilization while maintaining comprehensive data collection for educational analytics.

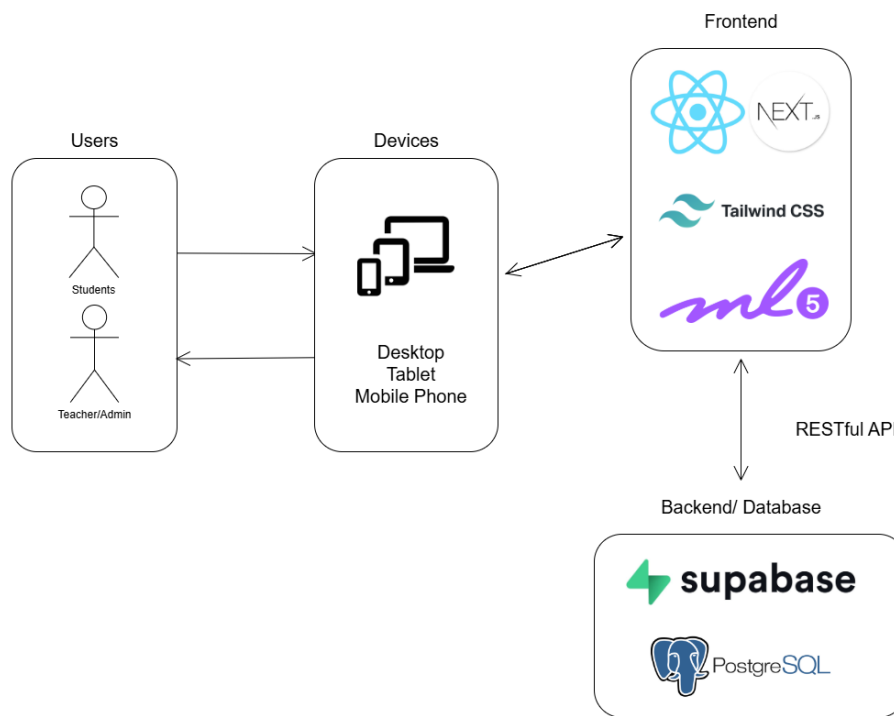


Figure 8: Overall System Architecture Design

3.3 Rapid Application Development (RAD)

Rapid Application Development (RAD) methodology (Figure 9) was first introduced by James Martin in a book named “Rapid Application Development” (Martin, 1991). Martin explains that RAD is a development lifecycle specially designed to support instant and development and to yield higher-quality results as compared to other traditional methodologies. In short, RAD is a methodology that can increase the quality of completed

system while reducing the time taken to develop it. In order to increase the quality of the completed system, the RAD methodology incorporates users into the development process. User participation initiates contact between developers and clients, which can improve both the proposed system and the user's satisfaction.

In this section, the phases that will be covered are Requirements and User Design but not so much of the iterative phases since the development have not started yet, therefore, there is no prototype of system yet. Requirements consist of planning and analysis section that will be from gathering of requirement via interview with respondents who are parents with young children or preschooler teachers. At the same time, UML diagrams are designed to better understand the flow and functional requirements of the system.

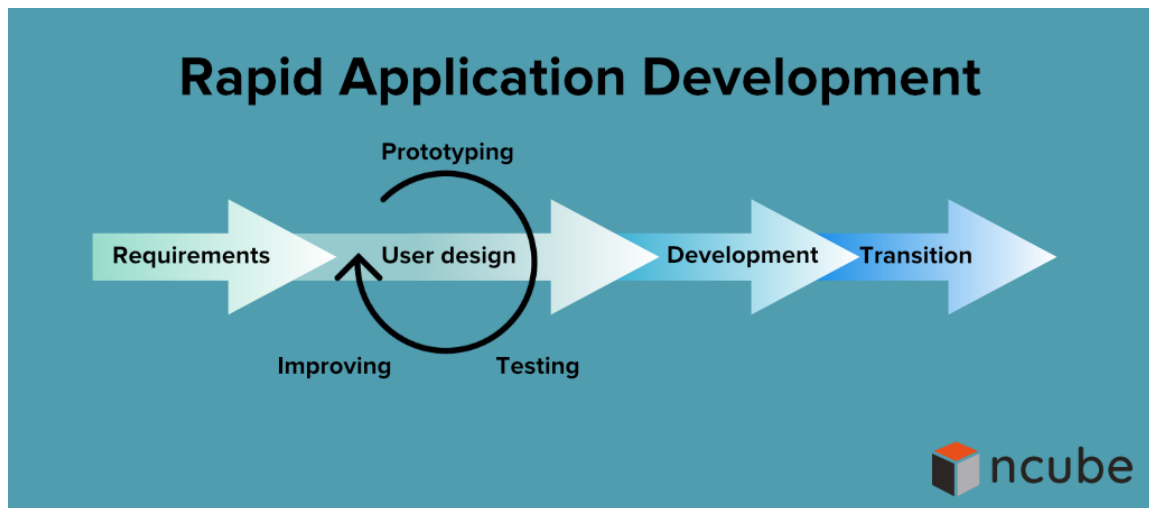


Figure 9: Graphic Illustration of Rapid Application Development (Demchenko, 2020)

3.3.1 Requirements

The following section will describe each phase of the chosen Rapid Application Development (RAD) model. During this phase, requirements were collected through interview sessions to better understand the challenges and techniques used by teachers and parents with young children to overcome the vocabulary retention issue. These data then will be analysed to design a system that introduces doodle recognition to allow young children to improve their vocabulary retention.

Five respondents, who are either preschool educators or parents with young children, have been invited for an interview session. The meetings were conducted separately via

different platforms as some respondents preferred phone call and some preferred Google Meet. The questions discussed during interview session can be referred on Appendix A

Before the interview began, context about project like the attempted problem to be overcome and the objective was briefed as well as doubt were clarified. Every session was kept to a maximum of 20 minutes to allow sufficient time to cover all the questions and provide flexibility for in-depth discussion with follow-up questions that may arise.

The interviews with preschool teachers and parents revealed several key insights into the challenges and opportunities for enhancing vocabulary retention in young children. Firstly, respondents consistently cited short attention spans, difficulty with abstracting concepts, and maintaining motivation as significant obstacles. Secondly, while traditional methods like flashcards and songs are widely used, there is a strong interest in incorporating more creative approaches, such as drawing and doodling. This aligns with the proposed doodle recognition system, which aims to leverage the enjoyment of drawing in young children to facilitate vocabulary retention and acquisition.

Furthermore, respondents expressed positive views on the potential of drawing and doodling to enhance vocabulary learning. They believed that these activities could make learning more engaging and memorable, allowing children to express their understanding creatively and connect learning to their natural inclinations. The strong support for visual learning provides a strong foundation for development of the doodle recognition system.

Respondents, especially teachers expressed a preference for a balance approach to assessment, combining multiple-choice questions with open-ended tasks. This suggests that the system should incorporate both quantitative feedback (e.g., accuracy in percentage) and qualitative feedback (e.g., descriptive comments) to provide a comprehensive assessment of learning.

In conclusion, the interview findings strongly support the development of a doodle recognition system for vocabulary retention. The system should be designed to be engaging and interactive, addressing the specific challenges identified by respondents. By effectively combining the benefits of drawing and doodling with the power of technology, the system has the potential to significantly improve vocabulary retention for young children.

Functional and Non-Functional Requirement for Proposed System

Based on the inputs given from respondents and similar applications, the requirement for functional and non-functional features of the system are stated under Table 3 below:

Table 3: Functional and Non-Functional Requirement for Proposed System

Requirements	Description	Type
Canvas for Doodling	A drawing canvas must allow users to doodle freely and include features for erasing and clearing the canvas.	Functional
Doodle Recognition	The system should recognize the doodle and predict the drawing	Functional
Feedback on Doodle Accuracy	The system should provide quantitative feedback with percentage of the accuracy and qualitative feedback (e.g., "Very good", "Needs improvement") on the drawn doodle	Functional
Pre-test and Post-test Functionality	Allow users to take a vocabulary pre-test and post-test to evaluate retention by matching words to picture	Functional
Result Recording	The system should store users' pre-test and post-test results for evaluation.	Functional
Progress Tracking and Reports	Allow users to track results and make evaluation on performance and progress of learning and vocabulary retention.	Functional
Doodle Game for practice	Doodle game with list of vocabularies for children to learn and practice doodling.	Functional
Responsive Design	The application should be responsive across all devices (desktop, tablet, and mobile phones).	Non-Functional
Touchscreen Optimization	Ensure application supports touch interactions for drawing on mobile and tablet devices.	Non-Functional

Use Case Diagram

The use case diagram in Figure 10, illustrates the functional interactions between actors and the system for the Doodle Recognition System. Two primary actors are identified: "Young Children" and "Teacher/Admin." Young Children interact with the system for vocabulary learning activities such as pre-tests, doodle game, and post-tests, while Teacher/Admin accesses the dashboard for managing results and tracking student progress. The diagram encapsulates the system's core functionalities, emphasizing user roles and corresponding actions, ensuring streamlined navigation and purpose-specific interactions.

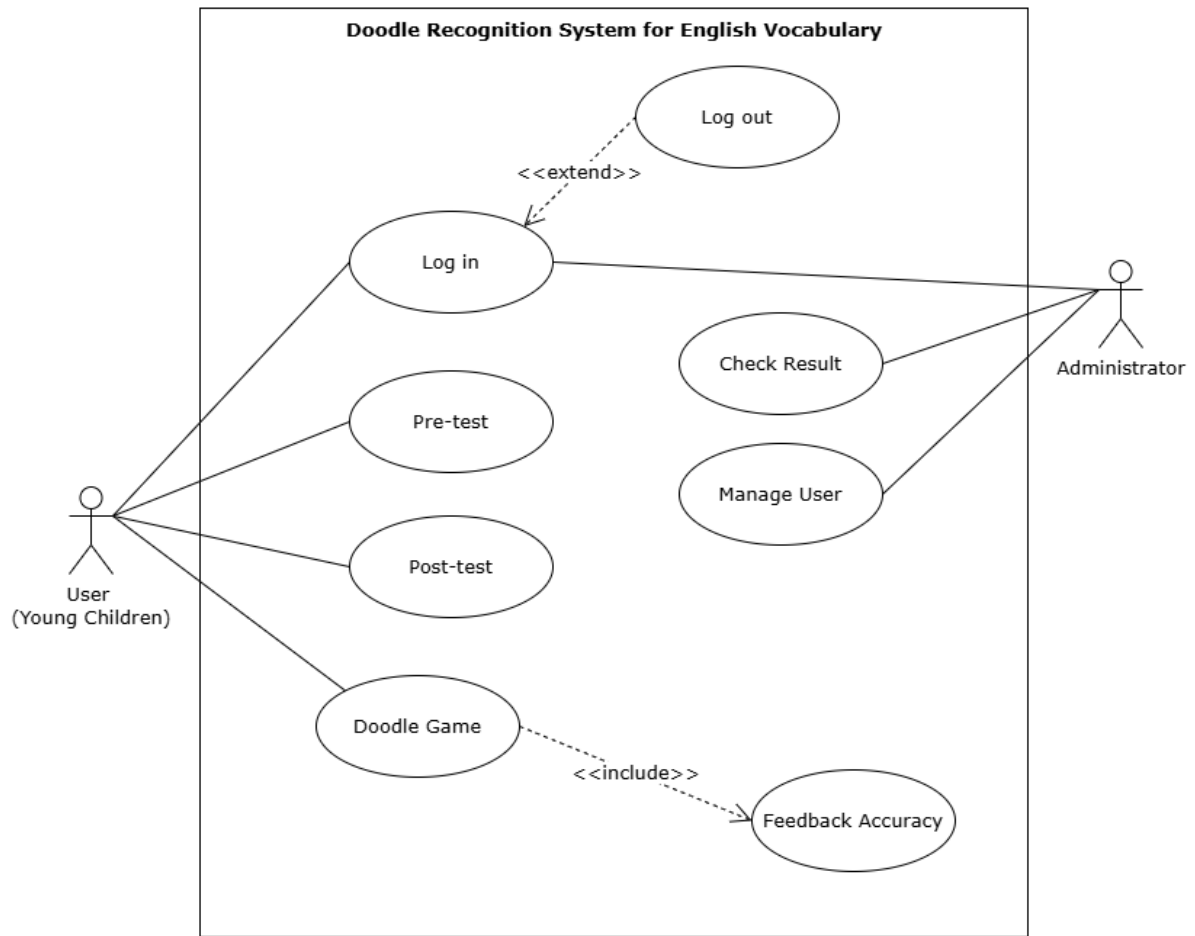


Figure 10: Use Case of Doodle Recognition System for English Vocabulary

Use Case Specification

1. Log in

Table 4: Use case specification of Log in

Use Case:	Log in
Short Description:	Since no registration is needed here, users will enter an assigned credential to log in. However, admin will have to key in the correct credential to access the admin page.
Actors:	User and Administrator
Pre-conditions:	1. Admin already have an account.
Post-conditions:	1. User can access the system 2. Admin can access the admin page
Main Flow of Events:	
1. The use case is initiated when the User first visits the system. [A1] 2. The User will be required to fill up necessary information before going to the main page. [A2] 3. User confirms and proceeds to the next page. 4. The use case is terminated.	

Extend → Log out	
Alternative Flow(s):	[A1] Administrator wants to access the admin page - Admin will enter the credential required. - The use case is terminated. [A2] User enters incorrect or missing details - Error message will notify user. - User attempts to re-enter information Post-condition → Admin access the admin page.
Exception Flow(s):	N/A

2. Log out

Table 5: Use case specification of Log out

Use Case:	Log out
Short Description:	When the User and Administrator decides that they do not want to proceed with the system anymore or would like to allow other users to use it, they can switch account by logging out.
Actors:	User and Administrator
Pre-conditions:	- User already enter their details at the start of the application - Admin already log into admin page
Post-conditions:	User and admin successfully logged out of the system.
Main Flow of Events:	
- The User and Admin navigates back to the menu - The User and Admin click on log out button [E1] - The use case terminated.	
Alternative Flow(s):	N/A
Exception Flow(s):	[E1] User or Admin cancel log out - The user or admin decides not to log out - Return to main menu - Use case terminated

3. Pre-test

Table 6: Use case specification of Pre-test

Use Case:	Pre-test
Short Description:	User will be answering questions for their pre-test to evaluate their ability prior to using the system. The answers will be evaluated and stored in the database.
Actors:	User
Pre-conditions:	- Have not taken a Pre-test before. - Have not done practice on system. - Have logged in successfully.

Post-conditions:	1. Have their results displayed and stored in database.
Main Flow of Events:	
	1. The user selects pre-test. 2. The user gets navigated to the pre-test page and can start answering the questions [E1]. 3. The user submits the answer and obtain their result 4. The user is navigated back to main menu. 5. Use case is terminated.
Alternative Flow(s):	N/A
Exception Flow(s):	[E1] User decides to not complete the pre-test 1. The user clicks on menu button. 2. The user confirms exiting the progress. 3. The user gets navigated back to main menu. 4. Use case is terminated

4. Post-test

Table 7: Use case specification of Post-test

Use Case:	Post-test
Short Description:	User will be answering questions for their post-test to evaluate the ability post using the system. The answer will be evaluated and stored in the database for comparison to the pre-test's result.
Actors:	User
Pre-conditions:	1. Have completed their pre-test. 2. Have done practices with the system.
Post-conditions:	1. Have their results displayed and stored in database.
Main Flow of Events:	
	1. The user selects post-test. 2. The user gets navigated to the post-test page and can start answering the questions [E1]. 3. The user submits the answer and obtains their result. 4. The user is navigated back to main menu. 5. Use case is terminated.
Alternative Flow(s):	N/A
Exception Flow(s):	[E1] User decides to not complete the post-test 1. The user clicks on menu button. 2. The user confirms exiting the progress. 3. The user gets navigated back to main menu. 4. Use case is terminated.

5. Doodle Practice

Table 8: Use case specification of Doodle Practice

Use Case:	Doodle Practice
Short Description:	User can explore the vocabulary that they would like to doodle. They will be navigated to where they can practice doodle according to the word chosen.
Actors:	User
Pre-conditions:	1. Have completed their pre-test
Post-conditions:	1. Able to practice vocabulary
Main Flow of Events:	
1. After completing pre-test, user is allowed to browse and access the vocabularies 2. User can select their desired vocabulary to practice 3. User will be navigated to the practice page, where a canvas with drawing tools and doodle recognition will be available. [E1] 4. User submits their doodle for review. 5. Use case terminated Include → Feedback Accuracy	
Alternative Flow(s):	N/A
Exception Flow(s):	[E1] User decides not to continue practice or doodling 1. The user clicks menu button 2. The user confirms exiting the progress. 3. The user gets navigated back to main menu. 4. Use case is terminated.

6. Manage User

Table 9: Use specification of Add User

Use Case:	Manage User
Short Description:	For user to use the system, admin will have to create a new user profile for the user (young children) as well as edit and delete their information. This process can only be done by admin.
Actors:	Admin
Pre-conditions:	1. Logged into admin account.
Post-conditions:	1. Created account for user.
Main Flow of Events:	
1. The admin chooses to make a new user profile. [A2, A3] 2. The admin fills in required details of user. [A1] 3. The admin submits details and stores in database. 4. Use case terminated.	
Alternative Flow(s):	[A1] Admin decides to not continue creating a new user 1. The admin cancels the form to fill in required details of user. 2. The use case is terminated.

	[A2] Admin wants to edit user details 1. The admin selects a specific user 2. Update user information [A3] Admin wants to delete user 1. The admin selects a specific user 2. Delete user.
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7. Feedback Accuracy

Table 10: Use case specification of Feedback Accuracy

Use Case:	Feedback Accuracy
Short Description:	After doodling and system have recognized the doodle, the system will provide quantitative and qualitative feedback.
Actors:	User
Pre-conditions:	1. Have completed their doodle
Post-conditions:	2. Receive feedback of how accurate the doodle is.
Main Flow of Events:	
1. The user completes and submits the doodle for recognition. 2. The system returns feedback on how accurate the doodle is. [A1] 3. The use case is terminated.	
Alternative Flow(s):	[A1] User decides to reattempt their doodle; in case it is not accurate. 1. After submitting and receiving feedback, the user can choose to resubmit a new doodle. 2. The user erases and make a new doodle. 3. The user submits the new doodle for new feedback. 4. The use case is terminated
Exception Flow(s):	N/A

Activity Diagram

The activity diagram shows the activities that will be carried out in the Doodle Recognition System.

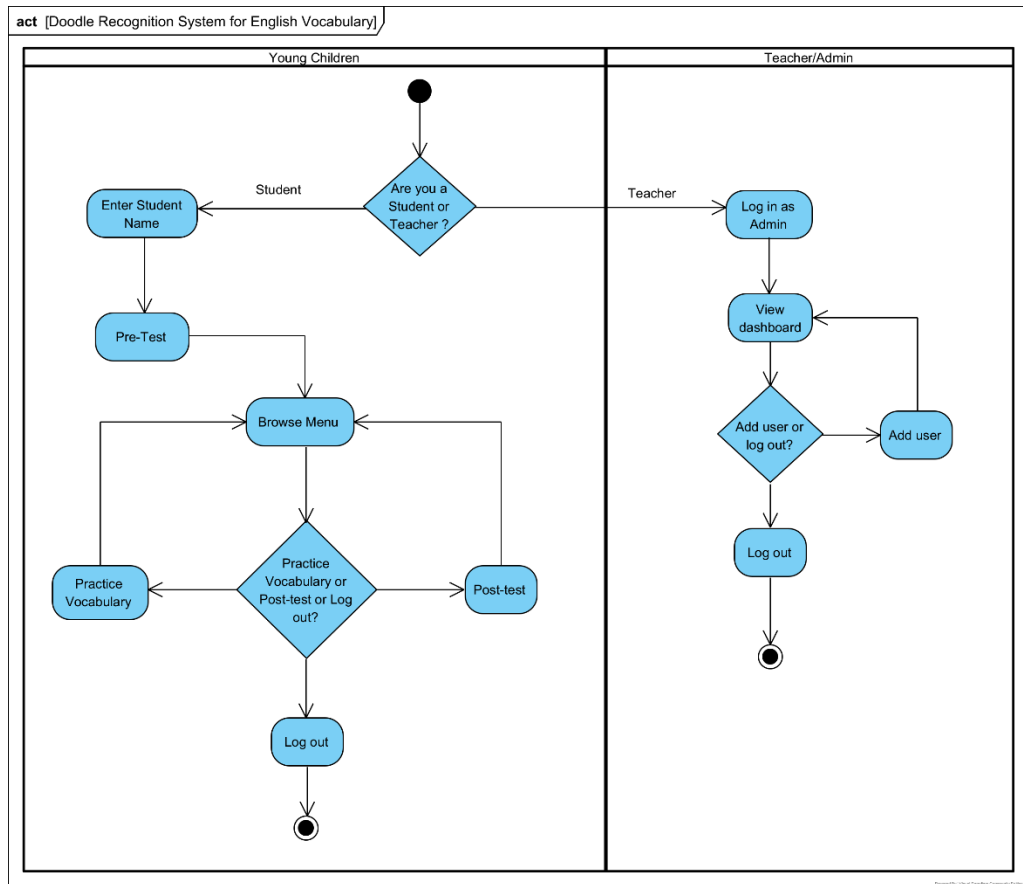


Figure 11: Activity Diagram of Doodle Recognition System for English Vocabulary

Based on Figure 11, there are two swim lanes separate the actors involved in the use of this application which are, Young Children and Teacher/Admin. In the beginning the system will allow users to choose if they are a student or teacher. If they are a teacher or admin, they will be navigated to admin page where they will be asked to log in as admin. One of the main features of teachers and admin is 1) to be able to view dashboard to track progress and student's results from pre-test and post-test 2) and to add new users for the young children.

For young children, to log in they are only required to select their profile to proceed to the browse menu. This log in method aims to make the process easy for young children. However, the admin needs to create a new user first in order to have the profile for them. Features like Pre-test, Vocabulary Practice, Post-test as accessible to user. If the user is

a new or have no record of pre-test results, they are required to complete the pre-test in the beginning.

Sequence Diagram

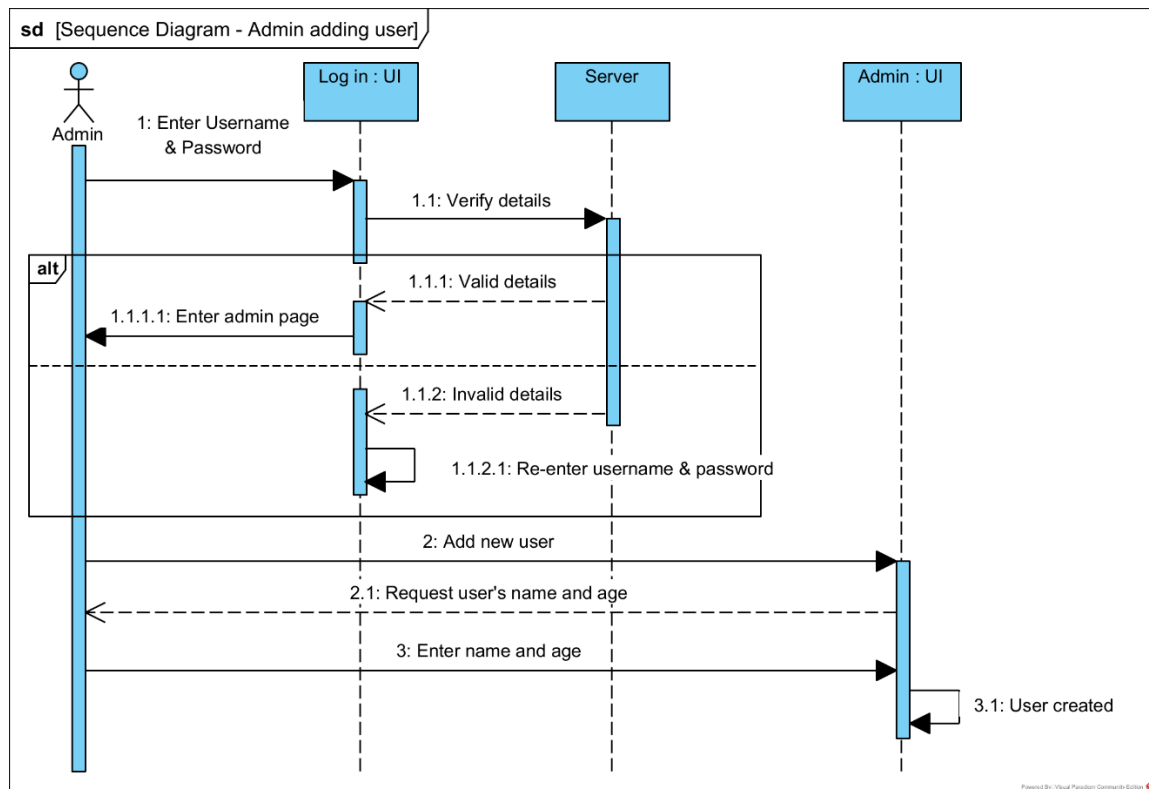


Figure 12: Sequence Diagram - Admin Adding User

The Sequence Diagram in Figure 12, demonstrates the steps involved when an admin logs into admin page and adds a new user to the system. Initially, the admin logs into the system, followed by navigating to the "Admin" page. The admin chooses to “add user” and inputs the new user’s details (student’s name and age), and the system verifies the data before storing it in the database. Confirmation is then displayed to the admin, completing the process. This flow ensures secure and accurate management of user information.

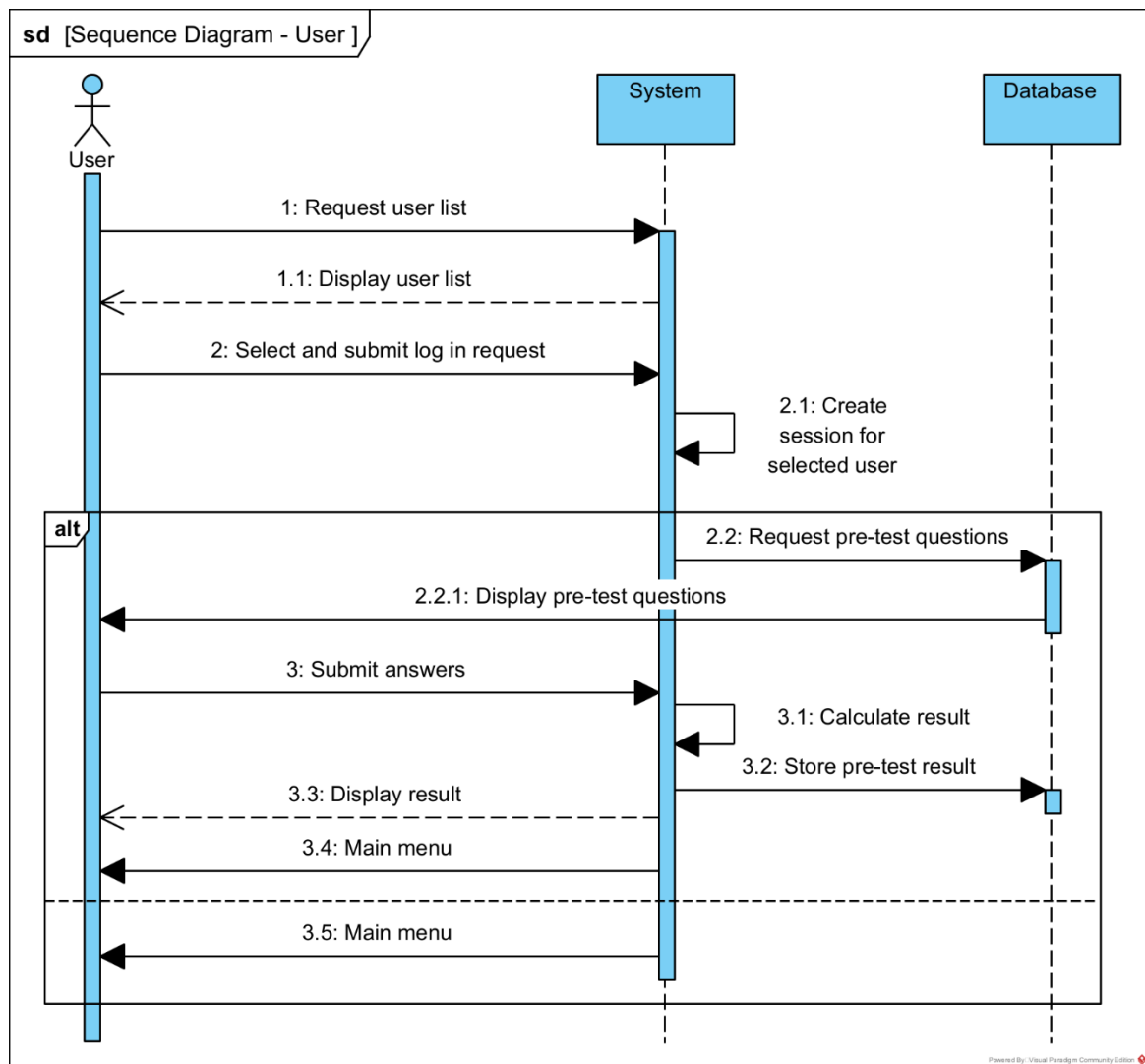


Figure 13: Sequence Diagram - User (Log in & Pre-test)

Figure 13 outlines the sequence of interaction when user logs in and begins a pre-test. The user selects their name from a dropdown or populated data. Upon entering, if the user has yet completed their pre-test, they are required to do before proceeding to the main menu. The system presents questions, collect responses, evaluate answer and displays the results. The structured process evaluates the user's baseline vocabulary knowledge before they start using the system.

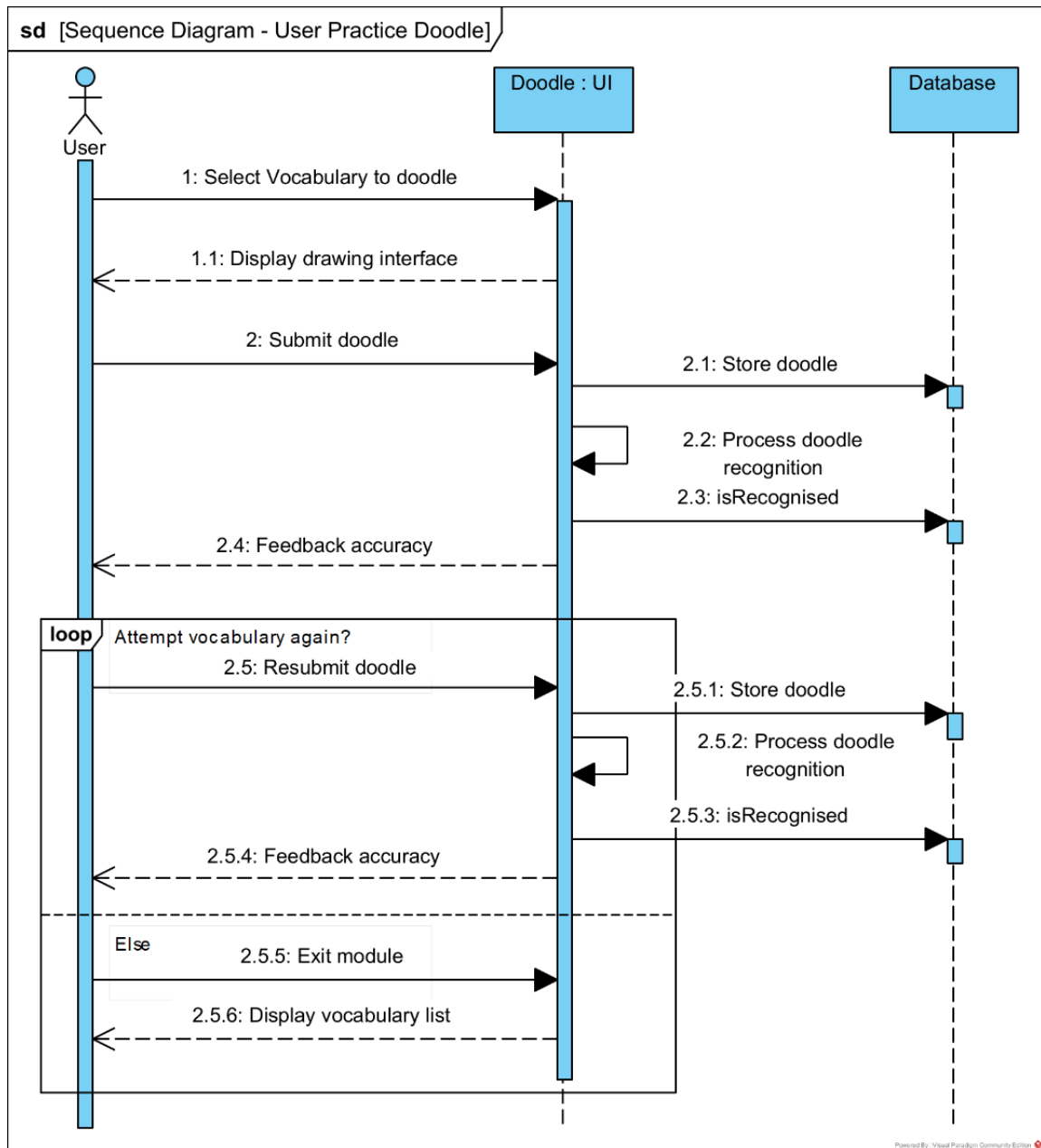


Figure 14: Sequence Diagram - User Practice Doodle

Figure 14 captures the steps for doodle practice session. The user selects a vocabulary word that they have not attempt from the menu. The system displays the selected word and a canvas for doodling. After the user submits their doodle, the system processes the input, evaluates its accuracy using the recognition model, and provides feedback. The cycle can repeat if the user chooses to retry or ends when the user exits to the main menu.

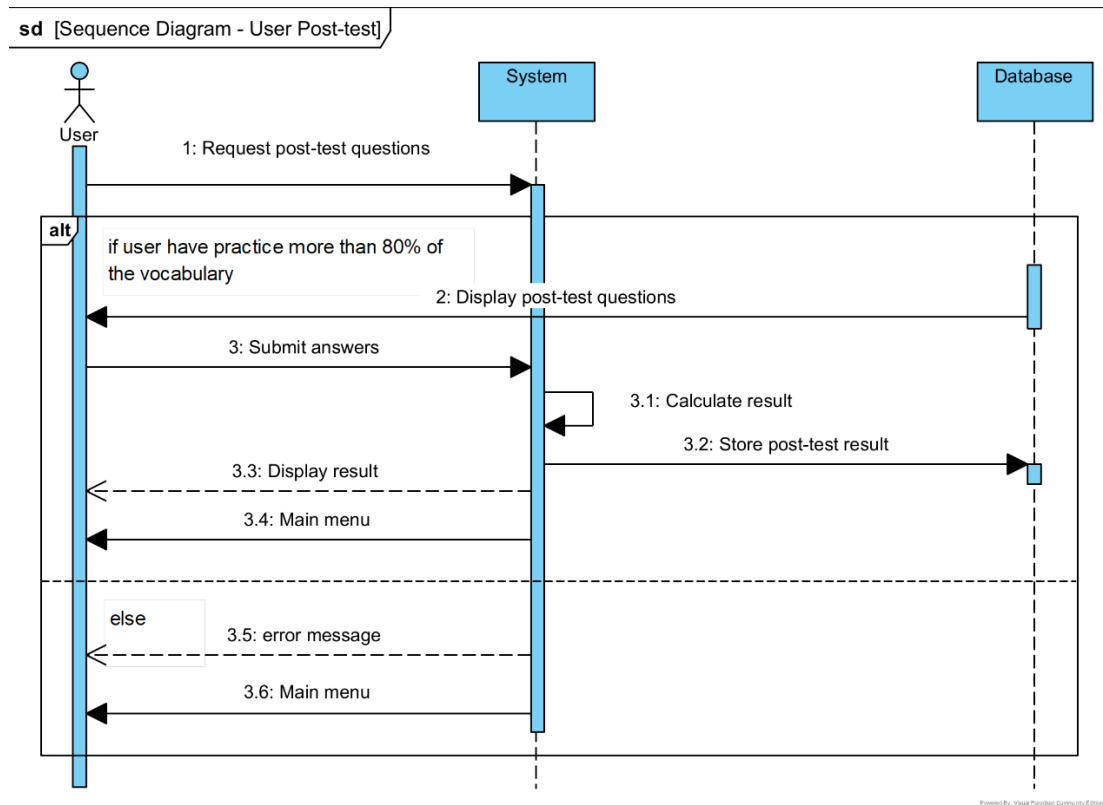


Figure 15: Sequence Diagram - User Post-test

Figure 15 shows the post-test sequence beginning with the user selecting the post-test option. The system presents a set of questions, similar to pre-test for the user to answer. Upon submission, the system evaluates the responses, store the result and display it. The post-test results then will be used to compare and evaluate their performance. This diagram emphasizes on the system's role in assessing vocabulary retention improvement of young children.

Class Diagram

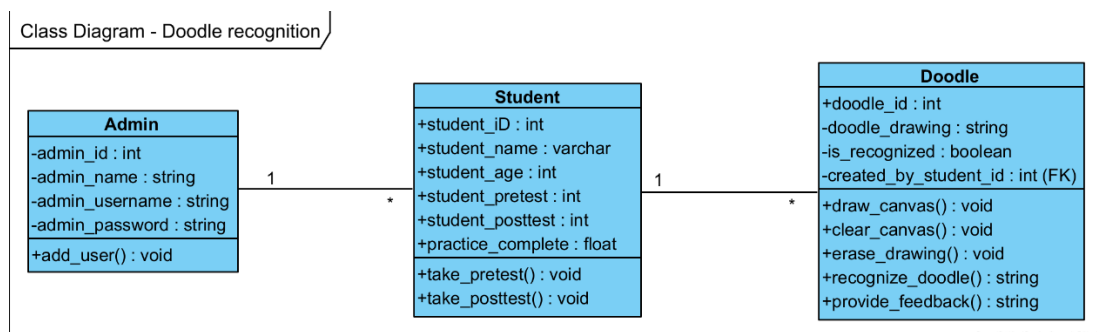


Figure 16: Class Diagram for System

The Class Diagram in Figure 16, demonstrates the structural design of the Doodle Recognition System. Key classes include “Student”, “Admin” and “Doodle”. Attributes and methods for each class are defined to manage data and interactions effectively. The relationships between classes reflect system cohesion and functionality.

Software and Hardware Requirements

Table 11: Software Requirements for Proposed System

Software	Description	Purpose
Next.js	A React-based web framework that provides server-side rendering, static site generation, and optimized client-side functionality for building modern web applications	Creates a responsive, performant frontend interface with automatic optimization features and seamless integration with machine learning libraries
React	A JavaScript library for building user interfaces through reusable components and efficient state management	Enables the creation of interactive drawing canvas components and real-time user interface updates essential for the doodle recognition system
Tailwind CSS	A utility-first CSS framework that provides low-level utility classes for building custom designs without writing traditional CSS	Ensures consistent, responsive styling across all devices while maintaining design flexibility and reducing development time
ml5.js	A JavaScript machine learning library built on TensorFlow.js that makes machine learning accessible for creative coding and web applications	Implements client-side doodle recognition using pre-trained DoodleNet models, enabling real-time inference without server dependency
DoodleNet	A pre-trained convolutional neural network model specifically designed for recognizing hand-drawn sketches and doodles	Provides accurate doodle classification capabilities for vocabulary learning exercises, processing drawings directly in the browser environment
Supabase	An open-source Backend-as-a-Service platform built on PostgreSQL that provides database, authentication, and real-time API functionality	Manages user authentication, stores learning progress data, handles real-time synchronization, and provides secure API endpoints for data operations
Visual Studio Code	A lightweight, extensible integrated development environment with comprehensive support for JavaScript, TypeScript, and modern web development	Supports efficient coding, debugging, and project management with extensions for Next.js development and database integration
PostgreSQL	A powerful, open-source relational database management system integrated within Supabase infrastructure	Stores complex relational data including user profiles, vocabulary progress, test results, and maintains data integrity through ACID compliance
Node.js	A JavaScript runtime environment that enables server-side JavaScript execution and package management through npm	Provides the runtime environment for Next.js development and manages project dependencies including machine learning libraries

Git	A distributed version control system for tracking changes in source code and coordinating collaborative development efforts	Maintains project history, enables version management, and facilitates collaborative development through branching and merging capabilities
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Table 12: Hardware Requirements for Proposed System

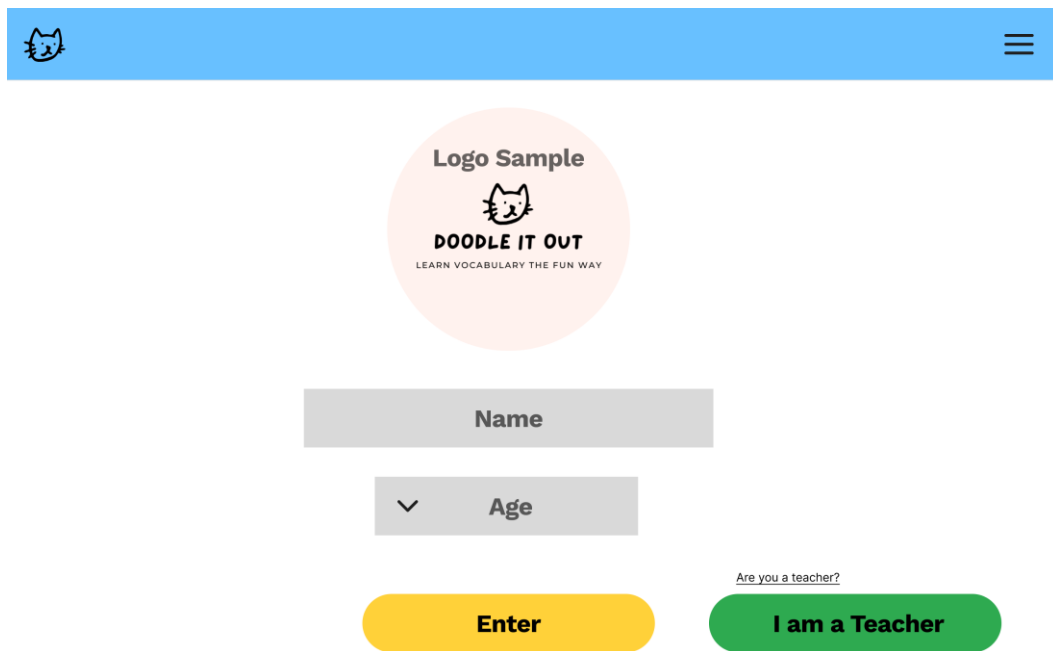
Hardware	Requirements	Description
Development Laptop/PC	Processor: Intel Core i5 or AMD Ryzen 5 RAM: 8 GB Storage: 256 GB SSD GPU (Optional): NVIDIA GTX 1050 or equivalent for faster model training.	Required for developing, training the model, and testing the application.
Tablet	Processor: Quad-core 1.8 GHz RAM: 4 GB Display: 10-inch screen, 1080p resolution OS: Android 8.0+ or iOS 12+	A touchscreen device for testing the app's functionality, especially the drawing canvas.
Smartphone	Processor: Octa-core 1.8 GHz RAM: 3 GB Display: 5.5-inch screen, 720p resolution OS: Android 8.0+ or iOS 12+	For mobile testing to ensure the app's compatibility and responsiveness.

3.3.2 User Design

The most crucial step for Rapid Application Development is the user design phase. In this section, prototype of the system will be showcased and reviewed in an iterative manner. For this project, the prototype will be reviewed and tested by the developer and supervisor to ensure that the system meets the requirements in the next section. This allows any additional requirement or change of requirement are welcomed and will be refined and improved.

However, the iterative phases of prototype, testing and improving will be carried out in Chapter 4. For this chapter the user design will provide the wireframe of the User Interface designs. The wireframe was designed using Figma application.

Login page



The login page features a blue header bar with a cat logo on the left and a hamburger menu on the right. Below the header is a circular logo with a cat face and the text "Logo Sample", "DOODLE IT OUT", and "LEARN VOCABULARY THE FUN WAY". The main form consists of a "Name" input field, an "Age" dropdown menu, and two buttons: a yellow "Enter" button and a green "I am a Teacher" button. A small link "Are you a teacher?" is positioned above the "I am a Teacher" button.

Logo Sample

DOODLE IT OUT

LEARN VOCABULARY THE FUN WAY

Name

Age

Enter

Are you a teacher?

I am a Teacher

Figure 17: User Interface of Log in Page

In this page (Figure 17), User which are the young children will be asked to fill in their name and age. This will be used for data collection especially for their pre-test and post-test results. As for the Teachers or Admin, a designated button is introduced to navigate them to the admin page and authenticate themselves with username and password.

Main menu (Browse Category)

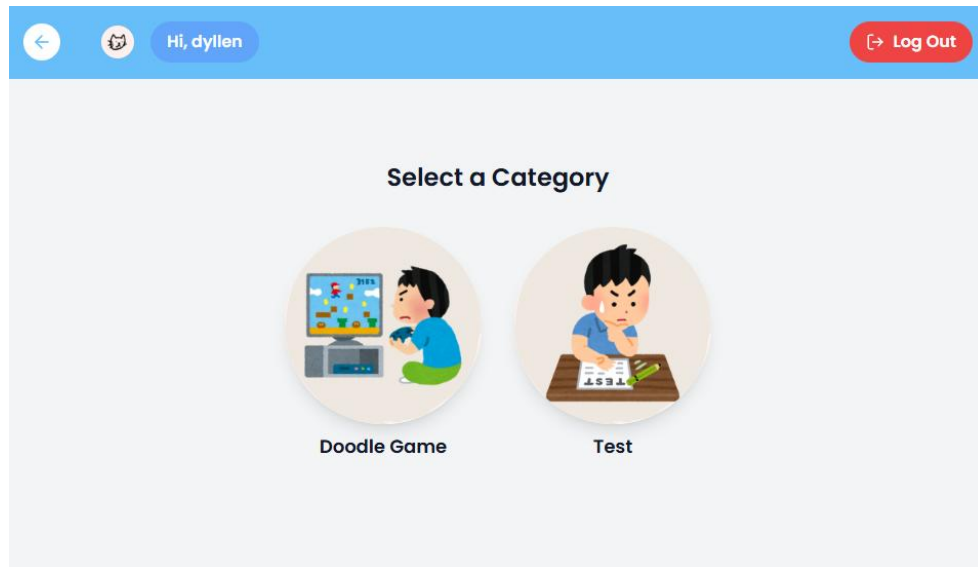


Figure 18: Main menu of Doodle Recognition System

The main menu (Figure 18) is where the users can browse through the items that they can practice doodling with “Doodle Game”. Besides that, the user can also take their test or post-test. This page will not be accessible if the user has not completed their pre-test.

Doodling Vocabulary page

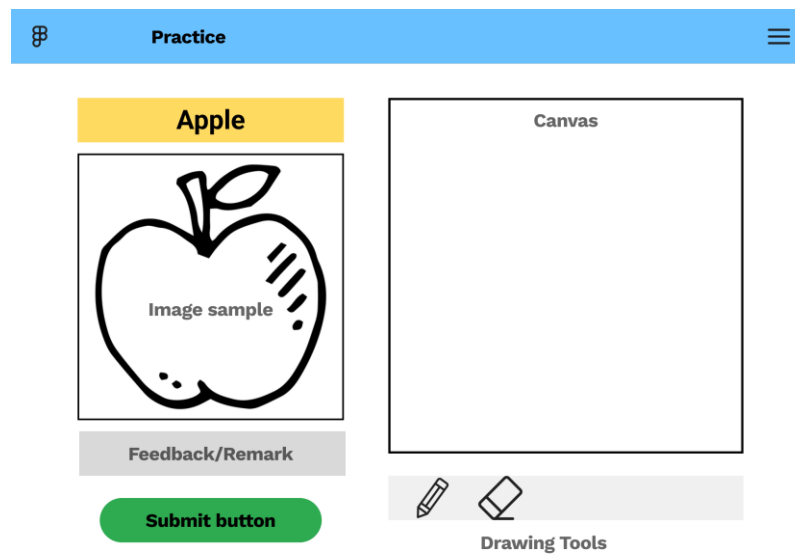


Figure 19: User Interface of Doodle Practice with Vocabulary

In this page (Figure 19) is where users can doodle on the canvas with a doodle sample. After clicking on the submit button, the system will attempt to recognise the image and

make guesses while also providing feedback on what they predicted, and how accurate is the prediction. Following with a qualitative remark like “Very good!” or “Needs improvement” depending on the percentage of accuracy.

Pre-test and Post-test page

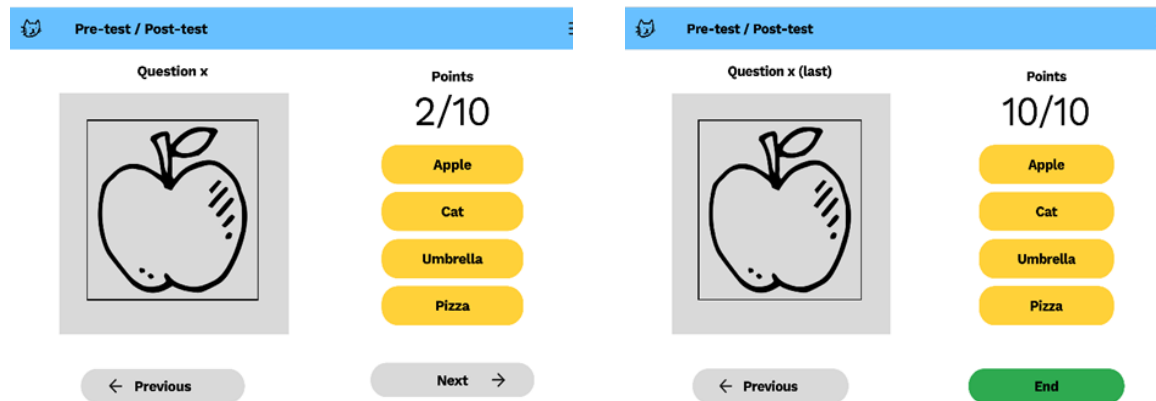


Figure 20: User Interface of the Pre-test and Post-test page

Figure 20 shows the prototype of the user’s interface when taking the pre-test of the post-test. This will be for evaluating the user’s vocabulary retention skills after doing practices. A picture for the users to identify which word does the picture belong to. Each questions answered correctly will grant them a point and result can be reviewed at the end of the test.

3.3.2.1 Prototyping

The first iteration of user design is prototyping the system based on the analysis and wireframe design that were proposed initially. Prototyping will focus on the implementation of doodle recognition first, then proceeding into the other features like performing pre-test and post-test, storing results, admin page and others. Details will be covered in Chapter 4 along with the process of implementing doodle recognition in the system based on the second objective. However, the user interface design done on Figma was used as a prototype in the earlier stage for planning and feedback purposes.

3.3.2.2 Testing

Testing will be done by developer, supervisor and potential young children on the prototype. Any feedback is welcome and recorded for the next user design phase for

improvement of usability of system. Details will be covered in Chapter 5, along with the report of pre-test and post-test to test for the third objective. However, the user interface design on Figma was used for testing and gathering feedback from supervisor.

3.3.2.3 Improving

After collecting feedback and testing result, the system will be further improved. The improvement will be based on the prototype that will be done in the next chapter, but prior to that the user interface design on Figma that was improved after collecting feedback from supervisor. Therefore, the prototyping will continue based on any issue or change of requirement found after testing as a way of improvement.

3.3.3 Development

During this phase, the proposed system will be developed based on the complete prototype finalised from the user designing phase. A functional system will be coded by the developer in this phase and pushed to development environment before the transition phase. The functional system should consist of the working modules from use case. In this section, techniques and technology tools used during the development phase will be discussed.

The doodle recognition feature as the core component of the system, enabling young children to draw on a canvas and have their drawings recognized by the system. This project will adopt a pre-trained machine learning model DoodleNet (Shi, Y., 2019). DoodleNet is an image classification model specifically designed to classify simple drawings, making it suitable for recognizing doodle drawn by young children.

Dataset Preparation

DoodleNet is a Convolutional Neural Network (CNN) model trained on a dataset of simple doodle. The model is capable of classifying drawings into predefined categories, such as animal, food, and objects, which are the targeted vocabularies. However, not all categories from the Google Quick, Draw! Database will be used. Therefore, dataset is prepared by resizing images for a uniform resolution (28x28 pixels), normalized to range of [0,1], and augmented (rotation, scaling, and flipping) to enhance robustness.

Integration with the system

DoodleNet model will integrate into the system's backend to enable real-time doodle recognition. A RESTful API will be developed using Python and Flash to handle requests from the frontend. When a child submits a doodle, the image is sent to the backend API, where it is processed and passed to the fine-tuned DoodleNet model for classification. The model predicts the category of the doodle (e.g., "cat") and returns a confidence score (e.g., "85% accurate). This information will be displayed to the child with a more interesting manner like using stars to represent every 33.33% accuracy.

3.3.4 Transition

Although the transition phase is traditionally used in Rapid Application Development (RAD) to deploy a fully functional system to end-users, in this project, it serves a different purpose and align with the objective of this project. Instead of deploying the system as a product for widespread use, this phase will focus on finalizing the system for data collection in a controlled environment. Key tasks include ensuring the system is stable and functional for conducting pre-tests and post-tests, validating the accuracy of the doodle recognition feature, and preparing it to collect and store meaningful data for evaluating vocabulary retention. This phase will also involve creating detailed documentation for using the system effectively during research studies and ensuring basic security measures to safeguard participant data.

3.4 Summary

Chapter 3 outlines the requirements and design framework for the Doodle Recognition System using the Rapid Application Development (RAD) methodology. It details the system's architecture, including its components like frontend, backend, and database. Functional and non-functional requirements are defined, supported by use case diagrams and specifications. The chapter describes the iterative phases of prototyping, testing, and improvement, focusing on user interface design through Figma. The development and transition phases are highlighted, emphasizing stability and readiness for pre- and post-test data collection. The chapter concludes by showcasing the comprehensive application of RAD in aligning design and user needs.

Chapter 4: Implementation

4.1 Introduction

This chapter presents the implementation phase of the doodle recognition system designed to enhance vocabulary retention among young children. The implementation builds upon the project objectives, requirement analysis, and design specifications outlined in previous chapters. The development process followed an iterative methodology involving prototyping, testing, and continuous improvement. This chapter discusses the development tools and technologies employed, the system architecture implementation, database integration, and the core functional modules that constitute the complete system.

4.2 Development Tools and Technologies

The system was developed using a modern web development technology stack comprising Next.js, Supabase (PostgreSQL), Tailwind CSS, and several supporting libraries. The selection of these technologies was based on their performance characteristics, scalability potential, developer community support, and compatibility with project requirements.

Project Structure Overview

The project follows a structured organization that separates concerns and facilitates maintainability. The main directories include configuration files for environment variables and framework settings, application pages organized under the App Router architecture, reusable components for UI elements and business logic, utility libraries for database connectivity, and static assets for images and media files.

Table 13: fyp-doodlenet-with-supabase Project Structure Overview

Category	Path / File	Description
Configuration & Environment	<code>.env.local</code>	Environment variables (e.g., Supabase keys)
	<code>next.config.ts</code>	Next.js project configuration
	<code>tsconfig.json</code>	TypeScript configuration
	<code>postcss.config.js</code>	PostCSS configuration
	<code>tailwind.config.ts</code>	Tailwind CSS configuration
	<code>package.json</code>	Project dependencies and scripts
Documentation	<code>README.md</code>	Project documentation and setup instructions

Data	<code>questionBank.json</code>	Quiz/test questions
	<code>vocabularies.json</code>	Vocabulary data organized by categories
App Structure	<code>app/</code>	Main Next.js App Router directory
	<code>app/layout.tsx</code>	Root layout and global styles
	<code>app/menu/</code>	Category selection and game pages (e.g., <code>food/</code> , <code>animal/</code> , <code>object/</code>)
	<code>app/admin/</code>	Admin dashboard for managing students and results
Components	<code>components/</code>	Reusable UI and logic components
	<code>components/Navbar.tsx</code>	Navigation bar
	<code>components/TestPage.tsx</code>	Handles quiz/test logic and Supabase integration
	<i>(Other shared components)</i>	Buttons, modals, etc.
Library	<code>lib/</code>	Utility libraries (e.g., Supabase client setup)
Static Assets	<code>public/</code>	Images and other static files (e.g., doodle vocabulary images)
Utilities	<code>utils/</code>	Global helper functions
Templates & Examples	<code>template/</code>	Templates, tutorial components, and non-core example pages
Build Output	<code>.next/</code>	Auto-generated build output (should not be manually edited)

4.2.1 Next.js Framework

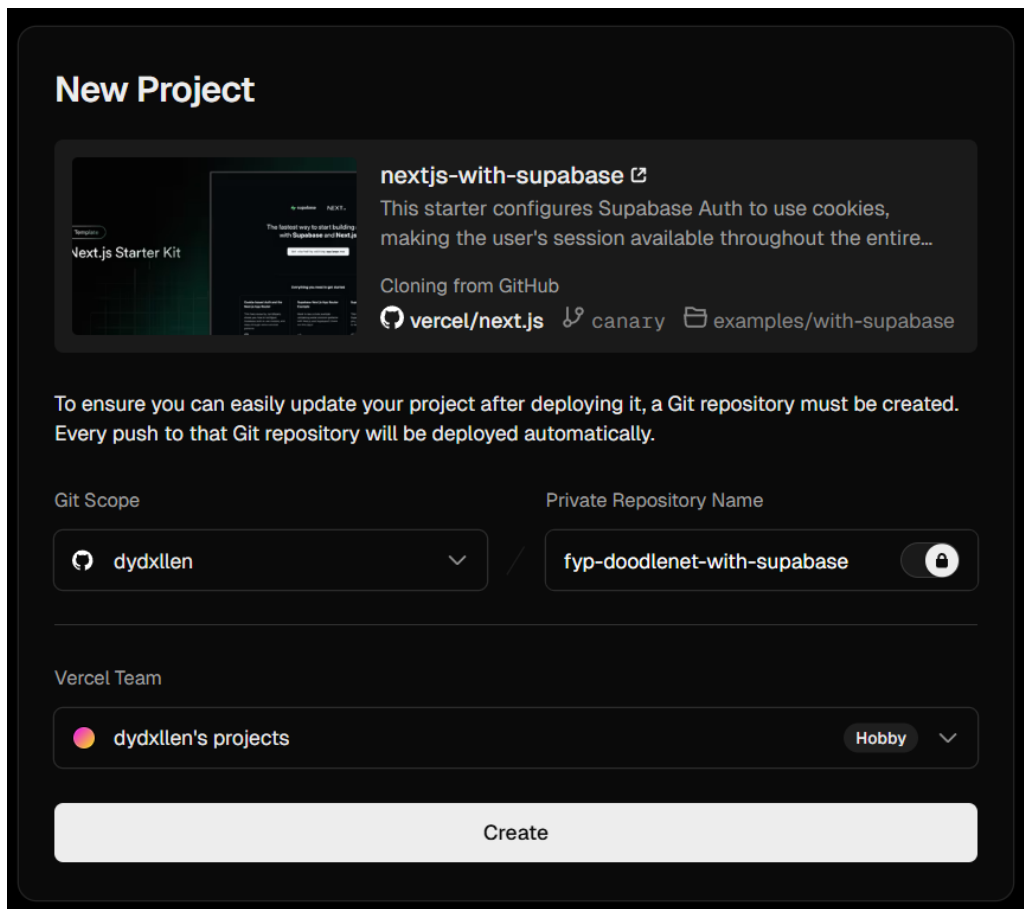
Next.js serves as the primary full-stack framework for both frontend and backend development. As a React-based framework maintained by Vercel, Next.js provides comprehensive support for client-side rendering, server-side rendering (SSR), static site generation (SSG), and API routing capabilities. These features are essential for delivering a scalable and responsive web application that can handle the interactive requirements of young learners.

The framework's ability to manage both frontend user interfaces and backend logic within a unified codebase made it particularly suitable for this project. The user interface was developed using HTML and Tailwind CSS for styling, while JavaScript handled application logic and backend interactions, particularly for communication with the Supabase database.

The project initialization utilized the official Supabase starter template for Next.js, which provided pre-configured authentication, database integration, and a scalable project structure. This approach accelerated development by providing established patterns for common functionality.

Project Initialization Steps:

Accessed template via <https://vercel.com/templates/next.js/supabase>. Deployed template to a new GitHub repository. I created my repository as *fyp-doodlenet-with-supabase* (Figure 21). Cloned the repository locally on Visual Studio Code (VSC) and install dependencies (Figure 22). After cloning project repository, run “`npm install`” to install Node.js package. Finally, try running the project on `localhost:3000` by using “`npm run dev`”. (Figure 23)



The screenshot shows the Vercel 'New Project' page. At the top, the title 'New Project' is displayed. Below it, a card for the 'nextjs-with-supabase' template is shown. The card includes a preview image of the 'Next.js Starter Kit', the title 'nextjs-with-supabase', a description 'This starter configures Supabase Auth to use cookies, making the user's session available throughout the entire...', and a link to 'Cloning from GitHub'. Below the card, a message states: 'To ensure you can easily update your project after deploying it, a Git repository must be created. Every push to that Git repository will be deployed automatically.' The form below this message has three sections: 'Git Scope' with a dropdown menu showing 'dydxllen', 'Private Repository Name' with a text input field containing 'fyp-doodlenet-with-supabase' and a lock icon, and 'Vercel Team' with a dropdown menu showing 'dydxllen's projects' and a 'Hobby' label. At the bottom, there is a large 'Create' button.

Figure 21: Nextjs + Supabase Template

```

MSI-PC@MSI MINGW64 ~/dyllen/fyp-doodlenet-with-supabase (main)
● $ npm install
Debugger listening on ws://127.0.0.1:60834/ac963bb5-08ce-4d13-895e-74f0d4bdbbe4
For help, see: https://nodejs.org/en/docs/inspector
Debugger attached.

up to date, audited 214 packages in 2s

40 packages are looking for funding
  run `npm fund` for details
$ npm install
Debugger listening on ws://127.0.0.1:60834/ac963bb5-08ce-4d13-895e-74f0d4bdbbe4
For help, see: https://nodejs.org/en/docs/inspector
Debugger attached.

```

Figure 22: Download node.js packages

```

MSI-PC@MSI MINGW64 ~/dyllen/fyp-doodlenet-with-supabase (main)
$ npm run dev
Debugger listening on ws://127.0.0.1:61023/054cdd86-ae44-40e2-86f2-40c763d12188
For help, see: https://nodejs.org/en/docs/inspector
Debugger attached.

> dev
> next dev --turbo
Debugger listening on ws://127.0.0.1:61059/67fcb31a-f154-4ec5-ae84-6832345cc49e
For help, see: https://nodejs.org/en/docs/inspector
Debugger attached.
Debugger listening on ws://127.0.0.1:61087/cac5e877-aacb-468a-992e-e09d9dc507bc
For help, see: https://nodejs.org/en/docs/inspector
Debugger attached.
▲ Next.js 15.2.4 (Turbopack)
- Local:      http://localhost:3000
- Network:    http://10.66.139.224:3000
- Environments: .env.local

✓ Starting...
✓ Compiled in 1188ms
✓ Ready in 5.3s

```

Figure 23: Run project on local

4.2.2 Supabase Database Platform

Supabase was selected as the backend-as-a-service (BaaS) platform, providing comprehensive data storage, user authentication, and real-time interaction capabilities. Built on PostgreSQL, Supabase offers a scalable, cloud-hosted database infrastructure with seamless integration into JavaScript-based applications.

The platform manages several critical data operations including administrator authentication for system management, storage of children's pre-test and post-test results for learning assessment, and persistent storage of test responses for detailed analysis.

The `@supabase/supabase-js` JavaScript client library was used throughout the project to perform secure read and write operations between the Next.js backend and the

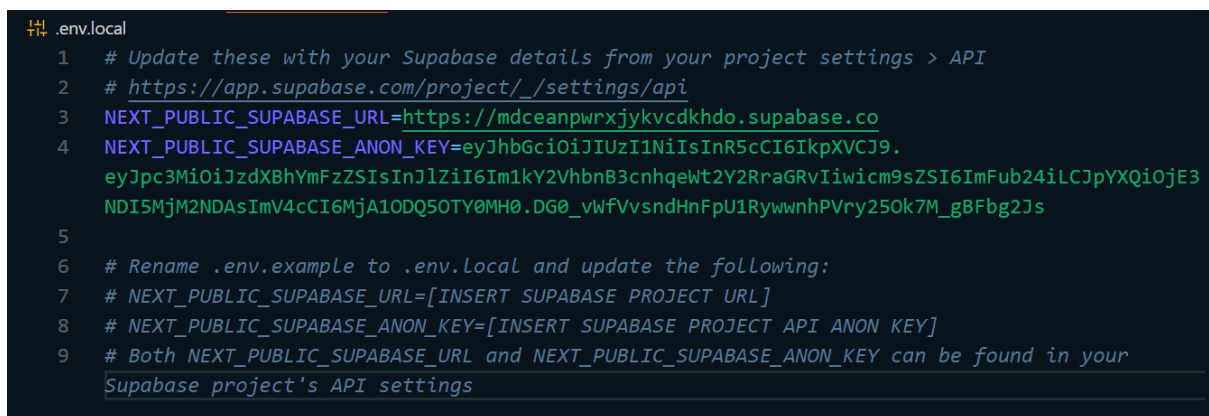
PostgreSQL database hosted on Supabase. Additionally, @supabase/ssr was employed to maintain authenticated sessions on the server side, ensuring persistence across page reloads and protecting sensitive data endpoints.

Configure Supabase connection to project:

To configure the connection of Supabase to project, file “.env.example” was renamed to “.env.local” and update the following:

```
NEXT_PUBLIC_SUPABASE_URL = [INSERT SUPABASE PROJECT URL]
NEXT_PUBLIC_SUPABASE_ANON_KEY = [INSERT SUPABASE PROJECT API ANON KEY]
```

Figure 24 shows an example from this project’s configuration for Supabase database.

A screenshot of a code editor showing the contents of a file named .env.local. The file contains configuration for a Supabase database connection. It includes comments in English and placeholder text for the Supabase project URL and API key. The API key is a long alphanumeric string. The file is numbered 1 through 9.

```
1 # Update these with your Supabase details from your project settings > API
2 # https://app.supabase.com/project/_/settings/api
3 NEXT_PUBLIC_SUPABASE_URL=https://mdceanpwrxyjykvcdkhdo.supabase.co
4 NEXT_PUBLIC_SUPABASE_ANON_KEY=eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.
  eyJpc3MiOiJzdXBhYmFzZSIsInJlZiI6Im1kY2VhbnB3cnhqewt2Y2RraGRvIiwicm9sZSI6ImFub24iLCJpYXQiOiE3
  NDI5MjM2NDAsImV4cCI6MjA1ODQ5OTY0MH0.DG0_vWfVvsndHnFpU1RywnhPVry250k7M_gBFbg2Js
5
6 # Rename .env.example to .env.local and update the following:
7 # NEXT_PUBLIC_SUPABASE_URL=[INSERT SUPABASE PROJECT URL]
8 # NEXT_PUBLIC_SUPABASE_ANON_KEY=[INSERT SUPABASE PROJECT API ANON KEY]
9 # Both NEXT_PUBLIC_SUPABASE_URL and NEXT_PUBLIC_SUPABASE_ANON_KEY can be found in your
  Supabase project's API settings
```

Figure 24: Configuring Supabase Database Connection

4.3 Database Creation and Integration

The database architecture forms the foundation of the system's data management capabilities, supporting persistent storage, retrieval, and management of user information, assessment results, and system interactions. The database implementation utilizes Supabase's PostgreSQL-based backend through a cloud interface.

4.3.1 Database Scheme

The database schema was designed to support four primary functional domains: student data management for user profiles and information, administrative authentication for system access control, assessment result logging for pre-test and post-

test performance tracking, and detailed answer storage for comprehensive learning analytics.

The central “students” table maintains essential user information including student identification, demographic data, and summary scores for both pre-test and post-test assessments. The “test_attempts” table records each assessment session with timing and scoring information, while the “student_answers” table provides detailed response logging for individual questions. This relational structure enables comprehensive tracking of learning progress and detailed analysis of vocabulary retention patterns. Whereas, the “admin” table maintains essential admin user information like username and password, which allows access to the database and analytics of student’s data.

The visual representation of the database scheme is shown in Figure 25 below:

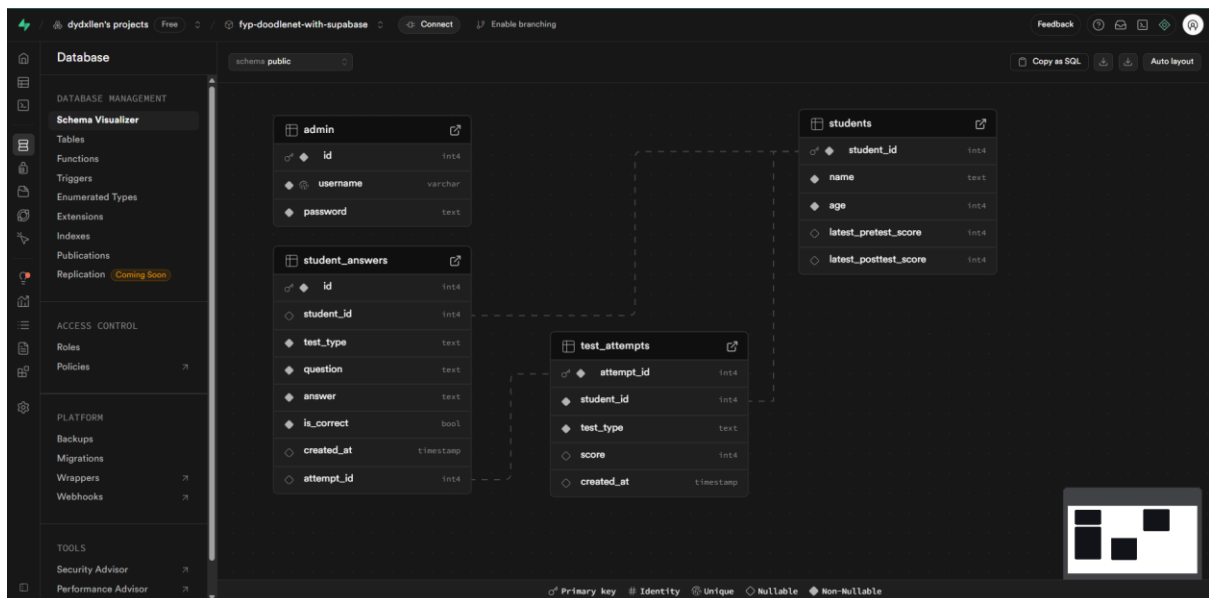


Figure 25: Database Schema for Doodle Recognition System

4.4 Core Modules Implementation

The Doodle Recognition System consists of several integrated modules, each developed to serve the primary objectives of enhancing vocabulary retention among young children through interactive drawing. This section describes the implementation of the three code modules: (1) Doodle Recognition, (2) Progress Tracking and User Management, and (3) Testing and Evaluation Mechanism. Each module was implemented iteratively, tested and refined based on development and user feedback.

4.4.1 Student Authentication Module

The student authentication system (Figure 26) implements a simplified sign-in process specifically designed for young learners. Rather than traditional password-based authentication, the system utilizes a name-based selection mechanism that eliminates the complexity of password management while maintaining user identification capabilities.

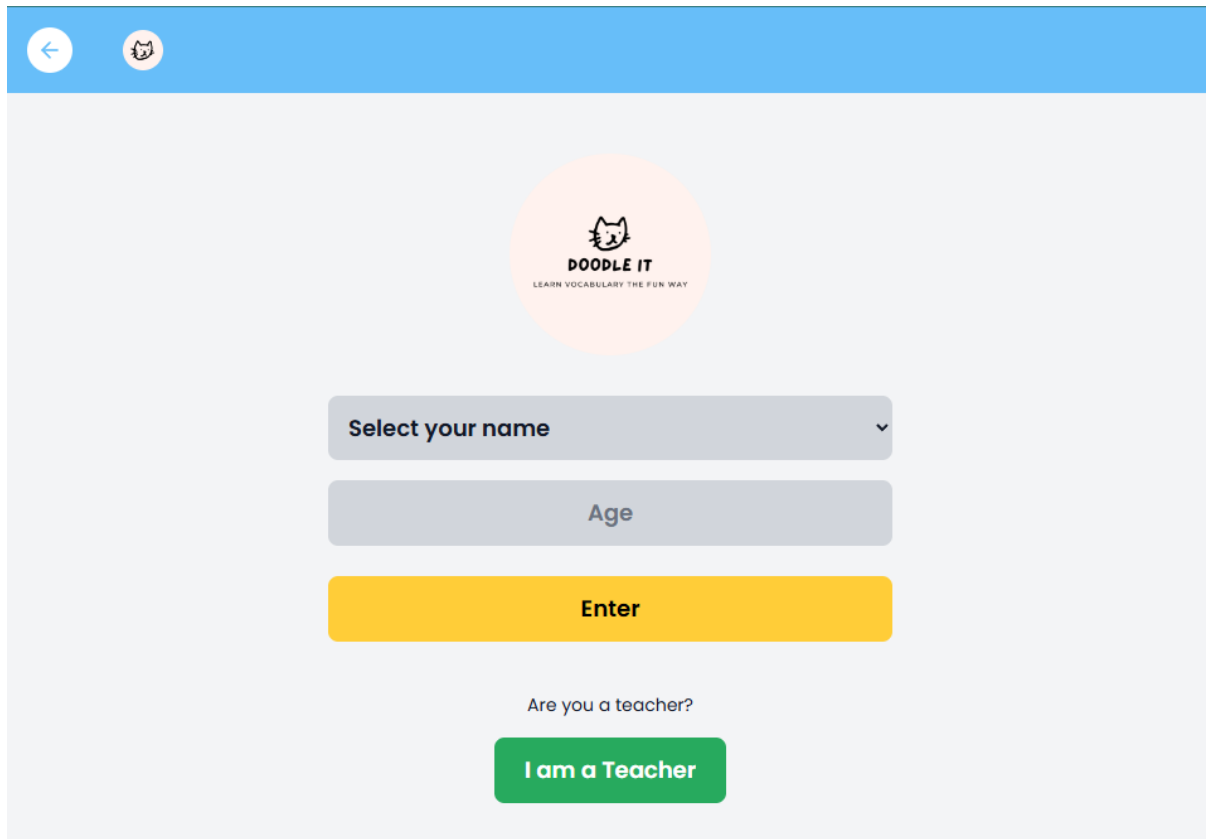
The image shows a web interface for a sign-in page. At the top, there is a blue header bar with a back arrow icon and a cat icon. Below the header, the main content area has a light gray background. In the center, there is a circular logo with a cat face and the text 'DOODLE IT' and 'LEARN VOCABULARY THE FUN WAY'. Below the logo, there is a form with three input fields: a dropdown menu labeled 'Select your name', a text input field labeled 'Age', and a yellow button labeled 'Enter'. Below the 'Enter' button, there is a link 'Are you a teacher?' and a green button labeled 'I am a Teacher'.

Figure 26: Student Sign-in page

The authentication module provides several key features including student selection from a pre-populated database, automatic age display based on student selection, error handling for incomplete selections, and intelligent routing based on assessment completion status.

Features and Implementation

The core authentication logic is implemented in the sign-in page component:

```
// Handle dropdown change
const handleNameChange = (event: React.ChangeEvent<HTMLSelectElement>) => {
```

```
const selectedUser = users.find((user) => user.name === event.target.value);
setSelectedName(selectedUser ? selectedUser.name : "");
setAge(selectedUser ? selectedUser.age.toString() : "");
setErrorMessage(""); // Clear error message when a name is selected
};
```

This function manages the student selection process by matching the selected name against the database records and automatically populating the corresponding age information. The error handling ensures that students cannot proceed without proper selection.

The authentication flow incorporates intelligent routing based on assessment (pre-test) completion status:

```
// Handle Enter button click
const handleEnterClick = async (event: React.MouseEvent<HTMLAnchorElement,
MouseEvent>) => {
  event.preventDefault();
  if (!selectedName) {
    setErrorMessage("Please select a name before proceeding.");
    return;
  }
  // Store student in LocalStorage
  localStorage.setItem("student", JSON.stringify({ name: selectedName, age }));

  // Fetch student_id and latest_pretest_score from students table
  const { data: studentData, error: studentError } = await supabase
    .from("students")
    .select("student_id, latest_pretest_score")
    .eq("name", selectedName)
    .single();

  if (studentError || !studentData) {
    setErrorMessage("Error fetching student information.");
    return;
  }

  // Check latest_pretest_score
  if (studentData.latest_pretest_score === null) {
    router.replace("/pre-test");
  } else {
    router.replace("/menu");
  }
};
```

This implementation demonstrates how the system determines the appropriate entry point for each student. Students who have not completed the pre-test are automatically directed to the assessment, while those who have completed it proceed directly to the main menu. The use of localStorage maintains session persistence across page reloads.

4.4.2 Assessment Module (Pre-test and Post-test)

The assessment module implements comprehensive testing functionality for measuring vocabulary retention before and after exposure to the doodle-based learning activities. The module utilizes a reusable component architecture that supports both pre-test and post-test configurations with identical functionality but different data handling. Figure 27 shows the user interface of the assessment, both pre-test and post-test have the same interface because they use the same component.

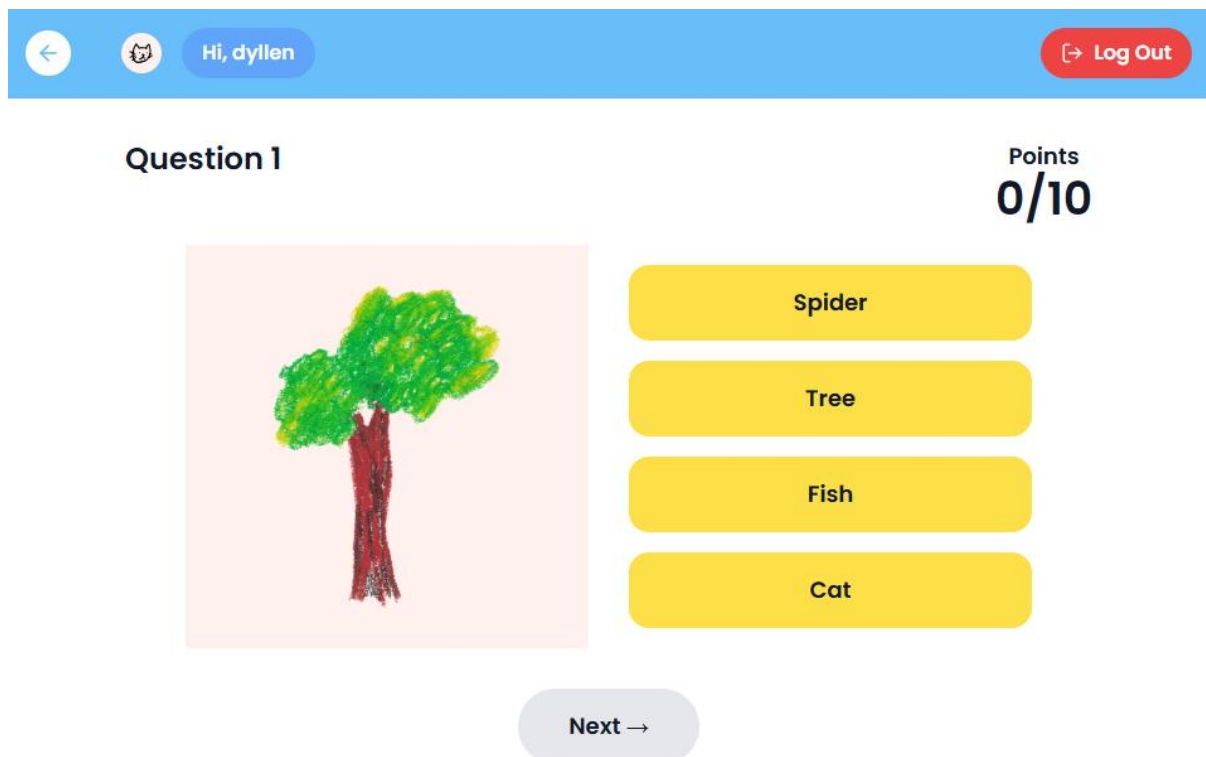


Figure 27: Assessment Module (Pre-test and Post-test)

Features and Implementation

The assessment system provides multiple choice questions with visual stimuli, real-time score tracking, immediate feedback mechanisms, and persistent result storage. The system randomly selects questions from a comprehensive question bank to ensure assessment variety while maintaining consistency in difficulty and content coverage.

The test initialization process demonstrates the random question selection mechanism:

```
const shuffled = React.useMemo(() => {
  const arr = [...questionBank];
  for (let i = arr.length - 1; i > 0; i--) {
    const j = Math.floor(Math.random() * (i + 1));
    [arr[i], arr[j]] = [arr[j], arr[i]];
  }
  return arr.slice(0, questionsCount);
}, [questionsCount]);
```

This implementation ensures that each assessment session presents questions in a randomized order, reducing the likelihood of pattern recognition and providing a more accurate measure of vocabulary knowledge.

The question bank where the test will display questions and choices from:

```
[
  {
    "image": "Apple",
    "choices": ["Carrot", "Apple", "Fish", "Car"],
    "answer": "Apple"
  },
  {
    "image": "Carrot",
    "choices": ["Carrot", "Tree", "Flower", "Lion"],
    "answer": "Carrot"
  },
  {
    "image": "Car",
    "choices": ["Car", "Spider", "Tree", "Apple"],
    "answer": "Car"
  },
  {
    "image": "Clock",
    "choices": ["Cat", "Clock", "Fish", "Lion"],
    "answer": "Clock"
  },
  {
    "image": "Flower",
    "choices": ["Carrot", "Spider", "Tree", "Flower"],
    "answer": "Flower"
  },
  {
    "image": "Tree",
    "choices": ["Spider", "Tree", "Fish", "Cat"],
    "answer": "Tree"
  },
  {
    "image": "Fish",
    "choices": ["Lion", "Fish", "Carrot", "Cat"],
    "answer": "Fish"
  },
  {
    "image": "Cat",
    "choices": ["Tree", "Lion", "Cat", "Car"],
    "answer": "Cat"
  }
]
```

```

    "answer": "Cat"
  },
  {
    "image": "Lion",
    "choices": ["Lion", "Carrot", "Spider", "Clock"],
    "answer": "Lion"
  },
  {
    "image": "Spider",
    "choices": ["Spider", "Carrot", "Tree", "Apple"],
    "answer": "Spider"
  }
]

```

The question bank is kept in a json file and being accessed by code to display question to user and match correct answers.

The answer selection and validation process incorporate immediate visual feedback:

```

const handleSelect = (choice: string) => {
  if (showFeedback) return;
  setSelected(choice);
};

const handleNext = () => {
  if (selected == null || showFeedback) return;
  setShowFeedback(true);

  if (selected === shuffled[current].answer) setScore(score + 1);
  const newAnswers = [...answers];
  newAnswers[current] = selected;
  setAnswers(newAnswers);

  const timeout = setTimeout(() => {
    setShowFeedback(false);
    setSelected(null);
    if (!isLast) {
      setCurrent(current + 1);
    }
  }, 1500);
  setFeedbackTimeout(timeout);
};

```

This code demonstrates how the system manages the question progression while providing immediate feedback. The one and a half second delay allows students to see the correct answer before proceeding, reinforcing learning through immediate feedback.

The assessment completion process includes comprehensive data persistence:

```

const handleEnd = async () => {
  // Calculate final score and prepare data
  const finalScore = finalAnswers.reduce(

```

```

    (acc, ans, idx) => acc + (ans === shuffled[idx].answer ? 1 : 0), 0
  );

  // Insert test attempt record
  const { data: attemptData, error: attemptError } = await supabase
    .from("test_attempts")
    .insert([
      {
        student_id,
        test_type: mode,
        score: finalScore,
      }
    ])
    .select("attempt_id")
    .single();

  // Insert detailed answer records
  const records = shuffled.map((q, idx) => ({
    student_id,
    attempt_id: attemptData.attempt_id,
    test_type: mode,
    question: q.answer,
    answer: finalAnswers[idx],
    is_correct: finalAnswers[idx] === q.answer,
  }));

  await supabase.from("student_answers").insert(records);

  // Update student summary score
  const scoreField = mode === "pre" ? "latest_pretest_score":
"latest_posttest_score";
  await supabase
    .from("students")
    .update({ [scoreField]: finalScore })
    .eq("student_id", student_id);
};

```

This implementation ensures comprehensive data collection for both individual question responses and overall assessment performance, enabling detailed analysis of learning outcomes and vocabulary retention patterns.

4.4.3 Doodle Recognition Module

The doodle recognition module represents the core interactive component of the system, enabling children to draw vocabulary representations and receive immediate feedback through automated image classification. This module integrates HTML5 canvas technology, React component architecture, and machine learning capabilities through the ml5.js library and “DoodleNet” model.

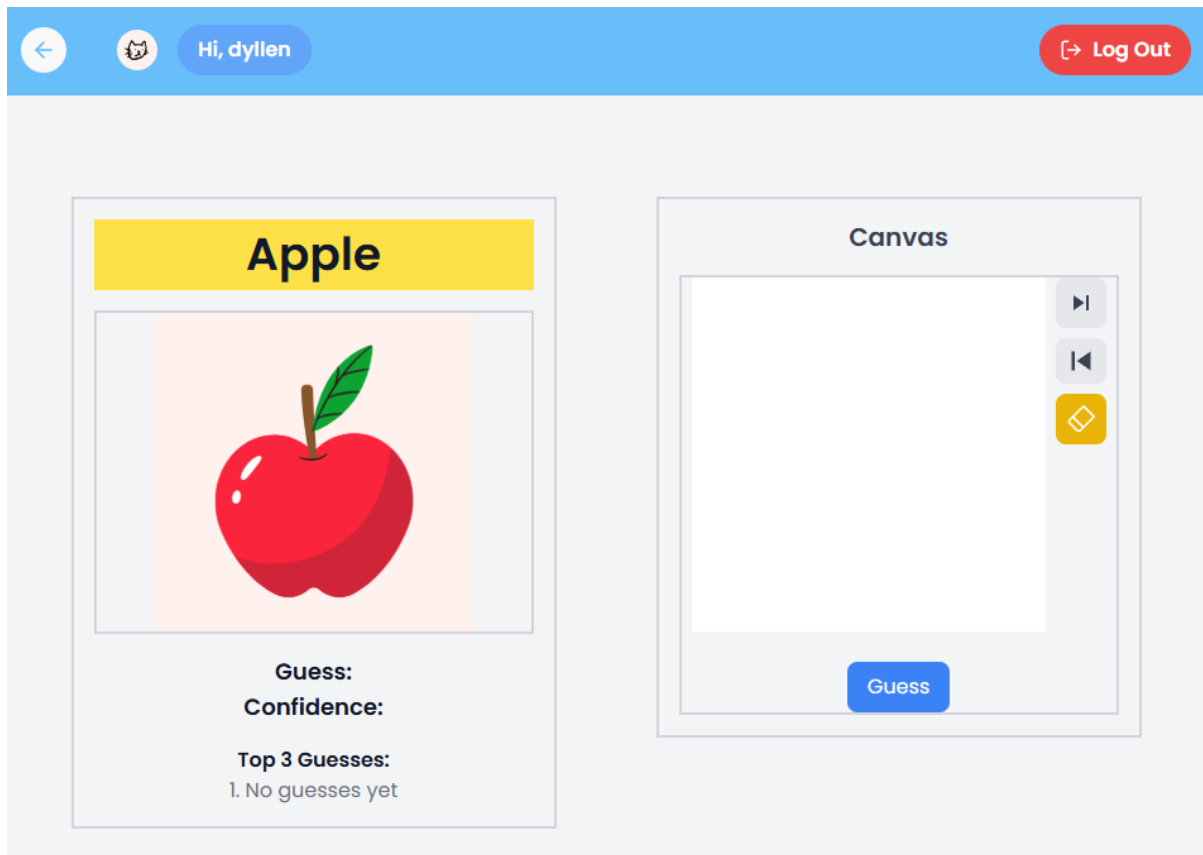


Figure 28: Doodle Recognition User Interface

“DoodleNet” is a pre-trained convolutional neural network (CNN) designed to classify hand-drawn images into over 300 object categories. It was trained on the “Quick, Draw!” dataset, which is a large-scale collection of doodles contributed by millions of users globally. This dataset includes a wide variety of drawing styles, which enhances the model’s robustness in recognizing imperfect or child-like sketches.

In the project, ml5.js was used to integrate “DoodleNet” directly into the browser environment. Unlike traditional machine learning workflows that require server-based model inference or external API calls, the entire classification process in this system occurs client-side, providing faster response times and ensuring data privacy.

As an example, the word “Apple” will be used as the target word to present scenarios of how the system respond to different inputs. In Figure 29, showed a positive recognition output when given a matching drawing input. The label under the image of an “Apple” was at 83.70% confidence and correctly matches the target word. In Figure 30, showed a negative recognition output when given a doodle of “Cat” which does not match the target word. Even though the recognition output label matched on the doodle of a cat with 96%

confidence, it is still incorrect as it does not match the target word. User can clear the canvas and try drawing again. Lastly, a “Try again” message is displayed when the model is unable to recognize a doodle with any word label as shown in Figure 31.

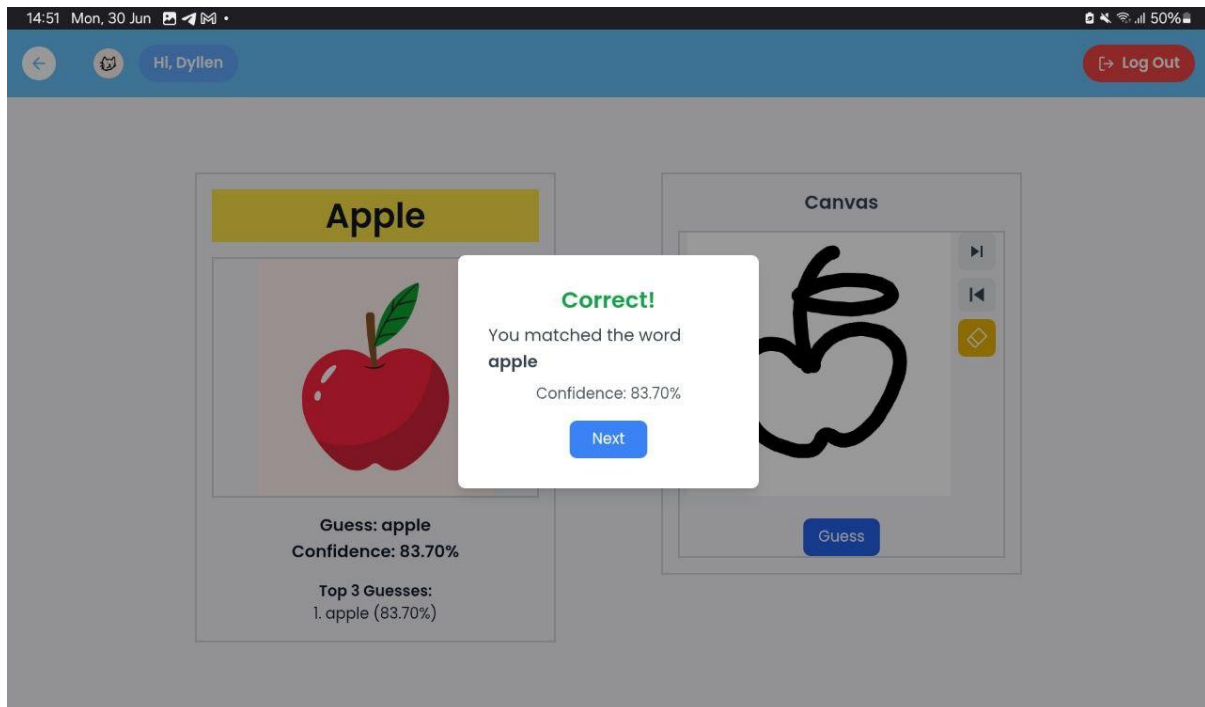


Figure 29: Successful recognition with correct matching

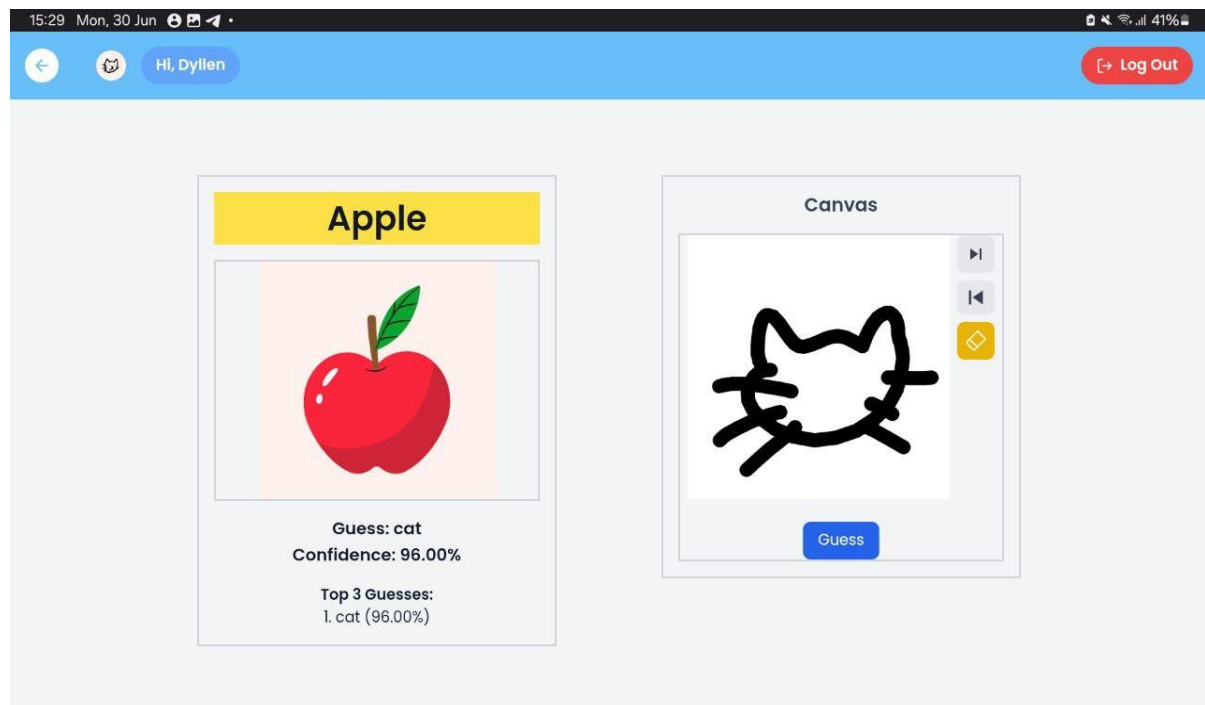


Figure 30: Successful recognition with incorrect matching

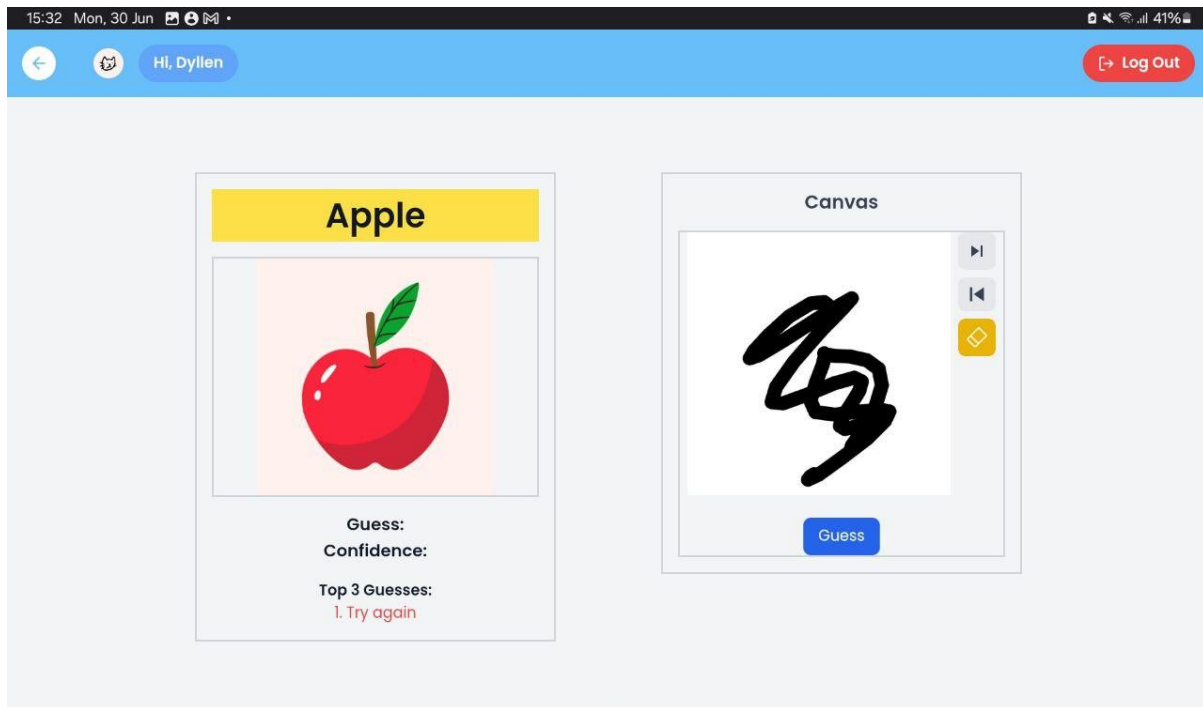


Figure 31: Unsuccessful recognition due to random scribble

Features and Implementation

The module provides real-time drawing capabilities, immediate doodle classification, confidence scoring, sequential vocabulary presentation, and success feedback mechanisms. The implementation utilizes client-side machine learning inference to ensure rapid response times and maintain data privacy.

The “DoodleNet” model integration process begins with dynamic library loading and model initialization:

```
const loadMl5AndP5 = async () => {
  if (!window.p5) {
    await new Promise<void>((resolve) => {
      const p5Script = document.createElement("script");
      p5Script.src = "https://cdnjs.cloudflare.com/ajax/libs/p5.js/0.9.0/p5.min.js";
      p5Script.async = true;
      p5Script.onload = () => resolve();
      document.body.appendChild(p5Script);
    });
  }

  if (!window.ml5) {
    await new Promise<void>((resolve) => {
      const ml5Script = document.createElement("script");
      ml5Script.src = "https://unpkg.com/ml5@0.12.2/dist/ml5.min.js";
      ml5Script.async = true;
    });
  }
}
```

```

        ml5Script.onload = () => resolve();
        document.body.appendChild(ml5Script);
    });
}
};

```

This code ensures that the required libraries are loaded dynamically, preventing conflicts and enabling client-side machine learning capabilities.

The drawing canvas initialization creates an interactive surface optimized for the DoodleNet model requirements:

```

const sketch = (p: any) => {
  p.preload = () => {
    if (!classifierRef.current) {
      classifierRef.current = window.ml5.imageClassifier("DoodleNet");
    }
  };

  p.setup = () => {
    const canvas = p.createCanvas(280, 280);
    canvas.parent(sketchContainerRef.current);
    p.background(255);
  };

  p.draw = () => {
    p.strokeWeight(15);
    p.stroke(0);
    if (p.mouseIsPressed) {
      p.line(p.pmouseX, p.pmouseY, p.mouseX, p.mouseY);
    }
  };
};

```

The canvas is configured to the 280x280 pixel resolution required by DoodleNet, with stroke settings optimized for child-friendly drawing. The drawing implementation supports both mouse and touch input for compatibility across devices.

The doodle classification process demonstrates the integration of machine learning inference with user interaction:

```

const handleGuess = () => {
  const canvas = document.querySelector("canvas");
  if (canvas && classifierRef.current) {
    classifierRef.current.classify(canvas, (error: any, results: any) => {
      if (error) {
        console.error(error);
        return;
      }
    })
  }
}

```

```

const normalize = (str: string) =>
  str.trim().toLowerCase().replace(/[\s_]+/g, "-");

const vocabSet = new Set(vocabularies.map((v) => normalize(v)));
const excludedWords = new Set(["camouflage", "syringe"]);

const filtered = results.filter((r: any) =>
  !excludedWords.has(normalize(r.label)) &&
  vocabSet.has(normalize(r.label))
);

const top3 = filtered.slice(0, 3).map((r: any) => ({
  label: r.label,
  confidence: r.confidence,
}));

if (onTopGuesses) onTopGuesses(top3);

if (filtered.length > 0) {
  const label = filtered[0].label.toLowerCase();
  const confidence = filtered[0].confidence;

  onGuess(label, confidence);

  if (normalize(label) === normalize(targetWord)) {
    onSuccess(label, confidence);
  }
}
});
};

```

This implementation demonstrates several key features of the classification system. The normalization function ensures consistent comparison between predicted labels and target vocabulary words. The filtering mechanism restricts predictions to the vocabulary set while excluding inappropriate words. The top-3 predictions provide transparency in the classification process, allowing students to see alternative interpretations of their drawings.

The success detection mechanism compares the highest-confidence prediction against the target vocabulary word using normalized strings to handle variations in formatting. When a match is detected, the system triggers success feedback, providing immediate positive reinforcement for correct drawings.

4.4.4 Admin Authentication System

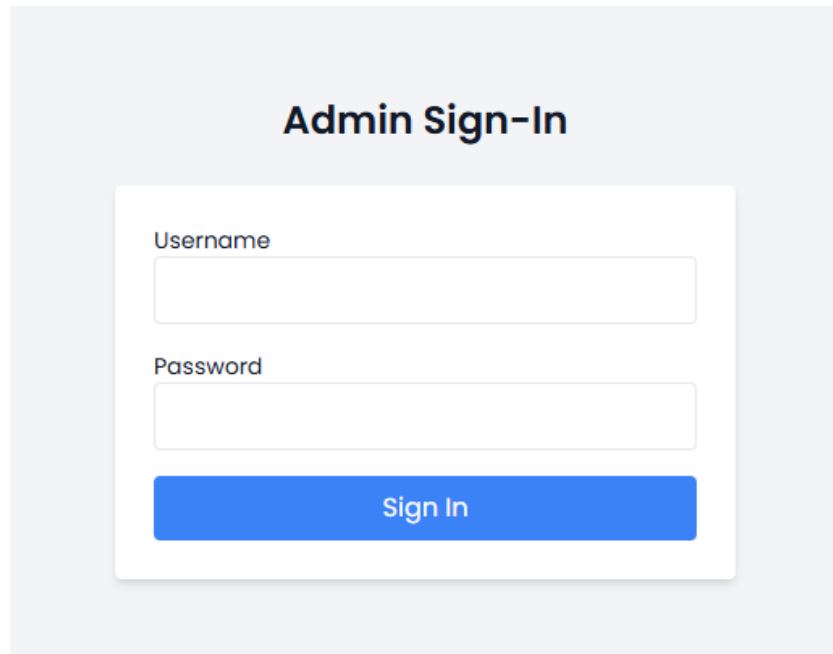
The image shows a web form titled "Admin Sign-In" in bold black text. Below the title is a white rectangular box containing two input fields. The first field is labeled "Username" in a small, light blue font, and the second field is labeled "Password" in the same font. Both fields are empty and have a light gray border. Below the password field is a solid blue button with the text "Sign In" in white, centered. The entire form is set against a light gray background.

Figure 32: Admin sign-in

The admin module implements a secure authentication system using bcrypt password hashing and session management through browser localStorage. The authentication process begins with the admin sign-in page, which validates credentials against the Supabase database.

```
const handleSignIn = async (e: React.FormEvent) => {
  e.preventDefault();
  const supabase = createClient();

  // Query the admin table to get the hashed password
  const { data: admin, error } = await supabase
    .from("admin")
    .select("*")
    .eq("username", username)
    .single();

  if (error || !admin) {
    setError("Invalid username or password");
    return;
  }

  // Compare the plain-text password with the hashed password
  const isValid = await bcrypt.compare(password, admin.password);
  if (!isValid) {
    setError("Invalid username or password");
    return;
  }
}
```

```
localStorage.setItem("admin", JSON.stringify({ username }));
router.push("/admin");
};
```

The authentication system employs industry-standard security practices, including password hashing with bcrypt and secure session management. Once authenticated, administrators gain access to the dashboard and user management features.

4.4.5 Data Analytics Dashboard

The dashboard provides comprehensive visualization of student performance and learning outcomes through multiple interactive charts and statistical summaries. The system aggregates data from student test attempts, vocabulary learning sessions, and demographic information to present actionable insights.

Statistical Overview Cards

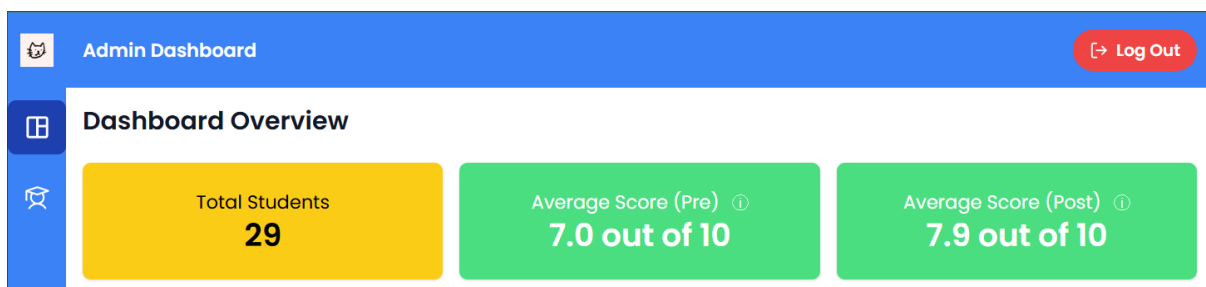


Figure 33: Statistical Overview Cards

The dashboard begins with summary statistics cards that provide immediate insights into system usage and performance:

```
const preTestScores = students
  .map(students => students.latest_pretest_score)
  .filter((score): score is number => score !== null && !isNaN(score));

const postTestScores = students
  .map(students => students.latest_posttest_score)
  .filter((score): score is number => score !== null && !isNaN(score));

let avgPreTest: number | null = null;
let avgPostTest: number | null = null;

if (preTestScores.length > 0) {
  avgPreTest = preTestScores.reduce((a, b) => a + b, 0) / preTestScores.length;
}
if (postTestScores.length > 0) {
```

```

    avgPostTest = postTestScores.reduce((a, b) => a + b, 0) /
    postTestScores.length;
  }

```

The statistical cards display total student enrolment, average pre-test scores, and average post-test scores. The scoring system implements color-coded visual feedback, with green indicating satisfactory performance ($\geq 5/10$) and red indicating areas requiring attention ($< 5/10$).

Age Distribution Analysis

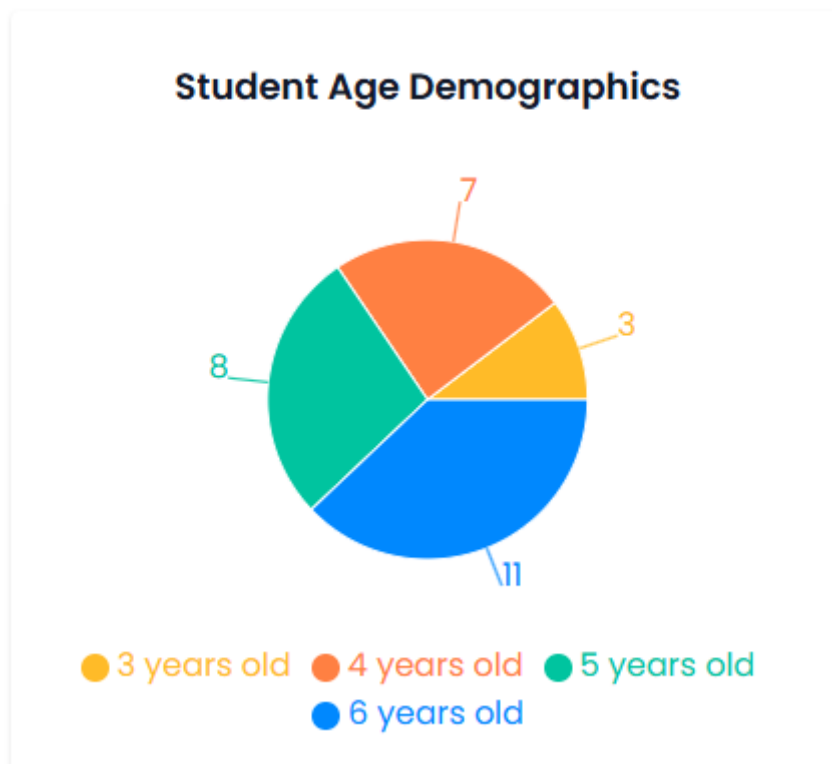


Figure 34: Age Distribution Analysis

The student age pie chart provides demographic insights into the user base, enabling administrators to understand the age distribution of participants:

```

const fetchAges = async () => {
  const supabase = createClient();
  const { data: students, error } = await supabase
    .from("students")
    .select("age");

  const ageCounts: Record<number, number> = { 3: 0, 4: 0, 5: 0, 6: 0 };
  students?.forEach((s) => {
    if (s.age >= 3 && s.age <= 6) ageCounts[s.age]++;
  });
}

```

```

setData(
  Object.entries(ageCounts).map(([age, count]) => ({
    name: `${age} years old`,
    value: count,
  })))
);
};

```

This visualization utilizes the Recharts library to create an interactive pie chart showing the distribution of students across age groups (3-6 years old), helping administrators understand their target demographic composition.

Pre/Post Test Performance Comparison

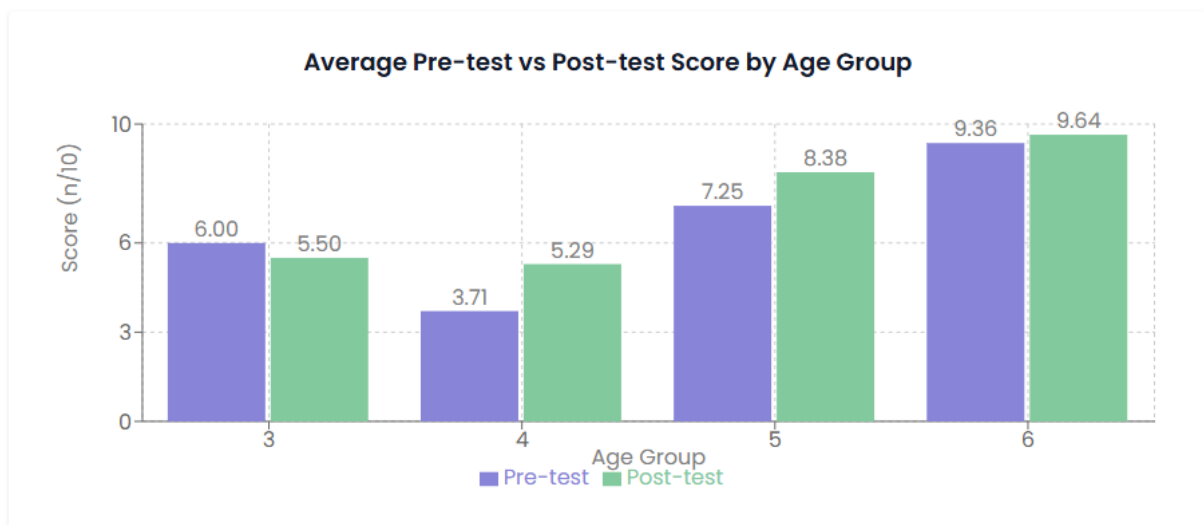


Figure 35: Pre/Post Test Performance Comparison

The system implements a comprehensive bar chart comparing pre-test and post-test performance across age groups:

```

ageGroups.forEach((age) => {
  const group = students.filter((s) => s.age === age);
  const preScores = group
    .map((s) => typeof s.latest_pretest_score === "number" ?
s.latest_pretest_score : null)
    .filter((v) => v !== null) as number[];
  const postScores = group
    .map((s) => typeof s.latest_posttest_score === "number" ?
s.latest_posttest_score : null)
    .filter((v) => v !== null) as number[];

  const preAvg = preScores.length ? preScores.reduce((a, b) => a + b, 0) /
preScores.length : 0;

```

```

const postAvg = postScores.length ? postScores.reduce((a, b) => a + b, 0) /
postScores.length : 0;

result.push({
  age: `${age}`,
  PreTest: Number(preAvg.toFixed(2)),
  PostTest: Number(postAvg.toFixed(2)),
});
});

```

This analysis enables administrators to assess the effectiveness of the learning intervention by comparing performance improvements across different age groups.

Vocabulary-Specific Performance Analysis

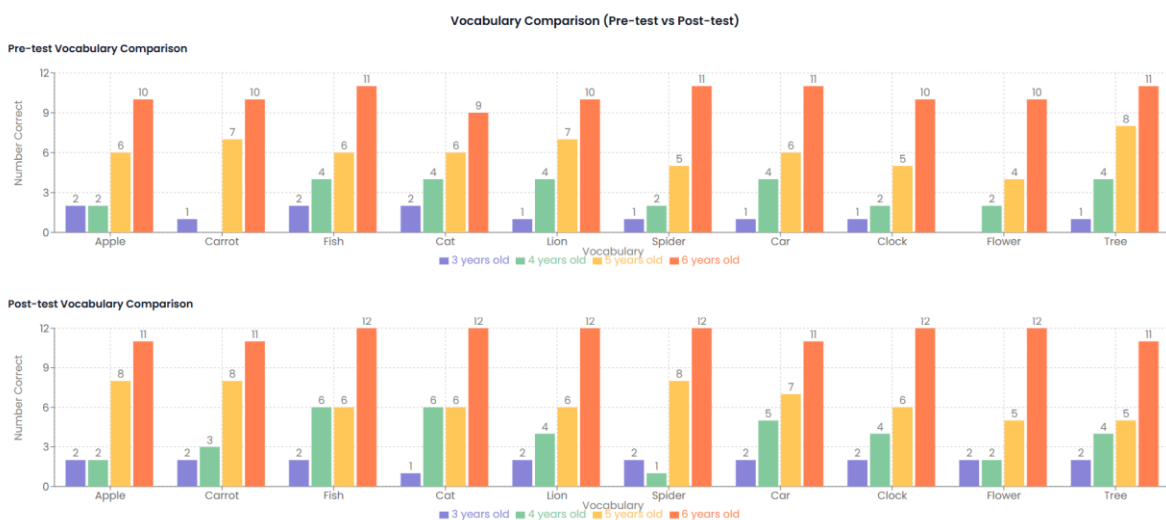


Figure 36: Vocabulary Performance Analysis

The dashboard includes detailed vocabulary comparison charts that break down performance by individual vocabulary items across age groups:

```

// Count correct answers for each vocab, age, and test type
for (const answer of validAnswers) {
  const vocab = answer.question;
  const student = Array.isArray(answer.students) ? answer.students[0] :
answer.students;
  const age = student.age;
  const testType = answer.test_type;

  if (VOCABULARIES.includes(vocab) && AGE_GROUPS.includes(age)) {
    if (testType === "pre") {
      preTestStats[vocab][age] = preTestStats[vocab][age] + 1;
    } else if (testType === "post") {
      postTestStats[vocab][age] = postTestStats[vocab][age] + 1;
    }
  }
}

```

}

This granular analysis allows educators to identify which vocabulary items are most challenging for specific age groups and adjust their teaching strategies accordingly.

4.5 Summary

The system architecture demonstrates a comprehensive approach to early childhood vocabulary learning through the integration of modern web technologies, machine learning capabilities, and data-driven educational insights, successfully leveraging client-side machine learning for real-time doodle recognition that provides immediate, engaging feedback to young learners while incorporating robust admin modules for effective system management and educational outcome tracking. The implementation showcases key technological achievements including real-time machine learning inference in the browser environment, comprehensive data visualization for educational analytics, and secure user management systems, all built within a modular architecture that enables scalable deployment and maintenance while providing educators with essential tools to monitor and enhance learning outcomes. The seamless combination of interactive learning experiences and administrative oversight creates a complete educational ecosystem that supports both student engagement and pedagogical effectiveness, successfully addressing the challenges of early childhood vocabulary acquisition while establishing the necessary infrastructure for evidence-based educational improvement. Moving forward, the next phase will focus on conducting testing towards the system's usability and evaluating user's vocabulary retention performance before and after using the system.

Chapter 5: Testing and Evaluation

5.1 Introduction

The testing and evaluation phase represents a critical component of the system's development lifecycle, to validate the functionality, reliability, and the effectiveness of doodle recognition in improving vocabulary retention among young children. This chapter discusses the assessment of project in both functional and non-functional testing methodologies to ensure the system meets its intended objectives and user requirements.

The primary purpose of the testing and evaluation process are to ensure robust system functionality across all modules, to validate the accuracy and reliability of the doodle recognition capabilities, and to assess the effectiveness of the system as a language learning tool for young children. The testing framework adopts a systematic approach that combines functional testing with user-centric evaluation methods to provide a holistic assessment of system performance.

The evaluation methodology has multiple testing phases, beginning with comprehensive functional testing to verify individual system components and their integration. This is followed by non-functional testing that focuses on user experience, system usability, and vocabulary retention improvement among young children. The testing approach are conducted manually to ensure comprehensive coverage of system features and user interactions.

Through systematic testing and evaluation, this chapter aims to demonstrate the system's capability to deliver accurate doodle recognition, provide engaging user interactions, and facilitate effective language vocabulary learning experiences for the target demographic of young children (3 to 6 years old).

5.2 Functional Testing

5.2.1 Unit Testing

Unit testing focuses on the individual components and modules that comprise the system architecture. Each module undergoes systematic testing to verify its functionality, data processing capabilities, and integration points with other system components. The

unit testing framework encompasses five primary modules that represent the core functionality of the doodle recognition for language learning system.

The testing methodology employs manual testing approaches to ensure comprehensive evaluation of user interactions, system responses, and data accuracy. Manual testing provides the flexibility to assess user experience elements and identify potential usability issues that automated testing might overlook. This approach is particularly valuable for evaluating the intuitive nature of the user interface for evaluation the intuitive nature of the user interface and the accuracy of the doodle recognition process.

Test Plan and Test Cases

The comprehensive test plan encompasses systematic evaluation of all major system modules through structured test cases that validate both functional requirements and user interaction scenarios. The following table presents the detailed test cases organized by module; each designed to verify specific functionality and ensure robust system performance.

Module User Management

Table 14: User Management (Student)

Module		User Management (Student)		Prepared by	Hoo Dy Llen		
Test Objective		Able to perform log in successfully		Pre-requisite	User details exist in database (student table)		
Test Case Description		Test case verifies the log in behaviour of users with different scenarios 1. Displays correct name and age when selected name. 2. When user's pre-test score = null, then navigated to pre-test page 3. When user's pre-test score ≠ null, then navigated to menu					
ID	Test Scenario	Test Steps	Test Data	Expected Result	Actual Result	Status	Severity of Failure
UM-01	Validate user login process	1. Users select name from the list 2. Observe and verify the age. 3. Click “Enter”	Name: Dy Llen	Displays accurate age of user and can access the menu	Performed as expected. Age displayed	Pass	High
UM-02	Log in without their pre-test being completed before.	1. Select name and observe age. 2. Click “Enter”	Name: Dy Llen Pre-test score: null	The user will be navigated to pre-test page to complete their pre-test before user can proceed to menu.	Performed as expected. User is navigated to pre-test page to complete first.	Pass	High
UM-03	Log in with their pre-test completed before	1. Select name and observe age. 2. Click “Enter”	Name: Dy Llen Pre-test score: null	The user will navigate to menu since they have completed their pre-test (pre-test score ≠ null)	Performed as expected. User is navigated to menu.	Pass	High

Table 15: User Management (Admin)

Module		User Management (Admin)		Prepared by	Hoo Dy Llen		
Test Objective		Able to perform log in and admin task (add, edit and delete user) and view database data.		Pre-requisite	Admin details exist in database (admin table)		
Test Case Description		Test case verifies the log in behaviour of admins with different scenarios 1. Log in 2. Add, edit and delete existing users					
ID	Test Scenario	Test Steps	Test Data	Expected Result	Actual Result	Status	Severity of Failure
UM-05	Validate admin log in with valid input	1. Fill in both valid username and password 2. Click “Enter”	Valid Username: admin1 Password: password123	Log in successful and have access to admin page.	Performed as expected. Admin session starts and can view admin page.	Pass	High
UM-06	Validate admin log in with invalid input - Username does not exist in database - Password does not match	1. Fill in invalid credentials (username and password that do not exist) 2. Click “Enter”	Invalid Username: admin@01 Password: abc112233	Show error message for invalid username since it does not exist. User is not allowed to access admin page.	Performed as expected. Error message show “Invalid username or password”	Pass	High
		1. Fill in invalid password to a username that exist. 2. Click “Enter”		Show error message for invalid password since it does not match the valid user. User is not allowed to access admin page.	Performed as expected. Error message show “Invalid username or password”	Pass	High
UM-07	Admin add new user to the database.	1. Click “Add User”. 2. Fill in required details for user like Student ID, Name and Age 3. Click “Add” to complete process.	Student ID: assigned Name: Test1 Age: 3	Create and save user detail successfully and display on admin page and database.	Performed as expected. User (student) created successfully with accurate details. New data Student ID: 1 Name: Test1 Age: 3 Pre-test score: 0	Pass	Medium

					<i>Post-test score: 0</i>		
UM-08	Admin edits existing user valid inputs	- Click on edit button on existing user from student table. - Existing user details like Name, Age, Pre-test score and Post-test scores are populated. - Admin edit the details and save. - Observe change displayed in admin page.	Existing user Name: dyllen1 Age: 6 Pre-test score: 0 Post-test score: 10	Show validation message and display change on the student table. Display change on student table accurately.	Performed as expected. Showed validation message “Student info has been updated” and display change on admin page’s student table accurately. <u>New data</u> Name: dyllen1 Age: 6 Pre-test score: 0 Post-test score: 10	Pass	Medium
UM-09	Admin edits existing user invalid inputs. Limits: Age: 3-6 Pre/Post-test score: 0-10	- Click on edit button on existing user from student table. - Edit student’s age from existing to 7. - Click save and observe validation message.	<u>Invalid data</u> Age: 7 Pre-test score: -1 Post-test score: 11	Show validation message for age invalid input and not change to be done.	Performed as expected. Showed validation message “Value must between 3 to 6 only”.	Pass	Medium
		- Edit pre-test score to “-1” - Click save and observe validation message.		Show validation message for pre-test invalid input and not change to be done.	Performed as expected. Showed validation message “Value must be greater than or equal to 0”.	Pass	Medium
		- Edit post-test score to “11” - Click save and observe validation message.		Show validation message for post-test invalid input and not change to be done.	Performed as expected. Showed validation message “Value must be lesser than or equal to 10”.	Pass	Medium

UM-10	Admin deletes an existing user.	1. Click on delete button on existing user from student table. 2. Checks on user's name and age for confirmation of deletion. 3. Confirms deletion of specific user. 4. Observe change displayed in admin page.	Existing user	Show a message to warn and confirm admin of the deletion of user. Display change on student table accurately	Performed as expected. Showed warning message for confirmation of deletion and display change applied.	Pass	Low
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Module Doodle Recognition and Canvas

Table 16: Doodle Recognition and Canvas

Module		Doodle Recognition and Canvas		Prepared by	Hoo Dy Llen		
Test Objective		Ensure canvas allows drawing, clearing, and submitting while doodle recognition returns results.		Pre-requisite	- Doodle recognition model is loaded - Canvas component is rendered - User is logged in		
Test Case Description		This test ensures that the canvas to doodle and doodle recognition are working correctly when given different test scenarios like submitting an unrecognizable doodle. Other tools for when user doodle on canvas are working as intended.					
ID	Test Scenario	Test Steps	Test Data	Expected Result	Actual Result	Status	Severity of Failure
DR-01	Verify drawing functionality on canvas.	1. Navigate to drawing interface. 2. Start doodling canvas. 3. Observe stroke appearance	Random doodle	Canvas displays smooth and clear continuous multiple strokes.	Performed as expected. User can draw smooth strokes which are displayed clearly on canvas.	Pass	High

DR-02	User clearing canvas after doodling on canvas.	1. Draw multiple strokes on canvas. 2. Click clear button 3. Observe canvas state.	Random doodle	Canvas is completely cleared, showing blank white surface.	Performed as expected. Canvas became completely clear and blank.	Pass	Medium
DR-03	User skips vocabulary	1. Doodle practice page displays a word, image, and empty canvas. 2. Click skip button 3. Observe word and image displayed before changes.	Vocabulary	Displays matching word and image with empty canvas, then a different set of word and image after skipping.	Performed as expected. Set of word and image changes at every skip.	Pass	Medium
DR-04	User skips vocabulary	1. Doodle practice page displays a word, image, and empty canvas. 2. Click skip button 3. Observe word and image displayed before changes.	Vocabulary	Displays matching word and image with empty canvas, then a different set of word and image after skipping.	Performed as expected. Set of word and image changes at every skip.	Pass	Medium
DR-05	Test doodle submission process	1. Complete a doodle on canvas 2. Click guess/submit button. 3. Verify submission confirmation.	Doodle: tree	System processes submission and provides appropriate feedback within 3 seconds	Performed as expected. System processes the submission with no error and provides feedback of doodle within 3 seconds.	Pass	High
DR-07	Verify canvas responsiveness across devices.	1. Access canvas on different screen size 2. Test drawing functionality 3. Verify touch/mouse input accuracy	Screen resolutions: Phone, Tablet and Laptop	Canvas maintains proportional drawing accuracy across all devices with <5% coordinate deviation	Performed as expected. Canvas maintains drawing accuracy with <5% coordinate deviation. Results are similar across devices.	Pass	Medium

DR-08	Test DoodleNet image classification model integration	1. Submit a clear, recognizable doodle 2. Wait for processing 3. Verify recognition result.	Doodle of apple, car, and cat	System correctly identifies the drawn object with only 3 attempts for each word and >80% confidence score.	Performed as expected. System identifies words correctly within 3 tries but confidence score range between 60% to 90%.	Pass	Medium
DR-09	Test handling of unclear/ambiguous doodles	1. Draw unclear or incomplete doodles. 2. Submit for recognition. 3. Verify system response.	Incomplete drawings, and scribbles Target word: "Apple"	System provides feedback on the doodle as guesses but does not match the target word after 3 attempts	Performed as expected. System provided feedback for 3 attempts but did not guess "Apple" for all the scribbles.		

Module Progress Tracking

Table 17: Progress Tracking

Module		Progress Tracking			Prepared by	Hoo Dy Llen	
Test Objective		Ensure that student’s progress is collected accurately via pre and post-test and displayed			Pre-requisite	- User are logged in - Pre-test: new user or have “null” value on pre-test score	
Test Case Description		This test ensures that scores are recorded correctly without any error or fallout. The images shown for each question should also be clear and matching to the correct answer. This provides student a smoother answering test questions.					
ID	Test Scenario	Test Steps	Test Data	Expected Result	Actual Result	Status	Severity of Failure
PT-01	Validate pre-test functionality	1. Initiate pre-test session 2. Complete test questions 3. Verify score calculation and storage	Pre-test with 10 vocabulary questions.	Pre-test scores are accurately calculated and store their questions and answers.	Performed as expected. Pre-test scores are accurately calculated and stored in database.	Pass	Medium

PT-02	Test post-test implementation	1. Complete learning activities 2. Initiate post-test 3. Complete test and verify results	Post-test with same 10 vocabulary questions	Post-test scores are accurately calculated and store their questions and answers.	Performed as expected. Post-test scores are accurately calculated and stored in database	Pass	
PT-03	Ensuring all question's image are matching to question's answer	1. Start pre or post-test. 2. Complete questions while observing the weather any mismatches.	10 questions on Pre and Post-test	The images should display clearly and matching to the correct answer for the question	Performed as expected.	Pass	

5.3 User Testing with Young Children

5.3.1 Objectives of User Testing

The user testing phase was designed to address the third research objective of this project, which aims to evaluate young children's vocabulary retention skills through pre-test and post-test assessments following their interaction with the doodle recognition system. This empirical evaluation serves as a critical component in determining the educational efficacy of integrating doodle recognition technology into early childhood English vocabulary learning.

The primary purpose of conducting user testing was to gather quantitative data that would demonstrate whether the proposed doodle recognition system could significantly enhance young children's ability to retain and recall vocabulary items. By implementing a controlled testing environment with standardized pre-test and post-test measurements, this study sought to establish a baseline understanding of participants' initial vocabulary knowledge and subsequently measure any improvements following their engagement with the interactive learning system.

Additionally, the user testing aimed to observe and document young children's behavioural responses and engagement levels when interacting with the doodle recognition technology, providing valuable insights into the system's usability and appeal to the target demographic. This comprehensive approach ensures that both quantitative learning outcomes and qualitative user experience factors are thoroughly evaluated.

5.3.2 Testing Procedure

The user testing was conducted through a systematic three-session approach in collaboration with a participating pre-school institution. Each testing session targeted approximately 10 students to ensure adequate individual attention and comprehensive data collection while allowing sufficient time to observe and document participants' behavioural responses during the learning activities.

The testing protocol consisted of three distinct phases: pre-test assessment, interactive system usage, and post-test evaluation. Both pre-test and post-test assessments comprised 10 multiple-choice questions, each presenting four possible answers to

accommodate the cognitive and reading capabilities of young children aged 3 to 6 years. Throughout this document, participating young children are referred to as "students" for consistency and clarity.

Pre-Test Phase

Students individually completed the pre-test assessment with minimal adult assistance to ensure authentic baseline measurements of their vocabulary recognition abilities. However, students aged 3 to 4 years received additional guidance and supervision due to their developmental requirements and limited independent task completion capabilities. The pre-test served as a benchmark indicator of students' existing ability to recognize and identify vocabulary words when presented with corresponding visual representations.

Interactive Learning Session

Following pre-test completion, students participated in structured group learning sessions, with approximately 5 students assigned to each supervising teacher or adult facilitator. The interactive learning activities were conducted in a circle formation to promote engagement and facilitate group participation.

The vocabulary learning session incorporated multiple learning modalities through the doodle recognition system. Initially, all students collectively recited and spelled each target vocabulary word, introducing phonetic and literacy elements into the learning process. Subsequently, students were instructed to create doodle representations of each vocabulary word while referencing provided visual guides. This drawing activity was specifically designed to develop fine motor skills while reinforcing visual-spatial learning connections.

Upon completion of each doodle, students submitted their drawings to the system, which generated recognition predictions and feedback. This interactive element introduced technological engagement and immediate response mechanisms that maintained student attention and motivation throughout the learning session. The provision of visual feedback and system responses created an engaging learning environment that encouraged active participation and sustained focus during vocabulary acquisition activities.

Post-Test Phase

After completing all 10 vocabulary items through the interactive learning session, students individually completed the post-test assessment. This evaluation measured potential changes in vocabulary recognition and retention abilities following their engagement with the doodle recognition system. The post-test utilized identical assessment parameters as the pre-test to ensure valid comparative analysis of learning outcomes.

Throughout the entire testing process, continuous teacher supervision and guidance proved essential for maintaining student focus and ensuring adherence to testing protocols. Adult facilitators provided necessary behavioural management and instructional support while minimizing direct assistance during assessment phases to preserve data integrity and validity of results.

5.4 Results and Discussion

5.4.1 Age Demographics

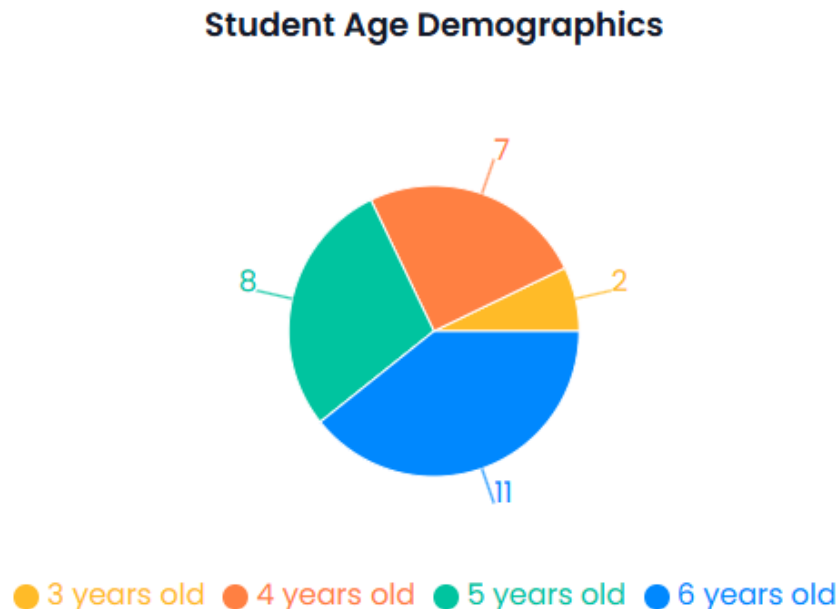


Figure 37: Student Age Demographics

The user testing involved a total of 28 students aged between 3 and 6 years old, providing a comprehensive representation of the target demographic for early childhood

vocabulary learning. In Figure 37, the age distribution was as follows: 2 students aged 3 years (7.1%), 7 students aged 4 years (25.0%), 8 students aged 5 years (28.6%), and 11 students aged 6 years (39.3%). This distribution demonstrates a slight skew toward older children within the target age range, with the majority of participants being 5 and 6 years old, representing 67.9% of the total sample.

The demographic composition is particularly valuable for this study as it encompasses the critical developmental period when children are rapidly acquiring vocabulary and developing fine motor skills necessary for drawing activities. The higher representation of older children (ages 5-6) provides substantial data for analyzing the system's effectiveness with students who possess more developed cognitive and motor abilities, while the inclusion of younger children (ages 3-4) offers insights into the system's accessibility and usability across different developmental stages.

5.4.2 Average Pre-test and Post-test scores by Age

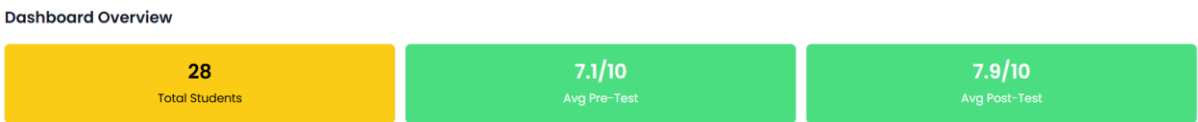


Figure 38: Total Students and Average Pre-test and Post-test

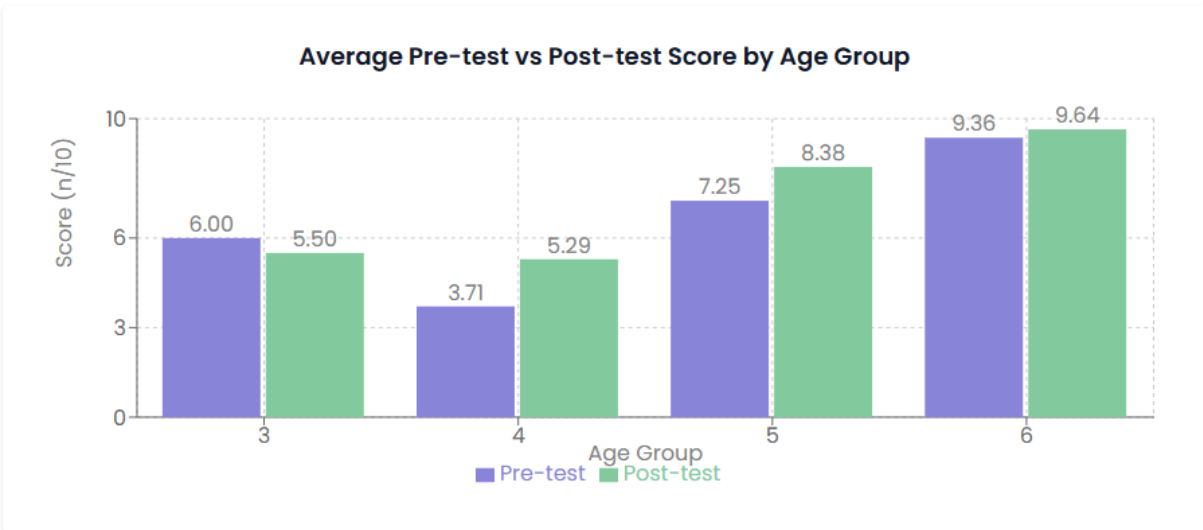


Figure 39: Average Pre and Post-test scores by Age Group

The comparative analysis of pre-test and post-test scores reveals significant improvements across all age groups shown in Figure 38, with an overall increase from an

average of 7.1/10 in the pre-test to 7.9/10 in the post-test, representing an 11.3% improvement in vocabulary recognition performance.

Detailed examination of age-specific performance patterns demonstrates varying degrees of improvement across different developmental stages shown in Figure 39. The 3-year-old group showed a modest improvement from 6.00 to 5.50, representing a slight decrease of 0.50 points. This unexpected result can be attributed to several developmental factors, including limited attention span, difficulty with sustained focus during testing sessions, and potential fatigue effects from the extended testing protocol. Additionally, 3-year-old children may have experienced cognitive overload from the multi-modal learning approach, which could have interfered with their ability to consolidate new vocabulary knowledge effectively.

The 4-year-old group demonstrated significant improvement, with scores increasing from 3.71 to 5.29, representing a substantial gain of 1.58 points or a 42.6% improvement. This age group showed the most dramatic improvement among all participants, suggesting that 4-year-old children are at an optimal developmental stage to benefit from the integrated doodle recognition approach. The combination of drawing activities, visual recognition, and interactive feedback appears to align well with their emerging fine motor skills and expanding cognitive capabilities.

The 5-year-old group exhibited consistent improvement, with scores rising from 7.25 to 8.38, representing an increase of 1.13 points or 15.6% improvement. This steady improvement indicates that children at this age can effectively engage with the multi-modal learning approach while maintaining focus throughout the testing process. Their more developed fine motor skills and enhanced attention span likely contributed to successful interaction with the doodle recognition system.

The 6-year-old group showed the smallest improvement margin, with scores increasing from 9.36 to 9.64, representing a gain of 0.28 points or 3.0% improvement. While this improvement is statistically modest, it should be noted that this age group achieved the highest absolute scores in both pre-test and post-test assessments. The limited improvement can be attributed to a ceiling effect, where students already possessed strong vocabulary recognition skills, leaving minimal room for substantial improvement through the intervention.

5.4.3 Vocabulary Comparison (Pre-test and Post-test)

The vocabulary-specific analysis reveals varying improvement patterns across different word categories, providing insights into the differential effectiveness of the doodle recognition system for different types of vocabulary items. Figure 40 shows the comparison between 10 vocabularies that were answered correctly to ages in pre-tests, while Figure 41 shows the comparison in post-tests.

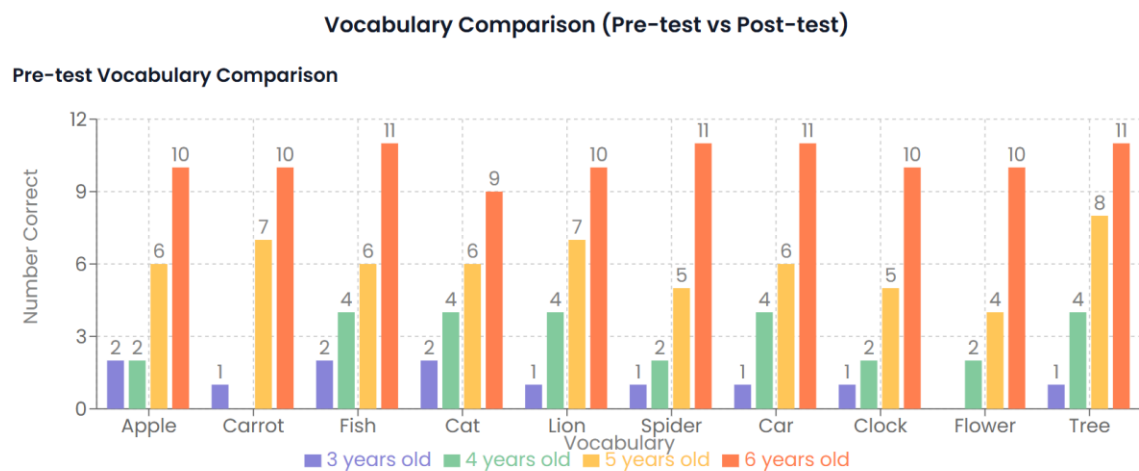


Figure 40: Pre-test Vocabulary Comparison between Ages

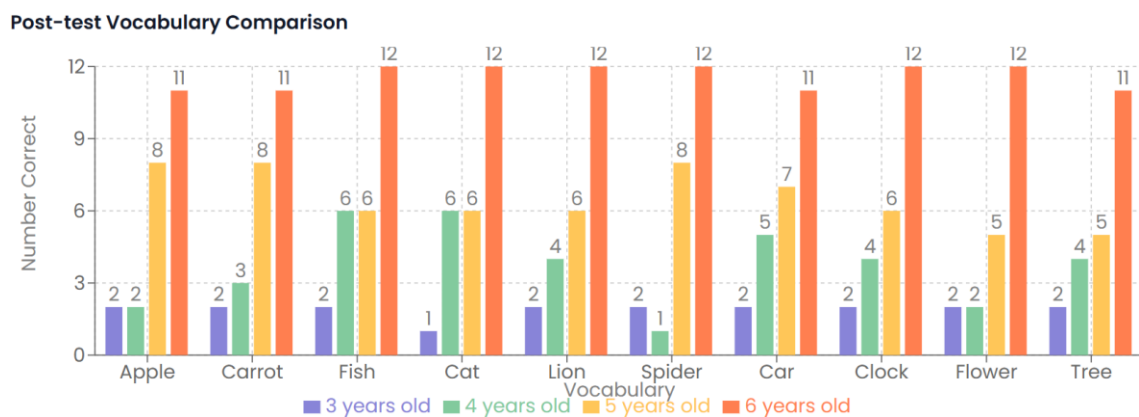


Figure 41: Post-test Vocabulary Comparison between Ages

Individual Vocabulary Performance Analysis

The performance on "Apple" vocabulary showed consistent improvement across most age groups. In the pre-test, 3-year-olds scored 2 correct responses, 4-year-olds scored 2

correct responses, 5-year-olds scored 6 correct responses, and 6-year-olds achieved 10 correct responses. Post-test results demonstrated improvement for younger children, with 3-year-olds maintaining 2 correct responses, 4-year-olds improving to 2 correct responses, 5-year-olds increasing to 8 correct responses, and 6-year-olds achieving 11 correct responses. The stability in performance for younger children suggests that "Apple" may be a familiar vocabulary item that did not require significant reinforcement.

The "Carrot" vocabulary showed remarkable improvement across all age groups. Pre-test performance was relatively low, with 3-year-olds scoring 1 correct response, 4-year-olds scoring 2 correct responses, 5-year-olds scoring 7 correct responses, and 6-year-olds achieving 10 correct responses. Post-test results demonstrated substantial improvement, with 3-year-olds improving to 2 correct responses, 4-year-olds increasing to 3 correct responses, 5-year-olds maintaining 8 correct responses, and 6-year-olds achieving perfect scores of 11 correct responses. The significant improvement suggests that the doodle recognition system was particularly effective for this vocabulary item, possibly due to the distinctive visual characteristics of carrots that translate well to drawing activities.

The "Fish" vocabulary demonstrated moderate improvement patterns. Pre-test scores showed 3-year-olds with 2 correct responses, 4-year-olds with 4 correct responses, 5-year-olds with 6 correct responses, and 6-year-olds with 11 correct responses. Post-test results indicated improvement for most groups, with 3-year-olds maintaining 2 correct responses, 4-year-olds achieving 6 correct responses, 5-year-olds maintaining 6 correct responses, and 6-year-olds achieving perfect scores of 12 correct responses. The improvement pattern suggests that fish-related vocabulary benefits from the visual-spatial learning approach inherent in doodle recognition activities.

Items such as "Spider" and "Clock" showed varied improvement patterns, with some age groups demonstrating significant gains while others showed minimal change. This variation suggests that the effectiveness of the doodle recognition system may depend on the visual complexity and familiarity of vocabulary items to children at different developmental stages.

Factors Influencing Vocabulary Improvement

Several factors contribute to the observed improvement patterns in vocabulary recognition performance. The multi-modal learning approach combining visual,

kinaesthetic, and auditory elements appears to enhance vocabulary retention, particularly for children aged 4-5 years. The drawing component engages fine motor skills while reinforcing visual memory, creating multiple pathways for vocabulary acquisition and retention.

The interactive feedback provided by the doodle recognition system serves as immediate reinforcement, helping children connect their drawing attempts with vocabulary recognition. This immediate feedback loop is particularly beneficial for maintaining engagement and motivation during the learning process.

Age-related developmental factors significantly influence improvement patterns. Younger children (3-4 years) may benefit from the kinaesthetic aspects of drawing but may struggle with the cognitive demands of the complete learning protocol. Older children (5-6 years) demonstrate more consistent improvement, suggesting that their developed fine motor skills and enhanced attention span optimize their interaction with the system.

The ceiling effect observed in 6-year-old participants indicates that the current vocabulary set may be too elementary for this age group, suggesting the need for age-appropriate vocabulary selection in future implementations of the system.

5.5 Conclusion

Based on the comprehensive testing and evaluation presented in this chapter, the doodle recognition system demonstrates significant potential as an effective tool for enhancing vocabulary learning among young children aged 3-6 years. The functional testing confirmed robust system performance across all modules, including user management, doodle recognition capabilities, and progress tracking mechanisms, with all critical test cases achieving pass status. The user testing with 28 preschool children revealed an overall 11.3% improvement in vocabulary recognition scores, with particularly notable gains observed in 4-year-old participants (42.6% improvement) and consistent improvements across 5-year-old children (15.6% improvement). While 3-year-old children showed minimal improvement due to developmental constraints and 6-year-old children experienced ceiling effects due to their already advanced vocabulary knowledge, the results collectively demonstrate that the integration of doodle recognition technology with multi-modal learning approaches can effectively enhance vocabulary retention through engaging, interactive experiences. The successful validation of both

technical functionality and educational efficacy establishes a strong foundation for the system's practical implementation, setting the stage for the comprehensive conclusions and recommendations for future development that will be discussed in Chapter 6.

Chapter 6: Conclusion and Future Work

6.1 Summary of Work Done

This project successfully developed and evaluated a doodle recognition system designed to enhance vocabulary learning for young children aged 3 to 6 years old. The research was conducted through a systematic approach that encompassed system design, implementation, and comprehensive user testing to assess the educational effectiveness of integrating doodle recognition technology into early childhood vocabulary acquisition.

The project commenced with extensive research into existing doodle recognition technologies and educational methodologies for young children, establishing a theoretical foundation for the system design. A web-based application was developed incorporating machine learning algorithms capable of recognizing and interpreting children's drawings, providing immediate feedback and interactive learning experiences. The system was designed with age-appropriate user interfaces, featuring intuitive navigation and engaging visual elements suitable for the target demographic.

The implementation phase involved the integration of doodle recognition capabilities with vocabulary learning modules, creating a comprehensive educational platform that combines drawing activities with traditional vocabulary instruction. The system incorporates multiple learning modalities, including visual recognition, kinesthetic drawing activities, and auditory reinforcement through word pronunciation and spelling exercises.

A rigorous user testing protocol was established and conducted with 28 young children from a collaborating pre-school institution. The testing methodology employed pre-test and post-test assessments to measure vocabulary retention improvements following interaction with the doodle recognition system. The testing was conducted across three separate sessions, ensuring adequate data collection while maintaining participant engagement and attention.

The evaluation results demonstrated measurable improvements in vocabulary recognition performance, with an overall increase from 7.1/10 in pre-test scores to 7.9/10 in post-test scores, representing an 11.3% improvement across all participants. Age-specific analysis revealed varying improvement patterns, with 4-year-old children

showing the most significant gains (42.6% improvement), while 6-year-old participants demonstrated ceiling effects due to their already advanced vocabulary knowledge.

6.2 Strengths of the System

The developed doodle recognition system demonstrates several significant strengths that contribute to its effectiveness as an educational tool for young children's vocabulary learning.

The multi-modal learning approach represents a primary strength of the system, integrating visual, kinaesthetic, and auditory learning elements to accommodate different learning styles and preferences. This comprehensive approach ensures that children can engage with vocabulary learning through multiple sensory channels, enhancing retention and recall capabilities. The combination of drawing activities, visual recognition tasks, and auditory reinforcement creates a rich learning environment that addresses the diverse developmental needs of young learners.

The interactive feedback mechanism provides immediate responses to children's drawing attempts, maintaining engagement and motivation throughout the learning process. This real-time feedback system helps children understand the connection between their drawings and vocabulary recognition, reinforcing learning through positive reinforcement and encouraging continued participation in the educational activities.

The age-appropriate user interface design successfully accommodates the cognitive and motor skill limitations of young children. The system features intuitive navigation, large interactive elements, and visually appealing graphics that capture and maintain children's attention during learning sessions. The interface design considerations ensure accessibility for children across the target age range of 3 to 6 years old.

The system's ability to engage fine motor skill development while simultaneously reinforcing vocabulary learning provides additional educational value beyond traditional vocabulary instruction methods. The drawing component encourages the development of hand-eye coordination and artistic expression while serving the primary educational objective of vocabulary acquisition.

The web-based implementation ensures broad accessibility and ease of deployment in educational settings, requiring minimal technical infrastructure while providing consistent performance across different devices and platforms. This accessibility factor enhances the system's potential for widespread adoption in pre-school and early childhood education environments.

6.3 Limitations and Potential Issues

Despite the positive outcomes achieved, the doodle recognition system exhibits several limitations and potential issues that may impact its broader applicability and effectiveness in diverse educational contexts.

The age-related performance variations revealed through user testing indicate that the system may not be equally effective across all developmental stages within the target age range. The observed decrease in performance among 3-year-old participants suggests that the system's cognitive demands may exceed the developmental capabilities of the youngest users, potentially limiting its applicability for very young children. Conversely, the ceiling effects observed in 6-year-old participants indicate that the current vocabulary selection may be too elementary for older children within the target demographic.

The doodle recognition accuracy represents a significant technical limitation that may impact user experience and learning effectiveness. Machine learning algorithms for recognizing children's drawings face inherent challenges due to the variability and artistic interpretation differences in young children's drawing abilities. Misrecognition of drawings may lead to frustration and disengagement, potentially undermining the educational benefits of the system.

The requirement for adult supervision and guidance throughout the learning process presents practical implementation challenges in educational settings with limited teacher-to-student ratios. The observed necessity for continuous adult support, particularly for younger children, may limit the system's scalability and practical deployment in resource-constrained educational environments.

The limited vocabulary scope of the current system restricts its long-term educational utility and may not provide sufficient content diversity to maintain sustained engagement over extended periods. The current implementation focuses on a specific set of vocabulary

items, which may become repetitive and less engaging for children who quickly master the available content.

Technical infrastructure requirements, including reliable internet connectivity and compatible devices, may present barriers to implementation in some educational settings, particularly in resource-limited environments or regions with inadequate technological infrastructure.

The system's dependency on children's drawing abilities may inadvertently disadvantage students with fine motor skill challenges or developmental delays, potentially creating equity issues in educational outcomes. Children who struggle with drawing activities may experience reduced learning benefits compared to their peers with more developed artistic abilities.

6.4 Future Improvements

Several strategic improvements could enhance the doodle recognition system's effectiveness, accessibility, and educational impact for young children's vocabulary learning.

Adaptive Learning Algorithms: Implementation of adaptive learning technologies could personalize the vocabulary difficulty and content selection based on individual children's performance patterns and developmental stages. An intelligent system could automatically adjust vocabulary complexity, provide additional support for struggling learners, and offer advanced challenges for high-performing students, ensuring appropriate educational experiences across diverse ability levels.

Enhanced Doodle Recognition Accuracy: Advancing the machine learning algorithms through expanded training datasets specifically focused on children's drawings could significantly improve recognition accuracy. Incorporating age-specific drawing pattern recognition and allowing for greater artistic interpretation flexibility would reduce misrecognition incidents and improve overall user experience.

Expanded Vocabulary Database: Developing a comprehensive vocabulary database with age-appropriate content across multiple difficulty levels would extend the system's educational utility and maintain long-term engagement. The expanded content should

include thematic vocabulary sets, seasonal topics, and culturally relevant items that reflect diverse learning contexts and student backgrounds.

Multi-language Support: Implementing multi-language capabilities would expand the system's accessibility and applicability in diverse educational settings, supporting vocabulary learning in multiple languages and accommodating multilingual learning environments common in early childhood education.

Progress Tracking and Analytics: Developing comprehensive progress tracking and analytics capabilities would enable educators and parents to monitor individual children's learning progress, identify areas requiring additional support, and make data-driven instructional decisions. Detailed performance analytics could also inform curriculum planning and instructional strategies.

Offline Functionality: Implementing offline capabilities would address technical infrastructure limitations and ensure consistent access to the educational content regardless of internet connectivity issues. Offline functionality would particularly benefit educational settings in resource-limited environments.

Accessibility Features: Incorporating accessibility features such as alternative input methods, visual and auditory accommodations, and support for children with diverse learning needs would ensure equitable access to the educational benefits of the system.

6.5 Reflection

The development and evaluation of this doodle recognition system has provided valuable insights into educational technology for young children, demonstrating both significant potential and inherent challenges in this domain.

This project highlighted the complexity of designing technology for diverse developmental stages within the 3-6 year age range. The varying learning outcomes across age groups reinforced that young children are not a homogeneous population and require carefully tailored educational interventions that account for rapid developmental changes during early childhood.

The successful multi-modal learning approach validated the importance of engaging multiple learning modalities in early childhood education. The integration of kinaesthetic,

visual, and auditory elements demonstrated technology's potential to enhance rather than replace traditional educational methods. However, implementation challenges, particularly the need for continuous adult supervision and varying age-group effectiveness, emphasized that successful educational technology must address practical constraints alongside learning effectiveness.

The user testing experience revealed the methodological complexities of conducting research with young children, including maintaining engagement, ensuring valid data collection, and accommodating developmental variations. These insights inform best practices for future research in this demographic.

The project illuminated both opportunities and limitations of integrating AI technologies into early childhood education. While doodle recognition capabilities offer innovative learning experiences, accuracy limitations and supervision requirements highlight current boundaries of AI applications in educational contexts.

This research contributes empirical evidence of learning effectiveness while identifying critical improvement areas, providing valuable guidance for future educational technology development. The experience reinforces that successful educational innovation requires not only technical advancement but also deep understanding of child development, educational pedagogy, and practical implementation considerations in real-world educational settings.

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APPENDIX A: Gantt Chart

Table 18: Gantt Chart

#	TASK TITLE	START DATE	DUE DATE	DURATION (DAY)	START ON (DAY)
1	FYP 1				
1.1	Submission of Approved Brief Proposal	14/10/2024	20/10/2024	6	0
1.1.1	Supervisors and Examiners Reviews	21/10/2024	28/10/2024	7	6
1.2	Submission of Approved Full Proposal	29/10/2024	14/11/2024	15	13
1.3	Submission of Chapter 1	15/11/2024	21/11/2024	6	28
1.4	Submission of Chapter 2	22/11/2024	13/12/2024	21	34
1.5	Submission of Chapter 3	14/12/2024	05/01/2025	21	55
1.6	Submission of FYP 1 Final Report & Paper	06/01/2025	16/01/2025	10	76
1.7	Submission of FYP 1 Final Report after Amendment	25/01/2025	21/02/2025	26	86
2	FYP 2				
2.1	Revised Report Structure Submission	27/03/2025	01/04/2025	4	112
2.2	Submission of Chapter 4	01/04/2025	15/05/2025	44	116
2.3	Submission of Chapter 5 & 6	16/05/2025	31/05/2025	15	160
2.4	Submission of FYP 2 Final Report & others	31/05/2025	10/06/2025	10	175
2.5	FYP Symposium	10/06/2025	23/06/2025	13	185
2.6	Submission of FYP 2 Final Report after Amendment	01/07/2025	02/07/2025	1	198
3	Implementation and Testing				
3.1	Requirements & Planning				
3.1.1	Define scope & Key features	10/03/2025	14/03/2025	4	199
3.1.2	Research DoodleNet & tech stack	15/03/2025	21/03/2025	6	203
3.2	Prototype 1 - UI/UX & Core Features				
3.2.1	Rapid UI wireframe & Prototyping	22/03/2025	28/03/2025	6	209
3.2.2	Develop basic canvas for doodling	29/03/2025	04/04/2025	5	215
3.2.3	User testing on UI (Prototype 1)	05/04/2025	07/04/2025	2	220
3.3	Prototype 2 - Doodle Recognition				
3.3.1	Integrating DoodleNet for recognition	08/04/2025	14/04/2025	6	222
3.3.2	Test recognition accuracy & optimize	15/04/2025	21/04/2025	6	228
3.3.3	User testing (Prototype 2)	22/04/2025	24/04/2025	2	234
3.4	Prototype 3 - Assessment & Tracking				
3.4.1	Implement pre-test & post-test	25/04/2025	01/05/2025	6	236
3.4.2	Develop progress tracking & reports	02/05/2025	08/05/2025	6	242
3.4.3	User testing (Prototype 3)	09/05/2025	11/05/2025	2	248
3.5	Refinement & Optimization				
3.5.1	Fix bugs & Improve UI	12/05/2025	18/05/2025	6	250
3.5.2	Performance testing & optimization	19/05/2025	25/05/2025	6	256
3.5.3	Final usability testing	27/05/2025	30/05/2025	3	262
3.6	Documentation & Presentation				
3.6.1	Write final report	30/05/2025	05/06/2025	5	265
3.6.2	Prepare slides & demo	06/06/2025	12/06/2025	6	270
3.6.3	Final submission & presentation	23/05/2025	23/06/2025	30	276

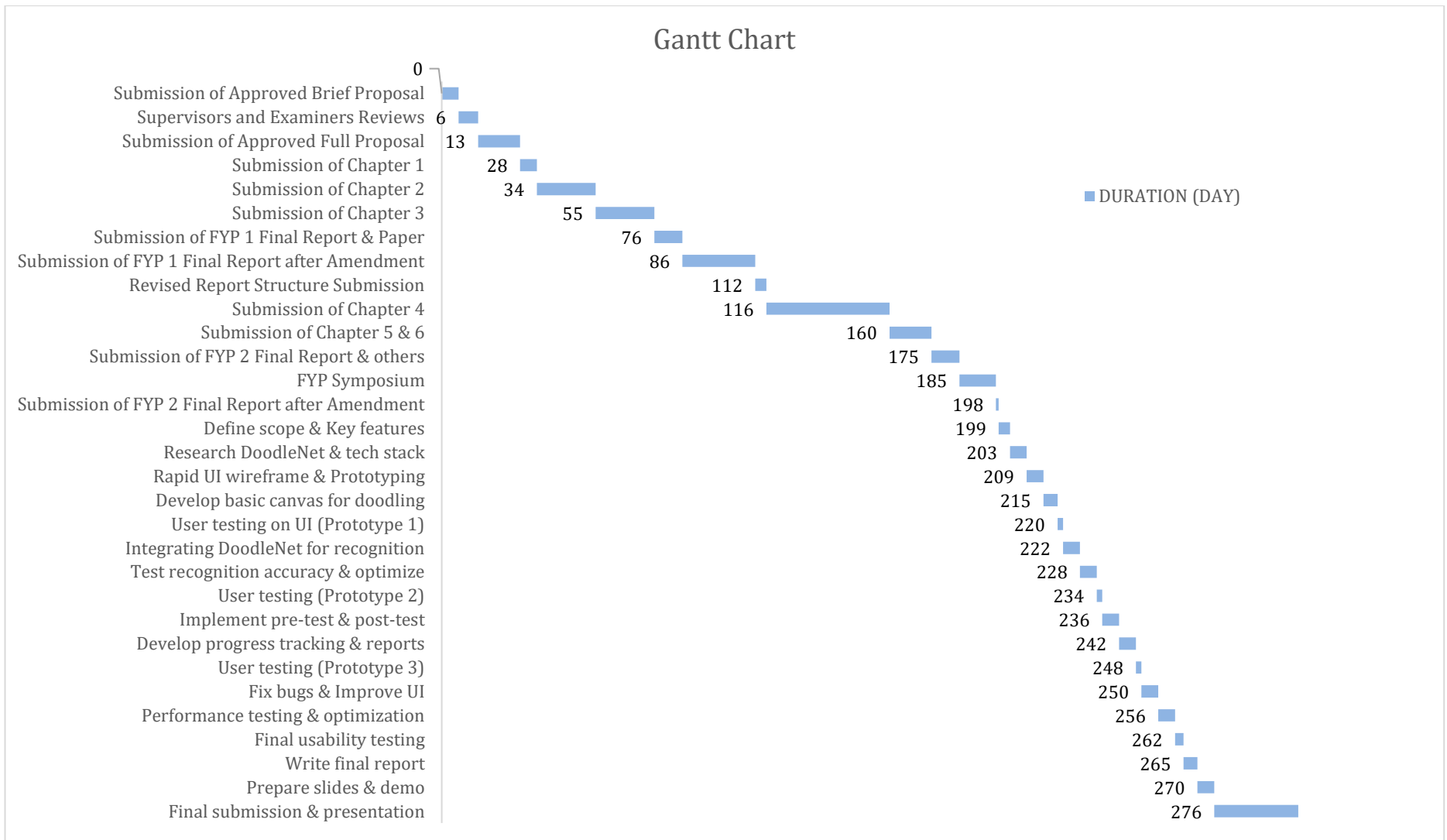


Figure 42: Gantt Chart

APPENDIX B: Interview Questions for Requirement Gathering

Interview Questions:

1. What challenges do you face in helping young children learn and retain English vocabulary?
2. What are some most effective techniques you have found for teaching English vocabulary to young children?
3. How do you think incorporating drawing and doodling could help children learn and remember new English words?
4. How comfortable and engaged are young children in your experience with using electronic devices for learning activities? What strategies do you use to keep them interested and motivated?
5. When assessing vocabulary learning, do you find that children perform better on multiple-choice or open-ended when answering questions? Example, when asked to name the image or doing matching with choices.
6. What are your thoughts on using technology as a learning approach for young children? How could technology be used to track individual progress and provide tailored support?