MANDARIN LEARNING APP FOR ENGLISH-SPEAKING CHILDREN

BY

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ABSTRACT

Mandarin has become one of the most important languages in the world due to China's significant influence on economics, politics, and culture. Although its economic and political rise has increased its importance, learning Mandarin as a second or foreign language remains a considerable challenge, particularly for native English-speaking children due to tonal variations, complex grammar, and limited access to engaging and age-appropriate resources. However, most existing learning applications, such as Duolingo, HelloChinese, Studycat, and ChineseSkill, provide learning materials that teach Mandarin via English but lack essential features, including real-time translation, text or image summarization, and personalized learning paths. These applications often prioritize vocabulary over critical language skills, such as pronunciation and grammar, while adopting a one-size-fits-all approach that does not adapt to individual proficiency levels. This project aims to deliver a user-friendly mobile application that helps English-speaking children aged 10 to 12 effectively learn Mandarin through English as an assisting language, addressing limitations in existing applications. The proposed application provides interactive lessons and exercises that cover Pinyin, Chinese characters, grammar, and speaking skills. Advanced features such as real-time translation and a summarization tool are integrated into the proposed application for self-directed learning. It also includes interactive elements, such as real-time feedback and a reward system, to motivate the children throughout the learning process. To ensure personalization, the system includes an entry-level test and leverages a Support Vector Machine model to predict learner performance. This model achieved 97% accuracy and 95.65% F1-score, allowing the application to recommend target review sessions for learners predicted to perform poorly. The proposed application is developed using agile methodology and technologies such as Android Studio, Amazon Web Services, Firebase, Jupiter Notebook, the Gemini API, FastAPI and Google Translation packages.

Area of Study (Maximum 2): Mobile Application Development

Keywords (Maximum 5): Mandarin Learning, Children Education, Personalized Learning, Mobile Application, Machine Learning

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LIST OF ABBREVIATIONS

HSK	Hanyu Shuiping Kaoshi
CSL	Chinese as Second Language
IDE	Integrated Development Environment
NoSQL	Not only Structured Query Language
OCR	Optical Character Recognition
API	Application Programming Interface
SDK	Software Development Kit

CHAPTER 1

Introduction

1.1 Problem Statement and Motivation

Mandarin has gained significant prominence as a second or foreign language inside and outside China [1]. The main reasons are that China is the largest country with a population and the second biggest economy globally, causing the increased interest in learning Mandarin as a pathway to economic opportunities and international trade. By 2100, 55.3% of countries worldwide will be widely using Mandarin [2]. Early Mandarin learning can lead to near-native pronunciation and better cognitive development, are proved in the study [3,4]. This can provide more opportunities in future academic and professional pursuits compared to their monolingual peers. However, learning Mandarin poses challenges for native English-speaking children. Pronunciation, tonal variations, and complex grammar make it difficult for them [5]. Traditional language classes are expensive and may not provide personalized attention. The studies in [6, 7] emphasized the promise of mobile applications as the future of education by showing them to be efficient tools for personalized and flexible learning.

Many existing Mandarin learning applications that leverage English as an assisting language, such as Duolingo [8], ChineseSkill [9], Studycat [10], and HelloChinese [11] often fall short of the different needs that different learners may have, which lack features such as real-time translation and text and image summarization, which are the most essential features allowing users to engage in immersive and self-directed learning.

Furthermore, some applications neglect critical language skills, such as speaking and grammar practices. For example, Duolingo [8] emphasizes vocabulary but provides insufficient speaking practice, and both Duolingo [8] and HelloChinese [9] provide inadequate grammar practices. Grammar is essential in language learning because it is the basis of effective communication and writing.

Moreover, the existing applications such as HelloChinese [9], StudyCat [10], and ChineseSkill [11] follow a one-size-fits-all approach, disregarding the individual differences in proficiency levels. This causes some children to be overwhelmed with advanced material or not receive enough challenges.

The motivation of this proposed application is to provide an accessible and interactive mobile application for English-speaking children who are non-native Mandarin learners, whereby children can easily learn Mandarin through English and promote bilingual education. This is because the importance of Mandarin and the value of bilingualism are increasingly growing. There are many applications for learning Mandarin from English available in the market, but most of the applications lack comprehensive and personalized learning preferences. This proposed application benefits users by offering a personalized and engaging Mandarin learning experience for English-speaking children. It facilitates vocabulary acquisition, promotes self-exploration, and guarantees that users receive appropriate challenges and assistance to progress effectively by integrating real-time translation, text and image summarization, interactive exercises, and personalized learning paths through machine learning. In short, the motivation of this project is to offer an effective Mandarin learning mobile application that assists English-speaking children in enhancing their Mandarin skills.

1.2 Objectives

This project aims to deliver an effective and comprehensive Mandarin learning application specifically designed for English-speaking children to improve their Mandarin language skills. The following are the project's objectives:

- To integrate advanced language learning features that promote self-directed learning, enabling enhancements of personalized learning preferences.
    - ➢ Develop a real-time translation function that supports both text and voice inputs to facilitate the process of learning new vocabulary and help the children gain a wide range of new vocabulary.
    - ➢ Implement text and image summarization features that allow the children to explore and summarize the learning material beyond the syllabus and tend to encourage them to explore topics of interest.

- To provide personalized learning paths that are suitable for children's pace and enhance their learning outcomes.
    - ➢ Implement an effective machine learning model that will predict future performance, making adjustments to the learning path and ensuring that children are appropriately challenged and supported.
    - ➢ Provides an entry-level test to ensure the content of the lessons and exercises aligns with the learning pace and ability of the children.

- To provide interactive and comprehensive lessons and exercises that hold the attention of children and enhance their language skills.
    - ➢ Provides thematic lessons and exercises that cover important areas such as Pinyin, Chinese Characters, grammar, and speaking to help children develop their Mandarin skills in all aspects.
    - ➢ Integrate a reward system that motivates children by awarding badges for achievements, encouraging consistent progress.

Implement a real-time feedback system to help the children to track their progress, understand what mistakes they committed, and strengthen their knowledge.

1.3 Project Scope and Direction

The project scope is as follows:

- **Target User:** Native English-speaking Children between the ages of ten and twelve. This age group was selected because cognitive and linguistic research highlights that children in middle to late childhood have strong abilities to acquire a second language while also being able to engage in structured and interactive digital learning.
- **Main Language:** Mandarin (primary focus for learning)
- **Assistant Language:** English (Support for explanations and translation)
- The **dataset** used to train the performance prediction model is obtained from Kaggle and titled **Student Exam Performance Prediction** [22]. This dataset is suitable because it contains two key input variables, which are study hours and previous exam score, to train a binary classification model to predict whether a user will pass or fail the current level assessment.
- This project will deliver a mobile application using **Flutter**.
- The **study and assessment resources** are derived from the Confucius Institute at the University of Manchester [23] and the official Hanyu Shuiping Kaoshi (HSK) textbooks [24, 25, 26]. This ensures that lessons and exercises are aligned with internationally recognized standards for Mandarin learning.
- The **image resource** for the lesson and exercise is retrieved from Freepik [27].

1.4 Contributions

The primary contribution of this project is to deliver an effective mobile learning application especially designed for English-speaking children to facilitate Mandarin language learning via English. Implementing the essential features that are lacking in the existing learning application, such as real-time translation and text and image summarization, will ease the learning process and promote a self-directed learning process. These features enable children to seamlessly translate and summarize Mandarin content, making it easier to explore and understand new vocabulary and other educational materials beyond the application. Furthermore, the proposed application of this project provides comprehensive exercises to help children enhance Mandarin skills in all aspects. By offering an interactive and personalized learning experience, the proposed application ensures the exercises provided align with their current proficiency levels and learning pace with game-based learning elements such as instant feedback. In order to make sure the children are capable of moving on to the next level, the proposed application applies a machine learning model to predict their performance before they proceed. As the demand for Mandarin learning continues to grow globally, particularly among English-speaking communities, an effective Mandarin learning application via English is important to enhance Mandarin language skills effectively and prepare them for the future.

1.5 Report Organization

The following chapters provide a detailed breakdown of this project. Chapter 2 reviews several existing Mandarin learning applications on the market, specifically designed for English-speaking children, as well as reviews of machine learning models. It includes a critical analysis of their features and limitations, followed by a proposed solution that solves the identified limitation. Chapter 3 outlines the system methodology, system requirements, and a timeline of milestones of this project. Chapter 4 presents detailed system design, including system architecture, use case diagram, and activity diagram. Chapter 5 covers the implementation of the application and highlights the implementation challenges. Chapter 6 discusses performance between the models and evaluates the system. Chapter 7 wraps up the report by summarizing the outcomes and recommendations.

CHAPTER 2

Literature Reviews

2.1 Introduction

This chapter focuses on reviewing the current similar learning application specifically developed for English-speaking children by analyzing its advantages and disadvantages and suggesting a solution that is more effective and addresses the current limitation that exists in the reviewed application. This chapter aims to find the gaps and propose solutions to address the limitations in the existing applications.

2.2 Evaluation of Existing Similar System

2.2.1 Duolingo

Duolingo [8] is a famous language learning app that includes courses in many languages, including Mandarin. This application intends to provide language learning that is cost-free, enjoyable, and available to all people. The application offers a personalized learning path for all users, allowing them to learn language at their own pace. The main features of Duolingo in Mandarin learning are that it provides gamified learning experiences for users, personalized learning paths, and interactive lessons. The study in [12] proved that Duolingo would be a useful application for beginners to learn Mandarin as a second language. Most of the participants had remarkable improvements in their scores, including those who had never studied Mandarin before.

One of the primary features of Duolingo is it offers a personalized learning path according to the level of the user. Upon registration, users can choose their starting level depending on their ability. For instance, if a user selects "I'm new to Mandarin," they will begin with their lesson as a beginner. If a user selects that they already know some basic Chinese, they will be given a test to assess their current level. According to the results, the application will suggest the users either start with more accessible lessons if they fail the test or continue with the current level, ensuring that users begin at the most suitable level for their skills.

Figure 2.1 shows that Duolingo provides a set of interactive lessons and practices for the user to practice their reading, writing, and listening skills. It requires the user to reattempt the wrong questions until the user passes the exercise to ensure that the user has the ability to move to the next level. Users enhance their range of vocabulary, sentence construction, and the reading of the words via interactive listening practice and writing prompts. This application is most accessible for English speakers, as lessons are conducted in English, which is widely spoken globally. However, one limitation of Duolingo is that free users can only have a certain number of "hearts". Each mistake consumes one heart, and the user needs to wait four hours to get it back. Users must pay in order to get unlimited hearts.

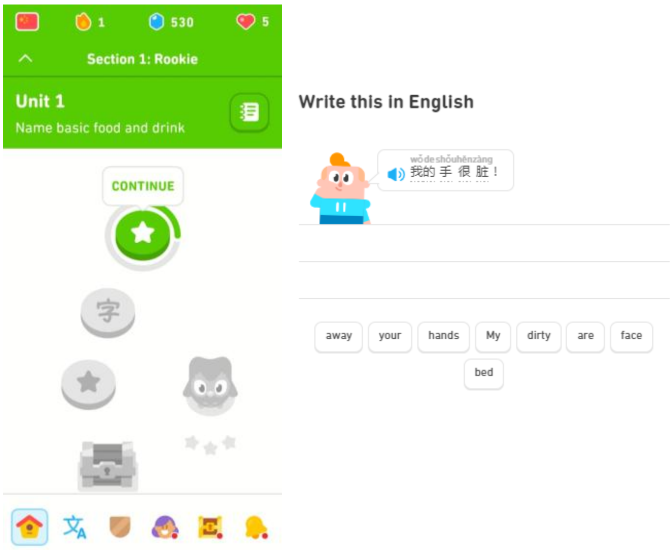
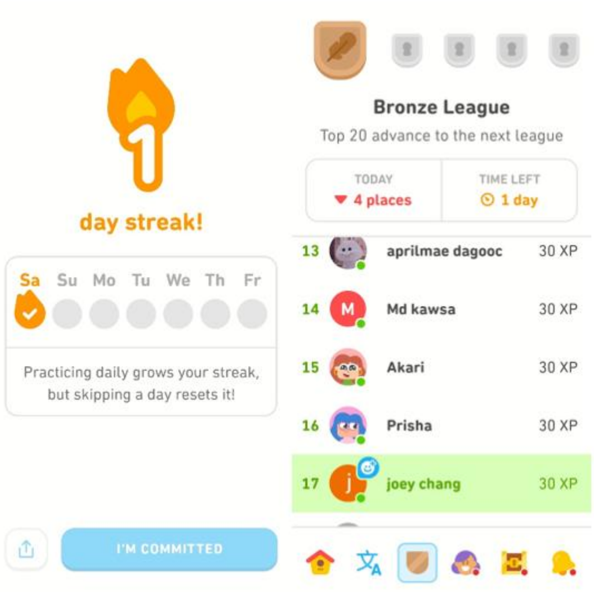


Figure 2.1 Homepage of Duolingo (Left) and Question of Exercise (Right)

Duolingo provides immediate feedback for each question and exercise, which reinforces learning. The application also contains a reward system that recognizes the progress of the user with performance metrics, streaks, and achievements. As shown in Figure 2.2, Duolingo contains gamified elements such as streaks, daily goals, and leaderboards, encouraging users to continue with the learning process. Users will get the streaks for daily learning, and the application sends reminders to encourage practice. If the users hit the mark of a targeted streak or achievement, the application will grant more incentives to them, and leaderboards are provided to enable users to track their progress against others.



Practicing daily grows your streak, but skipping a day resets it!

Top 20 advance to the next league

13	aprilmae dagooc	30 XP
14	Md kawsa	30 XP
15	Akari	30 XP
16	Prisha	30 XP
17	joey chang	30 XP

Figure 2.2 Streaks (Left) and Leaderboard (Right) in Duolingo

Meanwhile, Duolingo offers Pinyin and Hanzi lessons, which are essential components of learning Mandarin. Pinyin is a Latin alphabet-based transliteration of the Chinese phonetic system which helps users pronounce Chinese characters accurately [13]. Hanzi lessons help users recognize and understand Chinese characters, enabling them to improve their reading and writing skills [14]. By learning Pinyin, users can easily read and pronounce new words before mastering Hanzi.

To sum up, Duolingo is a helpful language learning tool because it adapts to learners through gamification and personalization. It allows the users to learn at their own pace by giving them opportunities to choose levels that match their proficiency level. Provides engaging lessons, rewards, and game-like features to keep users engaged and motivated. However, Duolingo has its drawbacks. For instance, the application mainly focuses on vocabulary with insufficient speaking practice in order for the users to master the pronunciation and lack of grammar explanations.

2.2.2 HelloChinese

HelloChinese [9] is a popular and comprehensive Mandarin language learning application, similar to ChineseSkill [11], oriented for the target group of English-speaking beginners of Mandarin, including children. This application is designed to help beginners and children in learning Mandarin from basic to conversational proficiency through effective and engaging guidance. The application consists of 46 units covering different language aspects such as pronunciation, vocabulary, grammar, and others [15]. It offers game-based learning, a speech recognition system to improve pronunciation and a spaced repetition system to help the user memorize the vocabulary [9].

HelloChinese offers users a game-based learning experience that keeps them motivated and engaged. Before starting the learning journey in HelloChinese, users must choose their level, either as a beginner or as basic in Mandarin. According to Figure 2.3, HelloChinese is designed for theme-based lessons. Each theme contains interactive lessons and exercises, which are designed like a game. For example, users can choose their answers and receive instant feedback. If the answer is correct, positive reinforcement is provided, such as receiving rewards for successful actions in an exercise.

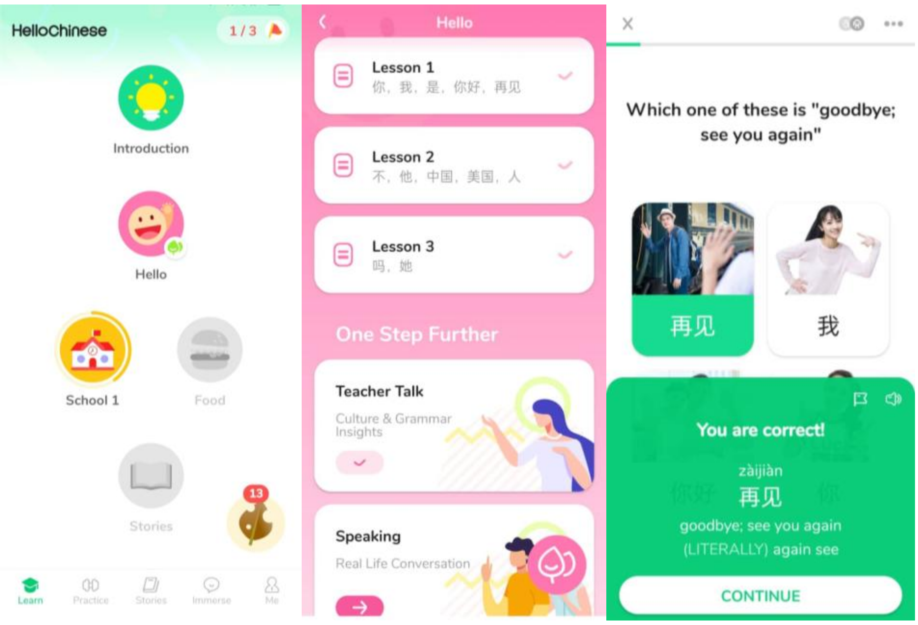
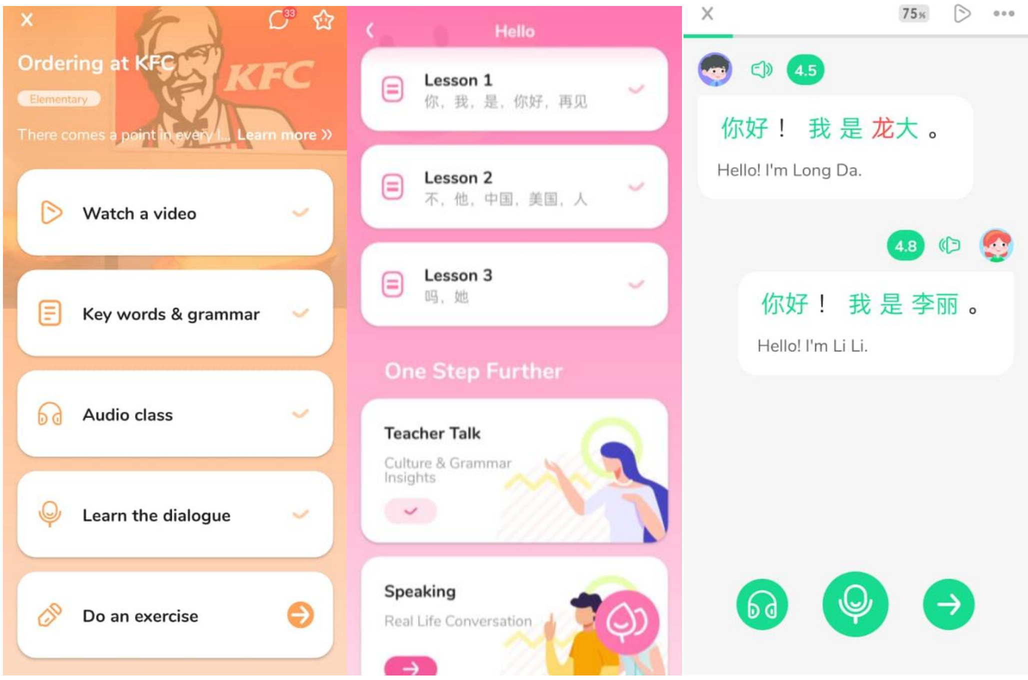


Figure 2.3 Interface of Learning Features in HelloChinese

Based on Figure 2.4, HelloChinese provides speaking exercises in daily life conversation practices and every theme-based lesson for the user to practice their pronunciation. Users listen to the provided audio and then repeat the sentences. The application will evaluate their pronunciation using the speech recognition system and give a rated score according to pronunciation accuracy. However, full access to all lessons and practices requires a Premium subscription.

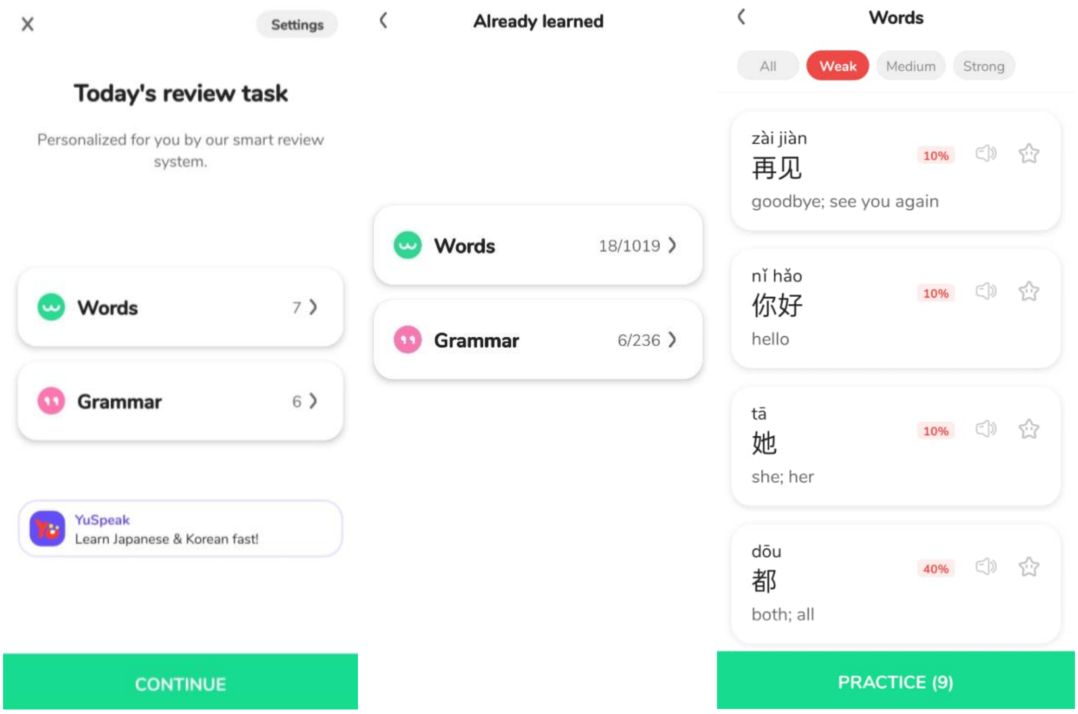


你好！ 我 是 龙大 。
Hello! I'm Long Da.

你好！ 我 是 李丽 。
Hello! I'm Li Li.

Figure 2.4 Speech Recognition Feature of HelloChinese

Furthermore, HelloChinese included a spaced repetition system for the purpose of vocabulary memorization [9]. According to [16], spaced repetition is an approach for going over the content at regular intervals, assisting in long-term memory retention. As shown in Figure 2.5, HelloChinese provides a spaced repetition where the users can revisit the vocabulary and grammar they have learned previously in the "Today's review task" or "already learned" feature. The spaced repetition review allows users to revisit any vocabulary and grammar they have studied. The application categorizes areas, based on the user's performance, as weak, medium, and strong and provides targeted review exercises to focus on areas needing improvement.



Today's review task

Personalized for you by our smart review system.

Words 7

Grammar 6

YuSpeak
Learn Japanese & Korean fast!

Words 18/1019

Grammar 6/236

zài jiàn
再见
10%
goodbye; see you again

nǐ hǎo
你好
10%
hello

tā
她
10%
she; her

dōu
都
40%
both; all

Figure 2.5 Spaced Repetition Feature in HelloChinese

Despite its strengths, the review in [15] highlighted that the primary weakness of this application is its improper handling of Chinese ontology, particularly for the repetition of monosyllabic verbs where the tone of the second vowel, which ought to take up a light sound, does not change. For example, in lesson two on Hobbies, the phrase "tīng tīng yīn yuè" means listening to music, showing the second repeated syllable in its original tone instead of the light tone.

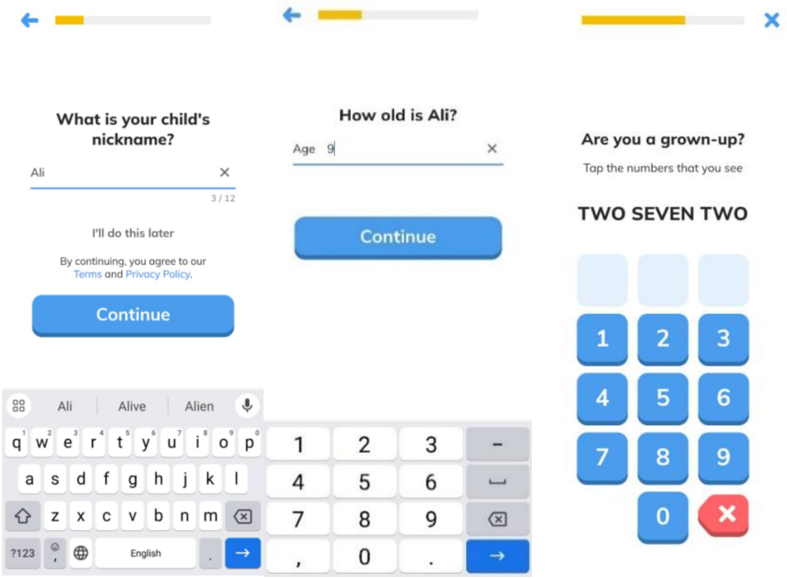
In addition, the study in [15] found that grammar teaching is poorly organized and over-simplified because new grammar rules would come now and then within a lesson without further explanation about the grammar rules.

In short, HelloChinese is an interactive Mandarin language application suitable for beginners and children who want to build a foundation in Mandarin. It contains many useful features such as game-based learning, spaced repetition review and speech recognition that help the users develop Mandarin skills in all aspects. However, the application has some shortcomings, such as Chinese ontology problems, insufficient explanation and organization of grammar, and requires a subscription fee to unlock all the lessons and practices.

2.2.3 Learn Chinese-Studycat

Learn Chinese-Studycat [10] is a very well-renowned Mandarin learning application for children. It won numerous awards, such as the National Parenting Award in 2018 and the 2022 ASU+GSV Summit Award [10]. It uses a game-based approach to make learning Mandarin fun and engaging, effectively attracting the attention of young learners, and thus, their interest in the learning process is maintained accordingly.

The biggest concerns of parents when choosing educational applications for their children are internet safety and the appropriateness of content. Studycat addresses these concerns by providing a secure learning environment that is free from advertisements when the user is using the application and ensuring all the contents are age-appropriate for children. This commitment to safety and quality has made it reliable for parents. Figure 2.6 shows that parents are required to enter the nickname and age of their child, and it has a simple verification test to verify whether the registrant is grown-up or not.



What is your child's nickname?

Ali

3 / 12

I'll do this later

By continuing, you agree to our Terms and Privacy Policy.

How old is Ali?

Age 9

Are you a grown-up?

Tap the numbers that you see

TWO SEVEN TWO

Figure 2.6 Registration Process of Studycat

After signing up, users are directed to a user-friendly homepage designed specifically for children. According to Figure 2.7 below, the homepage included various themed lessons and games covering topics such as animals, colors and foods. The intuitive interface and clear layout ensure easy navigation and are attractive to children. Although part of its lessons and exercises is free to use, full access requires a subscription.

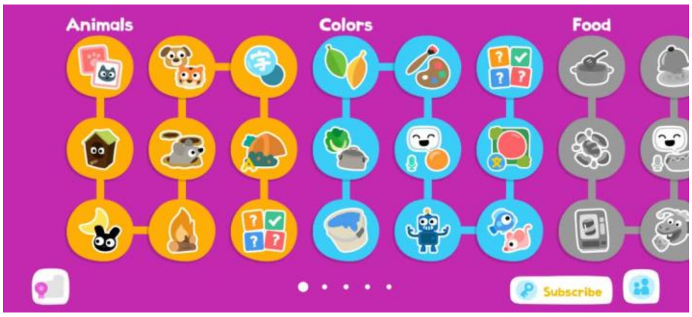


Figure 2.7 Homepage of Studycat

Based on Figure 2.8 below, Studycat offers customized learning because the user can set their difficulty level, which starts from easy, medium or hard. However, it is important to make sure the chosen difficulty level is in accordance with the user's skill. Each difficulty level includes the same themed lessons and interactive game-based exercises but will introduce vocabulary appropriate to the level. For example, Figure 2.9 depicts a matching game where the user must select matching animal pictures, and immediate feedback is provided based on the selection of the user. When the user clicks on each picture, an animal's name is spoken by a native Mandarin speaker to help children learn proper pronunciation. These interactive games-based exercises not only aid in language acquisition but also foster problem-solving and critical-thinking skills.

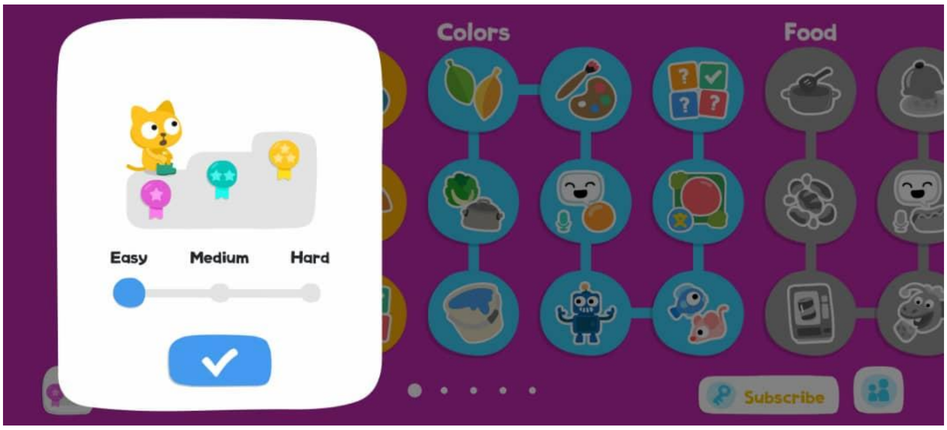


Figure 2.8 Difficulty Level Selection Feature

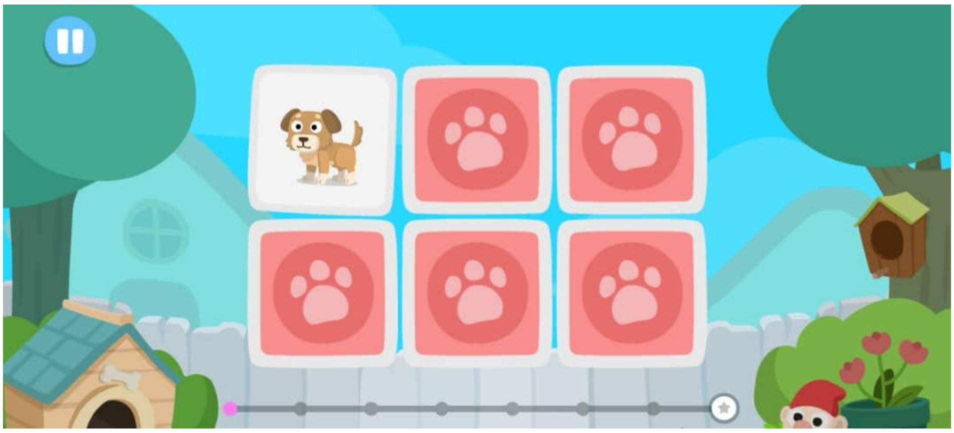


Figure 2.9 Matching Game in Animal Lesson

In conclusion, Studycat has successfully combined game features and language learning into a safe and interactive application. The application offers an interactive and positive environment in which to learn Mandarin through the different theme-based interactive lessons and games to build up his or her language skills. Moreover, it provides a distraction-free environment learning environment for the user to be free from any advertisements and interruptions and with ensured internet safety. However, the limitation of Studycat is that it does not provide basic users with personalized free practice and accessibility to all the lessons [10,17].

2.2.4 ChineseSkill

ChineseSkill [11] is a well-known application for beginners in learning Mandarin. It included more than five hundred entertaining and educational mini lessons that help users develop speaking, listening, reading, and writing skills. This application is designed by qualified Chinese as Second Language (CSL) educators and includes the vocabulary and grammar needed for passing Hanyu Shuiping Kaoshi (HSK) 3-4. The study in [18] found that ChineseSkill has been proved by earlier studies to be an effective game-based learning tool for enhancing CSL learning.

Based on Figure 2.10, ChineseSkill is divided into four main sections known as "learn", "review", "discover" and "me". The "learn" section provides the users with exploring the comprehensive lesson and practices given. The "learn" section offers several themes for learning, such as "Hello," "My Family," and "Food," guiding users to specific lessons related to each theme. The Lesson section has a feature called "Test Out" that allows users to skip the lessons after they pass the proficiency test, ensuring the users can progress according to their existing knowledge. The "Review" section gives flashcards and key points so the user can review it and lets users review and reinforce what they have learnt. The "Me" section displays the user profile and the overview of the XP score that the user gained through lessons and activities.

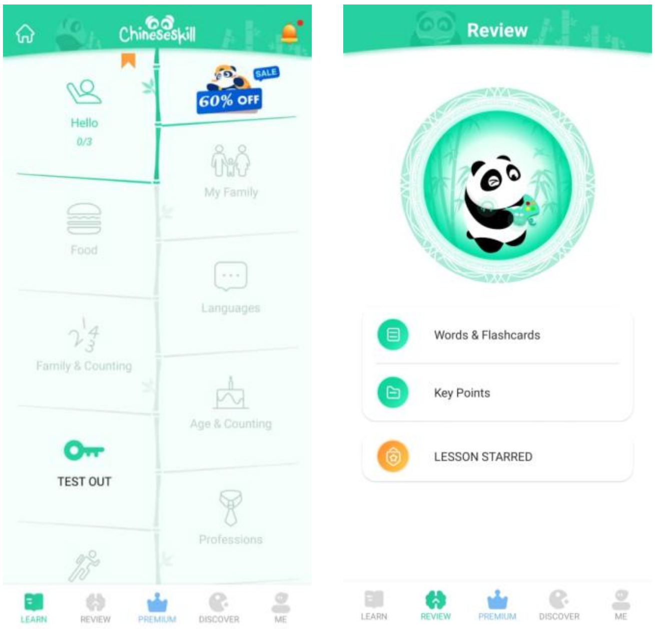
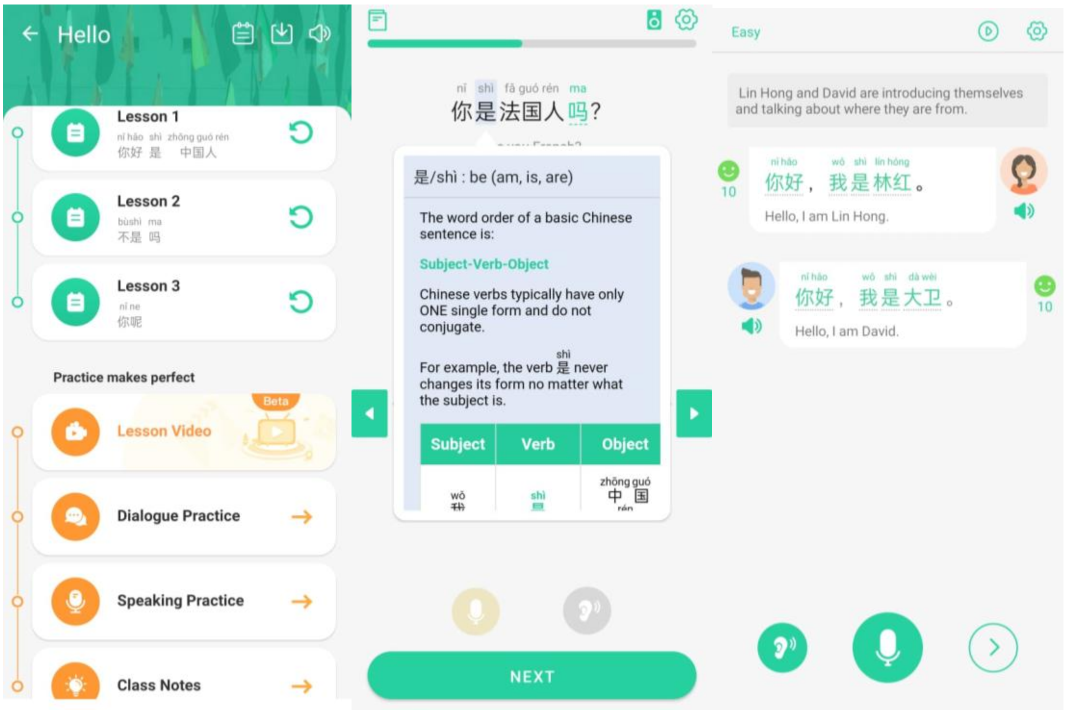


Figure 2.10 Homepage of Lesson (Left) and Review (Right)

Figure 2.11 shows that after the users select a theme, they can take the lessons and practices, including lesson video, dialogue practice, speaking practice and class notes. These hands-on activities enhance the critical thinking skill and language skills of the user. This application also provides detailed grammatical tips and explanations both during the lesson and in the class notes, making the review of key concepts of grammar from the lesson more accessible for the user. When one lesson is finished, users get XP points and detailed feedback showing them the mistakes they have made and the areas for improvement. ChineseSkill also makes use of speech recognition in speaking practice that analyzes the pronunciation of users against native dialogue and provides accuracy-based scores.



The word order of a basic Chinese sentence is:

Subject-Verb-Object

Chinese verbs typically have only ONE single form and do not conjugate.

For example, the verb 是 never changes its form no matter what the subject is.

Lin Hong and David are introducing themselves and talking about where they are from.

Hello, I am Lin Hong.

Hello, I am David.

Figure 2.11 Lessons and Exercises in ChinsesSkill

Based on Figure 2.12 below, there are additional resources in ChineseSkill under "Discover," which has three subcategories. First is "Arcade", where there are game activities that sharpen language skills. The second is "Speak Up", which provides situational dialogues relevant to daily life in China. Third is "Pronunciation", which teaches users Pinyin and pronunciation rules. The downside of this application was its requirement for users to subscribe to its premium version for access to lessons and full practice in both "Arcade" and Speak Up.

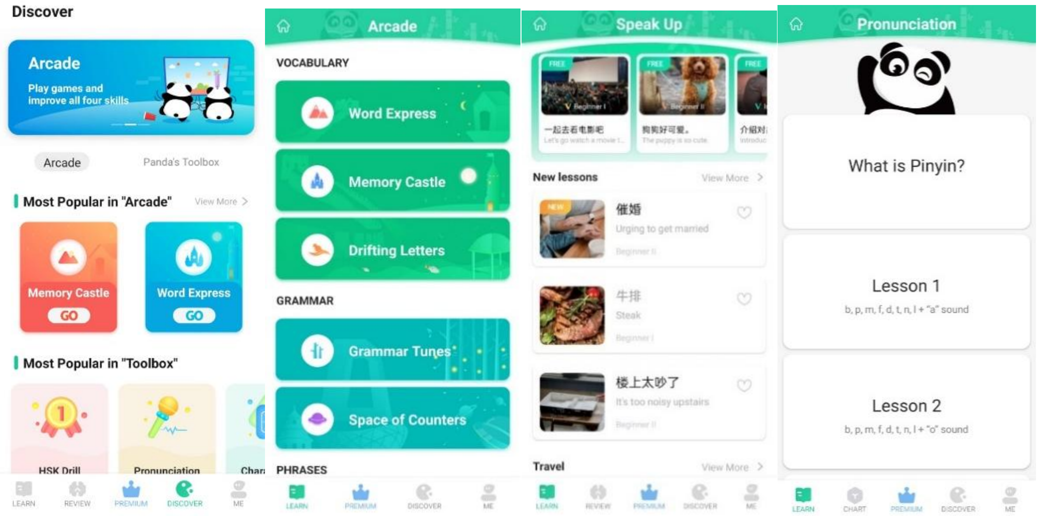
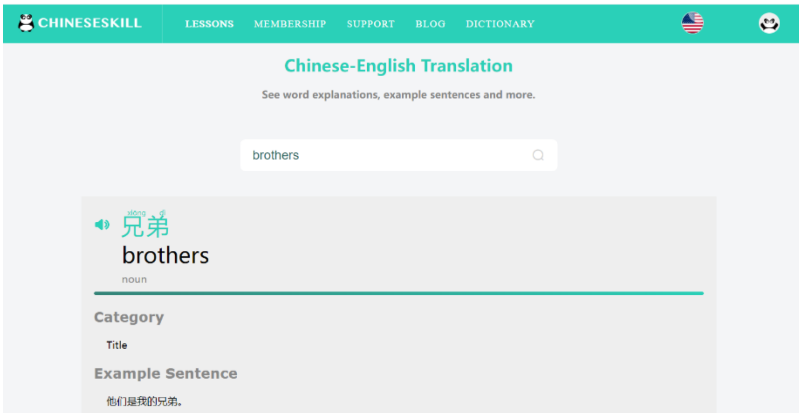


Figure 2.12 Discover Section of ChineseSkill

According to Figure 2.13, ChineseSkill includes a Chinese-to-English translation feature for translating single words from Mandarin to English or vice versa within the context of the lessons. However, this feature is restricted to text-based translations within the syllabus of the lesson in the application and is only available in the web version. This limits the situation in which the user can be exposed to vocabulary outside of the syllabus and reduces the self-learning opportunities for the users.



Chinese-English Translation

See word explanations, example sentences and more.

brothers

xiōng dì
兄弟
brothers
noun

Category
Title

Example Sentence
他们是我的兄弟。

Figure 2.13 Translation Feature in ChineseSkill

In short, ChineseSkill is a user-friendly Mandarin learning application designed for English-speaking beginners and children, offering a wide range of lessons to enhance the language skill and align with Hanyu Shuiping Kaoshi (HSK) 3-4 exam preparation. The game-based approach, comprehensive curriculum and practices, detailed grammar explanation, and speech recognition system provide an engaging and effective learning environment. However, some of its drawbacks are restricted access to premium content and the lack of real-time voice recognition translation, which may hold users back from an overall experience. Even so, ChineseSkill is still a useful tool for building a solid foundation in Mandarin.

2.3 Critical Analysis

This section critically analyses the learning applications reviewed in Section 2.2, including Duolingo [8], HelloChinese [9], Studycat [10], and ChineseSkill [11] as summarized in Table 2.3.1.

2.3.1 Duolingo

The advantage of this application is that it provides a gamified learning experience for users that enhances user engagement and motivation for continuous learning. It also provides free interactive lessons and exercises but requires users who do not pay a subscription fee to view some advertisements to explore all lessons. In addition, provides personalized learning path for every user to assists them in learning at their own pace and boosts their commitment to learning. However, there are some drawbacks of this application. This application offers inadequate speaking practices, and the basic user is limited by the "heart" system, which restricts learning if mistakes are made. Furthermore, this application lacks detailed grammar explanations that might make it difficult for the users to understand the construction of the sentences. It also lacks real-time voice recognition translation and text or image summarization features, making it less suitable for children who want to acquire the language in-depth.

2.3.2 HelloChinese

This application benefits users by integrating speech recognition technology to improve their pronunciation and speaking skills. The spaced repetition system in the application helps the user gradually reinforce the vocabulary over time while offering a game-based learning experience via interactive lessons and exercises with instant feedback. However, the limitations of this application include the restricted number of free lessons and practices for basic users, some occasional errors in Chinese ontology and insufficient grammar explanations. In addition, this application also lacks advanced features such as real-time voice recognition translation and text or image summarization, which hinder the opportunity for users to explore more new learning materials and immersive learning environments.

2.3.3 Studycat

Studycat provides its users with a disturbance-free and ad-free interactive learning environment, thus providing a safe and focused environment for the students. However, this application lacks the features of real-time voice recognition translation and text or image summarization, which makes it less efficient for users to practice communication skills in real situations and unable to explore and study the topics they are interested in. It also the user to pay a subscription fee in order for them to access all its lessons, including personalized practices, which could be a barrier to those who cannot afford the subscription fee.

2.3.4 ChineseSkill

ChineseSkill is a comprehensive English-to-Mandarin learning application with comprehensive grammar tips and explanations and a structured curriculum that benefits learners at different levels. The speech recognition technology applied to HelloChinese also extends to this application to improve the pronunciation of user. However, it limits free lessons and practices for users. Furthermore, this application does not support real-time voice recognition translation. It only provides a text-based translation that enables the user to translate the words in the syllabus and may limit its utility for immersive learning. Hence, it restricts the variety of vocabulary the user can acquire. The application also lacks text or image summarization features, which enhances the learning and writing skills of the users by enabling users to extract and summarize the text from the images or documents for further study.

2.3.5 Summary of Critical Analysis

Table 2.3.1 Summary of Critical Analysis

Applications	Advantages	Disadvantages
Learn Mandarin - Duolingo	1. Provide gamified learning experiences for users 2. Provide free interactive lessons and exercises 3. Provide a personalized learning path	Limited speaking practices Lack of grammar rules explanation Lack of real-time voice recognition translation Lack of text or image summarization
HelloChinese	1. Provides a spaced repetition system 2. Provide speech recognition for users to nail their pronunciation 3. Provide game-based learning	1. Limited free lessons and practices 2. Errors in Chinese Ontology Knowledge 3. Insufficient explanation of grammar 4. Lack of real-time voice recognition translation 5. Lack of text or image summarization
Learn Chinese - Studycat	1. Provide interactive lessons and exercises 2. No advertisement	1. Lack of real-time voice recognition translation 2. Lack of text or image summarization 3. Limited free lessons and practices 4. Required subscription fee for personalized practice

ChineseSkill	1. Provide a comprehensive curriculum and practices 2. Provide detailed grammar tips and explanations 3. Use speech recognition technology for the user to practice their pronunciation	1. Requires a subscription fee to access all lessons and practices 2. Only allows translation for a single word 3. Only available in text-based translation 4. Lack of real-time voice recognition translation 5. Lack of text or image summarization

2.4 Review of Machine Learning Models

Machine learning models are widely used in educational technology to predict student performance, recommend learning content, and adapt instructional pathways. For instance, prior research [28] used the historical student log data to train models that predict future performance in online teaching systems, thereby enabling adaptive learning paths. Similarly, the study in [29] also emphasized the role of a machine learning model in assisting educators to identify at-risk students early and improve academic outcomes.

In the context of Mandarin learning applications, the integration of machine learning offers the potential to deliver adaptive content that aligns with a child's current proficiency, guaranteeing that learning stays efficient and personalized. Among the numerous models available for classification tasks, Logistic Regression [39], Support Vector Machine [40], and Neural Networks [41] have been widely used in student performance prediction tasks because of their proven effectiveness on a variety of datasets. This section reviews these models, discusses their strengths and limitations, and relates their relevance to this project.

2.4.1 Logistic Regression

A supervised machine learning model that employed a set of independent variables to forecast the categorical dependent variable, known as Logistic Regression. Logistic regression converts the continuous value output of a linear regression model into a categorical outcome by applying the sigmoid function, which maps each actual input from the independent variables to a range between 0 and 1 [30].

Several studies highlight the effectiveness of Logistic Regression in educational prediction. For example, the study [31] demonstrated the effectiveness of the Logistic Regression model, using student demographic, activity, and achievement data, which achieved 91% accuracy, with 98% precision and recall, making Logistic Regression a reliable early-warning system. The simplicity of Logistic Regression also enables educators to interpret which features most strongly influence academic outcomes.

However, the comparative study [32] indicates that Logistic Regression showed moderate performance in predicting final exam outcomes compared to Neural Network and Support Vector Machine, which can capture non-linear relationships more effectively. This is because logistic regression has intrinsic limitations in capturing complicated, non-linear correlations within the data. Despite these limitations, Logistic Regression remains a valuable baseline model due to its ease of implementation, high interpretability, low computing cost, and accessibility of use [33].

2.4.2 Support Vector Machine

One of the common supervised machine learning model is the Support Vector Machine, which can be used for both classification and regression tasks. It finds the optimal hyperplane with the maximum margin, uses support vectors to define it, and applies the kernel trick for non-linear data [34].

Support Vector Machine has performed well on datasets used in education. A comparative study [35] reported that the Support Vector Machine outperformed Decision Trees (93%) and K-Nearest Neighbors (94.5%) with 95% accuracy in predicting student performance. The research in [36] found that the Support Vector Machine performed better than other prediction models, such as the Decision Tree and the K-Nearest Neighbor Algorithm, achieving the highest accuracy of 96%. These outcomes can be attributed to the Support Vector Machine's ability to manage nonlinear separability, resilience to overfitting, margin maximization, effectiveness in high-dimensional spaces, and the use of powerful kernel functions. However, there are some limitations in Support Vector Machine (SVM), which make it harder to interpret compared to logistic regression, and it may suffer from slow training when dealing with huge datasets [34].

2.4.3 Neural Network

Neural networks are deep learning and machine learning models that obtain inspiration from the human brain. It is constructed from interconnected neurons that process data, recognize patterns, and generate predictions [37].

Neural Networks have been widely used in educational prediction tasks. The study [32] stated that the performance of neural networks has been generally high compared to the K-Nearest Neighbor model when forecasting student achievement using midterm scores and student-related features. Another research [38] trained an Artificial Neural Network on non-personal student data and achieved 93.81% accuracy in predicting academic performance, allowing proactive interventions to reduce failure and withdrawal rates.

However, Neural Networks require large datasets to generalize effectively and are prone to overfitting on small datasets. In addition, they require more processing power than Support Vector Machine and Logistic Regression. Even if it is powerful, its black-box nature makes it less interpretable for educators seeking to understand the underlying factors that influence performance [37].

2.4.4 Summary of Machine Learning Models Review

Table 2.4.1 Summary of Machine Learning Models Review

Model	Advantages	Disadvantages
Logistic Regression	• Easy to implement and interpret. • Low computational cost. • Effective for early detection of struggling learners.	• Limited in capturing non-linear and complex relationships. • Lower accuracy compared to advanced models like Support Vector Machine and Neural Networks [32]. • Performance decreases with high-dimensional datasets.
Support Vector Machine	• High prediction accuracy (up to 96%) [35, 36]. • Handles non-linear data well using kernel trick. • Robust against overfitting and effective in high-dimensional spaces.	• Less interpretable than Logistic Regression. • Training can be slow on very large datasets. • Model selection (kernel choice, hyperparameters) can be complex.
Neural Networks	• Capable of capturing complex non-linear patterns. • Achieve high accuracy in prediction tasks generally [32, 38]. • Flexible architecture adaptable to many tasks.	• Require large datasets to perform well. • Risk of overfitting on small datasets. • Computationally intensive (requires more resources). • Less interpretable (“black-box” nature).

In conclusion, previous research supports the application of these models as viable options for predicting learner performance, and each offers distinct strengths and limitations for predicting learner performance in a Mandarin learning application. Following this practice, this project uses these three models for experimentation, compares their performance on relevant student datasets, and chooses the best model to integrate into the proposed application.

2.5 Proposed Solution

The proposed application aims to offer a practical and user-friendly learning application for children that focuses on learning Mandarin via English and overcoming the weaknesses found in similar existing applications. The proposed application focuses on key areas, including providing comprehensive exercises, personalized learning paths, real-time translation, and text and image summarization to help user enhance their Mandarin proficiency in all aspects.

First of all, the major limitations of all the reviewed existing applications are the lack of real-time translation and text or image summarization features. This limited the capability of the user to explore new vocabulary and study materials outside the syllabus of the application. In this regard, the proposed application will include real-time translation that would work for both voice and text content. The users can translate Mandarin to English and vice versa, making immersive learning more accessible and allowing the user to acquire more new vocabulary beyond what is covered in the application syllabus.

Additionally, the proposed text and image summarization feature will enable users to scan the Mandarin text from the images and summarize the content. This feature gives users an opportunity to access more study materials outside the application, improving their reading and writing skills and helping them gain a broader vocabulary.

One drawback of certain existing applications is their failure to offer personalized learning experiences that align with the user's proficiency level. The proposed application will start with an entry-level test to evaluate the current level of proficiency of the user. Based on the result, the application will assign the exercises that are appropriate for their level of understanding. This ensures that they are not overwhelmed or under-challenged and allows them to learn at their own comfort level.

The proposed application will include interactive elements, which provide real-time feedback and rewards when users complete exercises. This approach increases user engagement as well as motivation during the learning process. The proposed application also covers detailed grammar practices, which are often missing in the existing application, that specifically teach the essential grammar rules via exercises that help the users to build a solid foundation in Mandarin.

Furthermore, a machine learning model that can predict users' future performance will integrate into the proposed application. This model can predict whether a user has the capability to succeed at a particular level based on their previous assessment score and study hours. If the model predicts the user is not capable to pass the current level assessment, the proposed application will provide focused review sessions on areas where users need to reinforce. For example, if a user repeatedly makes a mistake on a particular grammar concept, then in such cases, the proposed application will provide additional practice so that the user will be equipped with the capability to advance to the next level.

To sum up, this proposed application addresses the limitations of the reviewed application by offering the features of unlimited lessons and exercise access, personalized learning paths, real-time translation, and text and image summarization. These improvements will make learning more accessible and flexible for every user, including children with different levels of language proficiency.

CHAPTER 3

System Methodology/Approach

3.1 Proposed Method/Approach

The development methodology used in this project to develop the proposed application is Agile. This is because Agile methodology is suitable for the small project team and complicated projects due to its adaptability and iterative nature [19]. Unlike traditional methodology such as Waterfall, Agile is more flexible and more adaptive to quickly changing requirements during the development cycle to ensure the final system with excellent quality and fulfils the demand and expectation of the user [19]. This is particularly important for this project as the environment and needs of the children may change further.

The agile method allows the breakdown of the project into smaller and more manageable sections where the features, such as real-time translation and game-based elements, are developed incrementally. Each of these sections is incrementally completed, tested, and integrated into the main system in stages, able to detect and resolve the issue early. Furthermore, Agile emphasizes automated testing to ensure the new features are functioning expectedly before they are integrated into the main system [20].

Figure 3.1 illustrates the six phases involved in the agile development cycle, which is an iterative cycle. The first phase is to identify the key features and user requirements for this learning application, such as real-time translation, text or image summarization and personalized learning path. Also, outline the time and work required to complete this project. The second phase is to find out how the system will function and transform the proposed solution into a structured design, detailing the logical, physical, and architectural aspects of the system. Then, come to the development phase, break down the development process into sprints, and each sprint concentrates on developing one specific feature or module. In the testing phase, integrate the newly developed code into the main project repository after each sprint and perform automated testing to make sure the system operates correctly and that the newly added features function as expected. In the deploy phase, deploy the system to a testing environment or release it to the user once it is finalized. In the review phase, continuously review and update the system based on user feedback. Since Agile is an iterative methodology, it allows ongoing enhancement, whether to improve existing features or address new user requirements.

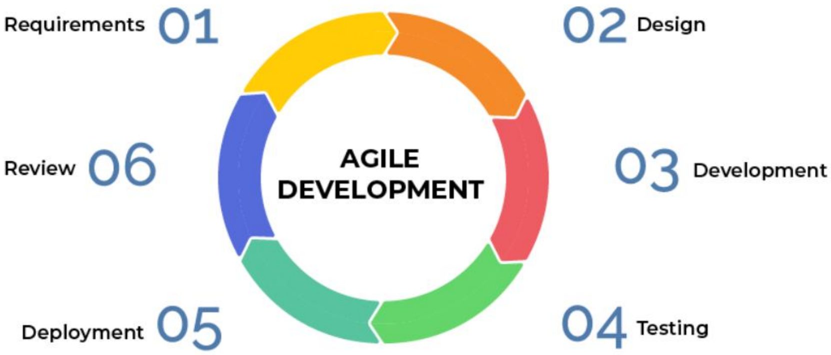


Figure 3.1 Agile Development Cycle [21]

3.2 System Requirement

3.2.1 Hardware

The hardware required in this project is a laptop that used to code the proposed application, and an Android mobile phone used for testing and running the proposed mobile application. Table 3.1 and 3.2 show the specification of Laptop and Android Mobile Phone that used in this project.

Table 3.1 Laptop specification

Description	Specifications
Model	Dell Vostro 3400
Processor	11th Gen Intel(R) Core (TM) i5-1135G7
Memory (RAM)	16GB
Operating System	Window 11 Home 64-bit
Storage	477 GB
Graphic	Intel Iris Xe Graphics
Display	14 inches Screen

Table 3.2 Mobile Phone Specification

Description	Specifications
Model	Honor X9c
Operating System	Magic OS 8 (Android 14)
CPU	Qualcomm Snapdragon 6 Gen 1
GPU	Adreno A710
Display Resolution	1224 x 2700 pixels
RAM	12GB
Storage	512GB

3.2.2 Software

Development Tools

1. Android Studio

   An official Integrated Development Environment (IDE) for creating mobile applications. It provides many tools and libraries that are useful for building and debugging mobile applications, and it supports Java and Kotlin languages.

2. Jupiter Notebook

   An open-source web application that offers more than forty programming languages and is useful for building and testing machine learning models.

3. Flutter

   An open-source framework for building cross-platform applications from a single codebase by using Dart programming languages. It provides many pre-designed widgets that appear native but are customizable.

4. Dart

   A programming language used with the Flutter framework to create mobile

   Applications.

Development Platform

1. Firebase

   A tool that makes it simpler for developers to create, maintain and expand their applications by providing pre-built backend elements. It stores the data in a database that is not only Structured Query Language (NoSQL) based and provides real-time databases and authentication services that improve the efficiency in creating and managing the user verification service.

2. Amazon Web Services (AWS)

   A cloud computing platform that offers on-demand services and infrastructure, such as databases and processing power, which allows developers to build or deploy applications without managing the physical servers.

   Services used:

   - AWS Lambda

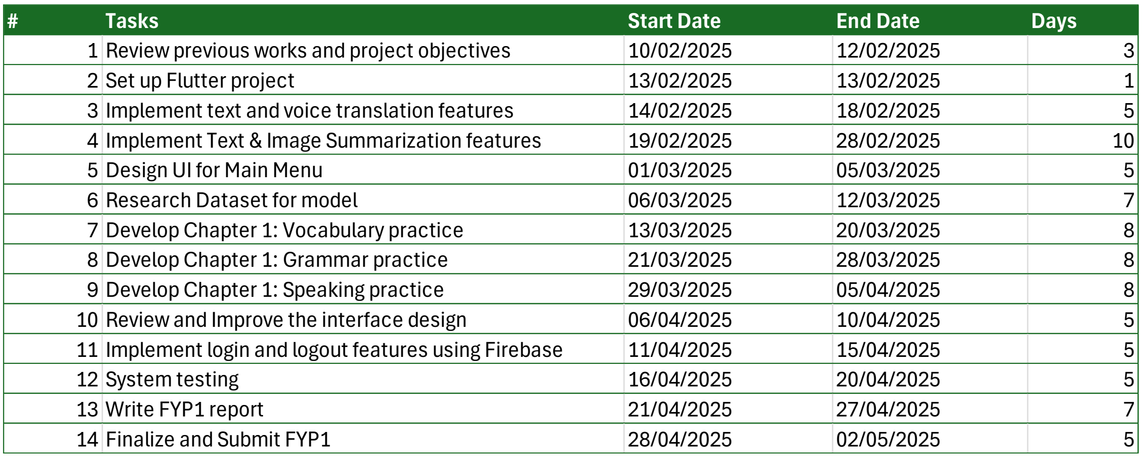
     A serverless computing solution, without having to provision or manage servers. In this project, Lambda is used to host and run the trained machine learning model, processing incoming requests from the application and returning predictions in real-time.

   - Amazon API Gateway

     A comprehensive managed solution for developing, releasing, and safeguarding Application Programming Interface (API) at scale, which serves as a gateway through which the application can connect to the backend services.

3.3 Timeline

3.3.1 Timeline of FYP1



#	Tasks	Start Date	End Date	Days
1	Review previous works and project objectives	10/02/2025	12/02/2025	3
2	Set up Flutter project	13/02/2025	13/02/2025	1
3	Implement text and voice translation features	14/02/2025	18/02/2025	5
4	Implement Text & Image Summarization features	19/02/2025	28/02/2025	10
5	Design UI for Main Menu	01/03/2025	05/03/2025	5
6	Research Dataset for model	06/03/2025	12/03/2025	7
7	Develop Chapter 1: Vocabulary practice	13/03/2025	20/03/2025	8
8	Develop Chapter 1: Grammar practice	21/03/2025	28/03/2025	8
9	Develop Chapter 1: Speaking practice	29/03/2025	05/04/2025	8
10	Review and Improve the interface design	06/04/2025	10/04/2025	5
11	Implement login and logout features using Firebase	11/04/2025	15/04/2025	5
12	System testing	16/04/2025	20/04/2025	5
13	Write FYP1 report	21/04/2025	27/04/2025	7
14	Finalize and Submit FYP1	28/04/2025	02/05/2025	5

Table 3.3 Task Completed in FYP1

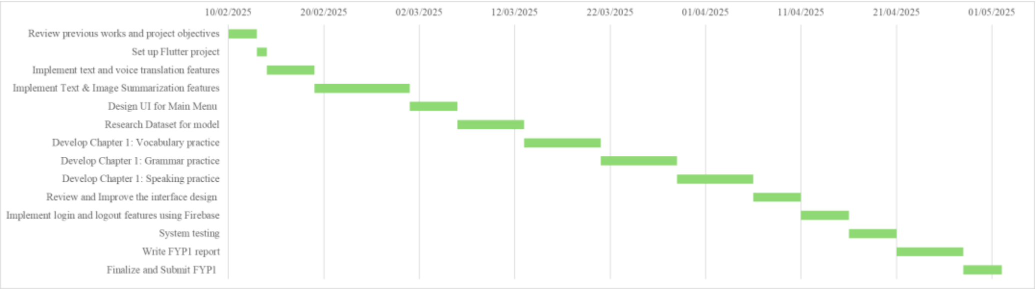
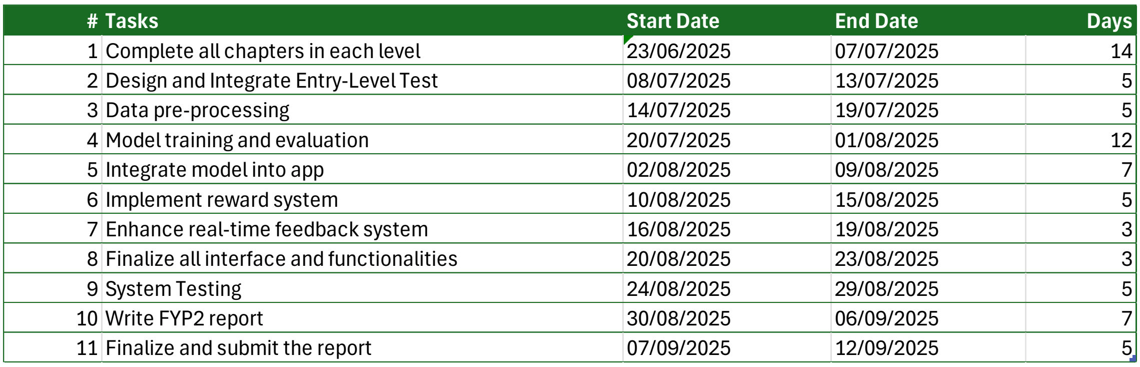


Figure 3.2 Gantt chart of FYP1 Timeline

Figure 3.2 illustrates the 12-week project timeline for FYP1, along with a list of the tasks performed during that time. The project begins with an initial setup and planning phase, which involves reviewing related works and setting up the Flutter development environment. To achieve one of the main objectives, the implementation of text and voice translation functionalities begins as soon as the setup phase is completed. Then, implementation for text and image summarization features takes place after the translation features are finished. For model training and integration to work during FYP2, finding and researching relevant datasets is vital. This step aids in identifying the data required for efficient model operation. The beginner level of Chapter 1 is then created, which is divided into three sections, which are speaking practice, grammar practice, and vocabulary practice. This aligns with the second key objective, which is to offer interactive and captivating activities that improve language acquisition. Next, the user interface of the application is reviewed and refined to ensure it is suitable for children. After that, Firebase is integrated to enable user authentication, improving functionality and security, and the user interface is examined and refined for improved use. After that, system testing is done to confirm the performance and stability of the application. Lastly, at the end of Week 12, the FYP1 report is completed and turned in.

3.3.2 Timeline of FYP2



#	Tasks	Start Date	End Date	Days
1	Complete all chapters in each level	23/06/2025	07/07/2025	14
2	Design and Integrate Entry-Level Test	08/07/2025	13/07/2025	5
3	Data pre-processing	14/07/2025	19/07/2025	5
4	Model training and evaluation	20/07/2025	01/08/2025	12
5	Integrate model into app	02/08/2025	09/08/2025	7
6	Implement reward system	10/08/2025	15/08/2025	5
7	Enhance real-time feedback system	16/08/2025	19/08/2025	3
8	Finalize all interface and functionalities	20/08/2025	23/08/2025	3
9	System Testing	24/08/2025	29/08/2025	5
10	Write FYP2 report	30/08/2025	06/09/2025	7
11	Finalize and submit the report	07/09/2025	12/09/2025	5

Table 3.4 Tasks to be Done in FYP2

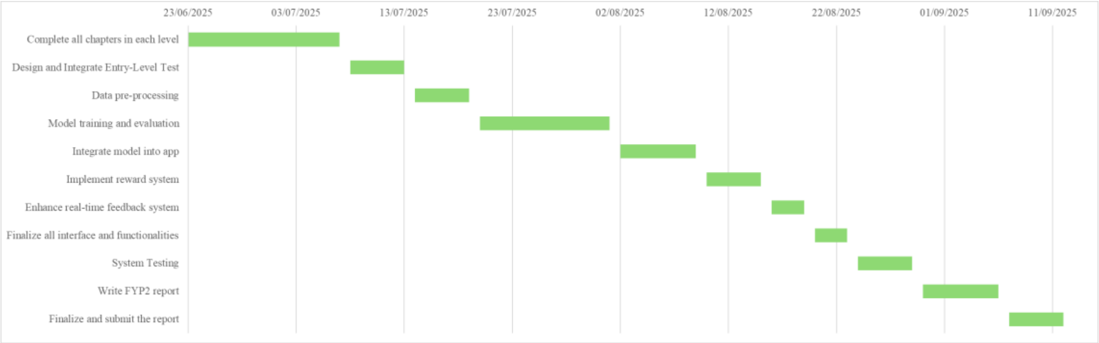


Figure 3.3 Gantt chart of FYP2 Timeline

Figure 3.3 illustrates the 12-week project timeline for FYP2, along with a list of the tasks that need to be done during that time. It starts with finishing every chapter at every level to ensure the content's foundation is solid and satisfies one of the main objectives. An entry-level test is then created and integrated to evaluate user proficiency at the beginning of the application. Data pre-processing is done to prepare the dataset for tasks involving machine learning after integrating the entry-level test into the application. The model is then trained and evaluated to ensure optimal performance. The trained model is incorporated into the application following a successful evaluation. In order to promote user engagement and participation, core feature enhancements are then put into place, such as creating a reward system and upgrading to a real-time feedback system. After feature development, the interface and all functionalities are finalized to guarantee consistency and usability. After that, a system testing phase is conducted to confirm the application's overall quality, stability, and performance. The project comes to an end when the development process is finished, and the final FYP2 report is written and submitted.

CHAPTER 4

System Design

4.1 Overview

This chapter explains the workflow of the proposed application in detail, along with the functions of its individual modules. The system architecture, use case diagram, and activity diagram are used to illustrate the system design and are accompanied by explanations. These diagrams highlight what the system should do from the user's point of view and provide an overview of the system's operations.

4.2 System Architecture Diagram

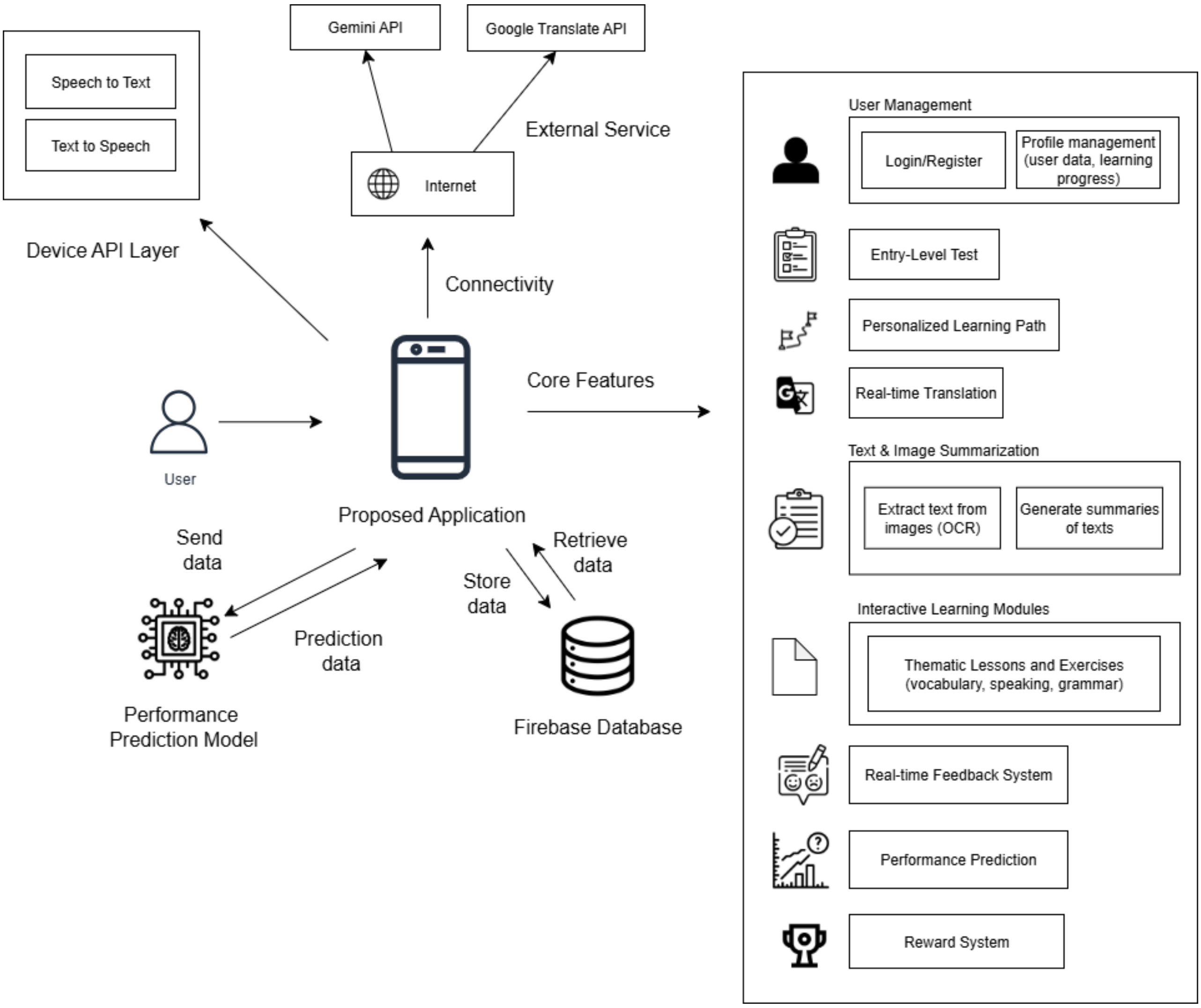


Figure 4.1 System Architecture Diagram

Figure 4.1 illustrates the system architecture diagram of the proposed application. The proposed application incorporates several components to provide a customized and engaging language learning experience. The user management feature is used to handle user accounts, allowing users to register and log in to the application. Additionally, it maintains their profiles, keeping track of their progress during the learning and preserving personal information. The entry-level test feature is provided to assess a new user's initial Mandarin proficiency. Then, the application offers a personalized learning path in which the level of difficulty of the learning material meets the current level of each user based on the result of entry-level test. Furthermore, the application also provides a real-time translation for both text and speech to help the understanding of new words or sentences encountered in real-life situations. This functionality performs Text-to-Speech and Speech-to-Text functions by leveraging the Google Translate Application Programming Interface (API) in combination with the device's Application Programming Interface (API) layer. The features of text or image summarization make it easier for the user to comprehend long text by using the Gemini Application Programming Interface (API). It extracts text from images via Optical Character Recognition (OCR) and then summarises the extracted text. A machine learning model for predicting performance is used to determine whether the user is likely to succeed or fail in the current level assessment. Based on the learner's performance trends, this model assists in determining whether they are prepared to move on to the level assessment or should receive additional support first. The application includes interactive learning modules with thematic lessons and exercises, a real-time feedback system for prompt reaction and correction, and a reward system to encourage ongoing involvement and progress to boost learning engagement. Finally, the Firebase database stores and manages all user data.

4.3 Use Case Diagram

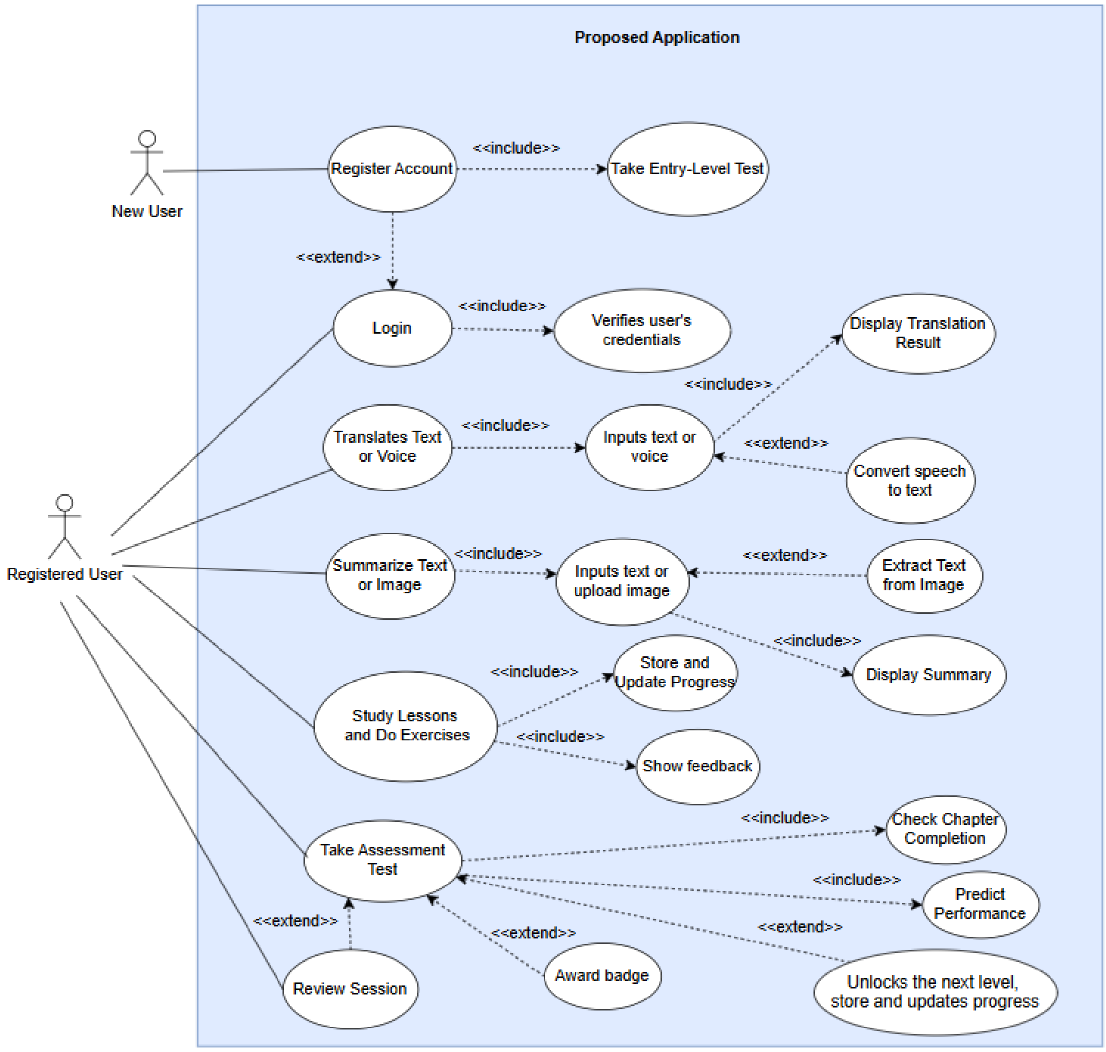


Figure 4.2 Use Case Diagram of Proposed Application

Figure 4.2 illustrates the use case diagram of the proposed application that shows the interactions between the system and its primary actors, namely the new user and the registered user, in completing various tasks within the application. The corresponding comprehensive case descriptions are given in Tables 4.1 through 4.8, as outlined in Section 4.4.

4.4 Use Case Description

Table 4.1 Use Case Description for “Register Account” Use Case

<table>
<tr><td><b>Use Case ID</b></td><td>UC001</td><td><b>Use Case Name</b></td><td>Register Account</td></tr>
<tr><td><b>Primary Actor</b></td><td colspan="3">New User</td></tr>
<tr><td><b>Brief Description</b></td><td colspan="3">Allow a new user to create an account and profile in the application.</td></tr>
<tr><td><b>Trigger</b></td><td colspan="3">User selects "Register" from the app’s login page.</td></tr>
<tr><td><b>Precondition</b></td><td colspan="3">User has not registered before.</td></tr>
<tr><td><b>Scenario Name</b></td><td><b>Step</b></td><td colspan="2"><b>Action</b></td></tr>
<tr><td rowspan="5"><b>Main Flow</b></td><td>1</td><td colspan="2">User opens the app and selects “Register” in login page.</td></tr>
<tr><td>2</td><td colspan="2">System prompts users to enter usernames, email and password.</td></tr>
<tr><td>3</td><td colspan="2">System validates input and creates a new user account.</td></tr>
<tr><td>4</td><td colspan="2">User logs in with the registered account.</td></tr>
<tr><td>5</td><td colspan="2">System prompts them to complete the Entry-Level Test before accessing lessons.</td></tr>
<tr><td rowspan="2"><b>Alternate Flows – Invalid input</b></td><td>3a.</td><td colspan="2">If input is invalid, system displays errors and requests correction.</td></tr>
<tr><td>3b.</td><td colspan="2">If email already exists, system displays "Account already exists" and prompts login.</td></tr>
</table>

Table 4.2 Use Case Description for “Take Entry-Level Test” Use Case

Use Case ID	UC002	**Use Case Name**	Take Entry-Level Test
Primary Actor	New User		
Brief Description	Evaluates the user’s initial Mandarin proficiency.		
Trigger	Successful registration.		
Precondition	User has just registered and logged in.		
Scenario Name	**Step**	**Action**	
Main Flow	1	System prompts the user to begin the Entry-Level Test when they log in for the first time.	
	2	User completes a set of test questions.	
	3	System evaluates the answers.	
	4	System calculates the scores and assigns user’s level based on result. Less than 50 marks is beginner level, 50 to 79 marks are intermediate level, and 80 and above is advanced level.	
	5	System displays the result to the user and stores the result and assigned level in Firebase.	
	6	User selects “Start Learning!”. System directs the user to the main menu, unlocking the assigned level while keeping higher levels locked.	

Table 4.3 Use Case Description for “Login” Use Case

Use Case ID	UC003	**Use Case Name**	Login
Primary Actor	Registered User		
Brief Description	Authenticates a returning user.		
Trigger	User selects Login option from the application’s start page.		
Precondition	User already has a registered account.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User enters email and password.	
	2	System verifies the credentials.	
	3	If valid, user gains access to the main menu.	
Alternative flow – Invalid Credentials	2a.	If the credentials are invalid, system displays error and allows the user to re-enter.	

Table 4.4 Use Case Description for “Translates Text or Voice” Use Case

Use Case ID	UC004	**Use Case Name**	Translates Text or Voice
Primary Actor	Registered User		
Brief Description	Provides translation for text or voice input using Google Translate API.		
Trigger	User selects “Translation” from main menu.		
Precondition	The user is signed in.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User selects “Translation” from main menu.	
	2	User selects the source and target languages.	
	3	User inputs text or voice. If the input is voice, the system performs speech-to-text and auto fill in the input field.	
	4	User selects the “Translate” button.	
	5	System sends requests to Google Translate API.	
	6	System receives the translation and displays it to the user.	
Sub Flow- Read the Translated Word	6a.	User selects the audio button to listen to the translated word or sentence.	
	6b.	System uses text-to-speech to read the translated word or sentence aloud.	
Alternative Flow– API Unavailable	5a.	If Google Translate API is not available, system shows error message.	

Table 4.5 Use Case Description for "Summarize Text or Image" Use Case

<table>
<tr><td><b>Use Case ID</b></td><td>UC005</td><td><b>Use Case Name</b></td><td>Summarize Text or Image</td></tr>
<tr><td><b>Primary Actor</b></td><td colspan="3">Registered User</td></tr>
<tr><td><b>Brief Description</b></td><td colspan="3">Allows the user to input text or upload an image, then generates a summarized version using the Gemini API.</td></tr>
<tr><td><b>Trigger</b></td><td colspan="3">User selects "Summarization" from main menu.</td></tr>
<tr><td><b>Precondition</b></td><td colspan="3">The user is signed in.</td></tr>
<tr><td><b>Scenario Name</b></td><td><b>Step</b></td><td colspan="2"><b>Action</b></td></tr>
<tr><td rowspan="9"><b>Main Flow</b></td><td>1</td><td colspan="2">User selects "Summarization" from the main menu.</td></tr>
<tr><td>2</td><td colspan="2">User selects "Paragraph" or "Bullet Points "as the output format.</td></tr>
<tr><td>3</td><td colspan="2">User inputs text or uploads image.
If an image is uploaded, the system extracts text using OCR and automatically places it in the text field.</td></tr>
<tr><td>4</td><td colspan="2">The system counts the number of words and displays the word count below the input text field.</td></tr>
<tr><td>5</td><td colspan="2">User selects the output language (English, Chinese, or Both) and the desired summary length.</td></tr>
<tr><td>6</td><td colspan="2">User selects "Make it Easier" button.</td></tr>
<tr><td>7</td><td colspan="2">System sends the text to Gemini API.</td></tr>
<tr><td>8</td><td colspan="2">The Gemini API returns the summarized result.</td></tr>
<tr><td>9</td><td colspan="2">System displays summary to the user in the chosen format and language.</td></tr>
<tr><td><b>Alternative Flow – Invalid File Format</b></td><td>3a.</td><td colspan="2">If the uploaded file format is invalid, the system prompts the user to retry.</td></tr>
<tr><td><b>Alternative Flow – API Unavailable</b></td><td>7a.</td><td colspan="2">If Gemini API is not available, system shows error message.</td></tr>
</table>

Table 4.6 Use Case Description for "Study Lessons and Do Exercises" Use Case

Use Case ID	UC006	**Use Case Name**	Study Lessons and Do Exercises
Primary Actor	Registered User		
Brief Description	Provides thematic lessons and exercises for user to complete.		
Trigger	User selects a chapter and activity (vocabulary, grammar, speaking) from selected level.		
Precondition	The user is signed in and has access rights to the selected level.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User selects a level (beginner, intermediate, advanced) from main menu.	
	2	User selects a chapter.	
	3	User selects an activity type (vocabulary, grammar, speaking).	
	4	System presents lesson content based on the selected chapter and activity.	
	5	User completes the lesson.	
	6	User selects "Continue" to attempt the exercise.	
	7	System presents the first question.	
	8	User selects an answer.	
	9	System checks the answer and provides immediate feedback. If answer is correct, display positive feedback to user. If answer is incorrect, display the mistake with detail explanation.	
	10	System checks whether more questions remain.	
	11	If questions remain, system continues presenting the next question (repeat steps 8–9).	
	12	System calculates the score, displays the result to the user, and stores it in Firebase.	
	13	System updates the user's progress.	

Table 4.7 Use Case Description for "Takes Assessment Test" Use Case

Use Case ID	UC007	**Use Case Name**	Takes Assessment Test
Primary Actor	Registered User		
Brief Description	Allow the user to attempt an assessment to move to the next level.		
Trigger	User selects Assessment Test in the selected level page.		
Precondition	The user is signed in and has access rights to the selected level.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User selects Assessment Test.	
	2	System checks whether all chapters at the current level have been completed.	
	3	System retrieves the user's study hours and most recent assessment score.	
	4	System uses the prediction model to estimate the user's performance.	
	5	If prediction indicates likely success, the system directs the user to begin the test.	
	6	User attempts the test.	
	7	If the user passes, the system unlocks the next level, updates progress, awards a badge, and stores the result in Firebase.	
Sub Flow – Performance Prediction: Likely to Fail	5a.	If the system predicts likely failure, it displays a message and offers the user the option to enter a review session before attempting the test.	
Alternate Flow – Incomplete Chapters	2a.	If the chapters are incomplete, the system notifies the user and allows them to either complete the remaining chapters or continue with the test.	
Alternate Flow – Test Failure	7a.	If the user fails, the system displays a failure message and allows the user to retry the assessment later.	

Table 4.8 Use Case Description for “Review Session” Use Case

Use Case ID	UC008	Use Case Name	Review Session
Primary Actor	Registered User		
Brief Description	Provides tailored review activities before assessment.		
Trigger	Triggered when the performance prediction model predicts that the user is likely to fail the assessment.		
Precondition	The user is signed in and has selected the level assessment.		
Scenario Name	**Step**	**Action**	
Main Flow	1	System retrieves user performance data from Firebase and identifies exercises with scores below 50 or not attempted.	
	2	The system generates a set of review questions based on weak areas.	
	3	User answers questions in the review session.	
	4	The system provides feedback for each answer. If correct, the system displays positive feedback messages. If incorrect, the system shows the correct answer with an explanation.	
	5	System checks whether all review questions are completed.	
	6	Once complete, the system calculates and displays the review session results.	
	7	User chooses the next action.	
Sub Flow – Proceed to Assessment	7a.	If the user chooses to proceed, the system directs them to the assessment test.	
Sub Flow – Retry Option	7b.	If the user chooses to retry the review session, steps 1–6 are repeated.	

4.5 Activity Diagram

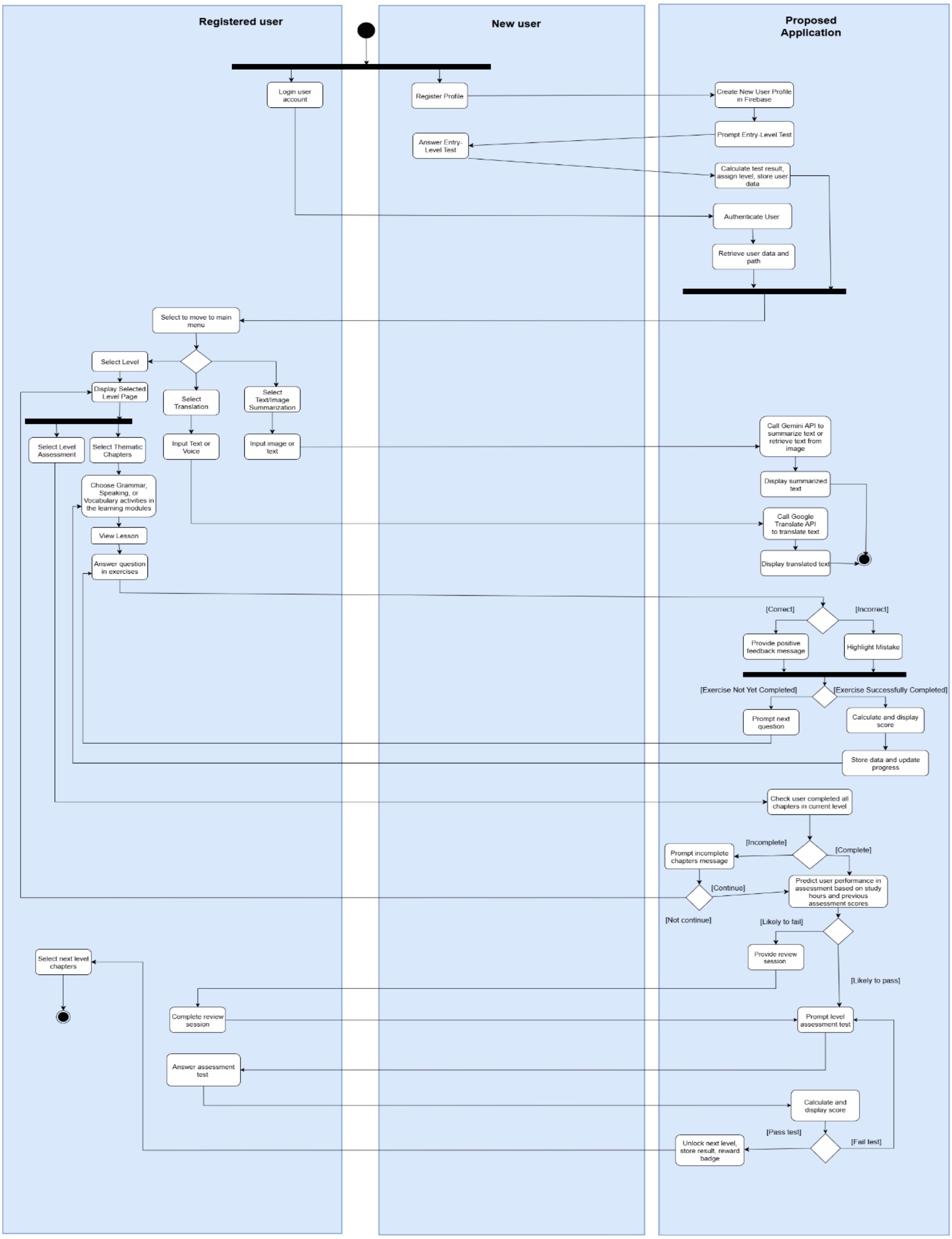

Registered user
New user
Proposed Application
Login user account
Register Profile
Create New User Profile in Firebase
Prompt Entry-Level Test
Answer Entry-Level Test
Calculate test result, assign level, store user data
Authenticate User
Retrieve user data and path
Select to move to main menu
Select Level
Display Selected Level Page
Select Translation
Select Text/Image Summarization
Select Level Assessment
Select Thematic Chapters
Input Text or Voice
Input image or text
Call Gemini API to summarize text or retrieve text from image
Display summarized text
Choose Grammar, Speaking, or Vocabulary activities in the learning modules
View Lesson
Call Google Translate API to translate text
Answer question in exercises
Display translated text
[Correct]
[Incorrect]
Provide positive feedback message
Highlight Mistake
[Exercise Not Yet Completed]
[Exercise Successfully Completed]
Prompt next question
Calculate and display score
Store data and update progress
Check user completed all chapters in current level
[Incomplete]
[Complete]
Prompt incomplete chapters message
[Continue]
Predict user performance in assessment based on study hours and previous assessment scores
[Not continue]
[Likely to fail]
Select next level chapters
Provide review session
[Likely to pass]
Complete review session
Prompt level assessment test
Answer assessment test
Calculate and display score
[Pass test]
[Fail test]
Unlock next level, store result, reward badge

Figure 4.3 Activity Diagram of Proposed Application

Figure 4.3 illustrates the user flow and processes of the proposed mobile application. Three swimlances are used to present the actions of a new user, a registered user, and the proposed application. Establishing a user profile is the first step for a new user. After successfully registering, a new user is prompted with an entry-level test. This entry-level test evaluates the user's current level of Mandarin language proficiency. Based on the test result, the application assigns the user to access exercises suitable for their level.

A registered user can access the main menu after logging in to choose a learning mode, including thematic lessons and exercises, translation, and summarization. In the thematic lessons and exercises mode, the user can choose a chapter and the type of activity they wish to engage in, such as vocabulary, grammar, or speaking. Once the activity is chosen, the user needs to study the lesson content and finish the associated exercises. As the user engages with exercises, the application evaluates their responses. The correct answers are acknowledged with positive feedback, and incorrect answers are highlighted to guide the user. If the exercise is incomplete, the application will prompt users to continue with the next question. Once an exercise is completed, the application calculates the score and updates the user’s progress accordingly.

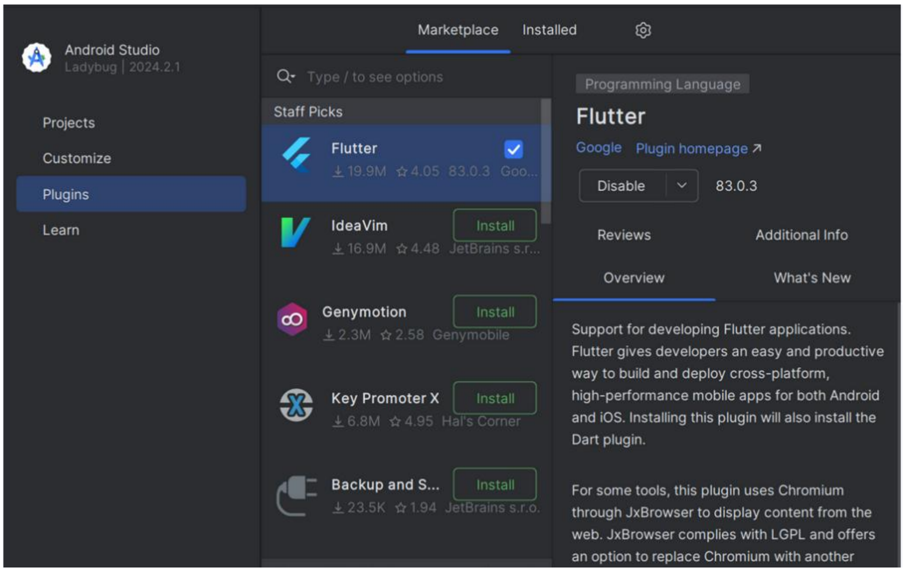
If the user selects the assessment test in the level, the application first checks whether all chapters at the current level have been finished. If not, the system informs the user and allows them to either proceed with the test or return to complete the remaining chapters. The performance prediction model will predict the user’s likelihood of passing based on the study time and the most recent assessment scores results of the user before the test begins. If the user has only taken the entry-level test, that result serves as a baseline. If the model predicts the user is likely to pass, the user can proceed directly to the assessment. Otherwise, the system provides a review session tailored to their previous performance in different activities. The user can move on to the level assessment after completing the review session if the user decides to do so. The user may also proceed straight to the assessment test if they choose not to participate in the review session. The users can move on to the next level and receive a badge only if they pass the level assessment test. Otherwise, the users are urged to retake the level assessment test until they pass it.

The translation feature allows users to input either text or voice. The application processes the input using Google Translate Application Programming Interface (API) to provide precise translations, which are subsequently shown to the user. For summarization features, users can input text or an image. When an image was uploaded, the application used optical character recognition (OCR) to extract text from it. The Gemini Application Programming Interface (API) is then used to summarize the extracted or directly entered text, and the user is shown the summarized content.

CHAPTER 5

System Implementation

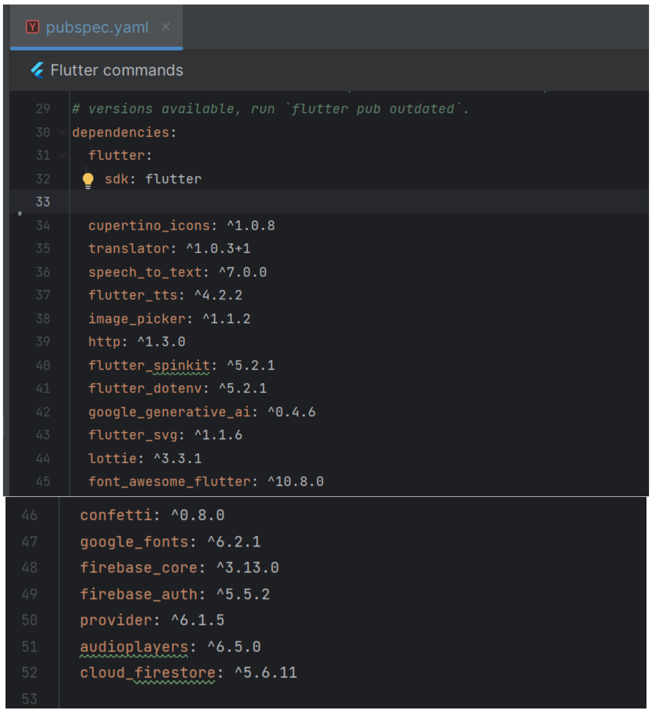
5.1 Setup Flutter Project



Support for developing Flutter applications. Flutter gives developers an easy and productive way to build and deploy cross-platform, high-performance mobile apps for both Android and iOS. Installing this plugin will also install the Dart plugin.

For some tools, this plugin uses Chromium through JxBrowser to display content from the web. JxBrowser complies with LGPL and offers an option to replace Chromium with another

Figure 5.1 Installed Flutter and Android Studio

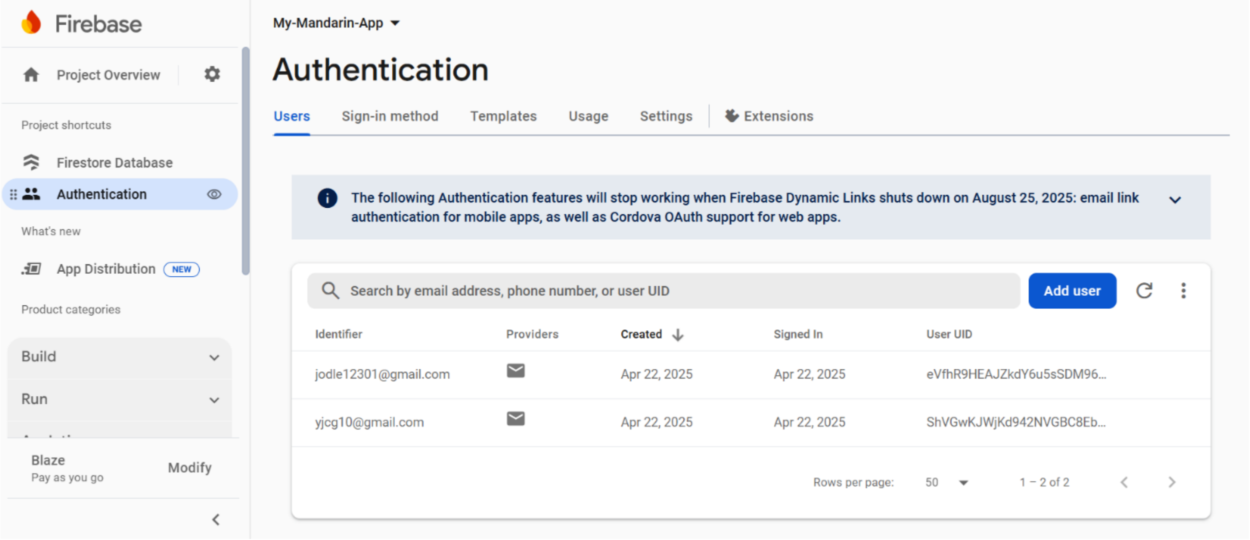


```yaml
# versions available, run `flutter pub outdated`.
dependencies:
  flutter:
    sdk: flutter

  cupertino_icons: ^1.0.8
  translator: ^1.0.3+1
  speech_to_text: ^7.0.0
  flutter_tts: ^4.2.2
  image_picker: ^1.1.2
  http: ^1.3.0
  flutter_spinkit: ^5.2.1
  flutter_dotenv: ^5.2.1
  google_generative_ai: ^0.4.6
  flutter_svg: ^1.1.6
  lottie: ^3.3.1
  font_awesome_flutter: ^10.8.0
  confetti: ^0.8.0
  google_fonts: ^6.2.1
  firebase_core: ^3.13.0
  firebase_auth: ^5.5.2
  provider: ^6.1.5
  audioplayers: ^6.5.0
  cloud_firestore: ^5.6.11
```

Figure 5.2 Flutter Project Dependencies

Figure 5.1 shows that the Flutter Software Development Kit (SDK) and Android Studio were successfully installed before the project development, as these tools are required for building the proposed mobile application. As shown in Figure 5.2, the pubspec.yaml file is included to set up the necessary function for the application. These dependencies include packages that support key application features such as speech recognition, Firebase integration, summarization, and translation.

5.2 Implementation of Login & Logout using Firebase



The following Authentication features will stop working when Firebase Dynamic Links shuts down on August 25, 2025: email link authentication for mobile apps, as well as Cordova OAuth support for web apps.

Identifier	Providers	Created ↓	Signed In	User UID
jodle12301@gmail.com	✉	Apr 22, 2025	Apr 22, 2025	eVfhR9HEAJZkdY6u5sSDM96...
yjcg10@gmail.com	✉	Apr 22, 2025	Apr 22, 2025	ShVGwKJWjKd942NVGBC8Eb...

Rows per page: 50 1 – 2 of 2

Figure 5.3 Firebase Authentication Dashboard

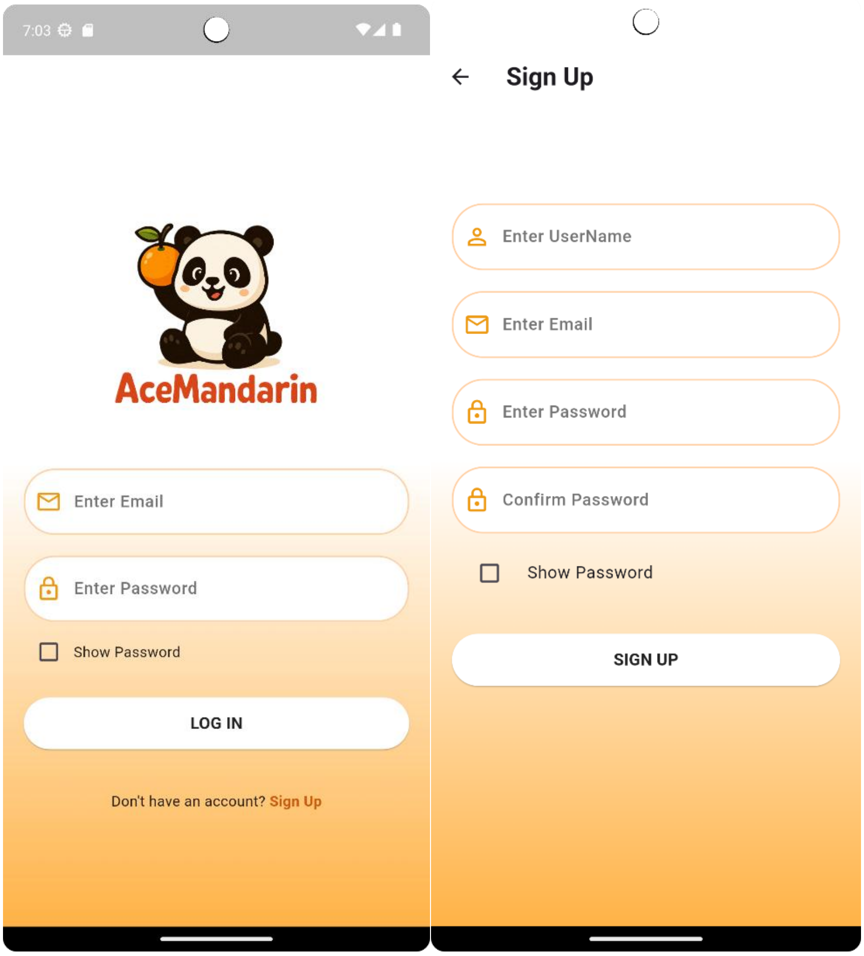
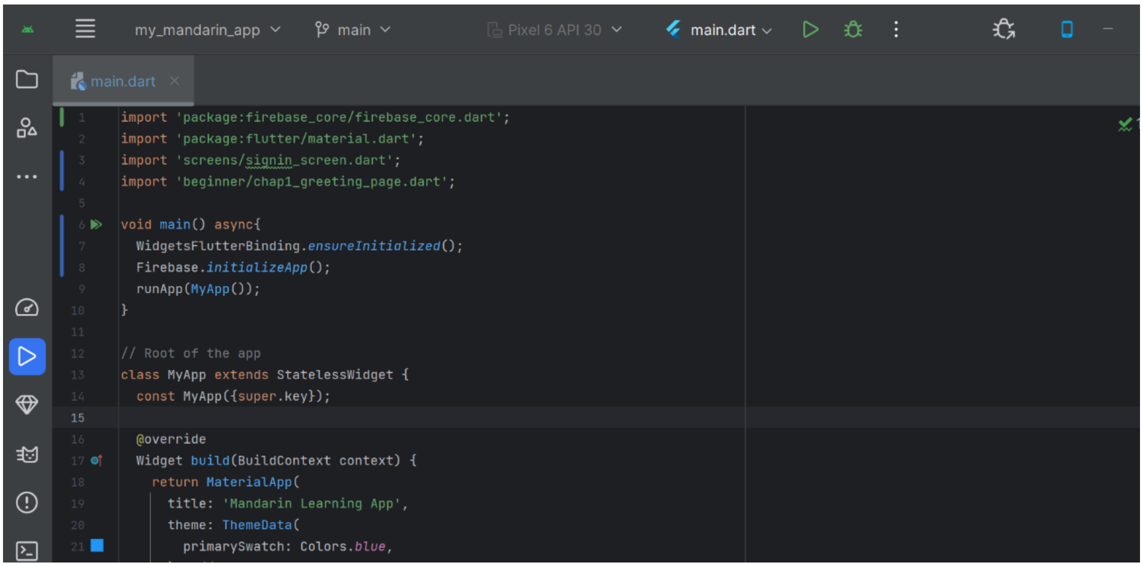
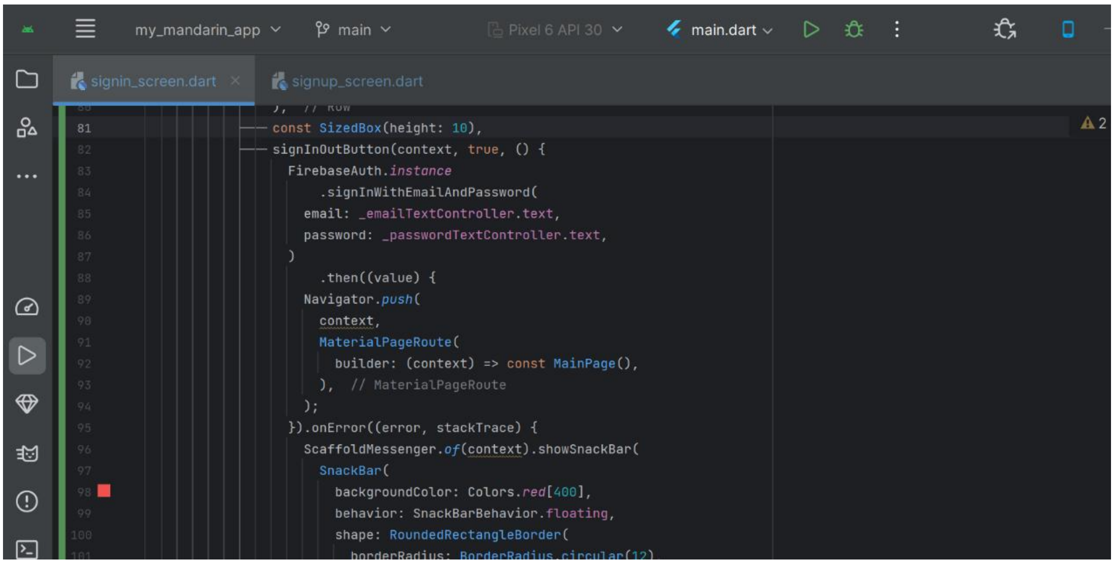


Figure 5.4 Login Page (Left) and Registration Page (Right)



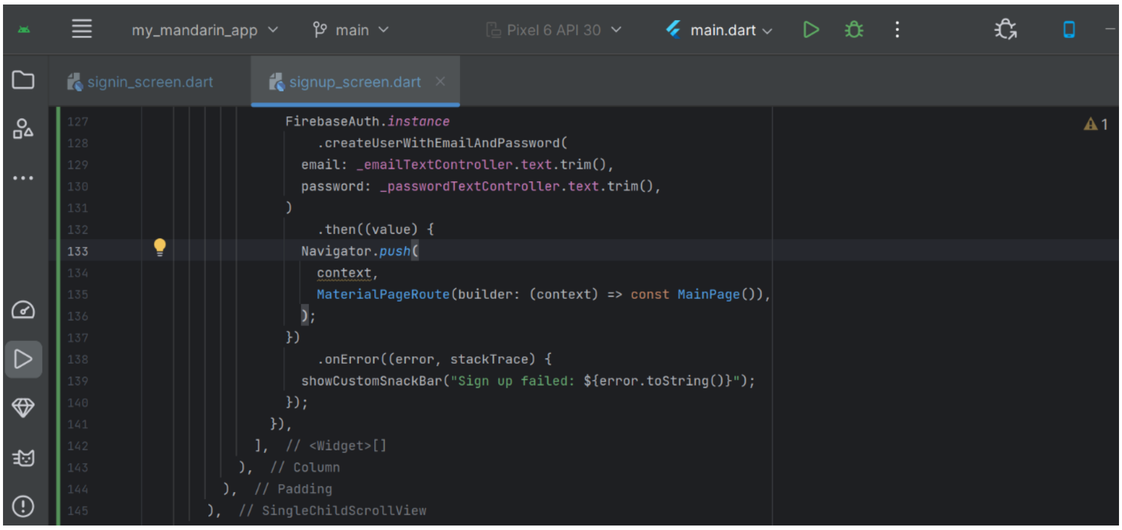
```
import 'package:firebase_core/firebase_core.dart';
import 'package:flutter/material.dart';
import 'screens/signin_screen.dart';
import 'beginner/chap1_greeting_page.dart';

void main() async{
  WidgetsFlutterBinding.ensureInitialized();
  Firebase.initializeApp();
  runApp(MyApp());
}

// Root of the app
class MyApp extends StatelessWidget {
  const MyApp({super.key});

  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      title: 'Mandarin Learning App',
      theme: ThemeData(
        primarySwatch: Colors.blue,
```

Figure 5.5 Code snippet for Initializes Firebase Service



```dart
), // Row
const SizedBox(height: 10),
signInOutButton(context, true, () {
  FirebaseAuth.instance
      .signInWithEmailAndPassword(
    email: _emailTextController.text,
    password: _passwordTextController.text,
  )
      .then((value) {
    Navigator.push(
      context,
      MaterialPageRoute(
        builder: (context) => const MainPage(),
      ),  // MaterialPageRoute
    );
  }).onError((error, stackTrace) {
    ScaffoldMessenger.of(context).showSnackBar(
      SnackBar(
        backgroundColor: Colors.red[400],
        behavior: SnackBarBehavior.floating,
        shape: RoundedRectangleBorder(
          borderRadius: BorderRadius.circular(12)
```

Figure 5.6 Code snippet for Firebase Login



```dart
          FirebaseAuth.instance
              .createUserWithEmailAndPassword(
            email: _emailTextController.text.trim(),
            password: _passwordTextController.text.trim(),
          )
              .then((value) {
            Navigator.push(
              context,
              MaterialPageRoute(builder: (context) => const MainPage()),
            );
          })
              .onError((error, stackTrace) {
            showCustomSnackBar("Sign up failed: ${error.toString()}");
          });
        }),
      ],  // <Widget>[]
    ),  // Column
  ),  // Padding
),  // SingleChildScrollView
```

Figure 5.7 Code snippet for Firebase Sign Up

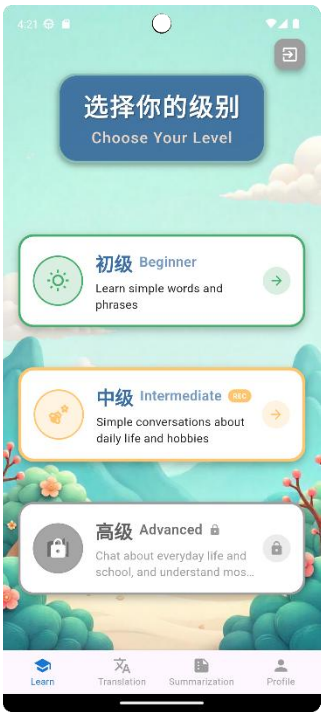
User authentication is an important part of any application that handles personal data or provide personalizes user experiences. Firebase Authentication service is used to manage login and registration functionalities for the application.

As shown in the left-hand side of Figure 5.4, login screen allows users to enter their registered email address and password. The user can get to the registration page by clicking the "Sign Up" text on the login page if they are new users. On the right-hand side of Figure 5.4, a registration page is provided for the users to create an account by entering their username, password, and personal email address. A "Confirm Password" section requires the user to input the password twice for verification to guarantee accuracy. Figure 5.3 illustrates the user detail added to the Firebase Authentication dashboard after successfully registering.

After successfully logging in or registering, the user is directed to the application's main menu. Every screen in the main menu has an "Exit" button to improve usability and make it simple for users to exit the application.

As shown in Figure 5.5, Firebase services are initialized using the Firebase.initializeApp() method. In Figure 5.6, the login functionality is implemented using FirebaseAuth.instance.signInWithEmailAndPassword, which authenticates users via email and password. Figure 5.7 demonstrates the sign-up functionality, where FirebaseAuth.instance.createUserWithEmailAndPassword registers a new user in Firebase Authentication with their email and password.

5.3 Thematic Lesson and Exercises



选择你的级别
Choose Your Level

初级 Beginner
Learn simple words and phrases

中级 Intermediate REC
Simple conversations about daily life and hobbies

高级 Advanced
Chat about everyday life and school, and understand mos...

Figure 5.8 Level Selection Page

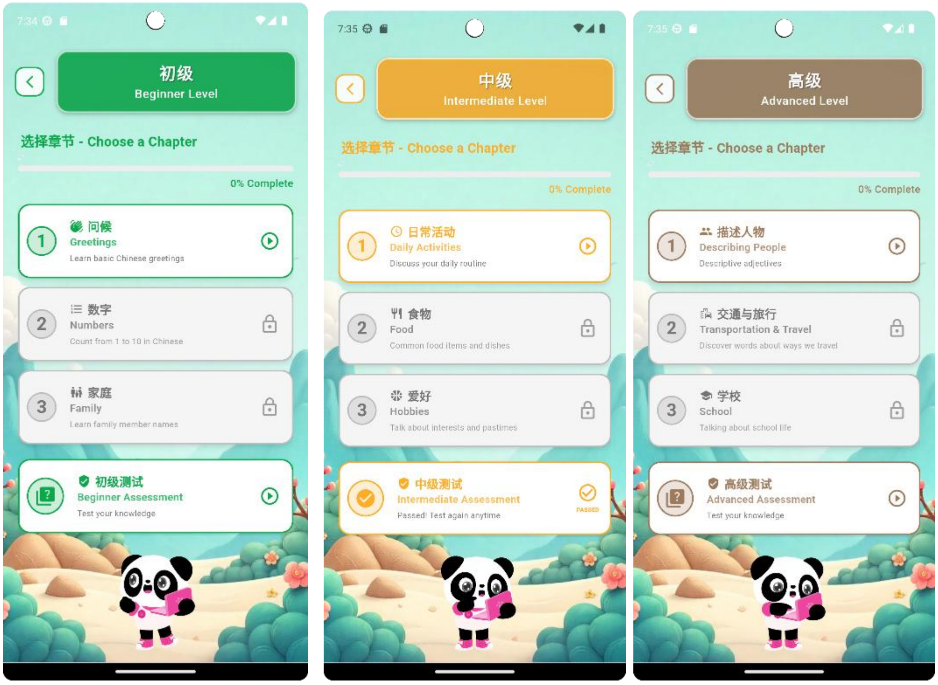


Figure 5.9 Beginner Level Page (Left), Intermediate Level Page (Middle), Advanced Level Page (Right)

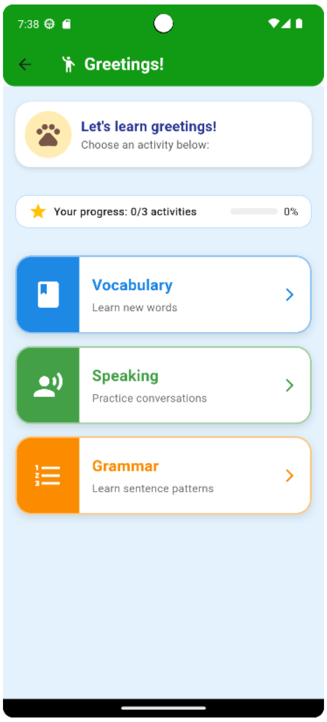
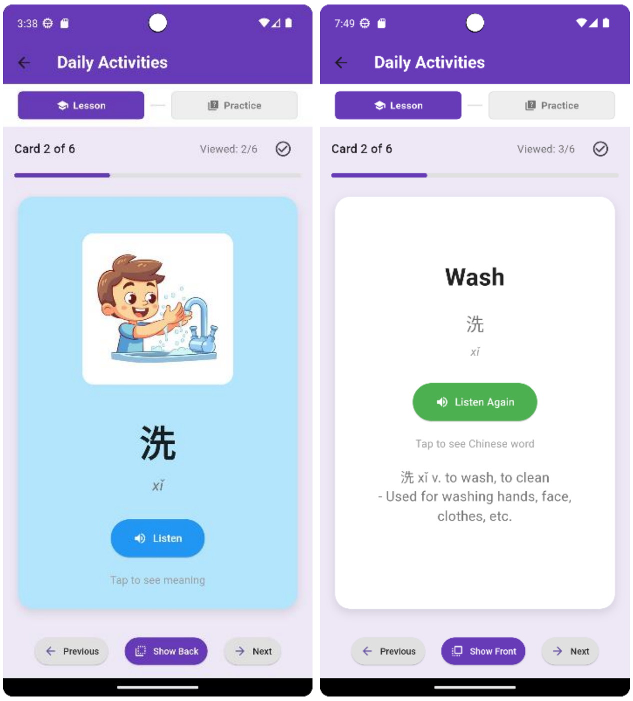


Figure 5.10 Learning Modules Page

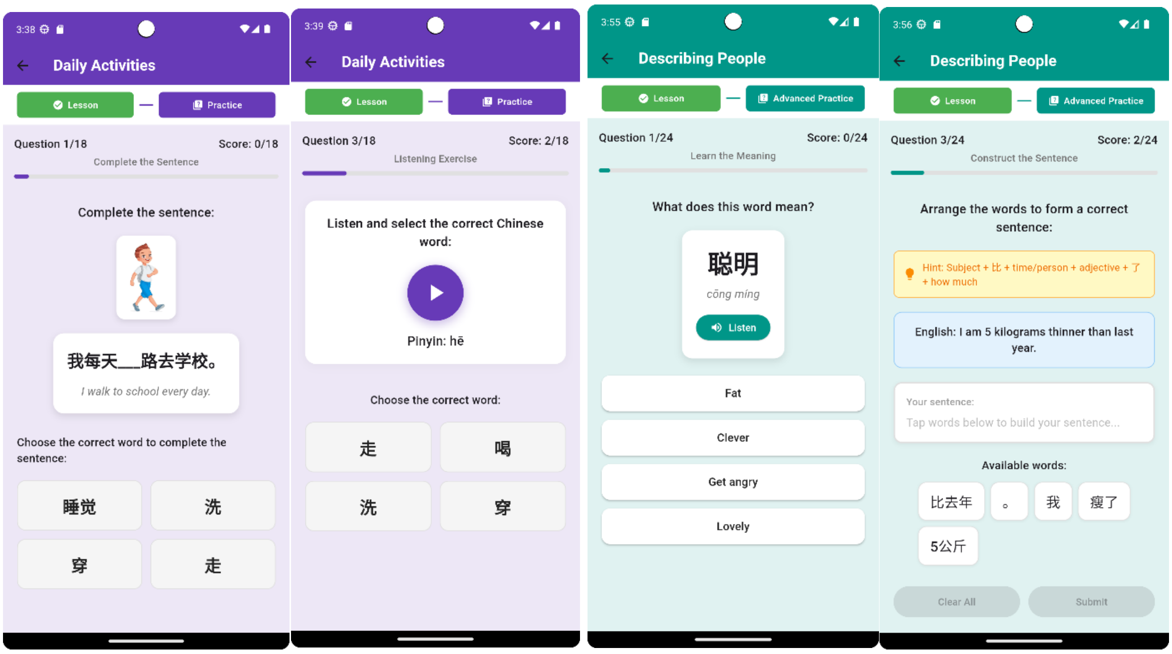
One of the main objectives of this project is to provide interactive and comprehensive exercises for children to enhance their language skills. The thematic exercises are organized into different levels and chapters to suit varying proficiency levels. As shown in Figure 5.8, users begin by selecting their level of proficiency on the level selection page. To encourage structured progression, higher-level exercises remain locked until the user has completed all exercises at the current level. After selecting a level, the application displays a list of themed chapters and an assessment test available within that level, as illustrated in Figure 5.9. Users can then choose an exercise to proceed to the learning module. In Figure 5.10, the learning modules are divided into three main activities, which are vocabulary, speaking, and grammar, each offering interactive and engaging activities tailored to enhance specific language skills.

5.3.1 Vocabulary Activity



洗 xǐ v. to wash, to clean
- Used for washing hands, face, clothes, etc.

Figure 5.11 Vocabulary Lesson



Complete the sentence:

我每天__路去学校。

I walk to school every day.

Choose the correct word to complete the sentence:

Listen and select the correct Chinese word:

Pinyin: hē

Choose the correct word:

What does this word mean?

聪明

cōng míng

Arrange the words to form a correct sentence:

Hint: Subject + 比 + time/person + adjective + 了 + how much

English: I am 5 kilograms thinner than last year.

Your sentence:

Tap words below to build your sentence...

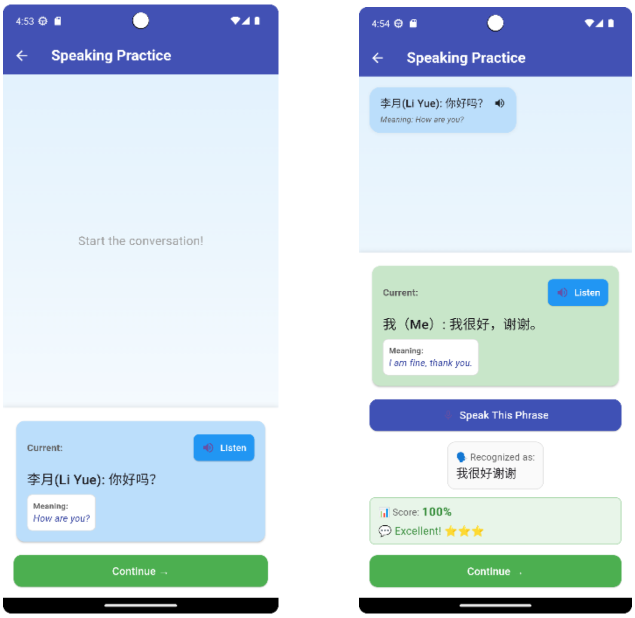
Available words:

Figure 5.12 Vocabulary Exercises

The vocabulary activity is designed to help users expand their word bank through interactive lessons and exercises. As shown in Figure 5.11, each lesson allows users to study vocabulary before attempting the exercises. Flashcards are provided for practice, tailored to different proficiency levels, and users can also learn the correct pronunciation of words by selecting the "Listen" button. The vocabulary is based on the word lists contained in each Hanyu Shuiping Kaoshi (HSK) level textbook [24, 25, 26].

After completing a lesson, users can proceed to vocabulary exercises. Figure 5.12 illustrates sample questions from different chapters across various levels. The exercises include multiple formats such as sentence completion, fill-in-the-blank, listening comprehension, translation, and sentence construction. The question types are adapted according to proficiency level. For example, sentence construction tasks only appear in advanced-level exercises. This is because the Hanyu Shuiping Kaoshi (HSK) 3 exam and higher usually contain this kind of question, as in the past year from [23]. By modelling the exercises after past exam formats, the activity helps users strengthen their test performance while gradually enhancing their vocabulary proficiency.

5.3.2 Speaking Activity



Start the conversation!

Current:
李月(Li Yue): 你好吗?
Meaning:
How are you?

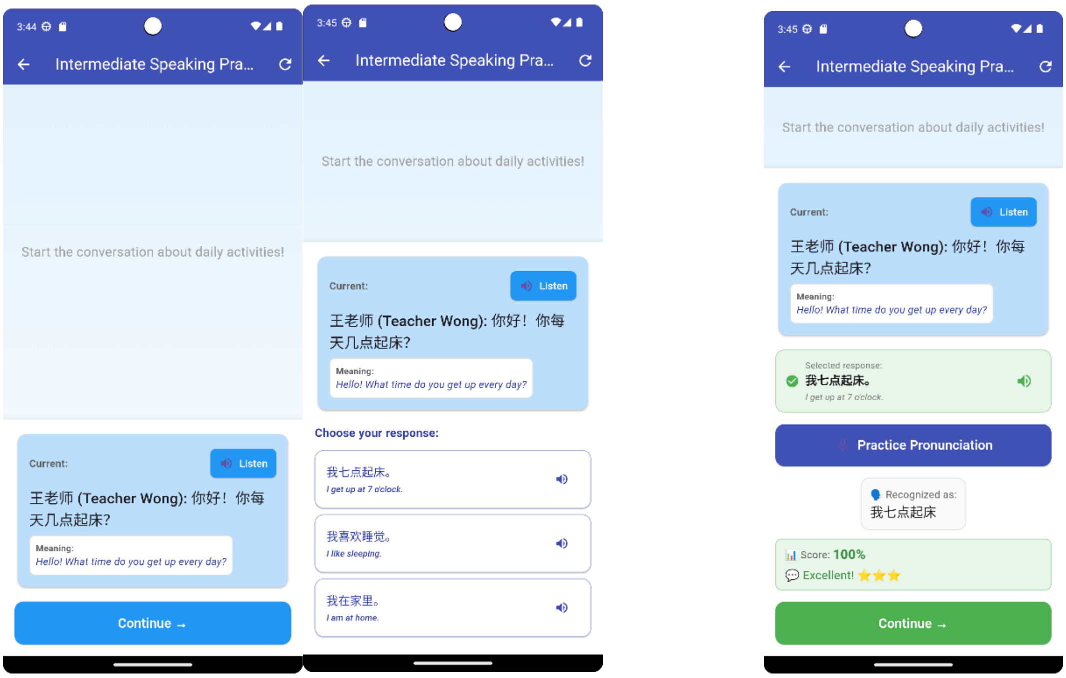
李月(Li Yue): 你好吗?
Meaning: How are you?

Current:
我（Me）：我很好，谢谢。
Meaning:
I am fine, thank you.

Recognized as:
我很好谢谢

Score: 100%
Excellent! ⭐⭐⭐

Figure 5.13 Beginner Level: System Dialogue Screen (Left) and User’s Practice Turn Screen (Right)


3:44
Intermediate Speaking Pra...
Listen
Continue →
3:45
Intermediate Speaking Pra...
Listen
3:45
Intermediate Speaking Pra...
Listen
Practice Pronunciation
Continue →

Start the conversation about daily activities!

Current:
王老师 (Teacher Wong): 你好！你每天几点起床?
Meaning:
Hello! What time do you get up every day?

Start the conversation about daily activities!

Current:
王老师 (Teacher Wong): 你好！你每天几点起床?
Meaning:
Hello! What time do you get up every day?

Choose your response:

我七点起床。
I get up at 7 o'clock.

我喜欢睡觉。
I like sleeping.

我在家里。
I am at home.

Start the conversation about daily activities!

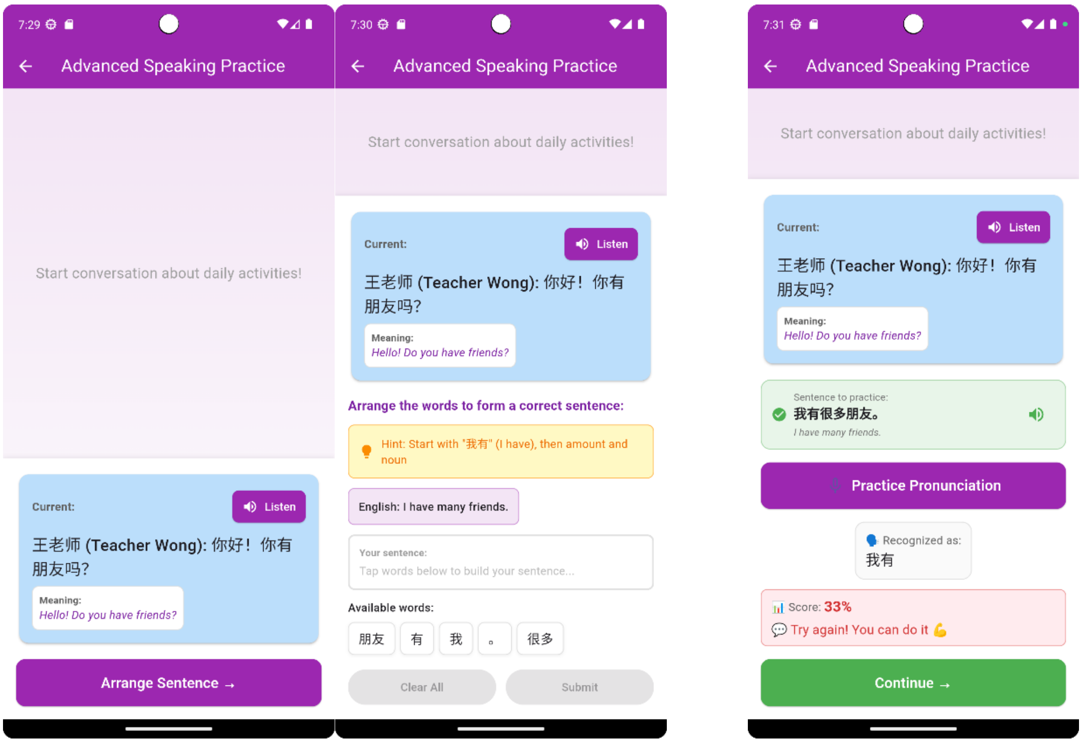
Current:
王老师 (Teacher Wong): 你好！你每天几点起床?
Meaning:
Hello! What time do you get up every day?

Selected response:
我七点起床。
I get up at 7 o'clock.

Recognized as:
我七点起床

Score: 100%
Excellent! ⭐⭐⭐

Figure 5.14 Intermediate Level: System Dialogue Screen (Left) and User’s Practice Turn Screen (Right)



Start conversation about daily activities!

Current:
王老师 (Teacher Wong): 你好！你有朋友吗？

Meaning:
Hello! Do you have friends?

Start conversation about daily activities!

Current:
王老师 (Teacher Wong): 你好！你有朋友吗？

Meaning:
Hello! Do you have friends?

Arrange the words to form a correct sentence:

Hint: Start with "我有" (I have), then amount and noun

English: I have many friends.

Your sentence:
Tap words below to build your sentence...

Available words:
朋友 有 我 。 很多

Start conversation about daily activities!

Current:
王老师 (Teacher Wong): 你好！你有朋友吗？

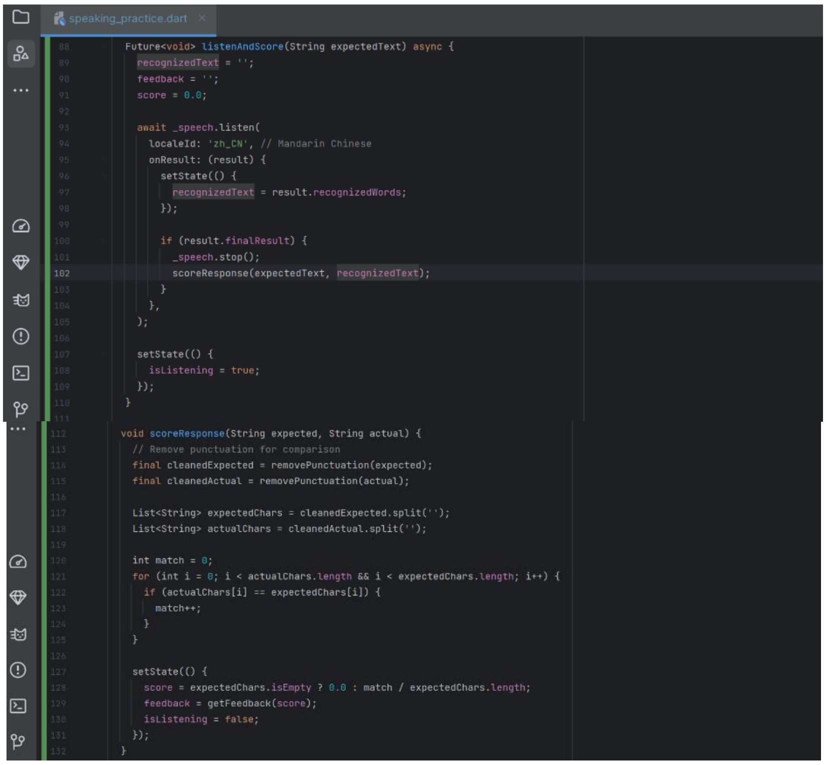
Meaning:
Hello! Do you have friends?

Sentence to practice:
我有很多朋友。
I have many friends.

Recognized as:
我有

Score: 33%
Try again! You can do it 💪

Figure 5.15 Advanced Level: System Dialogue Screen (Left) and User’s Practice Turn Screen (Right)



```
Future<void> listenAndScore(String expectedText) async {
  recognizedText = '';
  feedback = '';
  score = 0.0;

  await _speech.listen(
    localeId: 'zh_CN', // Mandarin Chinese
    onResult: (result) {
      setState(() {
        recognizedText = result.recognizedWords;
      });

      if (result.finalResult) {
        _speech.stop();
        scoreResponse(expectedText, recognizedText);
      }
    },
  );

  setState(() {
    isListening = true;
  });
}

void scoreResponse(String expected, String actual) {
  // Remove punctuation for comparison
  final cleanedExpected = removePunctuation(expected);
  final cleanedActual = removePunctuation(actual);

  List<String> expectedChars = cleanedExpected.split('');
  List<String> actualChars = cleanedActual.split('');

  int match = 0;
  for (int i = 0; i < actualChars.length && i < expectedChars.length; i++) {
    if (actualChars[i] == expectedChars[i]) {
      match++;
    }
  }

  setState(() {
    score = expectedChars.isEmpty ? 0.0 : match / expectedChars.length;
    feedback = getFeedback(score);
    isListening = false;
  });
}
```

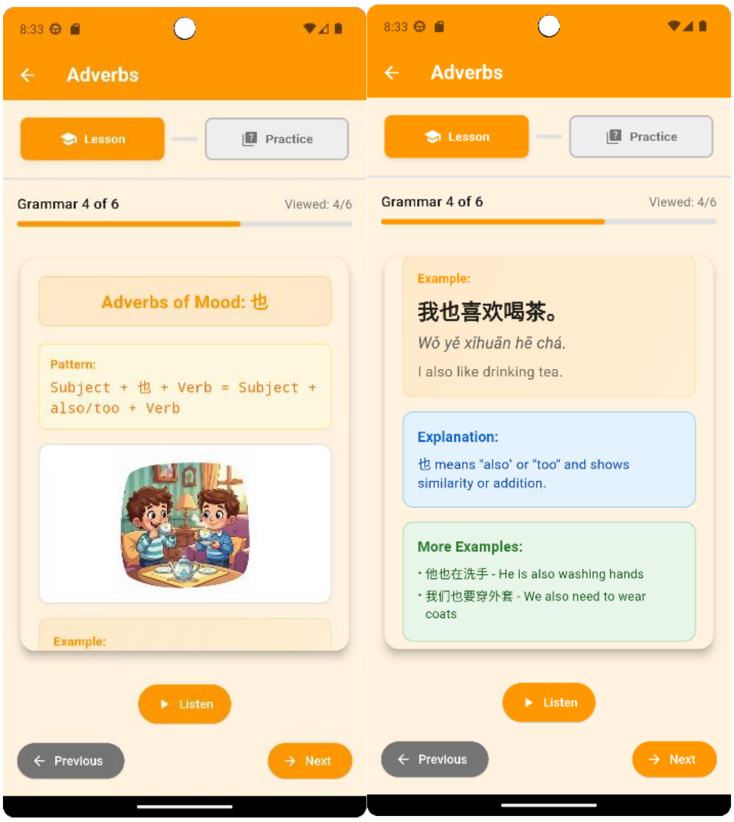
Figure 5.16 Code snippet of Speaking Practice

The application includes a speaking practice module that mimics real-life conversation by simulating a dialogue between the user and a virtual character to improve oral proficiency. As shown in Figure 5.13 on the left, the application begins by displaying a prompt message. After hearing the message by clicking the "Listen" button, the user can move on to their turn in the dialogue by clicking the "Continue" button. Figure 5.13 on the right shows that when the user turns, they can click the "Listen" button to hear the sample response and follow the pronunciation. Since this module is designed for beginners, a response message is provided for users to repeat, allowing them to practice speaking in a guided and supportive way. This setup helps users build confidence and fluency in responding to conversational prompts.

As shown in Figure 5.14, at the intermediate level, an additional challenge is introduced by requiring the user to select the correct response to a given question. After making the selection, the user is then prompted to practice the pronunciation of the chosen response. As illustrated in Figure 5.15, at the advanced level, the difficulty is further increased by requiring the user to construct a sentence in the correct sequence using the provided words. These tasks are designed to reinforce both vocabulary knowledge and grammatical accuracy, reflecting the complexity expected at higher proficiency levels.

As illustrated in the code snippet in Figure 5.16, the score is calculated by taking the speech input and comparing it to an expected string, and then assigning a score based on how closely the spoken text matches the expected one character by character. This interaction mimics real-life language use, helping users to become more comfortable with pronunciation, tone, and flow.

5.3.3 Grammar Activity



Grammar 4 of 6 Viewed: 4/6

Adverbs of Mood: 也

Pattern:

Subject + 也 + Verb = Subject + also/too + Verb

Example:

我也喜欢喝茶。

Wǒ yě xǐhuān hē chá.

I also like drinking tea.

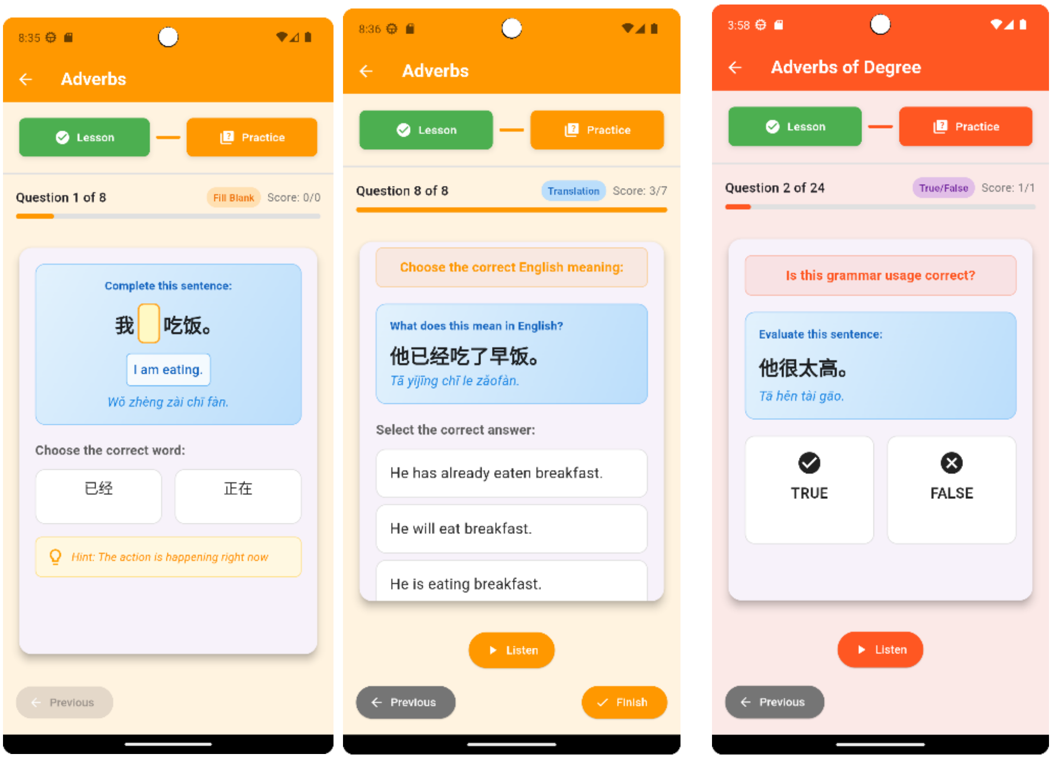
Explanation:

也 means "also" or "too" and shows similarity or addition.

More Examples:

- 他也在洗手 - He is also washing hands
- 我们也要穿外套 - We also need to wear coats

Figure 5.17 Grammar Lesson



Question 1 of 8 Score: 0/0

Complete this sentence:

我 吃饭。

I am eating.

Wǒ zhèng zài chī fàn.

Choose the correct word:

已经 正在

Hint: The action is happening right now

Question 8 of 8 Score: 3/7

Choose the correct English meaning:

What does this mean in English?

他已经吃了早饭。

Tā yǐjīng chī le zǎofàn.

Select the correct answer:

He has already eaten breakfast.

He will eat breakfast.

He is eating breakfast.

Question 2 of 24 Score: 1/1

Is this grammar usage correct?

Evaluate this sentence:

他很太高。

Tā hěn tài gāo.

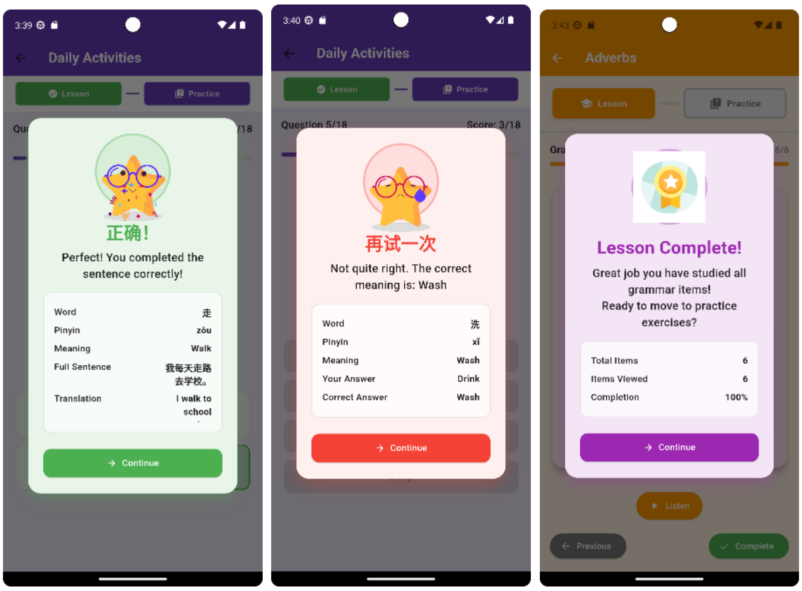
Figure 5.18 Grammar Exercises

The grammar activity module is designed to help users better comprehend the rules of grammar that are necessary for both writing and speaking. Users can begin by studying grammar concepts and then move on to exercises. Figure 5.17 illustrates a grammar lesson, which provides detailed explanations and examples to guide learning.

As shown in Figure 5.18, the grammar practice consists of different question formats, including fill-in-the-blank and true or false, for the grammar usage and translation exercise to reinforce key grammar concepts. When the user chooses the right response, the application provides positive feedback to acknowledge their success. When a user chooses a wrong response, supportive feedback points out the error and promotes more learning. The module ensures that students actively apply their knowledge in relevant circumstances through interactive features, improving their comprehension.

The grammar content is designed based on the grammar point list provided in [23], which is structured by proficiency level. At the beginner level, the focus is on personal pronouns, numerals, and interrogative pronouns. The intermediate level covers time adverbs, adverbs of mood, quantifiers, and conjunctions. At the advanced level, the content includes adverbs of degree, prepositions, and imperative sentence structures.

5.3.4 Real-time Feedback



正确!

Perfect! You completed the sentence correctly!

Word 走
Pinyin zōu
Meaning Walk
Full Sentence 我每天走路去学校。
Translation I walk to school

再试一次

Not quite right. The correct meaning is: Wash

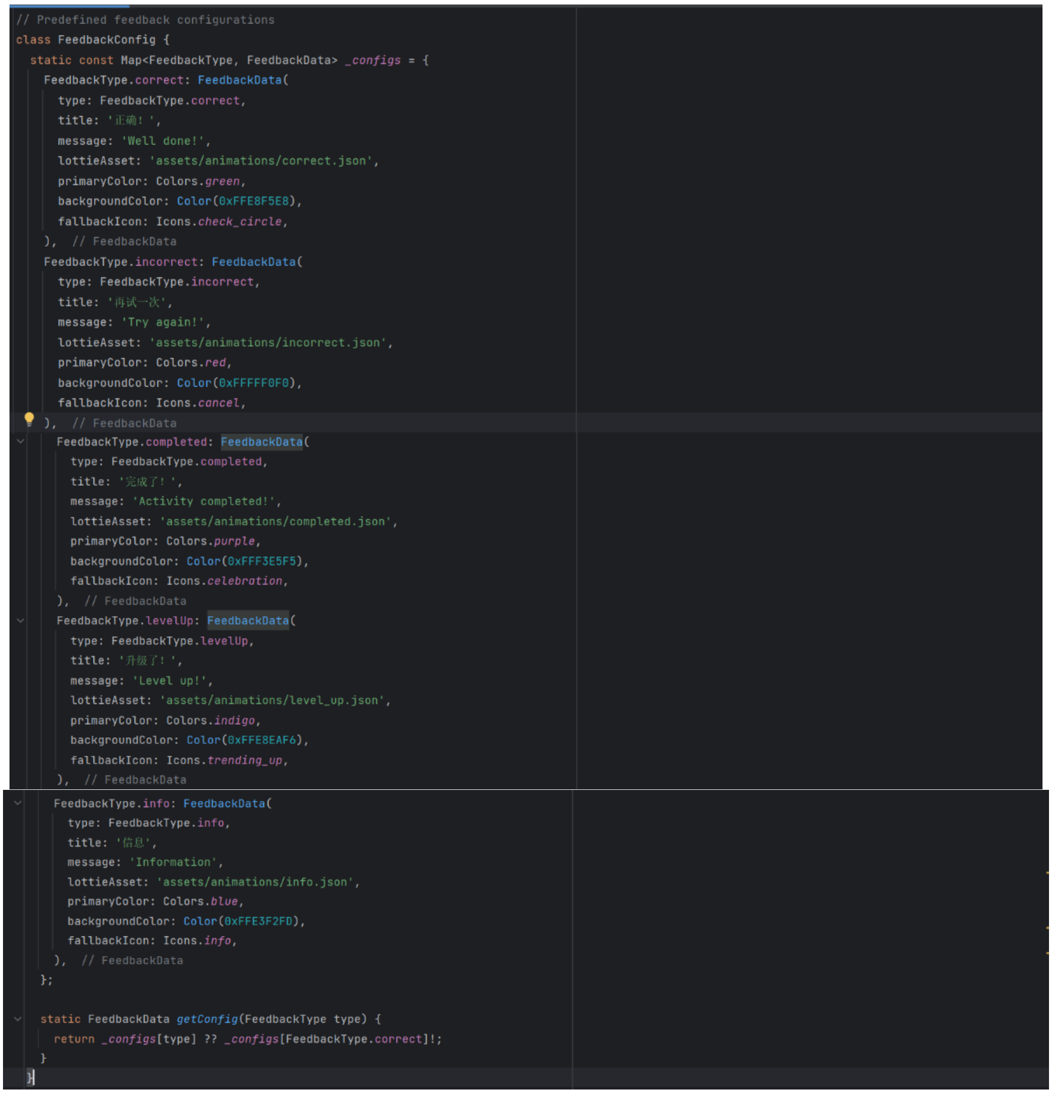
Word 洗
Pinyin xǐ
Meaning Wash
Your Answer Drink
Correct Answer Wash

Lesson Complete!

Great job you have studied all grammar items!
Ready to move to practice exercises?

Total Items 6
Items Viewed 6
Completion 100%

Figure 5.19 Real-time feedback: Correct (left), Incorrect (middle), and Completed (right)

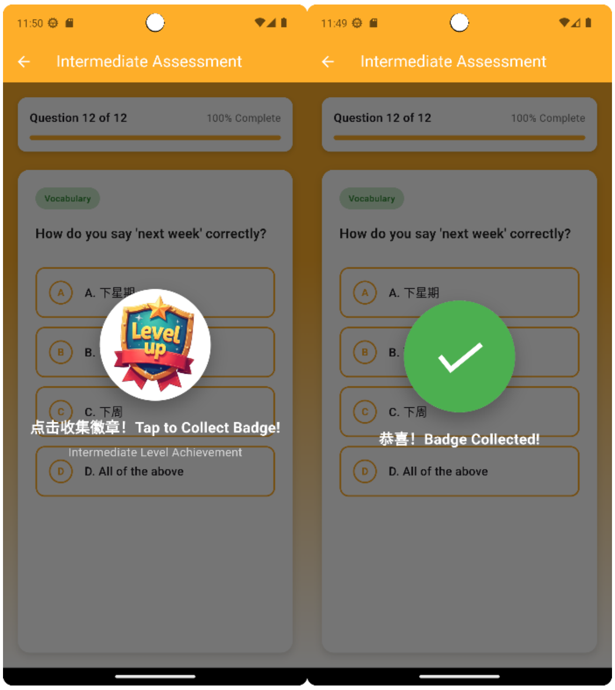


```
// Predefined feedback configurations
class FeedbackConfig {
  static const Map<FeedbackType, FeedbackData> _configs = {
    FeedbackType.correct: FeedbackData(
      type: FeedbackType.correct,
      title: '正确！',
      message: 'Well done!',
      lottieAsset: 'assets/animations/correct.json',
      primaryColor: Colors.green,
      backgroundColor: Color(0xFFE8F5E8),
      fallbackIcon: Icons.check_circle,
    ),  // FeedbackData
    FeedbackType.incorrect: FeedbackData(
      type: FeedbackType.incorrect,
      title: '再试一次',
      message: 'Try again!',
      lottieAsset: 'assets/animations/incorrect.json',
      primaryColor: Colors.red,
      backgroundColor: Color(0xFFFFF0F0),
      fallbackIcon: Icons.cancel,
    ),  // FeedbackData
      FeedbackType.completed: FeedbackData(
        type: FeedbackType.completed,
        title: '完成了！',
        message: 'Activity completed!',
        lottieAsset: 'assets/animations/completed.json',
        primaryColor: Colors.purple,
        backgroundColor: Color(0xFFF3E5F5),
        fallbackIcon: Icons.celebration,
      ),  // FeedbackData
      FeedbackType.levelUp: FeedbackData(
        type: FeedbackType.levelUp,
        title: '升级了！',
        message: 'Level up!',
        lottieAsset: 'assets/animations/level_up.json',
        primaryColor: Colors.indigo,
        backgroundColor: Color(0xFFE8EAF6),
        fallbackIcon: Icons.trending_up,
      ),  // FeedbackData
    FeedbackType.info: FeedbackData(
      type: FeedbackType.info,
      title: '信息',
      message: 'Information',
      lottieAsset: 'assets/animations/info.json',
      primaryColor: Colors.blue,
      backgroundColor: Color(0xFFE3F2FD),
      fallbackIcon: Icons.info,
    ),  // FeedbackData
  };

  static FeedbackData getConfig(FeedbackType type) {
    return _configs[type] ?? _configs[FeedbackType.correct]!;
  }
}
```

Figure 5.20 Code snippet for Predefined Feedback Configuration

A comprehensive and flexible feedback system is implemented to help the children track their progress, recognize mistakes, and accelerate learning. The application consists of various types of feedback, including correct feedback for right answers, incorrect Feedback for wrong answers, completion feedback for finishing activities, and level-up feedback for progress milestones. This system is designed to be customizable while maintaining sensible defaults, ensuring both ease of use and seamless integration. Figure 5.19 shows an example of real-time feedback for a correct answer selected, an incorrect answer selected, and lesson-completion feedback. Figure 5.20 presents the code implementation of a configuration class that is used to map each feedback type to its visual properties.

5.3.5 Reward System



Question 12 of 12 100% Complete

Vocabulary

How do you say 'next week' correctly?

A. 下星期

B.

C. 下周

D. All of the above

点击收集徽章！ Tap to Collect Badge!

Intermediate Level Achievement

Question 12 of 12 100% Complete

Vocabulary

How do you say 'next week' correctly?

A. 下星期

B.

C. 下周

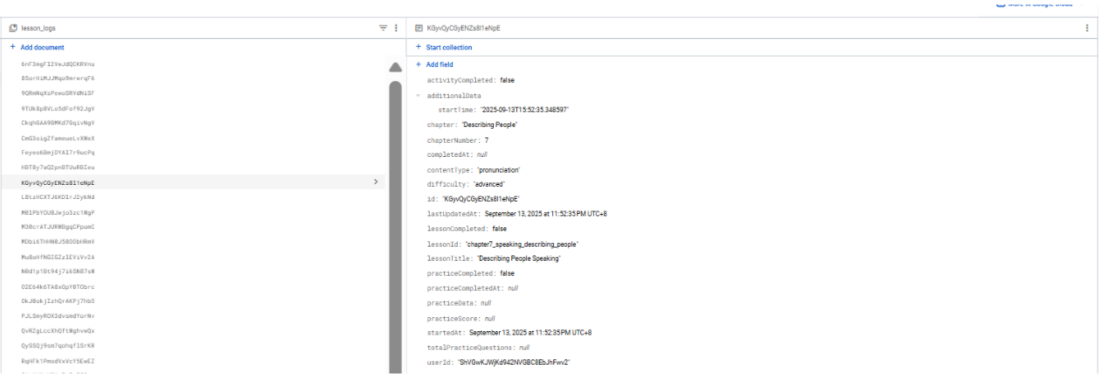
D. All of the above

恭喜！ Badge Collected!

Figure 5.21 Reward System

A reward system is implemented in this application to engage and motivate users toward continuous learning. For example, when a user successfully passes an assessment, the user is awarded a badge, which can be collected by tapping on it. Figure 5.21 shows the flow of the reward system. The total number of badges earned is recorded in the Achievements section of the profile page, as illustrated in Figure 5.24 below.

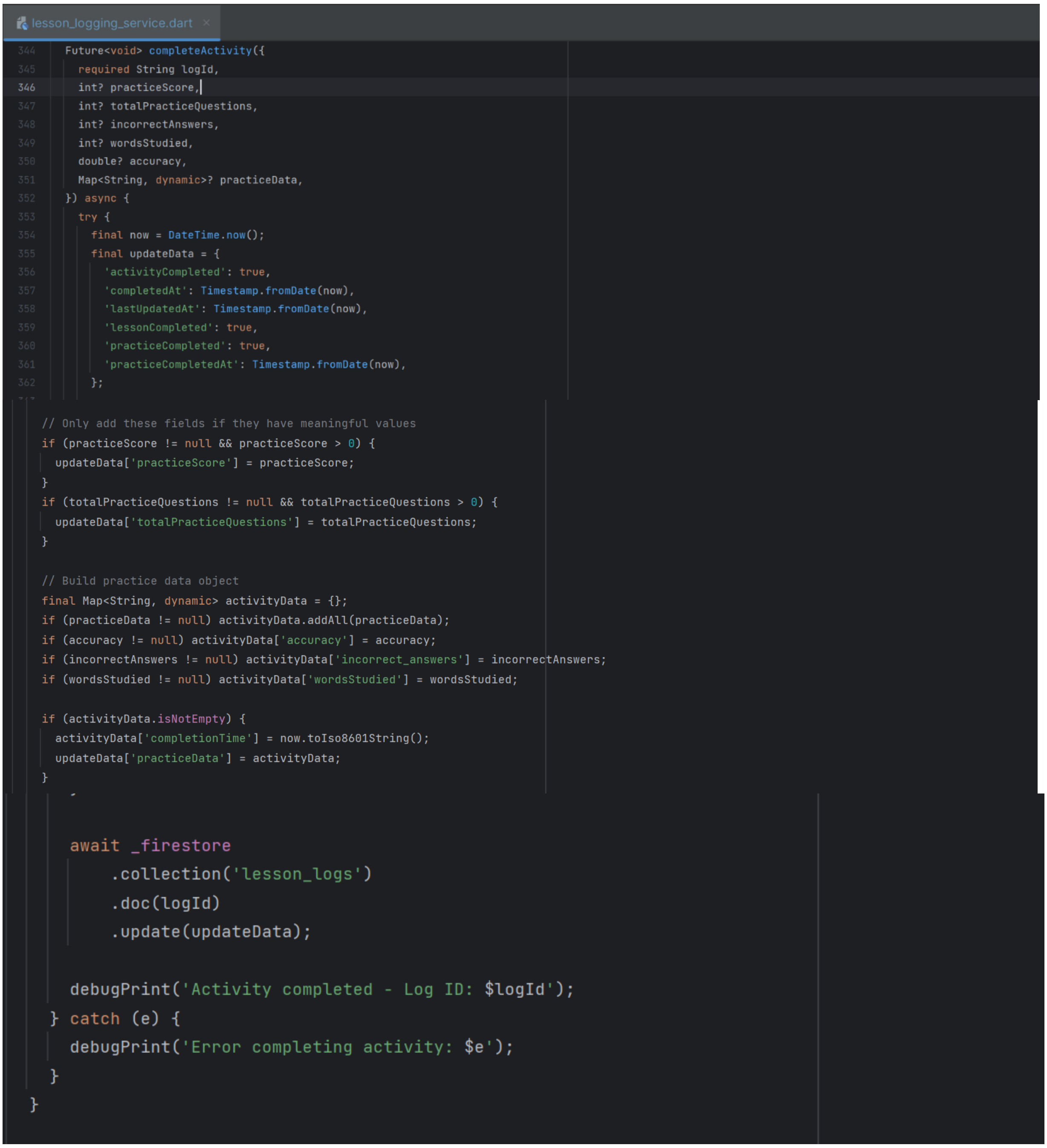
5.3.6 Log Activity to Firebase



```
6nF3mgF12VwJdQCKRVnu
85orHiMJJMqo9mrwrqF6
9QRmNqXsPewoSRVdNiSF
9TUk8p8VLo5dFof92JgV
CkqhGAA9BMKd7GqivNgV
CmG3oigZfameueLvXWeX
Feyeo6BmjDYA17r9ucPq
HBT8y7aQ2pnBTUuRBIeu
KGyvQyCGyENZs8l1eNpE
LBtzHCXTJ6KD1rJ2ykNd
M01PbYOU8Jwjo3zc1WgP
M30crATJURWBgqCPpumC
MDbi6THHN0J58O0bHRmV
MuBoHfNGIGZz1EViVv2A
N0d1p1Bt94j7i6SN87sW
O2E64k6TA8xGpY8TObrc
OkJ0okjIzhQrAKPj7hbO
PJLSmyROX3dvsmdYorNv
QvRZgLccXhQftWghvwQx
QySSQj9sm7qohqf1SrKR
RqHFk1PmodVxVcY5EwEZ
```

```
activityCompleted: false
additionalData
    startTime: "2025-09-13T15:52:35.348597"
chapter: "Describing People"
chapterNumber: 7
completedAt: null
contentType: "pronunciation"
difficulty: "advanced"
id: "KGyvQyCGyENZs8l1eNpE"
lastUpdatedAt: September 13, 2025 at 11:52:35 PM UTC+8
lessonCompleted: false
lessonId: "chapter7_speaking_describing_people"
lessonTitle: "Describing People Speaking"
practiceCompleted: false
practiceCompletedAt: null
practiceData: null
practiceScore: null
startedAt: September 13, 2025 at 11:52:35 PM UTC+8
totalPracticeQuestions: null
userId: "ShVGwKJWjKd942NVGBC8EbJhFwv2"
```

Figure 5.22 Log Activity to Firebase



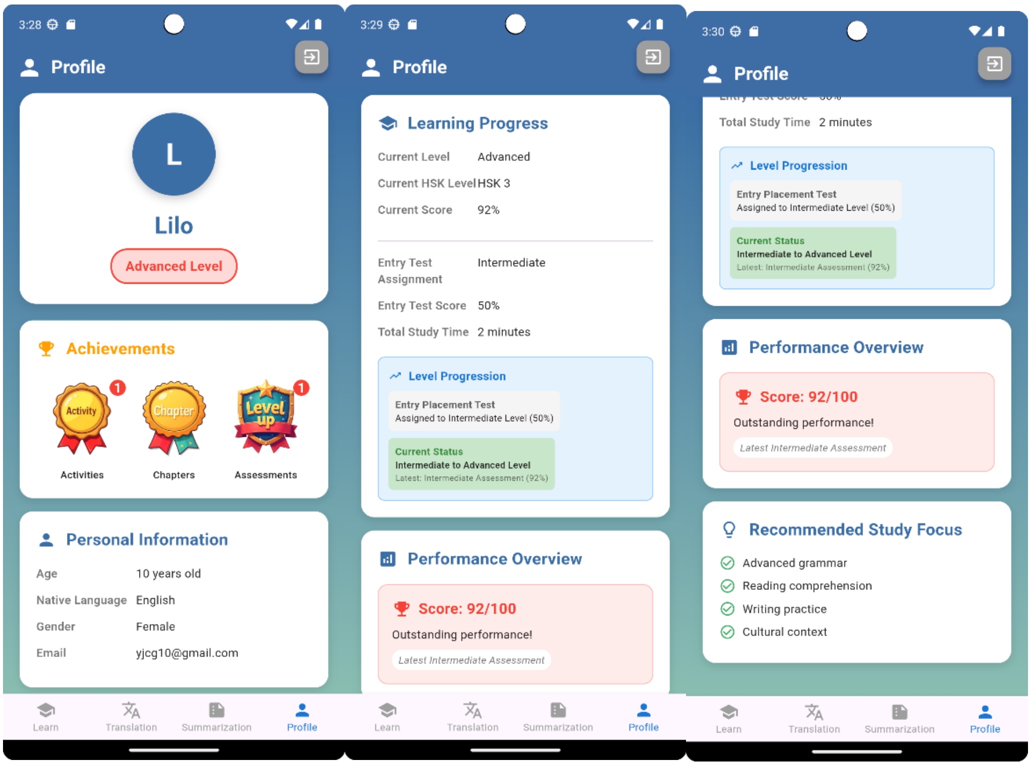
```dart
Future<void> completeActivity({
  required String logId,
  int? practiceScore,
  int? totalPracticeQuestions,
  int? incorrectAnswers,
  int? wordsStudied,
  double? accuracy,
  Map<String, dynamic>? practiceData,
}) async {
  try {
    final now = DateTime.now();
    final updateData = {
      'activityCompleted': true,
      'completedAt': Timestamp.fromDate(now),
      'lastUpdatedAt': Timestamp.fromDate(now),
      'lessonCompleted': true,
      'practiceCompleted': true,
      'practiceCompletedAt': Timestamp.fromDate(now),
    };

    // Only add these fields if they have meaningful values
    if (practiceScore != null && practiceScore > 0) {
      updateData['practiceScore'] = practiceScore;
    }
    if (totalPracticeQuestions != null && totalPracticeQuestions > 0) {
      updateData['totalPracticeQuestions'] = totalPracticeQuestions;
    }

    // Build practice data object
    final Map<String, dynamic> activityData = {};
    if (practiceData != null) activityData.addAll(practiceData);
    if (accuracy != null) activityData['accuracy'] = accuracy;
    if (incorrectAnswers != null) activityData['incorrect_answers'] = incorrectAnswers;
    if (wordsStudied != null) activityData['wordsStudied'] = wordsStudied;

    if (activityData.isNotEmpty) {
      activityData['completionTime'] = now.toIso8601String();
      updateData['practiceData'] = activityData;
    }

    await _firestore
        .collection('lesson_logs')
        .doc(logId)
        .update(updateData);

    debugPrint('Activity completed - Log ID: $logId');
  } catch (e) {
    debugPrint('Error completing activity: $e');
  }
}
```

Figure 5.23 Code snippet for Log Activity to Firebase

When a user accesses an activity within a chapter, the system logs the user’s activity to Firebase. The log records whether the user has completed the lesson and practices, along with additional details such as the score, completion time, and total number of questions attempted. This process is handled by the completeActivity function.

As shown in Figure 5.23, the code snippet of completeActivity function demonstrates how user activity is logged to Firebase. The activity logs are stored in the lesson_log collection within the Firebase database. Figure 5.24 presents an example of a log record from a pronunciation activity at the advanced level.

5.4 Profile Page



Profile

L

Lilo

Advanced Level

Achievements

Activities Chapters Assessments

Personal Information

Age	10 years old
Native Language	English
Gender	Female
Email	yjcg10@gmail.com

Profile

Learning Progress

Current Level	Advanced
Current HSK Level	HSK 3
Current Score	92%
Entry Test Assignment	Intermediate
Entry Test Score	50%
Total Study Time	2 minutes

Level Progression

Entry Placement Test
Assigned to Intermediate Level (50%)

Current Status
Intermediate to Advanced Level
Latest: Intermediate Assessment (92%)

Performance Overview

Score: 92/100
Outstanding performance!
Latest Intermediate Assessment

Profile

Total Study Time 2 minutes

Level Progression

Entry Placement Test
Assigned to Intermediate Level (50%)

Current Status
Intermediate to Advanced Level
Latest: Intermediate Assessment (92%)

Performance Overview

Score: 92/100
Outstanding performance!
Latest Intermediate Assessment

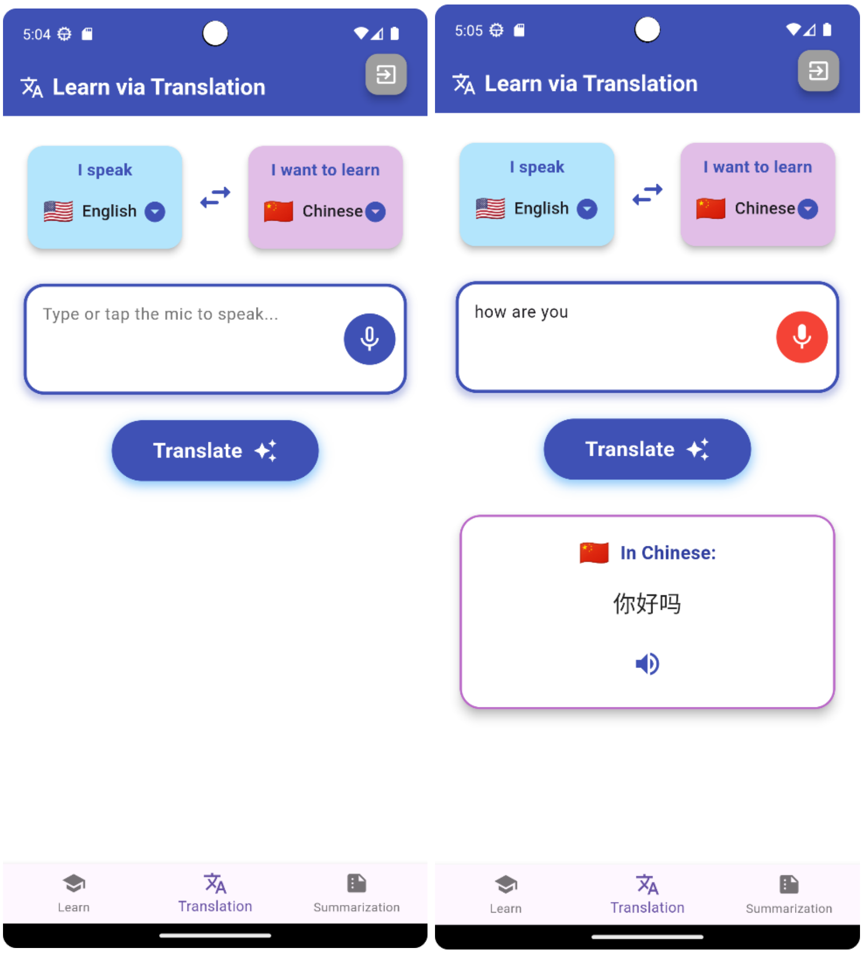
Recommended Study Focus

- ✓ Advanced grammar
- ✓ Reading comprehension
- ✓ Writing practice
- ✓ Cultural context

Figure 5.24 Profile Page

Figure 5.24 illustrates the profile page of the application that provides a comprehensive view of the user’s personal and learning details. It begins with the achievements section that shows user’s earned badges, which are awarded based on completed activities, chapters, and assessments to provide a sense of accomplishment and motivation as they advance through their studies. The personal information section shows the name, age, native language, gender, and email of the user. The learning progress section highlights the user’s current level, total study time, entry-level test score, and a visual level progression that records the progress from the entry level to the current level, along with the most recent assessment score. In the performance overview, users can view their latest assessment result, offering quick insight into their current standing.

5.5 Translation Feature

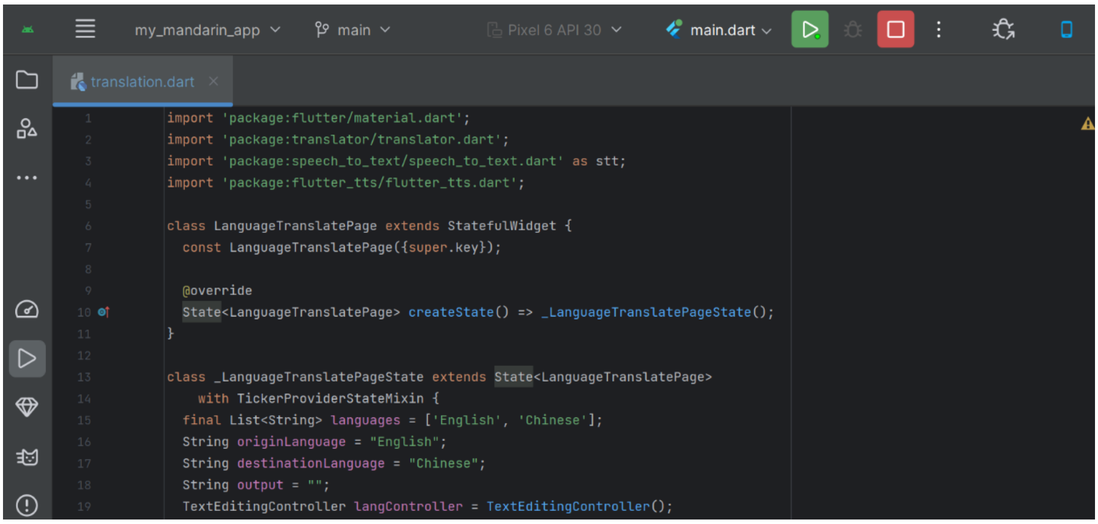


how are you

In Chinese:

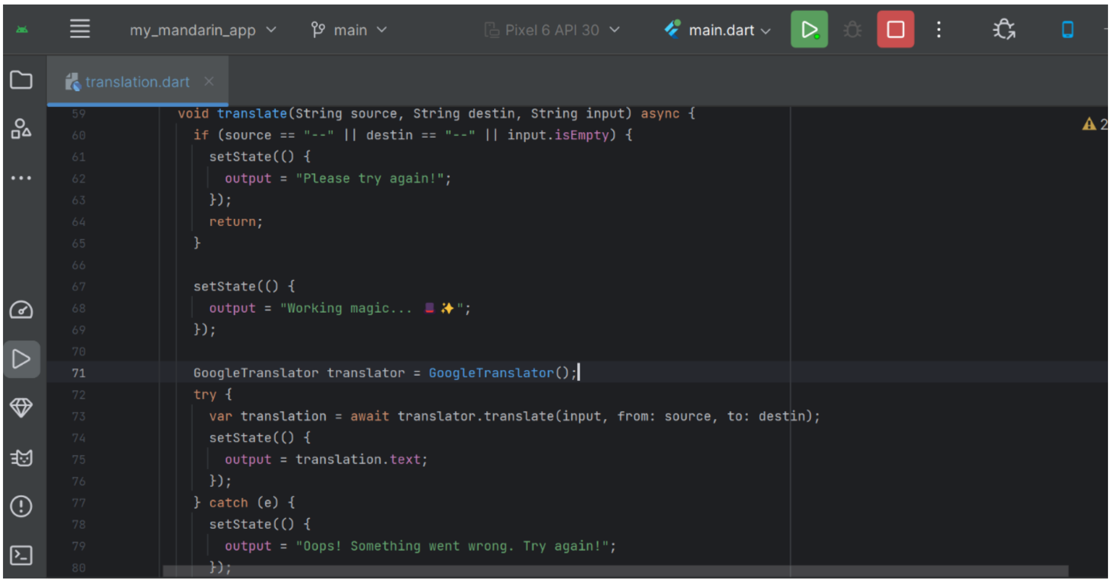
你好吗

Figure 5.25 Translation Page (Left) and Result of Translation Page (Right)



```dart
import 'package:flutter/material.dart';
import 'package:translator/translator.dart';
import 'package:speech_to_text/speech_to_text.dart' as stt;
import 'package:flutter_tts/flutter_tts.dart';

class LanguageTranslatePage extends StatefulWidget {
  const LanguageTranslatePage({super.key});

  @override
  State<LanguageTranslatePage> createState() => _LanguageTranslatePageState();
}

class _LanguageTranslatePageState extends State<LanguageTranslatePage>
    with TickerProviderStateMixin {
  final List<String> languages = ['English', 'Chinese'];
  String originLanguage = "English";
  String destinationLanguage = "Chinese";
  String output = "";
  TextEditingController langController = TextEditingController();
```

Figure 5.26 Code Snippet of Translation with Necessary Packages

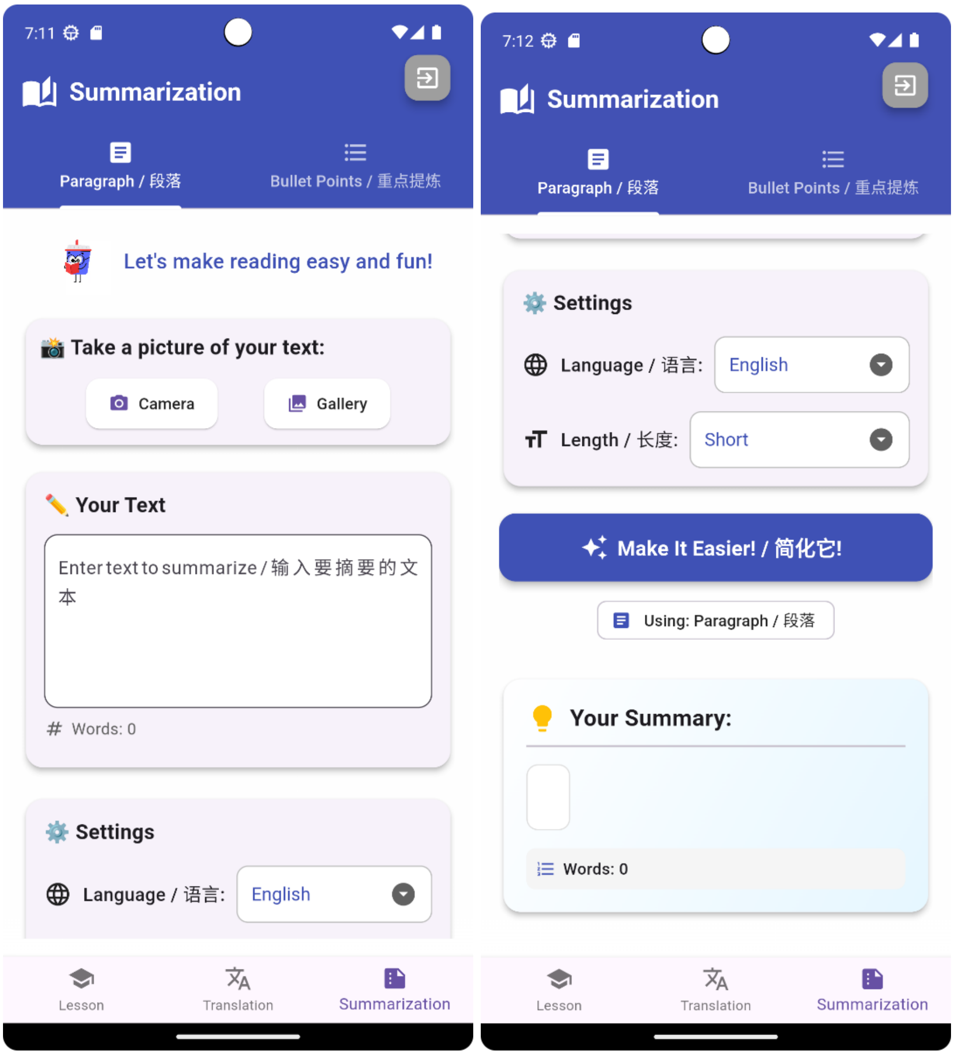


```dart
void translate(String source, String destin, String input) async {
  if (source == "--" || destin == "--" || input.isEmpty) {
    setState(() {
      output = "Please try again!";
    });
    return;
  }

  setState(() {
    output = "Working magic... 🟪✨";
  });

  GoogleTranslator translator = GoogleTranslator();
  try {
    var translation = await translator.translate(input, from: source, to: destin);
    setState(() {
      output = translation.text;
    });
  } catch (e) {
    setState(() {
      output = "Oops! Something went wrong. Try again!";
    });
```

Figure 5.27 Code Snippet of Calling Google Translation

One of this project's main objectives is integrating advanced language learning features, such as translation functions, to promote self-directed learning. This feature is helpful when users come across new terms and phrases while studying. As illustrated in Figure 5.25 on the left, the translation page in the proposed application contains a voice button for the user to input the voice, and then the recognized text will display in the text box. Alternatively, users can use the Google Translation packages included in Flutter to manually enter text in either Mandarin or English to be translated. The app supports translation from Mandarin to English and vice versa. Figure 5.25 shows the translated result displayed in the output box. In order to improve comprehension and pronunciation, an audio button is also included so that users may hear how the translated text is pronounced. Based on Figures 5.26 and 5.27, the code snippets demonstrate how essential packages such as translator, flutter_tts, and speech_to_text are used to implement this feature, including the logic for calling Google Translate services.

5.6 Text & Image Summarization Feature



Let's make reading easy and fun!

📸 Take a picture of your text:

✏️ Your Text

Enter text to summarize / 输入要摘要的文本

Words: 0

Settings

Language / 语言: English

Settings

Language / 语言: English

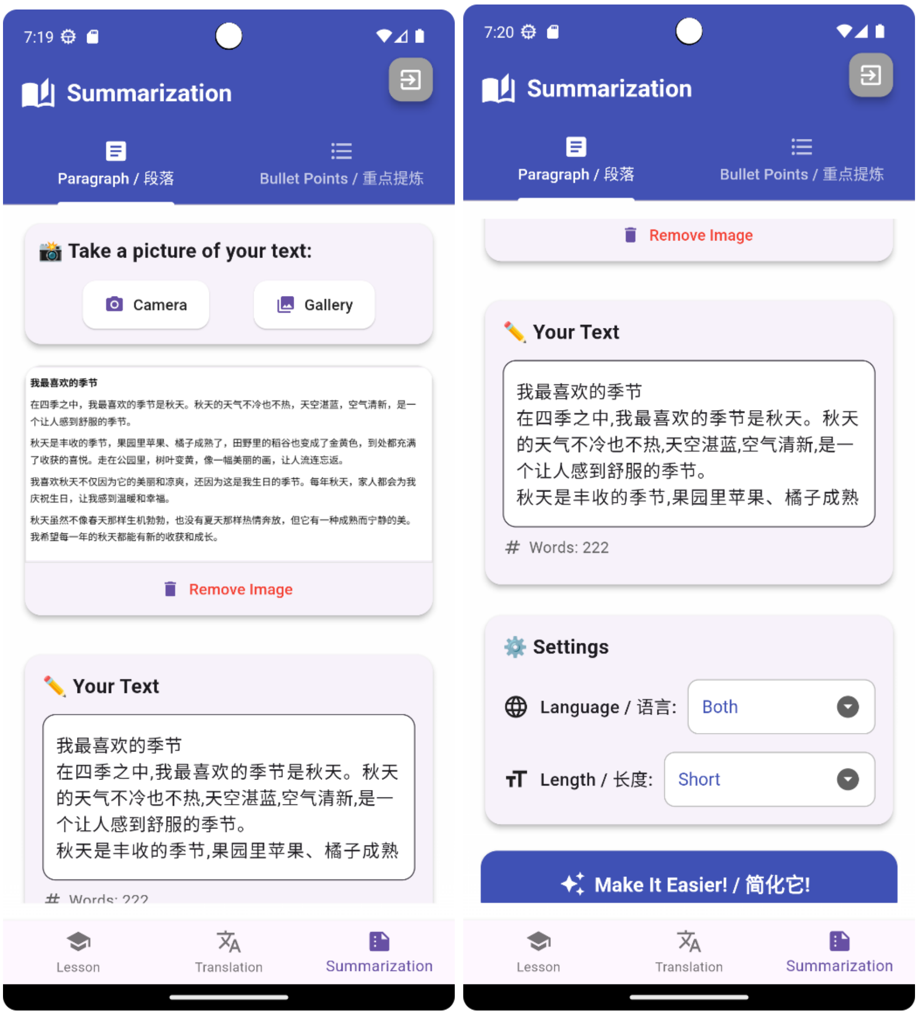
Length / 长度: Short

Using: Paragraph / 段落

Your Summary:

Words: 0

Figure 5.28 Summarization Page



我最喜欢的季节

在四季之中，我最喜欢的季节是秋天。秋天的天气不冷也不热，天空湛蓝，空气清新，是一个让人感到舒服的季节。

秋天是丰收的季节，果园里苹果、橘子成熟了，田野里的稻谷也变成了金黄色，到处都充满了收获的喜悦。走在公园里，树叶变黄，像一幅美丽的画，让人流连忘返。

我喜欢秋天不仅因为它的美丽和凉爽，还因为这是我生日的季节。每年秋天，家人都会为我庆祝生日，让我感到温暖和幸福。

秋天虽然不像春天那样生机勃勃，也没有夏天那样热情奔放，但它有一种成熟而宁静的美。我希望每一年的秋天都能有新的收获和成长。

✏️ Your Text

我最喜欢的季节
在四季之中,我最喜欢的季节是秋天。秋天的天气不冷也不热,天空湛蓝,空气清新,是一个让人感到舒服的季节。
秋天是丰收的季节,果园里苹果、橘子成熟

Words: 222

✏️ Your Text

我最喜欢的季节
在四季之中,我最喜欢的季节是秋天。秋天的天气不冷也不热,天空湛蓝,空气清新,是一个让人感到舒服的季节。
秋天是丰收的季节,果园里苹果、橘子成熟

Words: 222

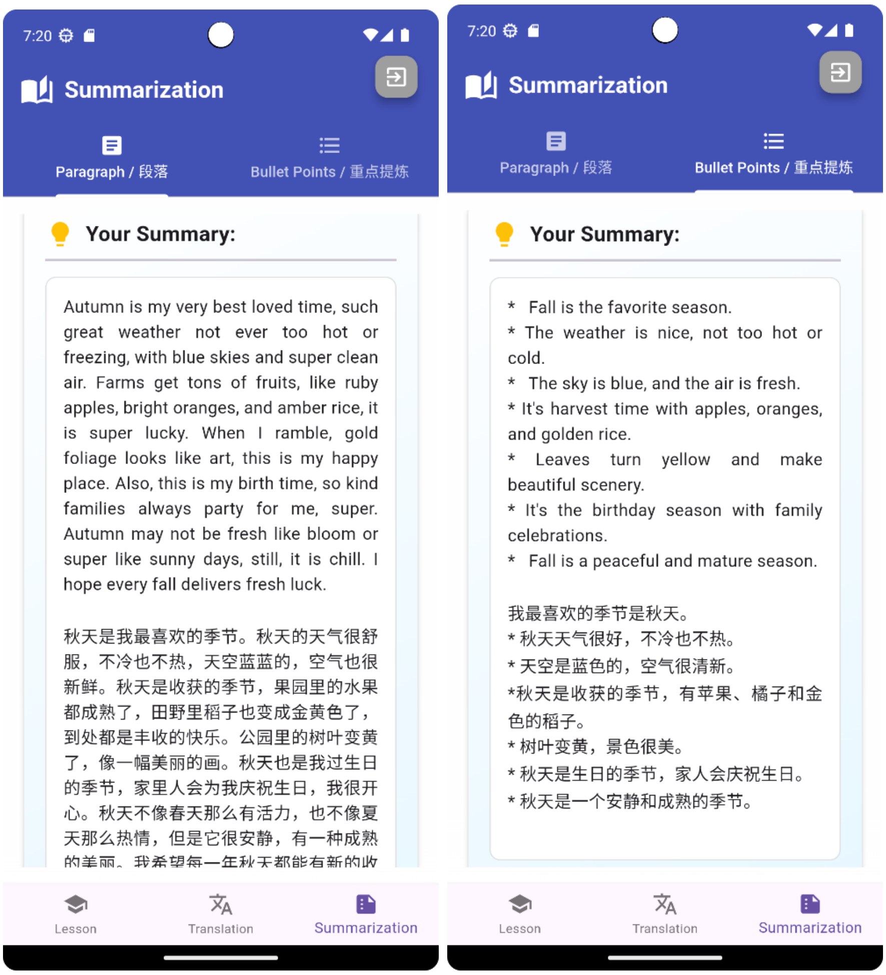
Settings

Language / 语言: Both

Length / 长度: Short

Figure 5.29 Image Text Extraction Result

The application integrates a summarization feature that supports text and image inputs, providing users with a flexible tool to condense learning content efficiently. As shown in Figure 5.28, users capture a new image or upload an existing image to summarize on the summation page. A text input box is also available for users who prefer to enter the text. Users can choose whether they want the summary output to be in Chinese, English, or both. The functionality allows users to customize the output to suit their preferences by providing three summary length options which are short, medium, and long. Figure 5.29 shows an example where the user uploads an image containing text. After employing optical character recognition (OCR) to extract the information, the application shows how many words were found in the input text field before producing the summary.



Your Summary:

Autumn is my very best loved time, such great weather not ever too hot or freezing, with blue skies and super clean air. Farms get tons of fruits, like ruby apples, bright oranges, and amber rice, it is super lucky. When I ramble, gold foliage looks like art, this is my happy place. Also, this is my birth time, so kind families always party for me, super. Autumn may not be fresh like bloom or super like sunny days, still, it is chill. I hope every fall delivers fresh luck.

秋天是我最喜欢的季节。秋天的天气很舒服，不冷也不热，天空蓝蓝的，空气也很新鲜。秋天是收获的季节，果园里的水果都成熟了，田野里稻子也变成金黄色了，到处都是丰收的快乐。公园里的树叶变黄了，像一幅美丽的画。秋天也是我过生日的季节，家里人会为我庆祝生日，我很开心。秋天不像春天那么有活力，也不像夏天那么热情，但是它很安静，有一种成熟的美丽。我希望每一年秋天都能有新的收

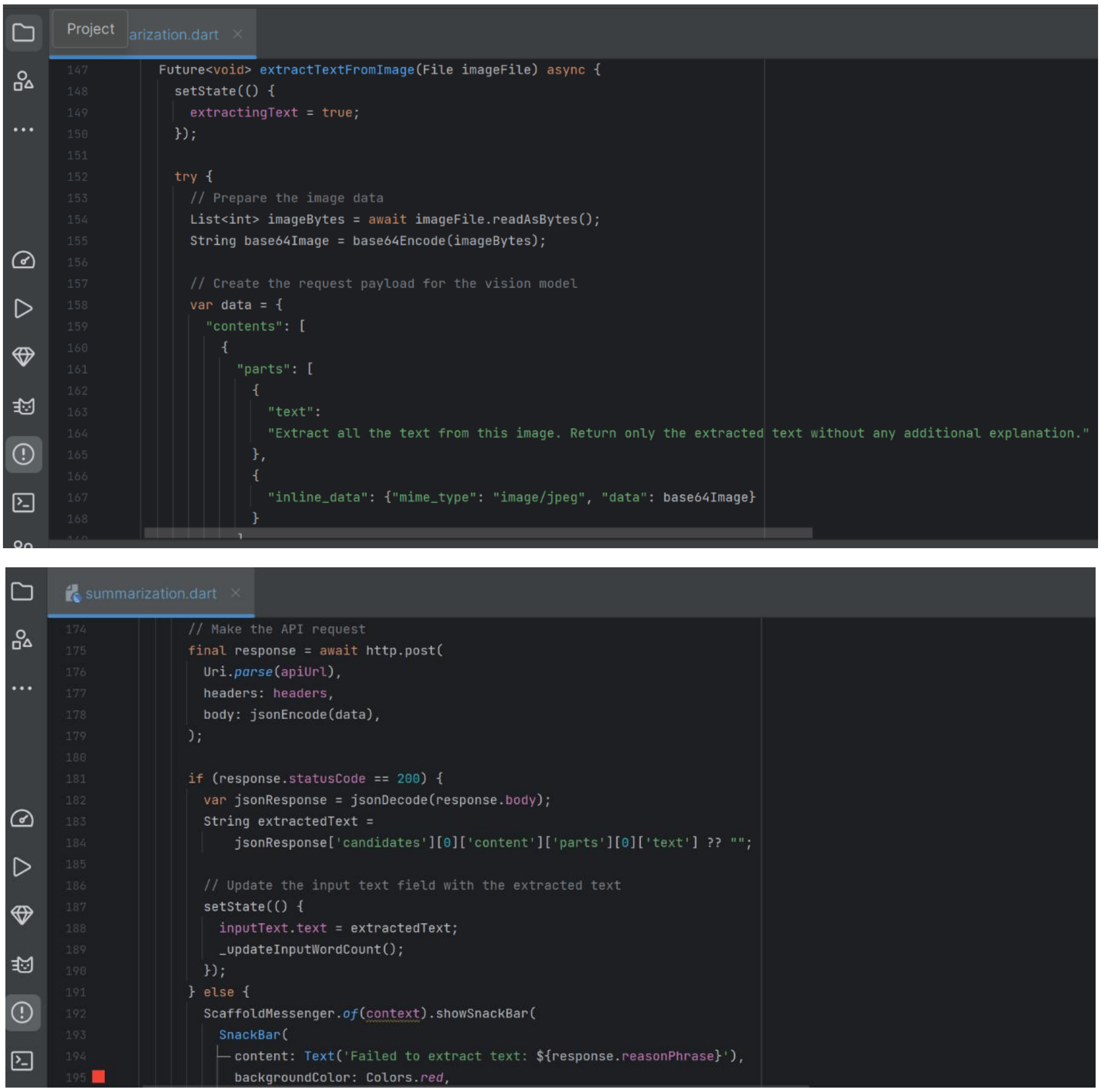
Your Summary:

* Fall is the favorite season.
* The weather is nice, not too hot or cold.
* The sky is blue, and the air is fresh.
* It's harvest time with apples, oranges, and golden rice.
* Leaves turn yellow and make beautiful scenery.
* It's the birthday season with family celebrations.
* Fall is a peaceful and mature season.

我最喜欢的季节是秋天。
* 秋天天气很好，不冷也不热。
* 天空是蓝色的，空气很清新。
*秋天是收获的季节，有苹果、橘子和金色的稻子。
* 树叶变黄，景色很美。
* 秋天是生日的季节，家人会庆祝生日。
* 秋天是一个安静和成熟的季节。

Figure 5.30 Paragraph Summary (Left) and Bulleted Summary (Right)

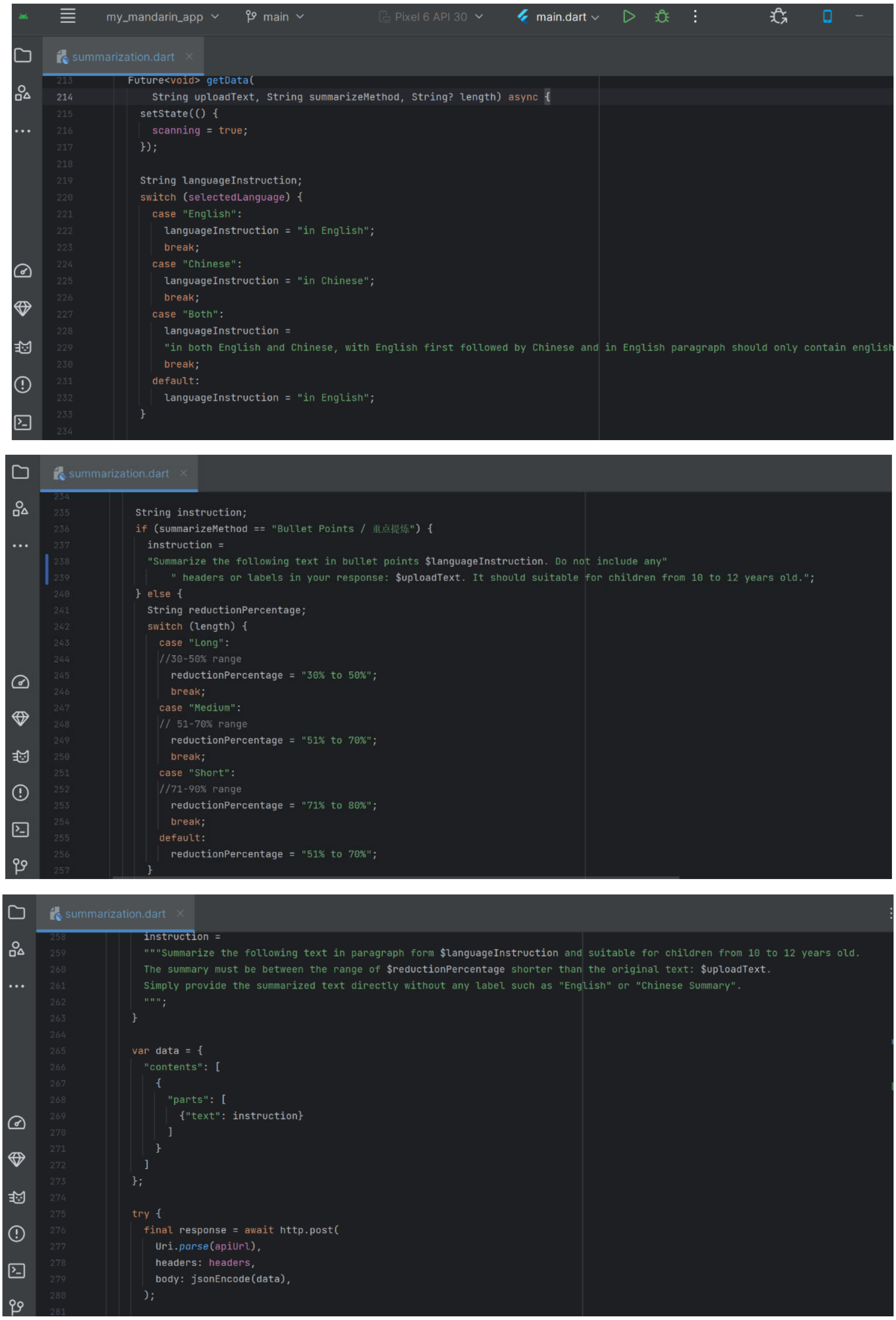
Figure 5.30 illustrates a tab bar provided at the top of the summarization page, allowing users to choose between two formats for their summarized result, such as paragraph form or bullet-point format. The result in paragraph form is displayed on the left side of the figure, while the bullet-point summary is shown on the right side. This dual-output approach accommodates various learning preferences, making sure that users are able to select the best format that fits their requirements. Additionally, the word count of the summarized result is displayed below the summary, helping users determine whether the summary meets their expectations in terms of length.



```
  Future<void> extractTextFromImage(File imageFile) async {
    setState(() {
      extractingText = true;
    });

    try {
      // Prepare the image data
      List<int> imageBytes = await imageFile.readAsBytes();
      String base64Image = base64Encode(imageBytes);

      // Create the request payload for the vision model
      var data = {
        "contents": [
          {
            "parts": [
              {
                "text":
                "Extract all the text from this image. Return only the extracted text without any additional explanation."
              },
              {
                "inline_data": {"mime_type": "image/jpeg", "data": base64Image}
              }
```

```
      // Make the API request
      final response = await http.post(
        Uri.parse(apiUrl),
        headers: headers,
        body: jsonEncode(data),
      );

      if (response.statusCode == 200) {
        var jsonResponse = jsonDecode(response.body);
        String extractedText =
            jsonResponse['candidates'][0]['content']['parts'][0]['text'] ?? "";

        // Update the input text field with the extracted text
        setState(() {
          inputText.text = extractedText;
          _updateInputWordCount();
        });
      } else {
        ScaffoldMessenger.of(context).showSnackBar(
          SnackBar(
            content: Text('Failed to extract text: ${response.reasonPhrase}'),
            backgroundColor: Colors.red,
```

Figure 5.31 Code Snippet of Calling Gemini API for OCR



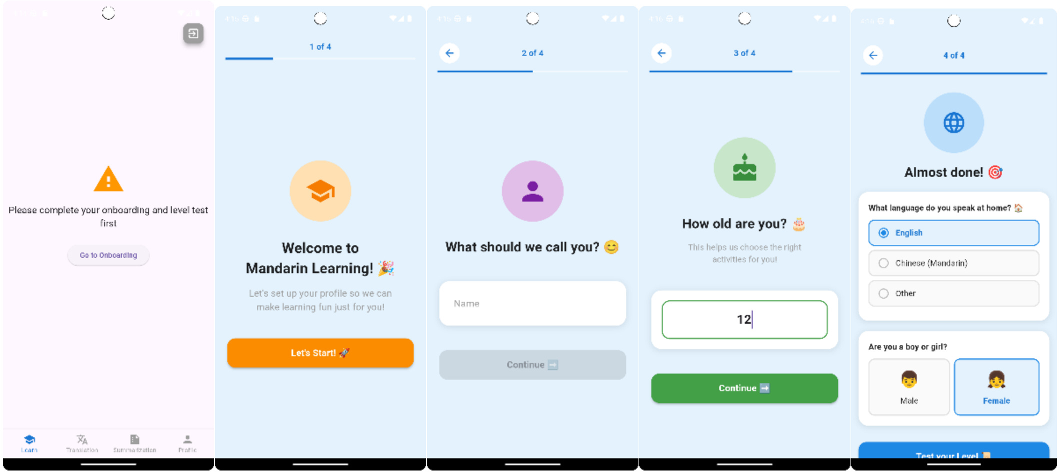
```
Future<void> getData(
    String uploadText, String summarizeMethod, String? length) async {
  setState(() {
    scanning = true;
  });

  String languageInstruction;
  switch (selectedLanguage) {
    case "English":
      languageInstruction = "in English";
      break;
    case "Chinese":
      languageInstruction = "in Chinese";
      break;
    case "Both":
      languageInstruction =
      "in both English and Chinese, with English first followed by Chinese and in English paragraph should only contain english
      break;
    default:
      languageInstruction = "in English";
  }

  String instruction;
  if (summarizeMethod == "Bullet Points / 重点提炼") {
    instruction =
    "Summarize the following text in bullet points $languageInstruction. Do not include any"
        " headers or labels in your response: $uploadText. It should suitable for children from 10 to 12 years old.";
  } else {
    String reductionPercentage;
    switch (length) {
      case "Long":
      //30-50% range
        reductionPercentage = "30% to 50%";
        break;
      case "Medium":
      // 51-70% range
        reductionPercentage = "51% to 70%";
        break;
      case "Short":
      //71-90% range
        reductionPercentage = "71% to 80%";
        break;
      default:
        reductionPercentage = "51% to 70%";
    }
    instruction =
    """Summarize the following text in paragraph form $languageInstruction and suitable for children from 10 to 12 years old.
    The summary must be between the range of $reductionPercentage shorter than the original text: $uploadText.
    Simply provide the summarized text directly without any label such as "English" or "Chinese Summary".
    """;
  }

  var data = {
    "contents": [
      {
        "parts": [
          {"text": instruction}
        ]
      }
    ]
  };

  try {
    final response = await http.post(
      Uri.parse(apiUrl),
      headers: headers,
      body: jsonEncode(data),
    );
```

Figure 5.32 Code Snippet of summarize text using Gemini model API

Based on Figure 5.31, the function extractTextFromImage is used to extract the text from the image. Before extracting the text from the image, the selected image needs to be converted to a Base64-encoded string so it can be sent to the API request body in the proper format the model understands. Then, the Gemini 2.0 Flash model analyzes the image and returns only the text it finds.

Figure 5.32 shows that the getData function, which is designed to summarize text using a Gemini model API, adapts the result based on language and formatting preferences, including language in English, Chinese, or both, the format in paragraph or bullet points, and summary length in long, medium, or short. To make sure the summary is suitable for children between the ages of 10 and 12, it provides instructions and dynamically constructs a prompt specific to these settings. Once the request has been sent, it counts words or characters based on the language specified, processes the answer to extract the summarized text, and refreshes the user interface with the outcome.

5.7 Entry-Level Test



Please complete your onboarding and level test first

1 of 4

Welcome to Mandarin Learning! 🎉

Let's set up your profile so we can make learning fun just for you!

2 of 4

What should we call you? 😊

Name

3 of 4

How old are you? 🎂

This helps us choose the right activities for you!

12

4 of 4

Almost done! 🎯

What language do you speak at home? 🏠

● English

○ Chinese (Mandarin)

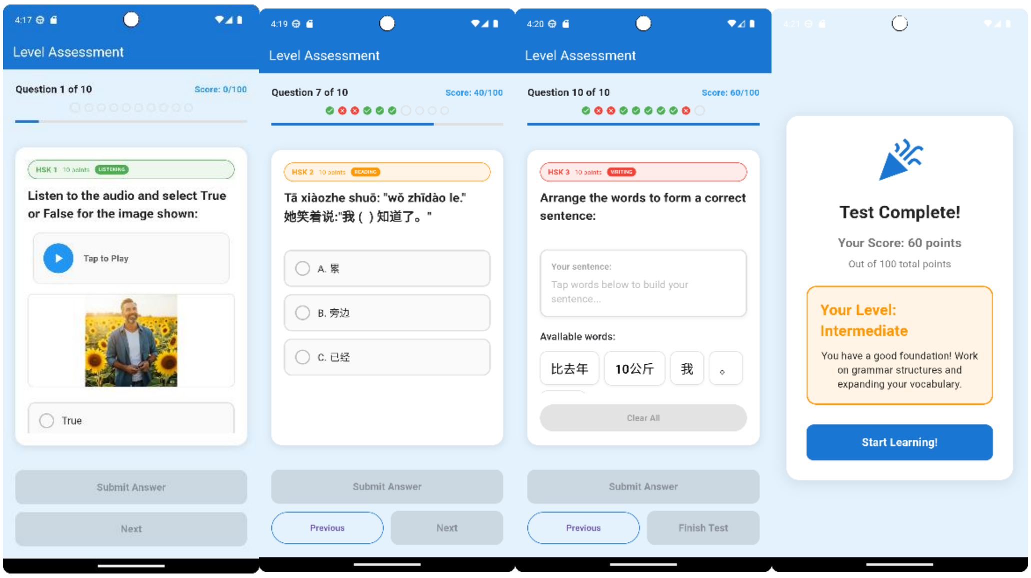
○ Other

Are you a boy or girl?

Male

Female

Figure 5.33 Onboarding page for New Users



Listen to the audio and select True or False for the image shown:

Tā xiàozhe shuō: "wǒ zhīdào le."
她笑着说:"我 ( ) 知道了。"

Arrange the words to form a correct sentence:

Your sentence:
Tap words below to build your sentence...

Test Complete!

Your Score: 60 points

Out of 100 total points

Your Level: Intermediate

You have a good foundation! Work on grammar structures and expanding your vocabulary.

Figure 5.34 Entry-level Test

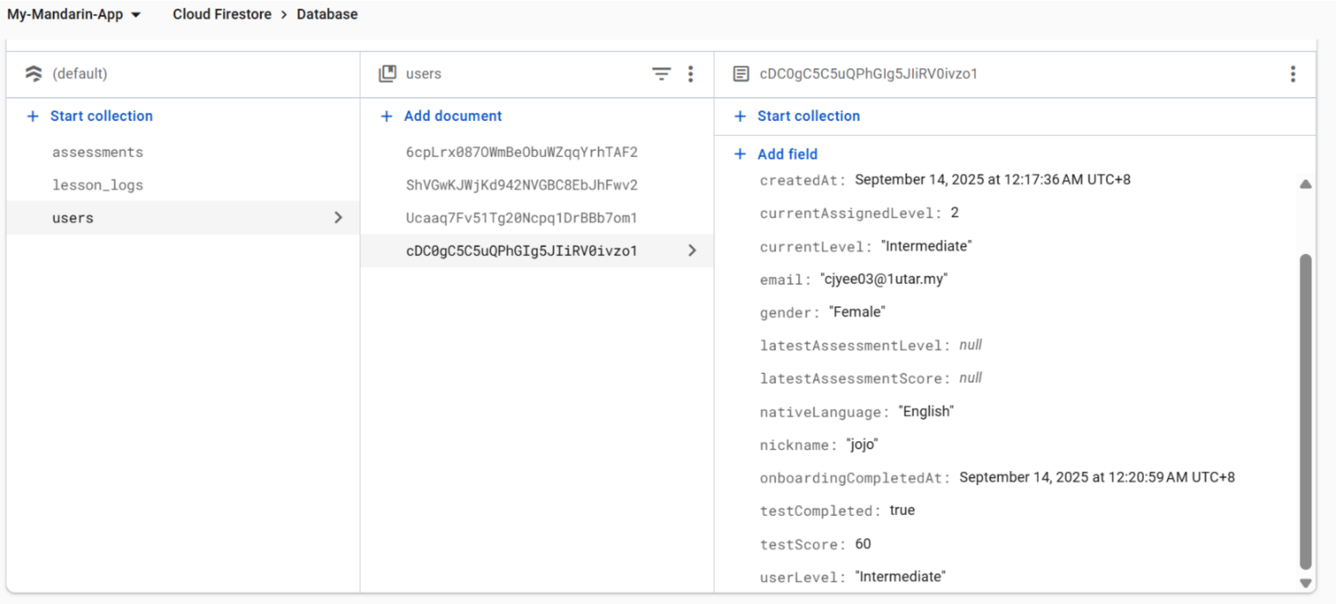
Figure 5.33 illustrates the onboarding page displayed when a new user accesses the application for the first time. At this stage, the user must now finish the onboarding process and attempt an entry-level test to determine their Mandarin language proficiency before accessing lessons and exercises. By selecting "Go to Onboarding", the application directs the user to complete a form that captures personal details such as name, age, gender, and native language spoken at home. As seen in Figure 5.34, the user moves on to the entry-level test after submitting. This test contains ten questions derived from past examination papers [23], with each question carrying ten marks. The test content is divided into three sections:

- Listening (four questions, consisting of two from HSK 1, one from HSK 2, and one from HSK 3)
- Reading (five questions, consisting of two from HSK 1, two from HSK 2, and one from HSK 3)
- Writing (one question from HSK 3)

Once the test is completed, the system calculates the total score and assigns the user to one of three proficiency levels:

1. Beginner (score below 50)
2. Intermediate (score between 50 and 79)
3. Advanced (score of 80 and above)

The user is subsequently presented with the allocated level and associated score, which are concurrently saved in the backend database. After that, the user can select "Start Learning!" to navigate to the level selection page, where lessons are made available based on the competency level specified.


My-Mandarin-App ▾ Cloud Firestore > Database

(default)

+ Start collection

assessments

lesson_logs

users >

users

+ Add document

6cpLrx087OWmBeObuWZqqYrhTAF2

ShVGwKJWjKd942NVGBC8EbJhFwv2

Ucaaq7Fv51Tg20Ncpq1DrBBb7om1

cDC0gC5C5uQPhGIg5JIiRV0ivzo1 >

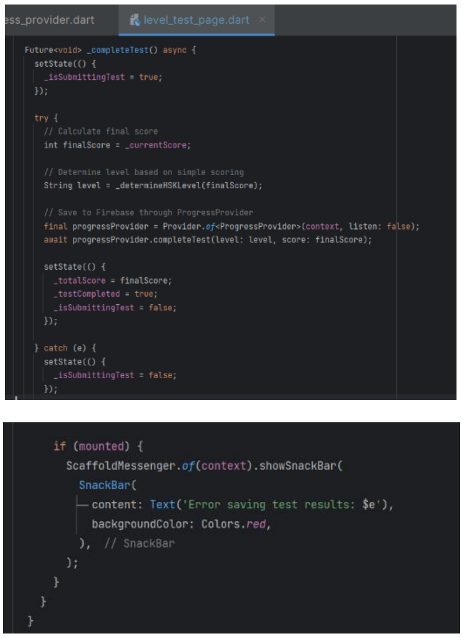
cDC0gC5C5uQPhGIg5JIiRV0ivzo1

+ Start collection

+ Add field

```
createdAt: September 14, 2025 at 12:17:36 AM UTC+8
currentAssignedLevel: 2
currentLevel: "Intermediate"
email: "cjyee03@1utar.my"
gender: "Female"
latestAssessmentLevel: null
latestAssessmentScore: null
nativeLanguage: "English"
nickname: "jojo"
onboardingCompletedAt: September 14, 2025 at 12:20:59 AM UTC+8
testCompleted: true
testScore: 60
userLevel: "Intermediate"
```

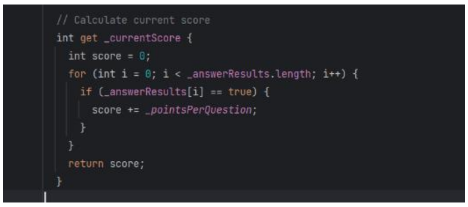
Figure 5.35 User records in Firestore Database



```
Future<void> _completeTest() async {
  setState(() {
    _isSubmittingTest = true;
  });

  try {
    // Calculate final score
    int finalScore = _currentScore;

    // Determine level based on simple scoring
    String level = _determineHSKLevel(finalScore);

    // Save to Firebase through ProgressProvider
    final progressProvider = Provider.of<ProgressProvider>(context, listen: false);
    await progressProvider.completeTest(level: level, score: finalScore);

    setState(() {
      _totalScore = finalScore;
      _testCompleted = true;
      _isSubmittingTest = false;
    });

  } catch (e) {
    setState(() {
      _isSubmittingTest = false;
    });
```

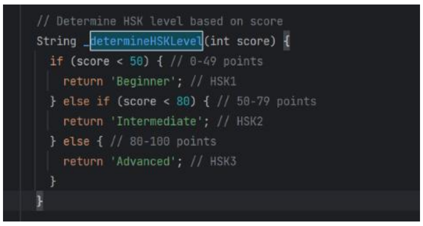
```
    if (mounted) {
      ScaffoldMessenger.of(context).showSnackBar(
        SnackBar(
          content: Text('Error saving test results: $e'),
          backgroundColor: Colors.red,
        ), // SnackBar
      );
    }
  }
}
```

Figure 5.36 Code snippet for the test completion and scoring method with Firebase integration



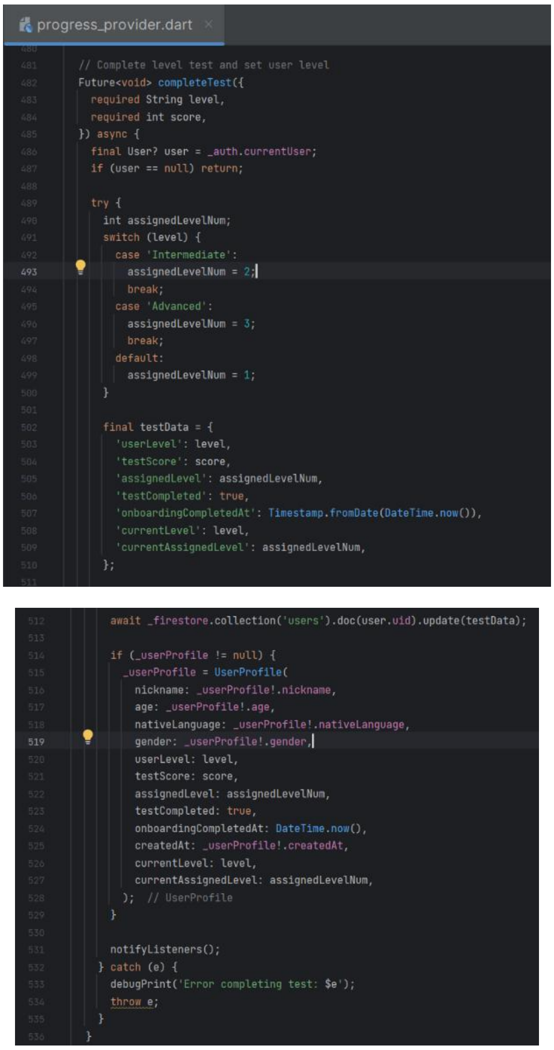
```
// Calculate current score
int get _currentScore {
  int score = 0;
  for (int i = 0; i < _answerResults.length; i++) {
    if (_answerResults[i] == true) {
      score += _pointsPerQuestion;
    }
  }
  return score;
}
```

Figure 5.37 Code snippet for calculating the current score



```
// Determine HSK level based on score
String _determineHSKLevel(int score) {
  if (score < 50) { // 0-49 points
    return 'Beginner'; // HSK1
  } else if (score < 80) { // 50-79 points
    return 'Intermediate'; // HSK2
  } else { // 80-100 points
    return 'Advanced'; // HSK3
  }
}
```

Figure 5.38 Code snippet for determining user's HSK level



```
// Complete level test and set user level
Future<void> completeTest({
  required String level,
  required int score,
}) async {
  final User? user = _auth.currentUser;
  if (user == null) return;

  try {
    int assignedLevelNum;
    switch (level) {
      case 'Intermediate':
        assignedLevelNum = 2;
        break;
      case 'Advanced':
        assignedLevelNum = 3;
        break;
      default:
        assignedLevelNum = 1;
    }

    final testData = {
      'userLevel': level,
      'testScore': score,
      'assignedLevel': assignedLevelNum,
      'testCompleted': true,
      'onboardingCompletedAt': Timestamp.fromDate(DateTime.now()),
      'currentLevel': level,
      'currentAssignedLevel': assignedLevelNum,
    };

    await _firestore.collection('users').doc(user.uid).update(testData);

    if (_userProfile != null) {
      _userProfile = UserProfile(
        nickname: _userProfile!.nickname,
        age: _userProfile!.age,
        nativeLanguage: _userProfile!.nativeLanguage,
        gender: _userProfile!.gender,
        userLevel: level,
        testScore: score,
        assignedLevel: assignedLevelNum,
        testCompleted: true,
        onboardingCompletedAt: DateTime.now(),
        createdAt: _userProfile!.createdAt,
        currentLevel: level,
        currentAssignedLevel: assignedLevelNum,
      );  // UserProfile
    }

    notifyListeners();
  } catch (e) {
    debugPrint('Error completing test: $e');
    throw e;
  }
}
```

Figure 5.39 Code snippet for saving a user's test results

As illustrated in Figure 5.35, user records are stored in the Firestore database under the user's collection. Each record contains both personal details and assessment results. In addition, timestamp fields such as createdAt and onboardingCompletedAt are recorded. Two fields, namely latestAssessmentLevel and latestAssessmentScore, are initially set to null and are updated whenever the user undertakes a new assessment.

As seen in Figure 5.36, the _completeTest() method controls the test completion procedure. This method first sets the flag _isSubmittingTest to indicate that submission is in progress. It then calculates the user's final score using the _currentScore method and determines the corresponding HSK level using the _determineHSKLevel method. Figures 5.37 and 5.38 show the code snippet of _currentScore method and _determineHSKLevel method.

Following this, the method invokes the completeTest() method within the ProgressProvider to record the results in Firestore. As shown in Figure 5.39, the completeTest() is responsible for storing the test results in the Firestore database and updating the local UserProfile state within the application. This ensures that both remote storage and local state management are synchronized. Furthermore, the method calls notifyListeners() to update any widgets that are dependent on the user profile data, thereby ensuring immediate reflection of the changes in the user interface.

If the process is successful, the application removes the submission flag and updates the user interface state with the test result. If there is an error, the flag is reset and the user is presented with an error message via SnackBar. This guarantees the seamless handling of user input and data persistence throughout the onboarding and test completion procedures.

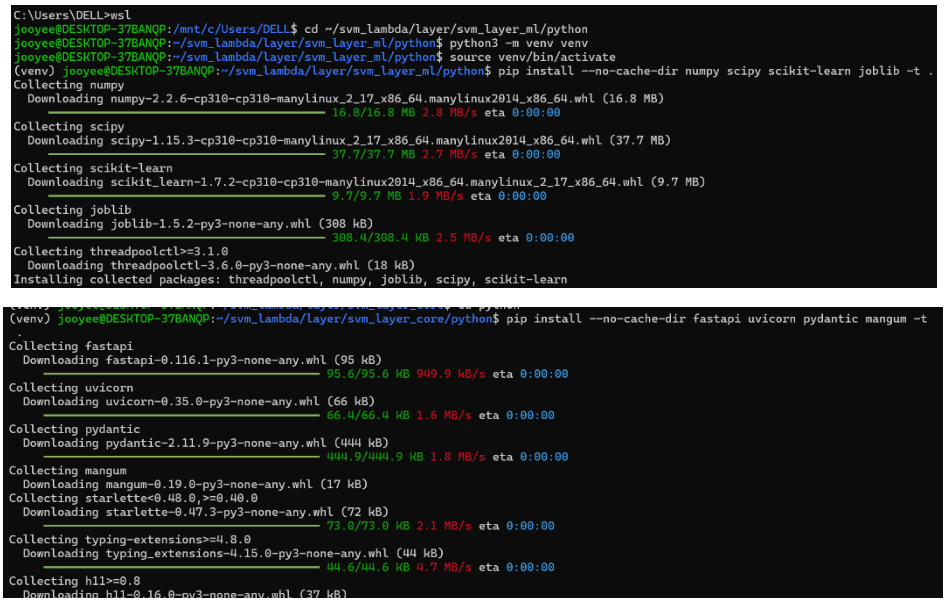
5.8 Performance Prediction Model

A performance prediction model was developed and integrated into the application to predict whether a user will pass or fail a level assessment. If the model predicts a failure, the system automatically recommends a review session before attempting the assessment. Three machine learning algorithms were considered, including Logistic Regression [39], Support Vector Machine [40], and Neural Networks [41] for model training.

Among these models, the Support Vector Machine [40] model was selected for deployment as it achieved the best performance during evaluation, which will be discussed in detail in Chapter 6. The model was trained in Jupyter Notebook, exported, and deployed on AWS Lambda. An API Gateway was configured to allow the application to send requests and receive prediction results. AWS Lambda was chosen because it provides a practical, cost-efficient, and scalable solution for hosting the model.

5.8.1 Model Deployment on AWS

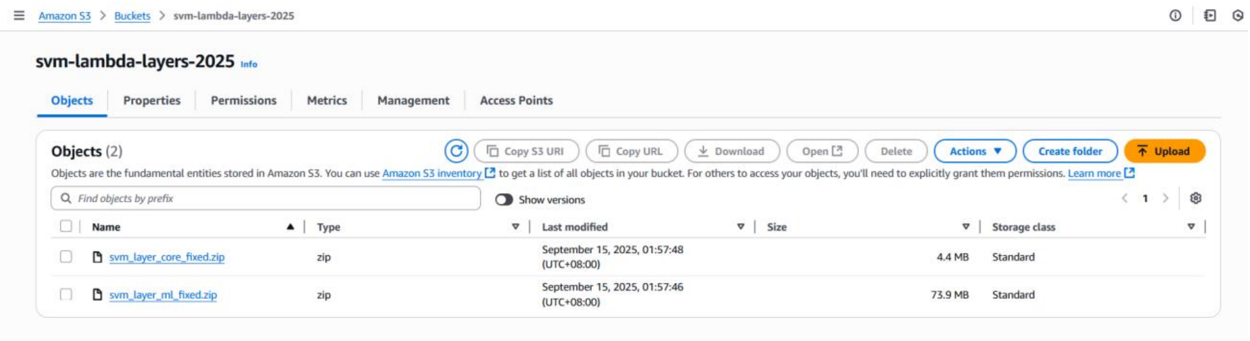
1. **Preparing Dependencies**



```
C:\Users\DELL>wsl
jooyee@DESKTOP-37BANQP:/mnt/c/Users/DELL$ cd ~/svm_lambda/layer/svm_layer_ml/python
jooyee@DESKTOP-37BANQP:~/svm_lambda/layer/svm_layer_ml/python$ python3 -m venv venv
jooyee@DESKTOP-37BANQP:~/svm_lambda/layer/svm_layer_ml/python$ source venv/bin/activate
(venv) jooyee@DESKTOP-37BANQP:~/svm_lambda/layer/svm_layer_ml/python$ pip install --no-cache-dir numpy scipy scikit-learn joblib -t .
Collecting numpy
  Downloading numpy-2.2.6-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (16.8 MB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 16.8/16.8 MB 2.8 MB/s eta 0:00:00
Collecting scipy
  Downloading scipy-1.15.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (37.7 MB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 37.7/37.7 MB 2.7 MB/s eta 0:00:00
Collecting scikit-learn
  Downloading scikit_learn-1.7.2-cp310-cp310-manylinux2014_x86_64.manylinux_2_17_x86_64.whl (9.7 MB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 9.7/9.7 MB 1.9 MB/s eta 0:00:00
Collecting joblib
  Downloading joblib-1.5.2-py3-none-any.whl (308 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 308.4/308.4 KB 2.5 MB/s eta 0:00:00
Collecting threadpoolctl>=3.1.0
  Downloading threadpoolctl-3.6.0-py3-none-any.whl (18 kB)
Installing collected packages: threadpoolctl, numpy, joblib, scipy, scikit-learn
```

```
(venv) jooyee@DESKTOP-37BANQP:~/svm_lambda/layer/svm_layer_core/python$ pip install --no-cache-dir fastapi uvicorn pydantic mangum -t
.
Collecting fastapi
  Downloading fastapi-0.116.1-py3-none-any.whl (95 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 95.6/95.6 KB 949.9 kB/s eta 0:00:00
Collecting uvicorn
  Downloading uvicorn-0.35.0-py3-none-any.whl (66 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 66.4/66.4 KB 1.6 MB/s eta 0:00:00
Collecting pydantic
  Downloading pydantic-2.11.9-py3-none-any.whl (444 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 444.9/444.9 KB 1.8 MB/s eta 0:00:00
Collecting mangum
  Downloading mangum-0.19.0-py3-none-any.whl (17 kB)
Collecting starlette<0.48.0,>=0.40.0
  Downloading starlette-0.47.3-py3-none-any.whl (72 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 73.0/73.0 KB 2.1 MB/s eta 0:00:00
Collecting typing-extensions>=4.8.0
  Downloading typing_extensions-4.15.0-py3-none-any.whl (44 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 44.6/44.6 KB 4.7 MB/s eta 0:00:00
Collecting h11>=0.8
  Downloading h11-0.16.0-py3-none-any.whl (37 kB)
```

Figure 5.40 Installation of the Required Packages in Linux



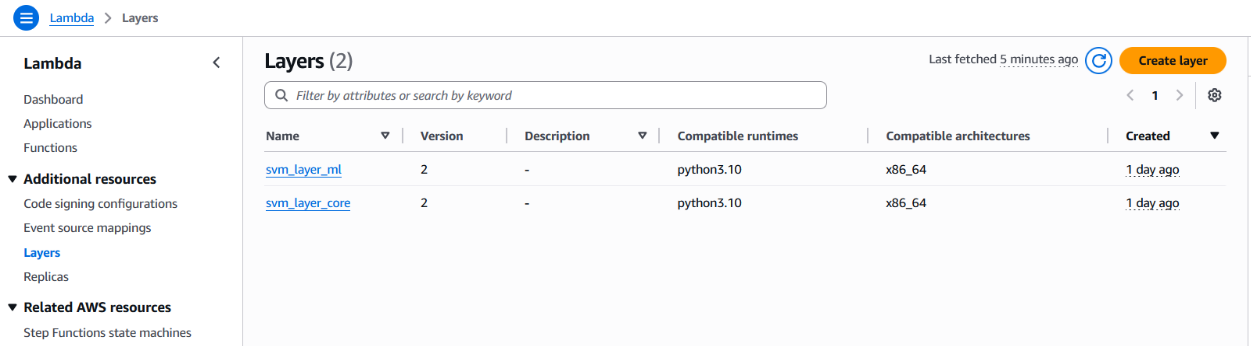
Objects are the fundamental entities stored in Amazon S3. You can use Amazon S3 inventory to get a list of all objects in your bucket. For others to access your objects, you'll need to explicitly grant them permissions. Learn more

□	Name	Type	Last modified	Size	Storage class
□	svm_layer_core_fixed.zip	zip	September 15, 2025, 01:57:48 (UTC+08:00)	4.4 MB	Standard
□	svm_layer_ml_fixed.zip	zip	September 15, 2025, 01:57:46 (UTC+08:00)	73.9 MB	Standard

Figure 5.41 Amazon S3 Console of "svm-lambda-layers-2025" Bucket

Figure 5.40 shows the code used to install the required packages into two separate folders for the Lambda layers within the Linux environment. The core layer includes the packages FastAPI, Uvicorn, Pydantic, and Mangum, while the machine learning layer contains NumPy, SciPy, scikit-learn, and joblib. After installation, each folder was compressed into a zip file and named "svm_layer_core_fixed" and "svm_layer_ml_fixed" respectively. Then, uploading both files to S3 allows them to be stored and retrieved reliably for integration into AWS Lambda. As shown in Figure 5.41, the "svm-lambda-layers-2025" bucket is created to store the two zip files. This is because the "svm_layer_ml_fixed" file exceeded the 10 MB direct upload limit for Lambda layers.

2. Creating the Lambda Function

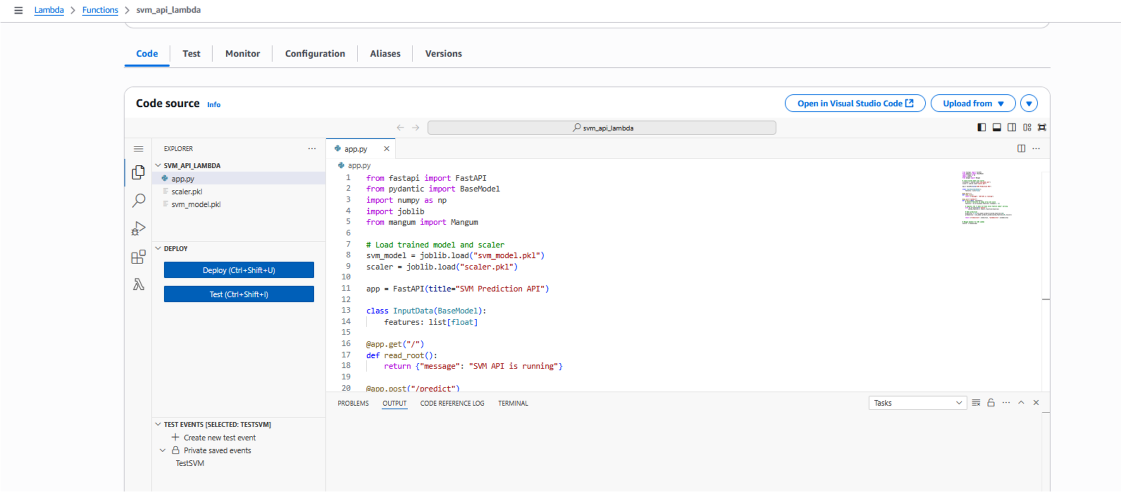


Name	Version	Description	Compatible runtimes	Compatible architectures	Created
svm_layer_ml	2	-	python3.10	x86_64	1 day ago
svm_layer_core	2	-	python3.10	x86_64	1 day ago

Figure 5.42 AWS Lambda console in the Layers Section

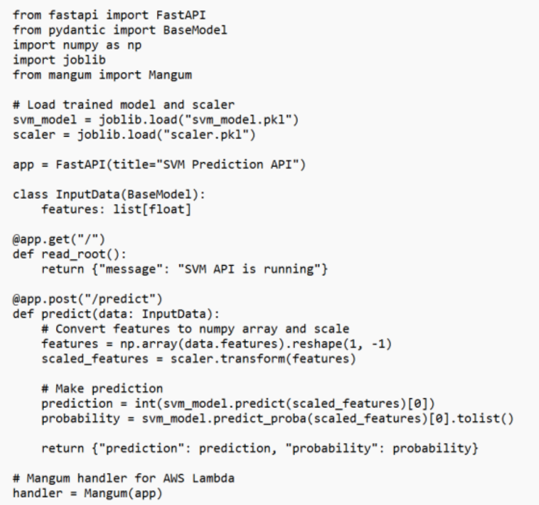
To enable deployment of the Support Vector Machine model, two Lambda layers were created which are "svm_layer_core" and "svm_layer_ml". These layers were uploaded from Amazon S3 using the previously stored zip files. Both layers were configured with the Python 3.10 runtime and the x86_64 architecture to ensure compatibility. Lambda layers are required to manage dependencies and reusable code efficiently across multiple Lambda functions.

Next, a Lambda function named “svm_api_lambda” was created. This function acts as the computational backend when integrated with API Gateway, enabling execution of the machine learning inference and the FastAPI application without the need for a dedicated server. The Lambda function executes only when triggered by API Gateway, making this approach lightweight, cost-efficient, and scalable.



```python
from fastapi import FastAPI
from pydantic import BaseModel
import numpy as np
import joblib
from mangum import Mangum

# Load trained model and scaler
svm_model = joblib.load("svm_model.pkl")
scaler = joblib.load("scaler.pkl")

app = FastAPI(title="SVM Prediction API")

class InputData(BaseModel):
    features: list[float]

@app.get("/")
def read_root():
    return {"message": "SVM API is running"}

@app.post("/predict")
```

Figure 5.43 AWS Lambda console for the function svm_api_lambda

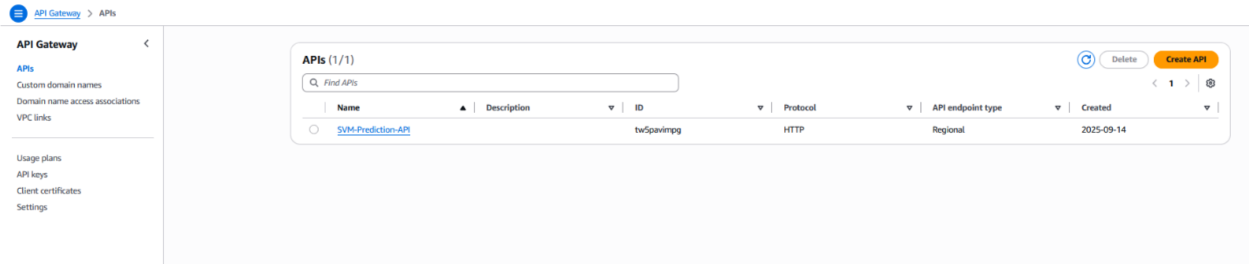


```python
from fastapi import FastAPI
from pydantic import BaseModel
import numpy as np
import joblib
from mangum import Mangum

# Load trained model and scaler
svm_model = joblib.load("svm_model.pkl")
scaler = joblib.load("scaler.pkl")

app = FastAPI(title="SVM Prediction API")

class InputData(BaseModel):
    features: list[float]

@app.get("/")
def read_root():
    return {"message": "SVM API is running"}

@app.post("/predict")
def predict(data: InputData):
    # Convert features to numpy array and scale
    features = np.array(data.features).reshape(1, -1)
    scaled_features = scaler.transform(features)

    # Make prediction
    prediction = int(svm_model.predict(scaled_features)[0])
    probability = svm_model.predict_proba(scaled_features)[0].tolist()

    return {"prediction": prediction, "probability": probability}

# Mangum handler for AWS Lambda
handler = Mangum(app)
```

Figure 5.44 Code of app.py

A deployment package was prepared containing three files, including app.py, scaler.pkl, and svm_model.pkl. These files were uploaded to the Lambda function. Figure 5.43 shows the AWS Lambda console for the function svm_api_lambda, where the uploaded files app.py, scaler.pkl, and svm_model.pkl are displayed. Figure 5.44 shows the code that is used to set up a REST API for the trained SVM model using FastAPI. The FastAPI application is wrapped with Mangum, which acts as a bridge between API Gateway and AWS Lambda, enabling cost-efficient and serverless hosting.

3. API Gateway Integration



Name	Description	ID	Protocol	API endpoint type	Created
SVM-Prediction-API		tw5pavimpg	HTTP	Regional	2025-09-14

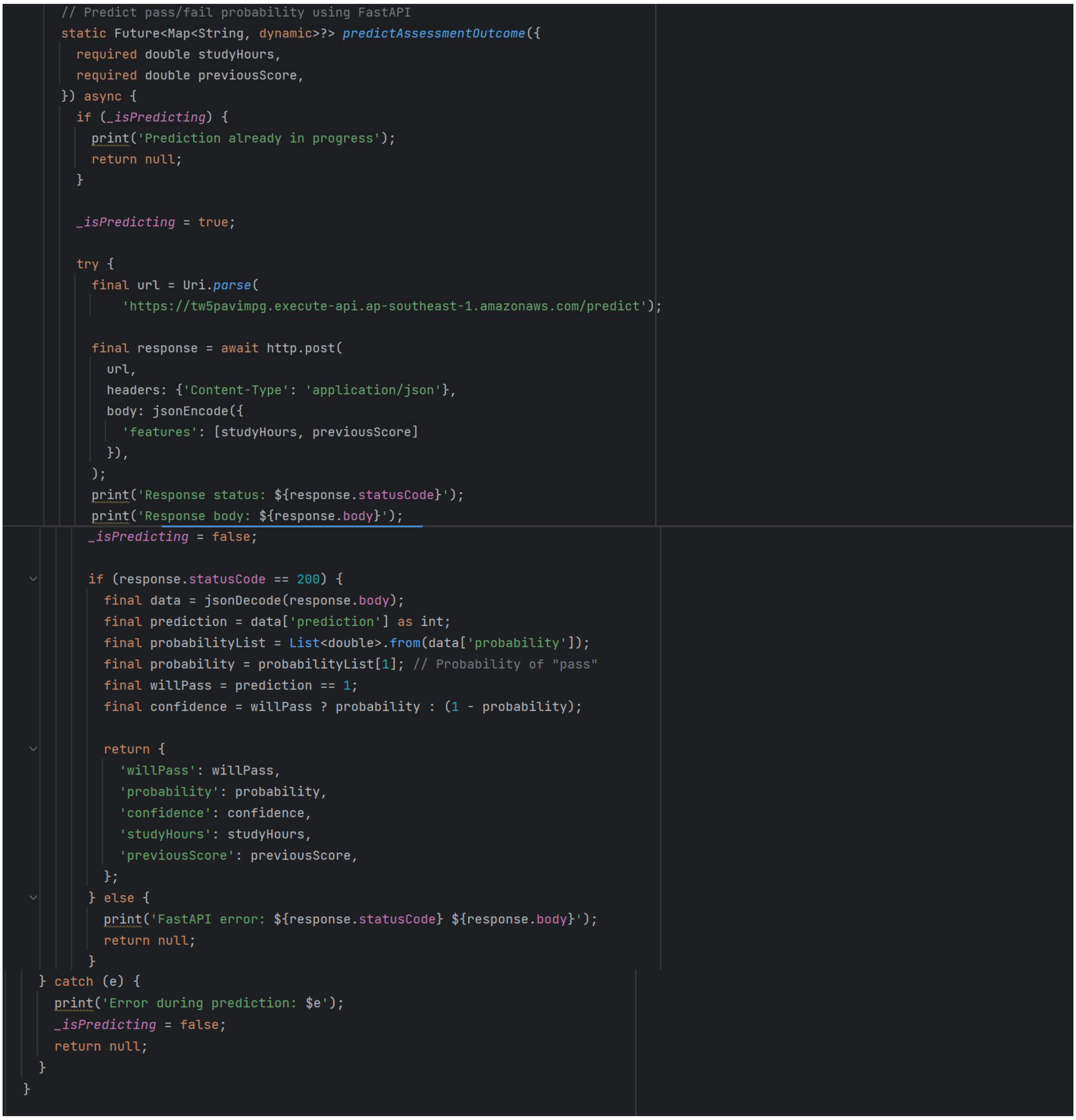
Figure 5.45 AWS API Gateway Console

An API named "SVM-Prediction-API" was created in API Gateway with the following configuration:

- API type: HTTP
- IP address type: IPv4
- Deployment setting: Auto-deploy enabled, ensuring that any changes to integrations, routes, or settings are automatically redeployed.

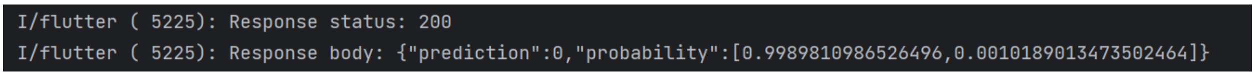
Figure 5.45 shows the created API "SVM-Prediction-API" in the AWS API Gateway Console. Then, a POST route was defined with the path /predict, and this route was integrated with the previously created Lambda function (svm_api_lambda). Once the configuration was completed, API Gateway generated an invoke URL in the Stages section, which serves as the endpoint for sending requests to the deployed model.

5.8.2 Model Operation in Application



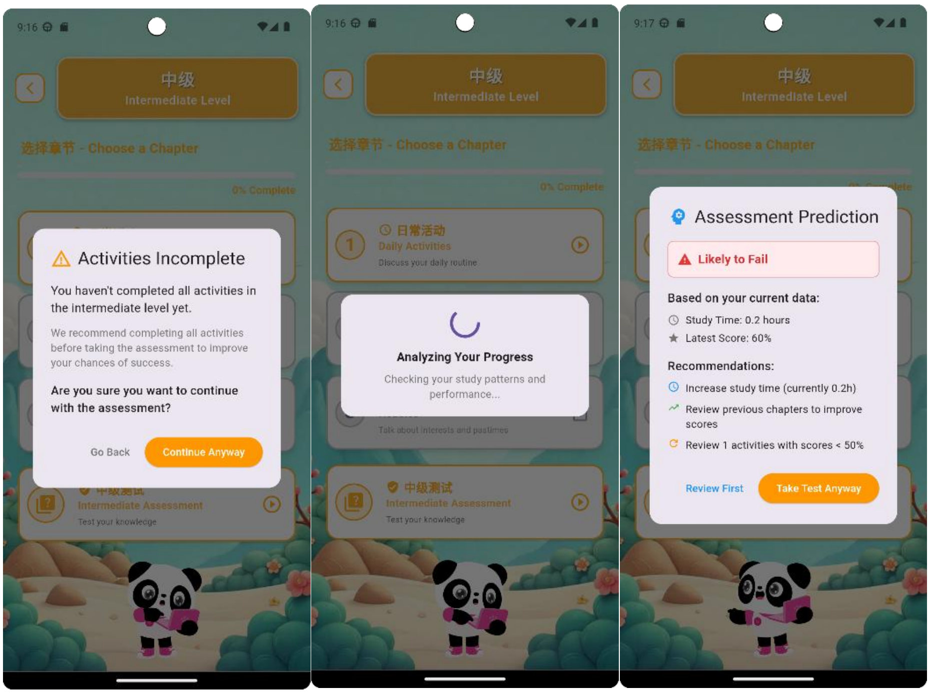
```
  // Predict pass/fail probability using FastAPI
  static Future<Map<String, dynamic>?> predictAssessmentOutcome({
    required double studyHours,
    required double previousScore,
  }) async {
    if (_isPredicting) {
      print('Prediction already in progress');
      return null;
    }

    _isPredicting = true;

    try {
      final url = Uri.parse(
          'https://tw5pavimpg.execute-api.ap-southeast-1.amazonaws.com/predict');

      final response = await http.post(
        url,
        headers: {'Content-Type': 'application/json'},
        body: jsonEncode({
          'features': [studyHours, previousScore]
        }),
      );
      print('Response status: ${response.statusCode}');
      print('Response body: ${response.body}');
      _isPredicting = false;

      if (response.statusCode == 200) {
        final data = jsonDecode(response.body);
        final prediction = data['prediction'] as int;
        final probabilityList = List<double>.from(data['probability']);
        final probability = probabilityList[1]; // Probability of "pass"
        final willPass = prediction == 1;
        final confidence = willPass ? probability : (1 - probability);

        return {
          'willPass': willPass,
          'probability': probability,
          'confidence': confidence,
          'studyHours': studyHours,
          'previousScore': previousScore,
        };
      } else {
        print('FastAPI error: ${response.statusCode} ${response.body}');
        return null;
      }
    } catch (e) {
      print('Error during prediction: $e');
      _isPredicting = false;
      return null;
    }
  }
```

Figure 5.46 Code Snippet for making the prediction request using FastAPI



```
I/flutter ( 5225): Response status: 200
I/flutter ( 5225): Response body: {"prediction":0,"probability":[0.9989810986526496,0.0010189013473502464]}
```

Figure 5.47 Sample of a Successful Response from the Model



Activities Incomplete

You haven't completed all activities in the intermediate level yet.

We recommend completing all activities before taking the assessment to improve your chances of success.

Are you sure you want to continue with the assessment?

Analyzing Your Progress

Checking your study patterns and performance...

Assessment Prediction

Likely to Fail

Based on your current data:

- Study Time: 0.2 hours
- Latest Score: 60%

Recommendations:

- Increase study time (currently 0.2h)
- Review previous chapters to improve scores
- Review 1 activities with scores < 50%

Figure 5.48 Example of the Application’s Performance Prediction Operation

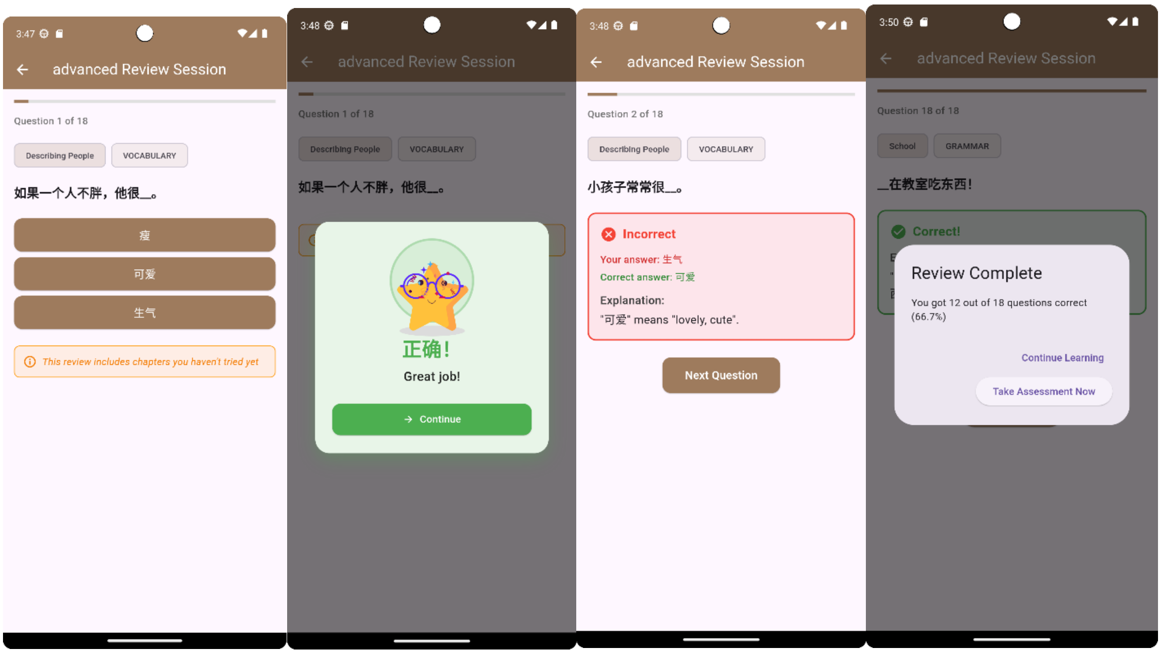
The Support Vector Machine model is not embedded directly within the Flutter mobile application. Instead, it is deployed on a cloud-based backend using FastAPI hosted on AWS Lambda, with Amazon API Gateway being used as the entry point for external requests. This architecture ensures that the computational workload is handled by the backend, keeping the mobile application lightweight and efficient.

As shown in Figure 5.46, the function predictAssessmentOutcome() acts as the integration point with the deployed model. This function collects the two input features which are study hours and previous exam score, and formats them into JSON for transmission to the backend model. A POST request is made to the API Gateway endpoint, which forwards the request to AWS Lambda. The Lambda function then executes the FastAPI service with the trained SVM model, processes the input features, and returns both the predicted class (Pass/Fail) and the associated probability as the model’s confidence score.

Next, the application interprets the response to guide user interaction. If the model predicts a high probability of success, the learner is permitted to proceed with the assessment. If the model predicts a high probability of failure, the application suggests completing additional review sessions before attempting the assessment, thereby improving the learner’s likelihood of success.

Figure 5.48 shows an example of the performance prediction operation in the application in the case that the learner has not completed all exercises in the current level. If the learner still chooses to continue with the level assessment, the application sends the request to the API Gateway endpoint and displays the prediction result along with recommended actions. The learner can then decide whether to review further or proceed with the assessment.

5.9 Review Session



Question 1 of 18

如果一个人不胖，他很__。

This review includes chapters you haven't tried yet

正确！

Great job!

Question 2 of 18

小孩子常常很__。

Incorrect

Your answer: 生气

Correct answer: 可爱

Explanation:

"可爱" means "lovely, cute".

Question 18 of 18

__在教室吃东西！

Correct!

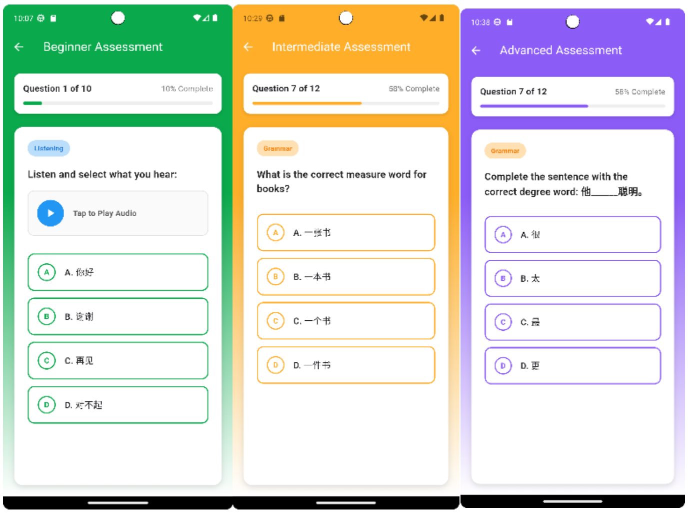
Review Complete

You got 12 out of 18 questions correct (66.7%)

Figure 5.49 Review Session

Figure 5.49 shows the review session that is provided to the user when the model predicts a high likelihood of failure. The review session is personalized based on the learner's performance in each activity. The application retrieves performance data from Firebase and identifies exercises that were either not attempted or scored below 50. A set of review questions is then generated to target these weak areas. During the review, immediate feedback with explanations is given to help the learner understand mistakes and reinforce learning. After completing the review session, the learner may choose to proceed with the assessment test or continue revising by practicing the review questions again.

5.10 Assessment Test in Each Level



Listen and select what you hear:

A. 你好
B. 谢谢
C. 再见
D. 对不起

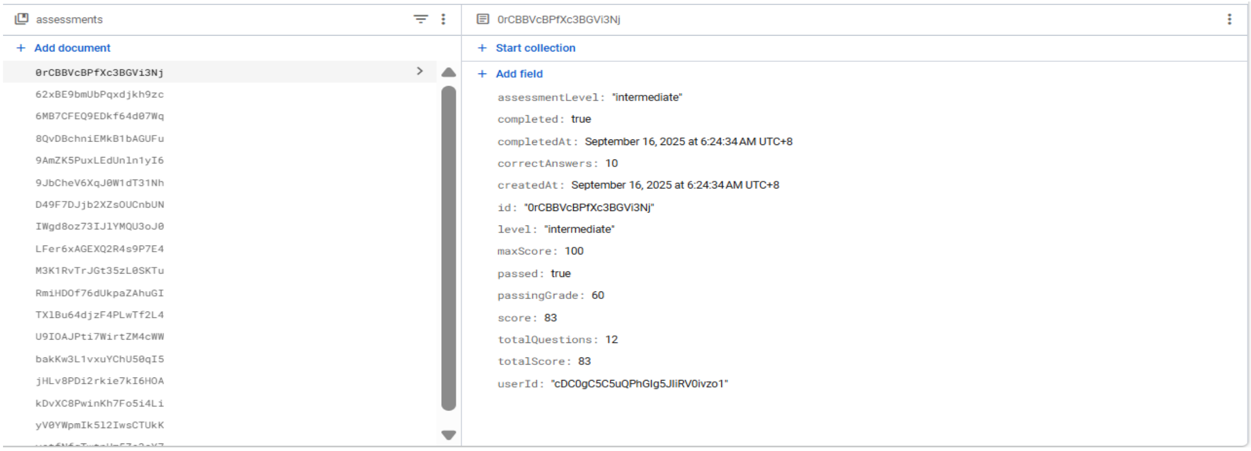
What is the correct measure word for books?

A. 一张书
B. 一本书
C. 一个书
D. 一件书

Complete the sentence with the correct degree word: 他_____聪明。

A. 很
B. 太
C. 最
D. 更

Figure 5.50 Assessment Test



```
0rCBBVcBPfXc3BGVi3Nj
62xBE9bmUbPqxdjkh9zc
6MB7CFEQ9EDkf64d07Wq
8QvDBchniEMkB1bAGUFu
9AmZK5PuxLEdUnln1yI6
9JbCheV6XqJ0W1dT31Nh
D49F7DJjb2XZsOUCnbUN
IWgd8oz73IJlYMQU3oJ0
LFer6xAGEXQ2R4s9P7E4
M3K1RvTrJGt35zL0SKTu
RmiHDOf76dUkpaZAhuGI
TXlBu64djzF4PLwTf2L4
U9IOAJPti7WirtZM4cWW
bakKw3L1vxuYChU50qI5
jHLv8PDi2rkie7kI6HOA
kDvXC8PwinKh7Fo5i4Li
yV0YWpmIk5l2IwsCTUkK
```

```
assessmentLevel: "intermediate"
completed: true
completedAt: September 16, 2025 at 6:24:34 AM UTC+8
correctAnswers: 10
createdAt: September 16, 2025 at 6:24:34 AM UTC+8
id: "0rCBBVcBPfXc3BGVi3Nj"
level: "intermediate"
maxScore: 100
passed: true
passingGrade: 60
score: 83
totalQuestions: 12
totalScore: 83
userId: "cDC0gC5C5uQPhGlg5JliRV0ivzo1"
```

Figure 5.51 Example of an Assessment Log Stored in Firebase

Figure 5.50 shows the assessment tests provided at the end of each learning level. The number of questions varies according to the learner's proficiency:

- 10 questions for the beginner level
- 12 questions for the intermediate level
- 15 questions for the advanced level

The passing threshold is set at 60 marks. When a learner passes the assessment, the test is marked as "passed" on the level selection page, and the next level is automatically unlocked. The assessment results are also logged into Firebase, specifically under the assessments collection, which records whether the learner successfully passed the test.

5.11 Implementation Issues and Challenges

During the development of the proposed application, one of the implementation challenges encountered was **designing lessons and exercises that are both appropriate and interesting for children** of different levels is a challenging task. This is because learning a language takes time, and it can be challenging to maintain the interest of the user over time. To address this, the application needs to track user progress and adaptively present varied and engaging material. Keeping the content entertaining and informative while maintaining adaptability increased the difficulty of implementation.

Another issue encountered when **deploying a Support Vector Machine model in a Flutter application** is its **lack of direct compatibility**. Flutter does not provide built-in support to run scikit-learn models. Unlike TensorFlow, which offers TensorFlow Lite for mobile deployment, Support Vector Machine does not have an official converter for integration into a mobile application. Manually porting the mathematical operations of the Support Vector Machine into Dart would be inefficient, error-prone, and difficult to maintain. To address this limitation, a bridge architecture was required to host the model externally and enable seamless integration with the Flutter application.

5.12 Concluding Remark

In summary, this chapter detailed the implementation of the proposed Mandarin language learning application, beginning with project setup and Firebase authentication for login and registration, followed by the development of thematic lessons and exercises in vocabulary, speaking, and grammar, supported by real-time feedback and a reward system. The advanced features like translation, summarization, entry-level testing, and assessment modules were incorporated to enhance self-directed learning and track user progress. A Support Vector Machine performance prediction model was deployed on AWS Lambda and connected through Application Programming Interface (API) Gateway, enabling seamless integration with the application to provide intelligent recommendations and personalized review sessions. This approach ensured that the model is accessed reliably, scaled in response to user demand, and maintained centrally. Despite challenges in designing suitable lessons and deploying machine learning models in Flutter, effective solutions were applied. As a result, a functional and adaptive Mandarin learning application was successfully developed, forming the basis for the system evaluation in the next chapter.

CHAPTER 6

System Evaluation and Discussion

6.1 Model Training and Evaluation

A machine learning model must be incorporated into the application for this project, based on the objective, to predict user performance in future assessment tests. This model aims to determine whether a user is likely to pass or fail based on their study hours and most recent assessment score. By providing these predictions, the proposed application can take immediate actions to support the user's learning progress.

For model training, Logistic Regression [39], Support Vector Machine [40], and Neural Networks [41] classification models were employed. This section outlines the process of developing and evaluating a machine learning model, from selecting essential libraries to data preprocessing, training, performance evaluation, fine-tuning, and serialization.

6.1.1 Logistic Regression

Logistic regression is a classification machine learning algorithm. It is particularly suitable for binary classification where the outcome falls into one of two categories. This algorithm utilizes the sigmoid function to transform outcomes into probability values ranging from 0 to 1, resulting in the characteristic "S"-shaped curve. In logistic regression, a threshold value, commonly set at 0.5, is used to determine the predicted class. If the sigmoid function outputs a value equal to or greater than the threshold, the input is categorized as Class 1. Otherwise, the input is categorized as Class 0 [30].

The Logistic Regression class in scikit-learn implements a regularized logistic regression classifier, supporting binary classification. It uses a penalty term to prevent overfitting with the default choice is L2. The hyperparameter C is the inverse of the regularization term that controls the strength of regularization [39]. The smaller values of C impose stronger regularization. The 'solver' parameter determines the optimization algorithm used to fit the model, and its choice is influenced by the dataset size, sparsity, and whether the problem is binary or multiclass. For example, "liblinear" is suitable for small datasets [39].

6.1.2 Support Vector Machine

Support Vector Machine [34] is a machine learning algorithm that is effective for binary classification tasks and well-suited for small datasets. Its objective is to find the hyperplane that optimizes the margin, which is the gap between the hyperplane and the closest data points from each class [34]. A larger margin generally leads to better generalization on unseen data. Support Vector Machine balances margin maximization and misclassification penalties using an objective function, typically incorporating hinge loss, where correctly classified points within the margin incur no penalty, and misclassified points incur a loss proportional to their distance from the margin. Even in cases where the data is not linearly separable, it uses kernel functions to implicitly map the data into a higher-dimensional space where it becomes linearly separable [34]. This allows it to find a decision boundary even for complex, non-linear patterns without explicitly computing the high-dimensional coordinates.

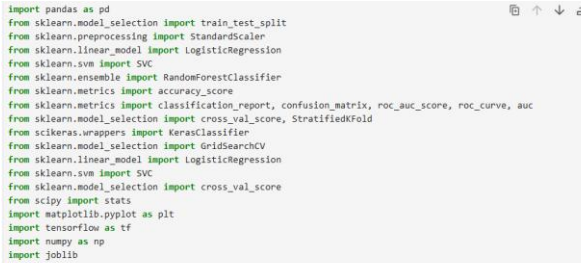
Several important hyperparameters affect the performance of the Support Vector Machine. The kernel parameter determines the type of transformation applied to the data for handling non-linear patterns. Common options include 'linear' for linearly separable data, 'poly' for polynomial feature spaces, and 'rbf', which is Radial Basis Function for distance-based transformations [34]. The C parameter controls the compromise between maximizing the margin and reducing classification errors [40]. A smaller C allows a wider margin with more tolerance for misclassifications, improving generalization, whereas a larger C forces the model to fit the training data more strictly, potentially leading to overfitting. The Radial Basis Function kernel's gamma parameter measures the impact of one training example [40]. While a large gamma concentrates on nearby points, producing more complex boundaries that may overfit the data, a small gamma takes into account points that are far away, resulting in smoother decision boundaries.

6.1.3 Neural Network

Neural networks are machine learning models that replicate the intricate workings of the human brain. Neural Networks learn complex, non-linear patterns in data. Its architecture typically consists of an input layer that receives data, hidden layers that utilize weighted sums and activation functions to perform transformations, and an output layer that produces results. Neural networks operate through iterative forward propagation, error assessment, and backpropagation. In forward propagation, weighted sums and activation functions are used to pass inputs through layers of neurons and generate outputs. A loss function measures the difference between expected and actual outcomes. Then, backpropagation computes gradients of this error and modifies the weights and biases via an optimization algorithm. The accuracy of neural networks is progressively increased through this cycle over multiple iterations [37].

Neural networks rely on several key hyperparameters that significantly influence their performance and generalization ability. The learning rate controls the speed at which a model adjusts its parameters during training. A small learning rate can slow convergence, while a large rate can cause instability. The capacity of the network is determined by the total number of hidden layers and the number of neurons per layer, with deeper or wider networks being more expressive but also more prone to overfitting. The activation function is a crucial hyperparameter, as it significantly impacts the model's performance and rate of convergence. Other important hyperparameters include the batch size, which affects the stability and speed of training, as well as regularization parameters [44].

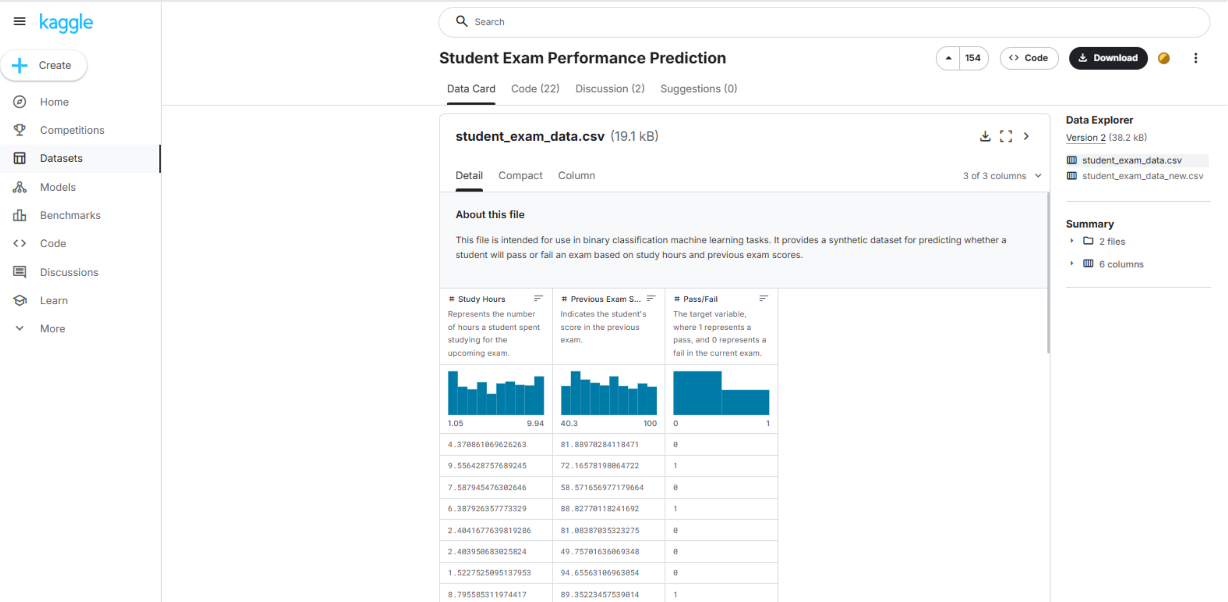
6.1.4 Data Preprocessing



```python
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score
from sklearn.metrics import classification_report, confusion_matrix, roc_auc_score, roc_curve, auc
from sklearn.model_selection import cross_val_score, StratifiedKFold
from scikeras.wrappers import KerasClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.model_selection import cross_val_score
from scipy import stats
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np
import joblib
```

Figure 6.1 Importing Necessary Libraries in Jupyter Notebook

Figure 6.1 illustrates that the necessary libraries were imported into Jupyter Notebook for model training and evaluation, including Pandas and NumPy, which were utilized for data handling and computation.



Student Exam Performance Prediction

student_exam_data.csv (19.1 kB)

About this file

This file is intended for use in binary classification machine learning tasks. It provides a synthetic dataset for predicting whether a student will pass or fail an exam based on study hours and previous exam scores.

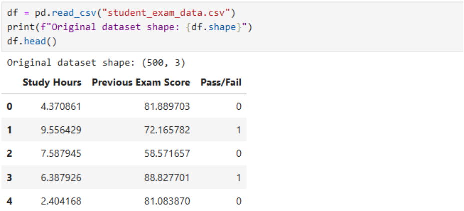
# Study Hours	# Previous Exam S...	# Pass/Fail
Represents the number of hours a student spent studying for the upcoming exam.	Indicates the student's score in the previous exam.	The target variable, where 1 represents a pass, and 0 represents a fail in the current exam.
4.370861069626263	81.88970284118471	0
9.556428757689245	72.16578198064722	1
7.587945476302646	58.571656977179664	0
6.387926357773329	88.82770118241692	1
2.4041677639819286	81.08387035323275	0
2.403950683025824	49.75701636069348	0
1.5227525095137953	94.65563106963054	0
8.795585311974417	89.35223457539014	1

Figure 6.2 Student Exam Performance Prediction Dataset on Kaggle

Table 6.1 Data Attributes of the Student Exam Performance Prediction Dataset

Data Attribute	Variable Type	Example	Remark
Study Hours	Numeric (Continuous)	4.37	Number of hours student studied for the upcoming exam.
Previous Exam Score	Numeric (Continuous)	81.89	Score obtained in the last exam (0–100).
Pass/Fail	Binary (Categorical)	0	Target variable: 1 = Pass, 0 = Fail.

The dataset used is the Student Exam Performance Prediction dataset [22], which consists of 500 samples with two input features and one binary output target label. Table 6.1 lists each attribute along with its corresponding variable type. This dataset is used because it contains relevant features, such as study hours and previous exam scores, that are suitable for building a model to predict a student's success (Pass/Fail) based on key performance indicators. This prediction is required to provide a personalized and effective learning path for children.

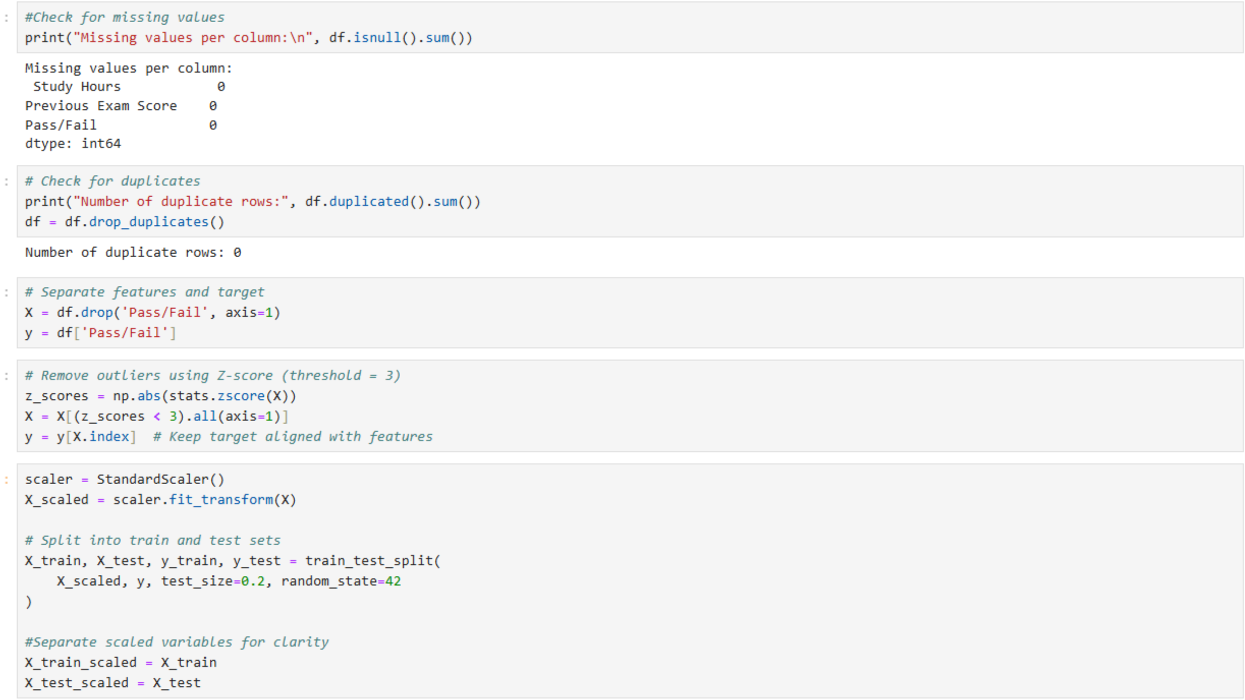


```
df = pd.read_csv("student_exam_data.csv")
print(f"Original dataset shape: {df.shape}")
df.head()
```

```
Original dataset shape: (500, 3)
```

	Study Hours	Previous Exam Score	Pass/Fail
0	4.370861	81.889703	0
1	9.556429	72.165782	1
2	7.587945	58.571657	0
3	6.387926	88.827701	1
4	2.404168	81.083870	0

Figure 6.3 Code Snippets of Load Dataset



```
#Check for missing values
print("Missing values per column:\n", df.isnull().sum())
```

```
Missing values per column:
 Study Hours            0
Previous Exam Score    0
Pass/Fail              0
dtype: int64
```

```
# Check for duplicates
print("Number of duplicate rows:", df.duplicated().sum())
df = df.drop_duplicates()
```

```
Number of duplicate rows: 0
```

```
# Separate features and target
X = df.drop('Pass/Fail', axis=1)
y = df['Pass/Fail']
```

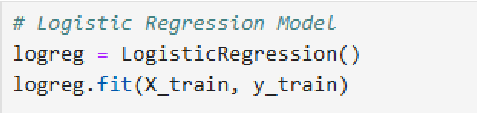
```
# Remove outliers using Z-score (threshold = 3)
z_scores = np.abs(stats.zscore(X))
X = X[(z_scores < 3).all(axis=1)]
y = y[X.index]  # Keep target aligned with features
```

```
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)

# Split into train and test sets
X_train, X_test, y_train, y_test = train_test_split(
    X_scaled, y, test_size=0.2, random_state=42
)

#Separate scaled variables for clarity
X_train_scaled = X_train
X_test_scaled = X_test
```

Figure 6.4 Code Snippets of Preprocessing Steps

Preprocessing is essential for enhancing accuracy and model performance, particularly when the dataset is relatively small. First, load the dataset and display its shape along with the first five samples. Then, checked for missing values and duplicate rows in the dataset. There are no missing values and duplicate rows. Next, the features X and target Y were separated, and Z-scores were computed to detect and remove extreme outliers, ensuring data reliability. StandardScaler is used to perform feature scaling, which is especially important for models such as Logistic Regression, Support Vector Machine, and Neural Networks that are sensitive to scale differences. Finally, the dataset was split into 80% training and 20% testing sets. Figures 6.3 and 6.4 illustrate the code used to load the dataset and perform the data preprocessing step.

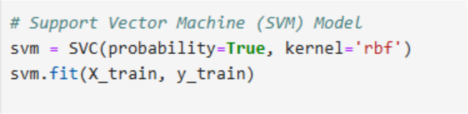
6.1.5 Model Training



```
# Logistic Regression Model
logreg = LogisticRegression()
logreg.fit(X_train, y_train)
```

Figure 6.5 Code Snippets of Logistic Regression Model Training

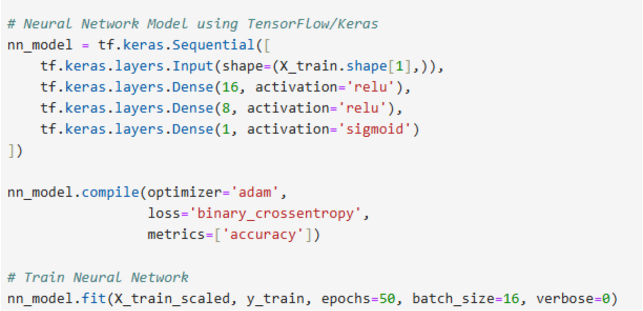
After preprocessing the data, a Logistic Regression classifier was created for this binary classification task. The training dataset was used to train the Logistic Regression model, which allowed the model to learn the weights of each feature to predict the probability that a sample belongs to a particular class.



```
# Support Vector Machine (SVM) Model
svm = SVC(probability=True, kernel='rbf')
svm.fit(X_train, y_train)
```

Figure 6.6 Code Snippets of Support Vector Machine Model Training

A Support Vector Classifier was also implemented using the radial basis function (RBF) kernel. The classifier was trained with the fit(X_train, y_train) function to determine the optimal hyperplane for separating the classes in the data.



```
# Neural Network Model using TensorFlow/Keras
nn_model = tf.keras.Sequential([
    tf.keras.layers.Input(shape=(X_train.shape[1],)),
    tf.keras.layers.Dense(16, activation='relu'),
    tf.keras.layers.Dense(8, activation='relu'),
    tf.keras.layers.Dense(1, activation='sigmoid')
])

nn_model.compile(optimizer='adam',
                 loss='binary_crossentropy',
                 metrics=['accuracy'])

# Train Neural Network
nn_model.fit(X_train_scaled, y_train, epochs=50, batch_size=16, verbose=0)
```

Figure 6.7 Code Snippets of Neural Network Model Training

For the neural network model training, the Sequential() class was used to build a neural network with an input layer corresponding to the number of features. 16 neurons with ReLU activation for the first hidden layer, 8 neurons for the second hidden layer, and 1 neuron with sigmoid activation for the output layer for binary classification tasks. Compiling the Neural Network using the optimizer='adam' with loss='binary_crossentropy which is a loss function for a binary classification task. Adaptive Moment Estimation (Adam) is one of the common optimizers that is able to handle sparse gradients and non-stationary targets effectively [42].

Then, train the model with 50 epochs, 16 for batch_size, and verbose is 0, which suppresses output logs while training.

6.1.6 Performance Metrics

Performance metrics evaluate models' accuracy, precision, recall, F1-score, and 5-fold cross-validation accuracy, providing a comprehensive understanding of their classification task performance. In this context, TP refers to true positives, TN is true negatives, FP refers to false positives, and FN refers to false negatives.

1. Accuracy is known as the overall proportion of correct predictions made by the model, and the formula is in equation (1).
2. Precision is the proportion of positive predictions made by the model that are correct, and the formula is shown in equation (2).
3. Recall is the fraction of real positive cases in a dataset that a model accurately detects, and the formula is indicated in equation (3).
4. F1-score is a balanced indicator of a classification model's performance that is a harmonic average of precision and recall and is shown in equation (4).
5. 5-Fold Cross-Validation is a method that divides a dataset into five folds, trains the model on four folds, and tests it on the remaining fold five times. The average accuracy of all five folds is taken into account to report the final performance. This method ensures that the model performs consistently across various dataset subsets and lowers the chance of overfitting.

Equations:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \tag{1}$$

$$\text{Precision} = \frac{TP}{TP + FP} \tag{2}$$

$$\text{Recall} = \frac{TP}{TP + FN} \tag{3}$$

$$\text{F1-Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \tag{4}$$

6.1.7 Model Evaluation

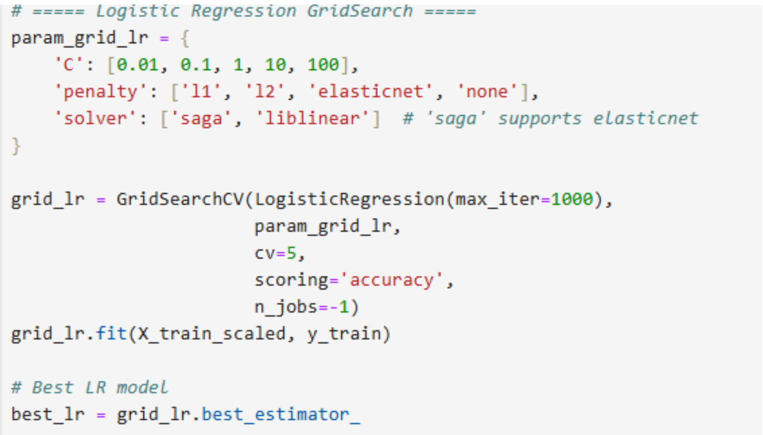
Table 6.2 Comparative Performance Metrics of Machine Learning Models

Model	Training Accuracy	Test Accuracy	Precision	Recall	F1 - Score	5-Fold CV Accuracy
Logistic Regression	0.8700	0.8600	0.8235	0.7778	0.8000	0.8675
Neural Network	1.0000	0.9800	1.0000	0.9444	0.9714	0.9875
Support Vector Machine	0.9975	0.9500	0.9697	0.8889	0.9275	0.9950

Logistic Regression [39], Support Vector Machine [40], and Neural Network [41] models were trained on the dataset to evaluate their performance based on the parameters discussed in Section 1.5. Table 6.2 presents a comparison of their performance metrics.

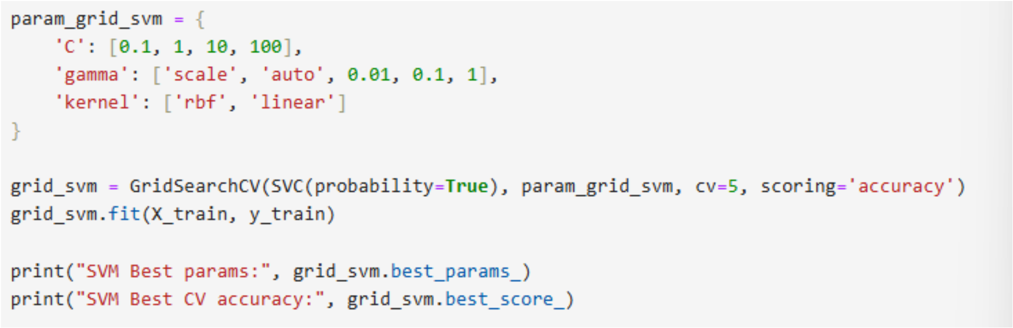
Logistic Regression achieved moderate performance, with a test accuracy of 86% and a recall of 77.78%, suggesting some underfitting. The neural network achieved a test accuracy of 98% and an F1 score of 97.14%. However, perfect training accuracy indicates potential overfitting, particularly given the small dataset and limited features. The Support Vector Machine demonstrated a strong balance between accuracy and generalization, achieving 95% test accuracy, an F1 score of 92.75%, and the highest average of 5-fold cross-validation accuracy results, along with a high precision of 96.97% and a recall of 88.89%. Overall, the Support Vector Machine provides the most reliable performance, and further fine-tuning is required to enhance its effectiveness and efficiency.

6.1.8 Model Fine-Tuning and Evaluation



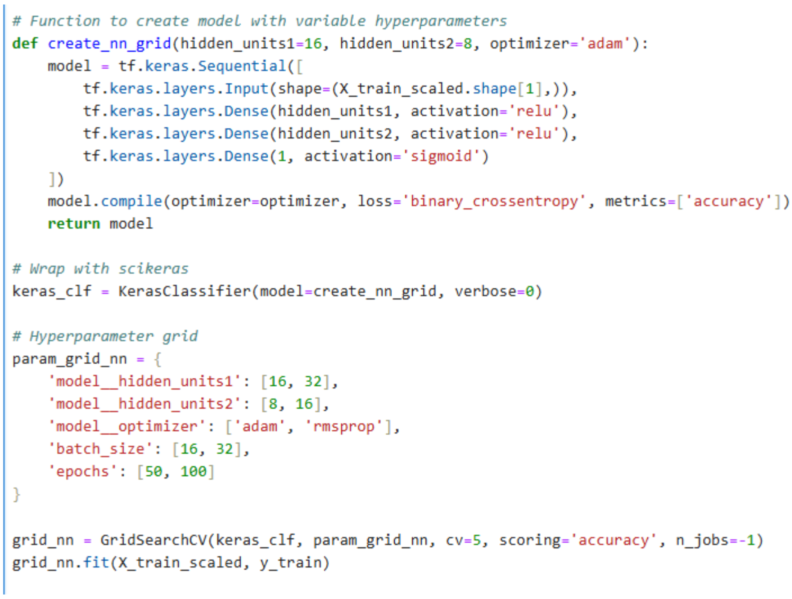
```
# ===== Logistic Regression GridSearch =====
param_grid_lr = {
    'C': [0.01, 0.1, 1, 10, 100],
    'penalty': ['l1', 'l2', 'elasticnet', 'none'],
    'solver': ['saga', 'liblinear']  # 'saga' supports elasticnet
}

grid_lr = GridSearchCV(LogisticRegression(max_iter=1000),
                       param_grid_lr,
                       cv=5,
                       scoring='accuracy',
                       n_jobs=-1)
grid_lr.fit(X_train_scaled, y_train)

# Best LR model
best_lr = grid_lr.best_estimator_
```

Figure 6.8 Code Snippets for Logistic Regression Hyperparameter Tunning



```
param_grid_svm = {
    'C': [0.1, 1, 10, 100],
    'gamma': ['scale', 'auto', 0.01, 0.1, 1],
    'kernel': ['rbf', 'linear']
}

grid_svm = GridSearchCV(SVC(probability=True), param_grid_svm, cv=5, scoring='accuracy')
grid_svm.fit(X_train, y_train)

print("SVM Best params:", grid_svm.best_params_)
print("SVM Best CV accuracy:", grid_svm.best_score_)
```

Figure 6.9 Code Snippets for Support Vector Machine Hyperparameter Tunning



```
# Function to create model with variable hyperparameters
def create_nn_grid(hidden_units1=16, hidden_units2=8, optimizer='adam'):
    model = tf.keras.Sequential([
        tf.keras.layers.Input(shape=(X_train_scaled.shape[1],)),
        tf.keras.layers.Dense(hidden_units1, activation='relu'),
        tf.keras.layers.Dense(hidden_units2, activation='relu'),
        tf.keras.layers.Dense(1, activation='sigmoid')
    ])
    model.compile(optimizer=optimizer, loss='binary_crossentropy', metrics=['accuracy'])
    return model

# Wrap with scikeras
keras_clf = KerasClassifier(model=create_nn_grid, verbose=0)

# Hyperparameter grid
param_grid_nn = {
    'model__hidden_units1': [16, 32],
    'model__hidden_units2': [8, 16],
    'model__optimizer': ['adam', 'rmsprop'],
    'batch_size': [16, 32],
    'epochs': [50, 100]
}

grid_nn = GridSearchCV(keras_clf, param_grid_nn, cv=5, scoring='accuracy', n_jobs=-1)
grid_nn.fit(X_train_scaled, y_train)
```

Figure 6.10 Code Snippets for Neural Network Hyperparameter Tunning

Table 6.3 Comparative Performance Metrics of Fine-Tuned Machine Learning Models

Model	Training Accuracy	Test Accuracy	Precision	Recall	F1 Score	5-Fold CV Accuracy
Logistic Regression	0.8750	0.8600	0.8438	0.7500	0.7941	0.8775
Neural Network	1.0000	0.9900	1.0000	0.9722	0.9859	0.9850
Support Vector Machine	**0.9975**	**0.9700**	**1.0000**	**0.9167**	**0.9565**	**0.9975**

Table 6.4 Best Hyperparameters of Fine-Tuned Machine Learning Models

Model	Best Hyperparameters
Logistic Regression	C = 0.1, penalty = l2, solver = saga
Support Vector Machine	C = 10, gamma = scale, kernel = rbf
Neural Network	batch_size = 16, epochs = 50, hidden_units1 = 32, hidden_units2 = 8, optimizer = rmsprop

For model fine-tuning, the goal is to identify the optimal hyperparameter that yields the best generalization on unseen data. Grid Search is used for hyperparameter tuning by systematically attempting each conceivable combination of predetermined values within a defined range [45].

For Logistic Regression, a parameter grid is defined with different values of C (regularization strength), including 0.01,0.1,1, 100 and 100, and penalty (l1, l2, elasticnet, none), and the solver, which is the liblinear or saga. Figure 6.8 shows the code for hyperparameter tuning using GridSearch for Logistic Regression.

For Support Vector Machine, the parameter grid explores different values of C (regularization), including 0.1, 1, 10, and 100, gamma (kernel coefficient), including the scale, auto, 0.01,0.1,1, and kernel type (linear or rbf). Figure 6.9 shows the code for hyperparameter tuning using GridSearch for the Support Vector Machine.

For Neural Network, a function build_model() is used to create a flexible neural network with adjustable learning rate, dropout rate, L2 regularisation strength, number of layers, and number of neurons per layer. The model is wrapped with KerasClassifier so it can work with scikit-learn’s tools. As shown in Figure 6.10, the parameter grid in Neural Network defines the potential values for the hyperparameters, and GridSearchCV with 5-fold cross-validation was used to evaluate the models and output the best parameter.

As shown in Tables 6.2 and 6.3, the Logistic Regression model achieved a reasonable test accuracy of 86% after fine-tuning, which is the same as the baseline model, with a training accuracy of 87.5%. It demonstrated a relatively high precision of 84.38% and a 5-fold cross-validation accuracy of 87.75%. However, the model still underfits and performs worse than the other models, even after fine-tuning. Only slight improvements were observed in precision from 82.35% to 84.38%, and cross-validation accuracy from 86.75% to 87.75%, while test accuracy remained unchanged. This suggests that Logistic Regression is too simple to capture complex data patterns compared to Support Vector Machine and Neural Networks.

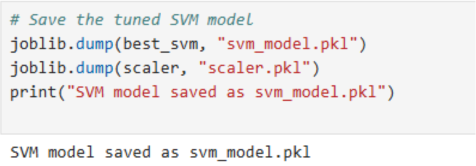
The Neural Network achieved the highest performance across most metrics, with 100% training accuracy, 99% test accuracy, and an F1 score of 98.59%, outperforming both Logistic Regression and Support Vector Machine. However, perfect training accuracy is a strong indicator of overfitting, particularly given the small dataset size and the use of only two input features. Although test accuracy improved slightly from 98% to 99% after fine-tuning, and recall increased from 94.44% to 97.22%, the cross-validation accuracy slightly decreased from 98.75% to 98.50%, suggesting reduced stability.

The performance of the Support Vector Machine was further optimized by hyperparameter tuning to enhance its performance. The best hyperparameter was determined for employing a Radial Basis Function kernel, a regularization parameter C of 10, and gamma set to scale. As shown in Table 6.4, the tuned Support Vector Machine model demonstrated a significant improvement over the baseline version. It achieved the best cross-validation accuracy of 99.75% among the tuned models and demonstrated strong generalization across various data subsets. Test accuracy increased from 95% to 97%, recall improved from 88.89% to 91.67%, and the F1-score rose from 92.75% to 95.65%. Importantly, the Support Vector Machine model demonstrated that all the positive predictions made by the model were correct, as evidenced by a perfect precision score. This reduces the chance of incorrectly determining that the student should fail.

Although the neural network achieved the highest test accuracy, it showed obvious evidence of overfitting and incurred higher computational costs compared to other models due to its complex architecture. Logistic regression tends to underperform compared to other models and lacks the capacity to model complex relationships.

In this case, the fine-tuned Support Vector Machine provides the best balance between generalization and performance. With a strong cross-validation accuracy of 99.75%, a high test accuracy of 97%, perfect precision, and no evidence of overfitting, it demonstrates both reliability and stability. Therefore, the fine-tuned Support Vector Machine was chosen as the final model for deployment in the proposed application.

6.1.9 Model Serialization



```
# Save the tuned SVM model
joblib.dump(best_svm, "svm_model.pkl")
joblib.dump(scaler, "scaler.pkl")
print("SVM model saved as svm_model.pkl")
```

```
SVM model saved as svm_model.pkl
```

Figure 6.11 Code Snippet for Saving Tuned Support Vector Machine Model and Scaler

As the Support Vector Machine model provides the best reliability and generalization based on the output result, the tuned Support Vector Machine model is saved to disk as a file named “svm_model”. joblib.dump(scaler, "scaler.pkl") is to save the scaler to ensure the exact same scaling is applied to new data before prediction. Both are saved using the joblib library, as it is the standard choice for scikit-learn models like the Support Vector Machine model, which does not have direct compatibility. The implementation of the model is presented in Chapter 5, Section 8.

6.2 Testing Setup and Result

Testing is an important step to verify that proposed applications operate according to their specified functionality and interaction. A test case is used to outline steps and the expected outcome based on user interaction. The test cases for the proposed application are compiled in the following tables.

- **Login & Registration**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC01	User enters valid email and password.	User is authenticated and navigates to the main menu.	Pass
TC02	User enters invalid credentials.	Error message is displayed, login denied.	Pass
TC03	New user registers with valid credentials	Account is created and stored in Firebase Authentication.	Pass

- **Lessons & Exercises**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC04	User selects a level and accesses exercises.	Lesson and exercise load correctly according to the selected difficulty level.	Pass
TC05	User attempt the question in vocabulary exercise.	Correct answers receive positive feedback, while incorrect answers show detail explanation.	Pass
TC06	User select the audio button to listen to vocabulary pronunciation audio.	Audio is played clearly.	Pass
TC07	User practices speaking by repeating conversation sentences.	Speech recognition captures input, compares with expected pronunciation, and gives score.	Pass

TC08	User attempts grammar fill-in-the-blank exercise.	Correct responses are accepted. While incorrect responses show explanation feedback.	Pass
TC09	User attempts sentence ordering grammar exercise.	Correct orders are validated with positive feedback. Incorrect order shows feedback with explanation.	Pass
TC10	User completes a full lesson (vocabulary /grammar).	Summary feedback is displayed with score, and suggestions.	Pass
TC11	User retries a failed lesson.	Lesson reloads with the same set of exercises for reattempt in different sequences.	Pass

- **Feedback & Reward System**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC12	User answers correctly or incorrectly.	Real-time feedback messages are displayed.	Pass
TC13	User completes an assessment.	Badge is awarded and displayed in achievements section.	Pass

- **Data Logging & Profile**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC14	User completes an activity that included lesson and exercise.	Activity is logged in Firestore with score and completion time.	Pass
TC15	User views profile and achievements.	Correct user details, badges, total study time and progress are displayed.	Pass

- **Translation**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC16	User inputs Mandarin sentence for translation.	English translation is displayed with correct text output.	Pass
TC17	User inputs English sentence for translation.	Mandarin translation is displayed with correct text output.	Pass
TC18	User requests audio output of translated text.	Clear text-to-speech audio is played in the target language.	Pass

- **Summarization**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC19	User uploads image with short text (1–2 sentences).	Extracted text is displayed and summarized correctly.	Pass
TC20	User uploads image with long text (paragraph).	Extracted text is summarized in both paragraph and bullet-point formats.	Pass
TC21	User inputs raw text directly for summarization.	Text is summarized accurately into shorter form.	Pass
TC22	User uploads image with no text.	Display no text contain in the image.	Pass
TC23	User pastes a long article (>500 words) for summarization.	Summarization generates concise results without crashing.	Pass

- **Entry Test, Prediction & Review**

Test Case ID	**Test Description**	**Expected Result**	**Result**
TC24	User completes entry-level test.	Score calculated and level assigned. Result logged to Firestore database.	Pass

TC25	User selects assessment test in chapter page without completing activities.	Display warning message prompting users to complete all activities first.	Pass
TC26	User attempts level assessment test in selected level chapter page.	Model predicts outcome (Pass/Fail) and recommends review if needed.	Pass
TC27	User enters review session if models predict failure in current level assessment.	Review questions generated from weak areas with immediate feedback.	Pass

6.3 Project Challenges

One of the main challenges of this project was the **limited availability of data and features** for training the prediction performance model. This limitation restricts the model's depth and generalization ability, as in real-world contexts, learners' performance is influenced by a greater number of variables, including motivation, consistency of practice, and individual learning styles.

In addition, the application was designed only for children aged 10 to 12 years, but even in narrow age range, learners **display greatly different learning styles and learning preferences,** and designing an application that accommodates such diversity proved challenging.

Another limitation was the **limited timeframes of project development and evaluation,** which restricted opportunities for iterative testing and refinement after the initial system deployment.

6.4 Objectives Evaluation

Overall, the project's objectives were successfully achieved.

- The **first objective**, which was to integrate advanced language learning features such as **real-time translation and text and image summarization**, was fully implemented. These features promote **self-directed learning,** enabling learners to engage with the content independently.
- The **second objective**, which involved developing a **performance prediction model**, was also met. The model demonstrated strong results with **97% test accuracy, 91.67% recall, 95.65% F1-Score, and 100% precision.** Furthermore, an **entry-level test** was integrated into the application to ensure that the content of the lesson and exercise aligns with children's Mandarin proficiency.
- The **third objective** was to design and implement **comprehensive lessons and exercises** supported by a **reward system and an immediate feedback mechanism**. This objective was successfully achieved, as the system was shown to enhance learner motivation, engagement, and overall language acquisition.

6.5 Concluding Remark

This chapter discussed the development of the performance prediction model from data processing and training to final evaluation. Support Vector Machine demonstrated the best balance between accuracy, precision, recall, and generalization among the models tested, making it the most suitable for practical deployment in the proposed application. The challenges, such as limited dataset size and variability in learner behavior, were acknowledged, highlighting areas for future improvement. The results from testing confirm that the application functions as working, providing a strong foundation for the final evaluation and discussion in the next chapter.

CHAPTER 7

Conclusion and Recommendation

7.1 Conclusion

This project aims to deliver an effective and engaging mobile application for English-speaking children aged 10 to 12 to learn Mandarin in a personalized and self-directed way. The cognitive advantages of early language acquisition and the significance of Mandarin growing worldwide are driving forces. However, traditional learning methods and many existing applications fall short, often lacking interactive features, tailored support, and effective handling of specific difficulties like tonal pronunciation and complex grammar.

To address these issues, this project developed a mobile application that incorporated real-time voice and text translation, text and image summarization, and thematic lessons and exercises covering speaking, vocabulary, and grammar for children to learn Mandarin effectively. The application also included a gamified reward system and a real-time feedback mechanism to motivate and engage children. An entry-level test is included to ensure that children start at the proper proficiency level while adaptive pathways guide their progress.

A fine-tuned Support Vector Machine performance prediction model was selected for deployment due to its strong and balanced predictive capability, achieving 97% test accuracy, and 95.65% F1-Score outperforming the other fine-tuned models. The model was deployed via AWS Lambda and made accessible through an API Gateway, which allows the application to send input variables and obtain real-time predictions. This approach enables the application to deliver intelligent predictions without compromising its performance and efficiency. Beyond its technical capabilities, the model's support for personalized review sessions, which provide adaptive learning pathways, adds to its usefulness.

In short, this project delivered a comprehensive Mandarin learning application with machine learning-driven personalization, along with interactive lessons and exercises, and advanced features for supporting learning. Despite limitations such as small dataset size and diversity of learner styles, this application demonstrates significant potential to improve Mandarin acquisition among English-speaking children and provides a strong basis for future development in intelligent and adaptive language learning.

7.2 Recommendation

There are several recommendations to enhance the functionality and performance of the proposed application, aiming to provide better user experience and support a wider range of learning styles.

First, implementing noise reduction techniques would enhance the accuracy of speech recognition, particularly in environments with significant background noise. Also, integrate the speech evaluation services that provide real-time feedback on fluency, accuracy, and intonation to provide the user with more precise and comprehensive feedback on their pronunciation.

Second, add more variables and data into the performance prediction model to increase the accuracy and adaptability across a broader range of learners. This would allow the application to generate more personalized learning paths. Moreover, implement a more detailed adjustment on the learning path where the difficulty levels change dynamically based on error trends and time spent on activities.

Third, the lesson content could be expanded beyond text, images, and flashcards by incorporating video-based lessons or animation-driven game-based learning modules to enhance children's engagement and broaden their learning preferences. Additional gamification elements, such as storylines and interactive challenges, could also be implemented to keep students motivated and focused for longer periods of time.

Lastly, user testing with real English-speaking children should be included in future studies to gather input and validate the application's effectiveness in real-world settings. Although this would greatly improve the application, since children's data would be involved, thoughtful ethical consideration is needed, including parental consent and data protection.

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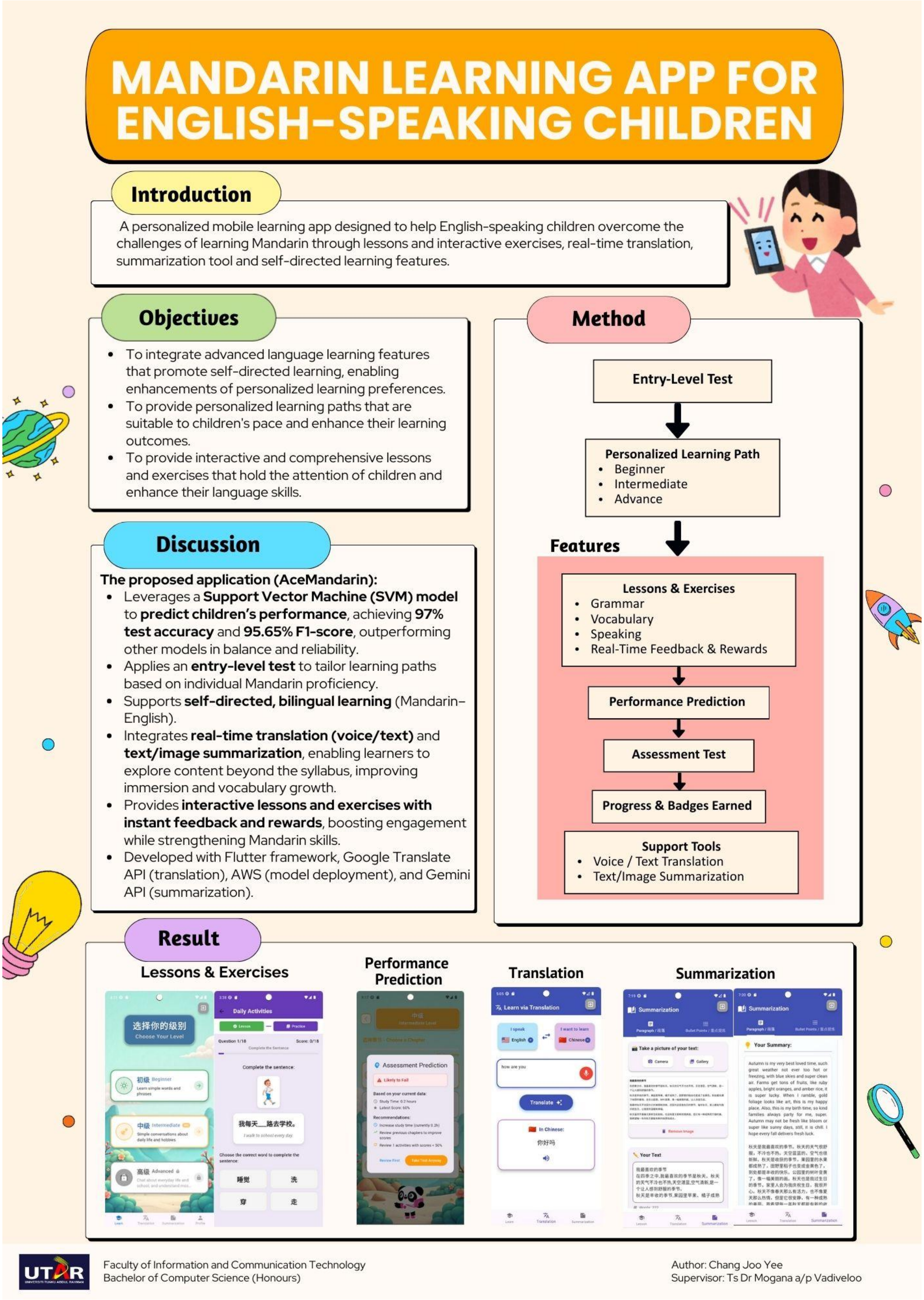

MANDARIN LEARNING APP FOR ENGLISH-SPEAKING CHILDREN

Introduction

A personalized mobile learning app designed to help English-speaking children overcome the challenges of learning Mandarin through lessons and interactive exercises, real-time translation, summarization tool and self-directed learning features.

Objectives

- To integrate advanced language learning features that promote self-directed learning, enabling enhancements of personalized learning preferences.
- To provide personalized learning paths that are suitable to children's pace and enhance their learning outcomes.
- To provide interactive and comprehensive lessons and exercises that hold the attention of children and enhance their language skills.

Discussion

The proposed application (AceMandarin):

- Leverages a **Support Vector Machine (SVM) model** to **predict children's performance**, achieving **97% test accuracy** and **95.65% F1-score**, outperforming other models in balance and reliability.
- Applies an **entry-level test** to tailor learning paths based on individual Mandarin proficiency.
- Supports **self-directed, bilingual learning** (Mandarin–English).
- Integrates **real-time translation (voice/text)** and **text/image summarization**, enabling learners to explore content beyond the syllabus, improving immersion and vocabulary growth.
- Provides **interactive lessons and exercises with instant feedback and rewards**, boosting engagement while strengthening Mandarin skills.
- Developed with Flutter framework, Google Translate API (translation), AWS (model deployment), and Gemini API (summarization).

Method

Entry-Level Test

Personalized Learning Path
- Beginner
- Intermediate
- Advance

Features

Lessons & Exercises
- Grammar
- Vocabulary
- Speaking
- Real-Time Feedback & Rewards

Performance Prediction

Assessment Test

Progress & Badges Earned

Support Tools
- Voice / Text Translation
- Text/Image Summarization

Result

Lessons & Exercises

Performance Prediction

Translation

Summarization

Autumn is my very best loved time, such great weather not ever too hot or freezing, with blue skies and super clean air. Farms get tons of fruits, like ruby apples, bright oranges, and amber rice, it is super lucky. When I ramble, gold foliage looks like art, this is my happy place. Also, this is my birth time, so kind families always party for me, super. Autumn may not be fresh like bloom or super like sunny days, still, it is chill. I hope every fall delivers fresh luck.

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