

LANGUAGE LEARNING APP FOR INTERMEDIATE LEARNERS

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1. ABSTRACT

Many existing language apps today cater to beginners, leaving intermediate learners struggling to find effective and personalised resources. This project aims to identify the most important aspects of language learning and create a full-stack application that leverages YouTube content, flashcards, multimedia, spaced-repetition and game-based learning to aid intermediate learners. Personal investigations such as surveys and interviews will be conducted to complement existing research. The app will have a focus on Mandarin Chinese.

2. DECLARATION

I declare that the material submitted for assessment is my own work except where credit is explicitly given to others by citation or acknowledgement. This work was performed during the current academic year except where otherwise stated.

The main text of this project report is words long, including project specification and plan.

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4. INTRODUCTION

The play store is oversaturated with language learning apps. What makes this any different?

Many of the apps in the market are costly and tend to tailor their content around beginner language learners. Currently, I am on the journey of studying Mandarin Chinese, but I am struggling to find resources to aid my learning. More specifically, there is a large amount of beginner-friendly content, but not enough for intermediate learners. The content topics are generic and are not personalised to my interests.

I therefore propose an app solution based on language learning research that seeks to integrate best language learning practices for intermediate learners using YouTube. Users can create flashcards from new vocabulary found from these YouTube videos and through a spaced repetition (SRS) system, be able to review these words in short, game-based exercises. These exercises encompass reading, writing and speaking and utilises multimedia from Google images. Additionally, research will encompass my own personal investigations through survey and interviews, research papers and analysis on the success of language apps such as Duolingo.

The objectives of this project are stated as follows:

Objective	Objective type
Create a minimal viable product of a language learning app	Primary
Transcripts can be generated from the app	Primary
App can identify important sentences and phrases from the transcripts	Primary
App can generate review questions relevant to the user	Secondary
A user evaluation form sent out to obtain user feedback at the end of the project	Secondary

5. CONTEXT SURVEY

It has been argued that languages did not necessarily evolve from speech, but from the innate human instinct of communication. At first, humans did not have words, but they expressed themselves with body gestures and hand movements. As they innovated, such as the creation of fire and the invention of tools, only then did they begin to communicate with their mouths, and thus along came the need for words [1]. Language therefore emerged from mimicking others, which we can see from studying the brains of monkeys; the same areas of their brains light up when watching another monkey perform a set of grasping movements [2]. Interestingly, the brain region for monkeys mimicking each other is the same brain region that lights up for human language.

What we can distil from this research is that we learn languages from copying and observing each other. By just observing another's movements, our own brain can help us infer their goals and intentions. This therefore gives us meaning behind their movements. If we relate this to language, by listening to a lot of content in that language, by watching their body movements, we can unconsciously infer the meaning of the words.

Language learning can thus be summarised into 4 important steps [3]:

1. Seek relevance
2. Obtain the content's basic meaning
3. Focus on only what you can understand
4. Build it into memory

For example, you may be fluent in English, but if you were thrown into a PhD study of physics and did not come from a physics background, you would also be lost by its terminology. The content has no personal relation to you (you have nothing to connect these new terminologies to), thus to build this knowledge into memory, you would first need to filter out the principles of the content and understand the basics. After that, you would have to work out how you can fit this new content into your existing knowledge.

Our brains work unconsciously and are constantly seeking out new patterns. In order to learn, our brains categorise the content into something we can group, then abstract it away such that we can form relationships. The methodology works because similar words are located close to each other in your brain. To do this, we need to constantly be seeing and using this content in different contexts (a method called “interleaving”) and creating analogies [4]. The idea of analogies links back to how we move this knowledge into our long-term memory, which is by creating relevance around this content.

If we take this through the lens of computer science, we can understand this idea of abstraction through how we code. If we have new words such as “car”, “motorbike”, “truck”, we can categorise these into a class called “vehicle”. As we build up these classes and abstract them away, we can more easily draw high-level relationships between them.

How can we apply this to achieving fluency? Fluency occurs when words fit together automatically. We do not necessarily have to think about the next word in a sentence, because our brain has already found the patterns and intuitively knows what words should come next.

Gabriel Wyner, the author of *Fluent Forever* [5], discusses how we can actively use language learning principles and apply them. Above, I discussed the four main principles of language learning. To apply them, here are the four main steps:

1. Pronunciation
2. Get the most frequent words to learn
3. Use comprehensible input
4. Output

We can see that these apply to the four principles earlier. With pronunciation, it is important to learn the rhythm of the words and the flow of the words. At the same time, we should be training our ears and our mouth to learn how to differentiate similar sounding words, and how to actually pronounce these words with our mouths. By getting the flow of the language, this applies to principle (2) of “obtaining the basic meaning”. Here, we are understanding the gist of the language.

The next step is getting the most frequent words to learn. This helps with principle (1) and (3) - seeking relevance and focusing learning on what you can understand. Before we read a whole chunk of text, we need to create anchors in our brains to latch on to. We have to give our brain context before learning new things, which can let the brain draw connections between ideas and the new words. It is also important that learners do not get bogged down by the nitty gritty of the language; they should instead try and understand the context and overall meaning of the text. When we provide the most important keywords to learn before giving the text, we are prioritising certain words for the learner to focus on, which can help direct their learning.

The third is using comprehensible input, relating to principle (1) (seeking relevance) and (4) (building it into memory). By choosing content that we like and content that we have built context with, we can draw connections in our brains. Wyner talks about how when we get new words, we can make it comprehensible by turning it into stories. We have previously discussed how analogies (and therefore stories) help turn new information into long-term memory. Wyner stresses how comprehensible input does not mean simply translating the words to understand it. He emphasises how we should directly link stories to images. For example, to learn the phrase “she is”, we can use the phrase “she is a doctor” and have a picture of a woman in a doctor suit.

Fourth, is output. Outputting is important because this is where we use the new words in different contexts. We can start to use the words in sentences that have a personal relation to us, reinforcing the words in our minds. Playing with the words in our minds also lets us deepen connections with words in that context, helping us draw links between words and start speaking fluently.

To further investigate the importance of creating analogies in our brain, a study [6] explored how analogical processes in human thinking and learning improved a person’s learning relational retrieval and transfer. In particular, it touches on five key characteristics of analogies: retrieval, mapping, evaluation, abstraction and re-representation. We can define these terms as retrieval meaning recalling a similar example from long-term memory, mapping as aligning the representational structures of two cases in memory to identify commonalities and make inferences, evaluation as the assessment of the analogy and its inferences, abstraction as extracting the common structure between the analogies, and re-representation as the adjustment of one or both representations to enhance the match between the two ideas.

The paper focuses on mapping, especially. It draws on the structure-mapping theory that analogical mapping is the process of establishing a structural alignment between two

represented situations and then projecting inferences [7]. In other words, two situations or concepts are aligned to find commonalities and make inferences between them.

Interestingly, this theory is not new at all; it was studied in a paper published in 1890 [8], which aimed to create a Structure-Mapping Engine (SME), a cognitive simulation for analogical matching. There are two important aspects; support, which measures how much an inference is based on the analogy you are making (where more support from the analogy is better) and extrapolation, measuring how much your inferences goes beyond what the analogy directly provides.

Only after mapping does ‘directionality’ emerge, where the meat of the understanding takes place as we explore the analogy further. We can relate this to language learning, where there may be certain phrases that are not very comprehensible, especially phrases that do not exist in their previous language. Chinese is rich with idioms, each with their own teachings behind them. Therefore, in order to tackle these more intermediate language phrases, learners must draw a high-level analogy to their pre-existing knowledge. Then, after a lot of exposure to this idiom in different contexts, reflecting and refining their previous analogies, will the words be engraved in their memory. An example given from paper [7] is the word “jail”. A similar word could be “prison”. An analogy could be “job”. Thus, if the learner was learning “jail”, instead of just showing them the word countless times, we can ask them to generate metaphors with the word and talk about their experiences or feelings with that word.

A paper on structural alignment [9] takes this further, exploring why analogies are so effective for memorisation. As we have discussed, our mental representations are hierarchical (we prioritise certain things) and are made up of categories with relations to each other. By comparing between two ideas, there is a structural alignment to find a maximal structurally consistent match between representations. This system favours interpretations that preserve the maximal connected related structure (we remember new information easier if we can draw many links to another idea). As our brain likes similarity, we can follow this logic that alignable differences (where the structure is the same) are more salient and easier to find in comparison, than non-alignable differences. Taking this idea into language learning, we can see this in similar sentence structures, or the negation of certain words. For example, “I like” and “I don’t like” are different, but we can remember them due to their alignable differences. Antonyms also work the same way; “up” is related to “down” even though they have opposite meanings.

Intermediate learners can benefit from analogical thinking, because they have a larger vocabulary range and a better understanding of grammar, enabling them to draw better connections. A current issue intermediate learners face is the lack of speaking and listening practice students get in a classroom setting [10]. However, it is through listening where learners can create analogies as they see the words in more contexts, and it is through speaking where learners can develop their own self-confidence in that language. The self-confidence ties in with pronunciation, as students are worried that they sound too foreign.

The most common methods of language learning taught in schools are usually through reading. To investigate the effectiveness of reading in the target language, I explored a paper on the effect of exposure frequency on vocabulary acquisition [11]. The research confirms that reading does serve as a significant source of vocabulary development, but in quite a surprising manner. Although the vocabulary growth is modest, it highlights that reading creates cumulative knowledge, and has a long-term positive impact on adult

vocabulary growth. What is paramount is the exposure of the new word in different contexts, which allows the learners to infer word meanings. We can link this back to the idea of how our brains remember better if they work through finding patterns themselves, which is why learning languages through pure translating back to your native language is not the most effective.

If reading only contributes to a modest impact on vocabulary, what are some of the strategies that have been proven effective for vocabulary retention? As already discussed, learning vocabulary is enhanced when we encounter words in context. Flashcards, mnemonics and translations are very common approaches for this, but to prove this assumption, we should assess vocabulary learning through immersion. VocabulARy, a study on learning vocabulary through augmented reality (AR) [12], is an AR application for vocabulary learning that visually annotates objects in AR, in the user's surroundings, with the corresponding words. The study took two groups, one that used the VocabulARy prototype and another that had an alternate AR system which did not show any additional visualisation of the keyword. Showing visualisations outperformed the other group in short-term retention, mental effort and task-completion time, and also scored significantly higher in delayed recall and learning efficiency.

VocabulARy builds upon Anonthanasap's work on mnemonics [13]. In his paper, a new educational system for second-language vocabulary learning is proposed, based on a mnemonic technique. Mnemonics are a retention technique that helps the recall of information through the use of visual or auditory clues. Vocabulary learners will seamlessly browse a collection of foreign words while suggesting phonetically related words of a known language for helping the memorization of unfamiliar languages. For example, the Japanese word for bread is "shokupan" which sounds like "sock and pan" in English. With this, the learner can imagine an image of frying a sock and putting it on a slice of bread, an example given from [12]. Further research [14] found that participants who used this method learned more words and also remembered more words after 6 weeks.

To evaluate this methodology, one paper addresses the development of an AR system called Arigato for language learning [15]. Its aim was to provide insights into the effectiveness of adaptive guidance in an AR environment for language learning, considering the following key metrics: engagement, mental effort and learning performance. The system allowed for four levels of variation in the type of guidance given to the learner; fixed amount, adaptive amount, fixed associations and adaptive associations. In the fixed condition, the learners receive a predetermined level of guidance that does not change based on their performance. For adaptive conditions, the amount of guidance adjusts based on the participants' performance. In association conditions, participants are presented with 3D AR models of objects corresponding to the vocabulary being learned.

The group that performed the best was the adaptive associations in all fields; behavioural engagement, cognitive engagement and learning performance. Participants were more interested in the adaptive-associations condition, re-emphasizing that mnemonics motivates learners to be more creative and enjoy using their minds more productively. Furthermore, the cognitive load in adaptive guidance (for both the adaptive amount and adaptive associations) were lower, and in recall tests, the group with adaptive associations outperformed the rest in all tests and learning efficiency.

How can we apply what we have learnt with speaking? As previously discovered, speaking is the biggest priority for intermediate learners.

Speaking is known for its difficulty due to message conceptualization and articulation. Second language learners struggle because they often lack linguistic and pragmatic resources [16]. They studied the strategies students took when practising speaking; metacognitive strategies were the most frequently employed throughout all stages of the task, which included task preparation, execution and follow-up. Participants used extensive planning to structure their arguments and to select appropriate vocabulary, then continuously monitored their performance by assessing their grammar, vocabulary and pronunciation. After, they completed self-evaluation. What we can gauge is that a good speaker actually comes from the planning and thought behind their sentences and arguments, rather than just constantly outputting speech. Bound with this, is the constant assessment of their own performance.

With this in mind, we can assess the current language learning apps on the market. In particular, I will be discussing the big three language learning apps, Babbel, Duolingo and Rosetta Stone.

Babbel focuses on achieving fluency through immersion of real-life dialogues [17]. It uses the idea of how a native learner would learn, by teaching vocabulary and grammar through practical dialogue examples in conversation. It guides the brain to connect the dots passively by learning new information based on the dialogue context. At the same time, it trains the learner's pronunciation skills. The main goal of Babbel is to curate content that is relevant to you, by creating content that connects to each other. It also emphasises the use of a spaced-repetition system, where you revisit the words in different contexts, spaced out over time.

Cognitive psychology has repeatedly shown the benefits of using short repetition practices in order to put new knowledge into long term memory [18]. Ebbinghaus stated that 'with any considerable number of repetitions a suitable distribution of them over a space of time is decidedly more advantageous than the massing of them at a single time'. The umbrella term for this phenomenon is the 'distributed practice effect' or 'spacing effect'.

Very early on, Ebbinghaus conducted experiments on himself to determine how to minimize the amount of time it took to relearn a set of material. He discovered that spacing the study of simple verbal material across several days rather than all in one day resulted in fewer relearning trials. From this initial study, many other studies branched from learning words, sentences and text passages.

In Glenberg's experiments, he discovered that increasing the amount of time between recall sessions benefitted retention to a point; after this point is reached, the additional intervals lead to a poorer retention. In other words, learners should start from shorter interstudy intervals until a certain interval, and maintain this.

Duolingo is a game-based learning app that stresses the importance of "learning-by-doing" through interactive lessons [19]. Similarly to Babbel, it uses the idea of your brain picking up patterns passively, and thus Duolingo does not teach grammar rules. It instead pushes learners to figure out the conjugation rules by themselves. By utilising AI, Duolingo adapts lessons to individuals, where the AI model tracks and adjusts the order and difficulty of exercises. The topics chosen to teach are based on school and institutions standards.

However, Duolingo is most known for its high engagement, due to its bite-sized lessons and gamification streaks, helping learners to stay motivated.

Finally, Rosetta Stone relies on dynamic immersion [20]. The idea is to use human senses in order to move new words into long-term memory. For example, learners are not given translations, but are instead encouraged to learn the words through the pictures. To achieve grammar, Rosetta Stone gives a few examples of a grammatical concept, then the words the learner should focus on gets highlighted. To achieve speech, they offer services that allow learners to read aloud, and as they do so, their pronunciation gets corrected.

Each language app has their own unique advantages and disadvantages. The use of forcing your brain to draw their own connections to recognise different patterns aligns with the research I have conducted above, and building content based on personal relevance (as Babbel and Duolingo do) has been proven to help retain information. Babbel's spaced repetition system is also very effective, especially as it reminds you of the words in a different context every time. A common misconception of learning is to constantly repeat information with flashcards, however not only is this boring, the brain starts to recognise the cards and trick itself into thinking it has the card remembered, when it actually has not. The spaced repetition system of Babbel means that the cards for the same word are not always the same, which forces the brain to recognise the words in different contexts.

Duolingo's strength comes with the gamification aspect. Its bite-sized lessons take less than 5 minutes to do, and learners can undergo "quests" with their friends, allowing them to push each other and support each other in learning. It also makes them feel more accountable when they miss their lessons, because their progress can be shown to their friends. As a personal user of Duolingo, I like how each exercise brings in new vocab to learn, but at the same time is very easy to complete. Furthermore, Duolingo consists of badge systems and rewards, in the hopes that students become more motivated and engaged in their content. Students should be intrinsically motivated to learn [21] (where the desire to learn comes from the student, rather than from external factors such as parental pressure), as this leads to better information retention. However, a substantial body of research suggests that the way we attempt to increase intrinsic motivation should be cautioned [22], because tangible rewards (such as badges) can shift a student's motivation from intrinsic to extrinsic. What they instead conclude is that gamification should be used for the fast feedback to the students.

Rosetta Stone's strength comes from the fact it uses sensory input. Different languages may contain words that do not exist in the learner's primary language. Thus, there is no direct translation. Therefore, images are incredibly useful for this, because it strips away the intermediary step of having your brain translate to a different language domain, where sometimes the word does not exist. Its stress on pronunciation and having a direct feedback loop is also useful in achieving fluency, because many learners struggle with pronunciation the most. Learning new languages also requires you to train new mouth muscles, muscles that may not be used in the learner's primary language.

When designing a language app, we can also stretch beyond what other language apps do and take a look at social media. Social media is addictive; among the 7.91 billion people as of 2022, the average time individuals spent using the internet was 6h 58 minutes per day, with an average use of social media platforms of 2h and 27 mins [23]. What sets social media apart is the personalization aspect, human connection and the fact people are free to

exchange ideas which build up on top of each other. We can see this through the most popular apps of January 2022, which are TikTok, Instagram, Facebook and Whatsapp, whose basic goal is to enable users to share and create content with each other.

The idea of social media is simple: help humans establish relationships [24]. As establishing relationships interferes with necessary life activities such as sleep, nutrition and work, its overuse can be seen as any other addiction as it can dominate a person's life. To establish relationships, people need to be able to connect and engage with others through the sharing of experiences and ideas. In fact, the definition of social media by Merriam-Webster states social media is a "form of electronic communication (such as websites for social networking and microblogging) through which users create online communities to share information, ideas, personal messages, and other content (such as videos)".

Drawing aspects of social media with language learning is an interesting field to explore; social media gives opportunities for students to understand more about other cultures through videos and blogs. On the other hand, there are many criticisms of using social media, one of the main reasons being addiction. In the context of language learning though, a study in Algeria investigated the effect of social media in writing [25]. In particular, a discussion was drawn between writing formally and informally, where on social media 90% highlighted their use of slang words and abbreviations. When asked about the reasons for informality in writing, the students gave reasons ranging from the fast and easy to use nature, as well as it being helpful in being able to express themselves. It gave them more freedom in writing in contrast to the formal way that obliged them to follow strict rules. The paper concluded that social media did indeed have an overall negative impact on the way students write, as the relaxing environment of social media encouraged students to write through abbreviations, symbols and slang words. In a social media context, this writing style is accepted, but inappropriate from an academic perspective.

The paper recommends integrating reading sessions within the lesson, where learners choose their favourite books, summarise it, and create a discussion with it. He argues that with this method, the students will be able to expand their knowledge and also see how the language is formed and how different words are combined together to make meaning. However, I would criticise this paper in that this paper was written through the lens of an academic context. There are many goals within the field of language learning; not everyone learns for the sake of academic writing. Social media's strength lies in getting quick ideas across and sparking conversation. Social media's personalisation aspect also means learners can choose what and who they want to learn from; there is plentiful content for those in the academic space, and others in entertainment.

Another paper focuses on microlearning and shows that gamification, infographics, videos, apps and social media may all be leveraged to provide this [26]. Microlearning allows lessons to be given in a short length of time and can be accessible at any time and from anywhere. It further explores how microlearning can increase student comprehension and retention, especially when lessons are broken down into digestible pieces. In the modern day, TikToks (a platform for short videos) are extremely easy to remember because of their short, effective nature, where all important information is concisely condensed into a few seconds. This is a great example of microlearning; the only downside is that microlearning is not effective when dealing with a narrow, intricate and complicated issue requiring an in-depth discussion.

An example of microlearning is Duolingo, as seen above. Microlearning is often known as gamification, where the critical difference lies with learning goals being masked as game-like activities. The gamification encourages students to participate more in the learning activities by providing them more enjoyable approaches. Duolingo is one of the most popular language apps, but how effective is it? We can back up Duolingo through a study done by Fang [27], which looks at English learning. The study begins with emphasising that despite the exponential growth of knowledge and information with the internet, the traditional “classroom + textbook” learning mode has failed to satisfy people’s needs of seeking knowledge. The new micro-learning approach has become popular among college students due to their ability to use mobile handheld devices, such as a mobile phone, and micro-learning concentrates on brief and independent messages. College students are therefore provided with the information they need anytime.

Using handheld devices also has its benefits. In language learning, mobile devices are great for quickly looking up new words, translating sentences or even finding answers to questions. It also provides a convenient means to access videos, music and content that can be applicable to language learning. With the billions of content available online, learners can also be exposed to different cultures and languages whenever they want. In learning, there is a ‘forgetting curve’ [28] which states that the process of forgetting gets slower and slower over time, as long as you keep repeating the content at timed intervals. Thus, having access to content anytime means that learners can harness the power of repetition and utilise it to their advantage. This is in contrast to the learning environment in schools, where students have to wait each week for a lesson to review their knowledge.

A case study we can use is X (previously Twitter), which is a microblogging platform. A paper looked especially at using X to foster foreign language learning [29], aiming to gain insights about learners’ perceptions of the use of X in language learning and how they feel about tweeting as an extracurricular activity throughout four weeks. X helps educators and learners benefit because the platform enhances student collaboration and interaction. Students can engage in meaningful communication and get immediate feedback, which as discussed previously, can help students learn more effectively.

Vygotsky, a plurilingual speaker, underlined the importance of connection in people’s perception of events. He developed a social constructivist theory, where he believed community plays a central role in the process of “making meaning” [30]. Education is not merely a cognitive basis for improvement, but also a socio-cultural activity. Learning takes place in a social context, where knowledge is acquired from interacting with each other and environments. Thus we introduce contextual variability, where cues such as mood, environment and mental images are encoded alongside items as they are learned. As these cues fluctuate overtime with the spacing of retrieval, the probability of successful recall increases. This links back with our previous research where we discovered the importance of seeing new vocabulary in different contexts and how the words can be used.

Many of the language learning applications today are focused on beginners, whose aim is to just familiarise themselves with the language. This means there is more emphasis on creating content around general, surface-level topics. Basic vocabulary and grammar structures are not enough to make students confident in speaking, which we have discovered comes from being able to plan out sentences with careful vocabulary and grammar choices (which depends on having a more specific vocabulary range and an

expansive grammar bank), as well as a fast, personalised feedback loop which does not come from traditional class lessons, as many students only see their teachers once a week.

The next steps are to question end-users (language learners and teachers) and identify their biggest frustrations with language learning, and to design an app that will address these. The aim is to provide a solution to intermediate chinese learners, implementing features that will be impactful and supportive to each student in their language learning journey.

6. REQUIREMENTS SPECIFICATION

7. SOFTWARE ENGINEERING PROCESS

Agile is a methodology for the continuous delivery of valuable software. As the end-goal is to create a full-stack application with iterative feedback from interviews throughout the building process, Agile is useful for producing many working iterations of a software solution quickly and also involving a wide range of stakeholders at all phases of the development process [31].

This means that on an ongoing basis, a product can be tested, examined and adjusted, rather than building a single product at the very end. Agile consists of the following practices (some were removed as it presumed the existence of teams instead of a solo project) [32]:

1. Daily meetings (short meetings should be introduced to keep everyone up to date with progress)
2. Demo (at the end of an iteration, a working product should be demonstrated to other stakeholders)
3. Iteration planning (for example a sprint backlog, to break down requirements to smaller work items, and planning of what features should be included in coming releases)
4. Iterative and incremental development (development is done in sprints. In each sprint, increments are added to a working piece of software)
5. Retrospectives (a way to reflect on what went well each sprint)
6. Task board (where progresses of tasks are visualised)

Since this project is to be done individually, the only meetings required to achieve (1) are weekly meetings with my supervisor. In this meeting, I will discuss my progress as well as setbacks I have faced that week. This will also achieve (5), where I reflect on each weekly sprint.

To achieve (2), after the development of a minimal-viable-product (MVP), interviews will be conducted per week to obtain user feedback. After the feedback, the MVP will be re-iterated over in the next sprint.

For (3), Notion, a note-taking app, will be used to track and plan new features brought up by interviewees. Each larger feature will be broken down into atomic levels so that each task is more manageable.

(4) will be achieved through weekly sprints, where the Notion page is reviewed and upcoming features planned for the sprint are tracked.

Finally, (6) is will be achieved through a progress log on Notion that will track the work done every time there is a new feature or bug fixed.

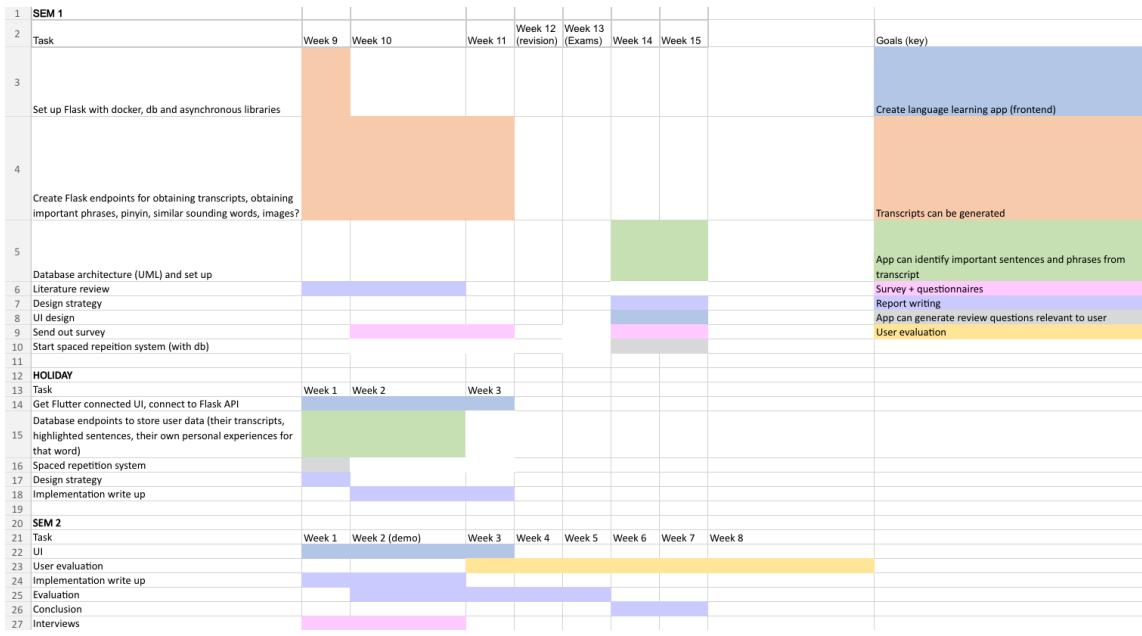


FIGURE 1. Initial project plan

The initial project plan seen in a GANTT chart (see Figure 1). As shown, there is a lot of leeway to allow for project flexibility. This is because the app is planned to evolve depending on user feedback during the building process. As you will find discussed below in the design and implementation sections, the project has diverted from the initial plan and has extended to contain many more features than what was initially expected.

The reason why weeks 1-8 were blank were because these weeks were used to understand the problem space and get familiar with Flask and Flutter.

You can read the progress log in Appendix Figure 25.

8. ETHICS

Regarding YouTube's developer policies [33] it is important to consider both ethical and legal aspects, including copyright issues. I will ensure that:

1. Content queried from YouTube is used only for language learning purposes, and the app will not misuse the content in any way.
2. Content queried from YouTube will be explicitly stated, as the video will be embedded into the app.
3. To protect the rights of content creators, the app will clearly credit the original creators of the video.
4. Videos will stop being shown if a content creator does not want their video shown on the app.
5. My app will transform the copyrighted material by incorporating it into a language learning context.
6. My app will not allow videos to be downloaded or be temporarily stored. The video will be transformed into transcripts designed just for language learning.
7. My app will only use publicly available content through the YouTube API.

This project will also require surveys and interviews from participants. Surveys will be conducted on Qualtrics and only accessible to students within the University of St Andrews. Every participant involved will be given a consent form to fill out as well as a Participant Information sheet, shown in the Appendix (Figure 26), which will describe how their data will be used and for what purposes. This data will be anonymised and deleted after the project submission date.

The signed ethical approval document can also be seen in the Appendix (Figure 27).

9. DESIGN

To understand the language learning space, we must first identify the main pain points of learners and what is currently missing from the apps available. I sent out a survey using Qualtrics to language learners of Asian languages and teachers in this area. The survey assessed the most commonly used language apps currently and what features specifically users liked the most. I also wanted to identify how certain apps kept loyal users and contrast them to other language apps that people are not very consistent with.

However, these questions gives a false sense that creating language apps is the only solution to learning a language. In fact there are many other resources available, such as using textbooks, attending in-person classes and more. Thus, the questions in the survey were not just limited to apps, but also learning methods students liked to use and why.

The results can be seen below and also in Findings. Also note that the bullet points in the infographics are comments provided by the survey-takers, where they were given the opportunity to write more in detail about a certain opinion.

Based on my survey, Duolingo was the most used language learning app, followed by Anki and Memrise. Students mentioned that the most useful functionalities were being able to listen to pronunciations, the gamification aspects (the ability to compete against friends through leaderboards and the short lessons which gives a feeling of progression), as well as spaced repetition. These findings match with my research seen in the Literature Review, but what was emphasised in the survey was the importance of User Experience (UX) and the app's User Interface (UI).

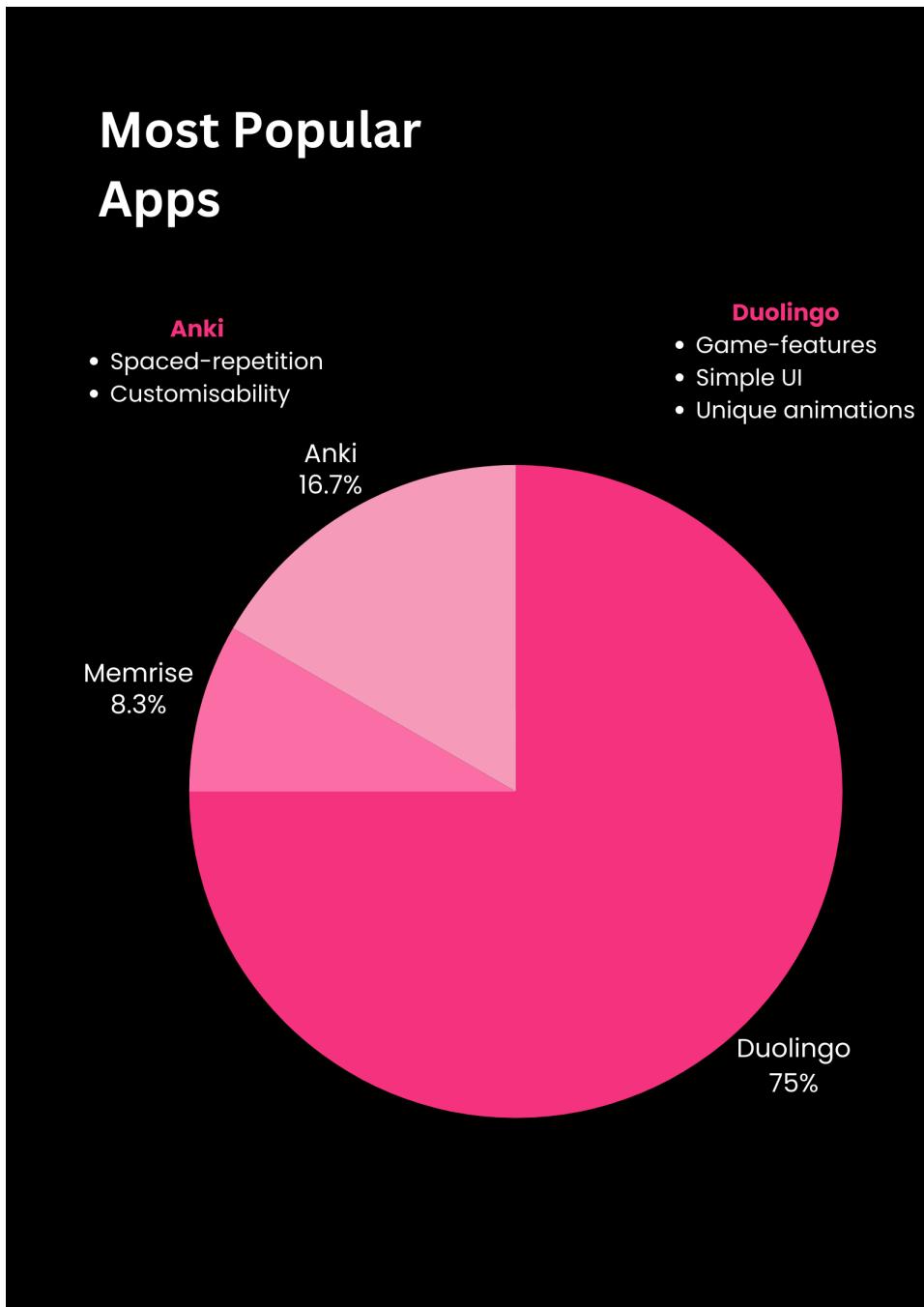


FIGURE 2. Most popular apps

Compared to the interfaces of competing language apps, Duolingo's design is attractive due to its simple animations, clean and intuitive design and game-like features. Those who preferred Anki generally prioritised more their spaced-repetition system and its practicality, however the percentage of those who preferred Duolingo to Anki was 75% to 17%. The customisability aspect of Anki comes from how users can create their own cards, fill it with their own sentences, audio and words. When done well, this provides a optimized experience for long-term memory retention due to its multi-sensory capabilities.

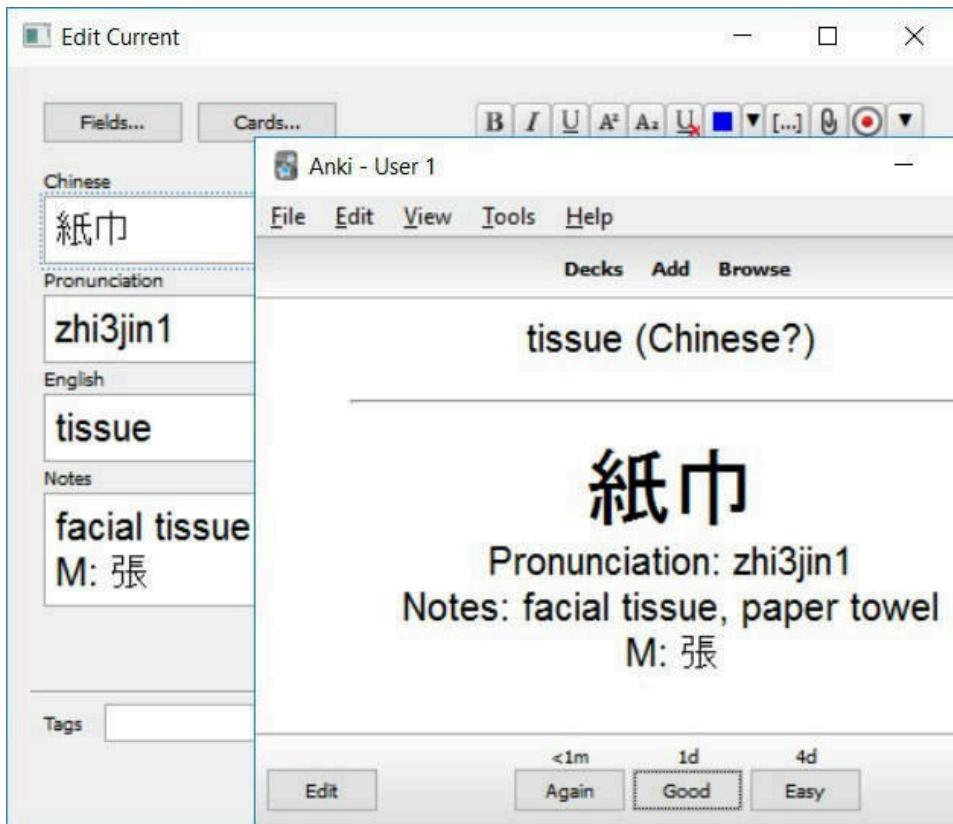


FIGURE 3. Example card creation

However, Anki may be challenging for beginners due to its complexity [34]. It requires a long setup time to understand the interface if a user is to design their own review deck. Thus, many learners opt to browse and find available pre-made decks online instead.

However, the majority of the learning experience comes from creating your own flashcards, re-emphasized in a study aimed to promote active learning. The new strategy used is called the ‘Flashcards-Plus’ (FP) [35] where, like traditional flashcards, students identify bold-faced terms from a textbook and write them on one side. Students then write the textbook definition on the other side. However, the FP strategy goes further; students write a definition for the same key word in their own words, and also generate a realistic example of the key term from their own lives that will increase retention.

The study concluded that students who used FP improved their exam performance more than those who did not use the strategy. However, the downside of this study lies within the possibility of those being exposed to the FP strategy are already actively searching for ways to improve their own grades and study habits, rather than their own improved grades stemming from this new FP strategy alone.

On the other hand, this study aligns with the idea of relating new learnings back to our own pre-existing knowledge.

From my survey findings, users appreciated the listening features of the apps the most. Interestingly, this matches with one of the challenges identified by teachers who took the survey, which was pronunciation.

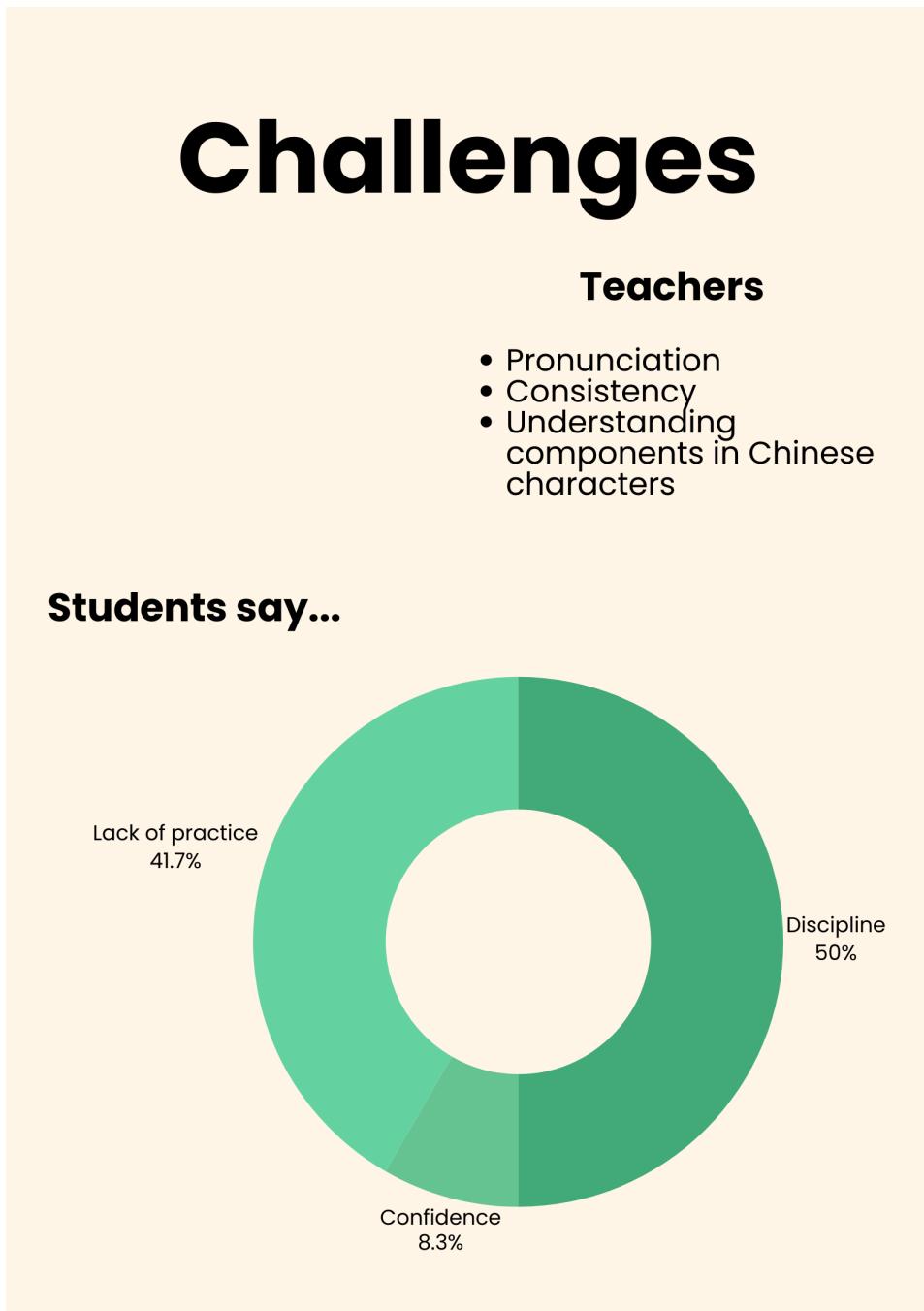


FIGURE 4. Challenges of language learning

In the Literature Review Section, Gabriel Wyner (the author of ‘Fluent Forever’) emphasised that pronunciation is one out of four main pillars of language learning. It is thus essential that we therefore include features in our own app to facilitate pronunciation practise. In the langage apps listed above, a common functionality is the ability to press on a word and listen to an automated recording of it. Whilst many apps stop there, Duolingo takes this further by incorporating speaking exercises into its games that assesses a user’s pronunciation as they repeat a sentence shown on their screen.

Speak this sentence



CAN'T SPEAK NOW

FIGURE 5. Duolingo's speech exercise

The teachers and students also align when talking about tackling consistency. 50% of the students surveyed mentioned discipline as being one of the main obstacles in language learning. I took this further, conducting semi-structured interviews where I asked Duolingo app users with streaks over 100 days what made them so consistent with the app.

They answered that they liked the competitive nature where they can compete against friends, the short lessons and the feeling of progression. In the literature review, I discussed the advantages and disadvantages competitive learning has on students, and so whilst my survey results do illustrate more of the benefits of competitiveness in learning, it does not give us the full picture. Duolingo's gamification encompasses both types of learners - those who want to compete, and those who want to work together to unlock chests and experience points (XP), through a feature where you can combine XP with friends. This

feature was also mentioned by another survey-taker in a separate interview, where it was stated it was their favourite attribute of the app.

According to [36], autonomy is one of the basic human needs, which contributes to a student's motivation for learning and achievement. It is a strong predictor of student engagement. In order to achieve autonomy, students need to find some degree of meaningful choice and purpose in their learning.

One method to achieve autonomy is by acknowledging a student's interests and building choice in a school's curricula. To understand students' interests, I invited the students to talk about their motivations for learning a language in the survey.

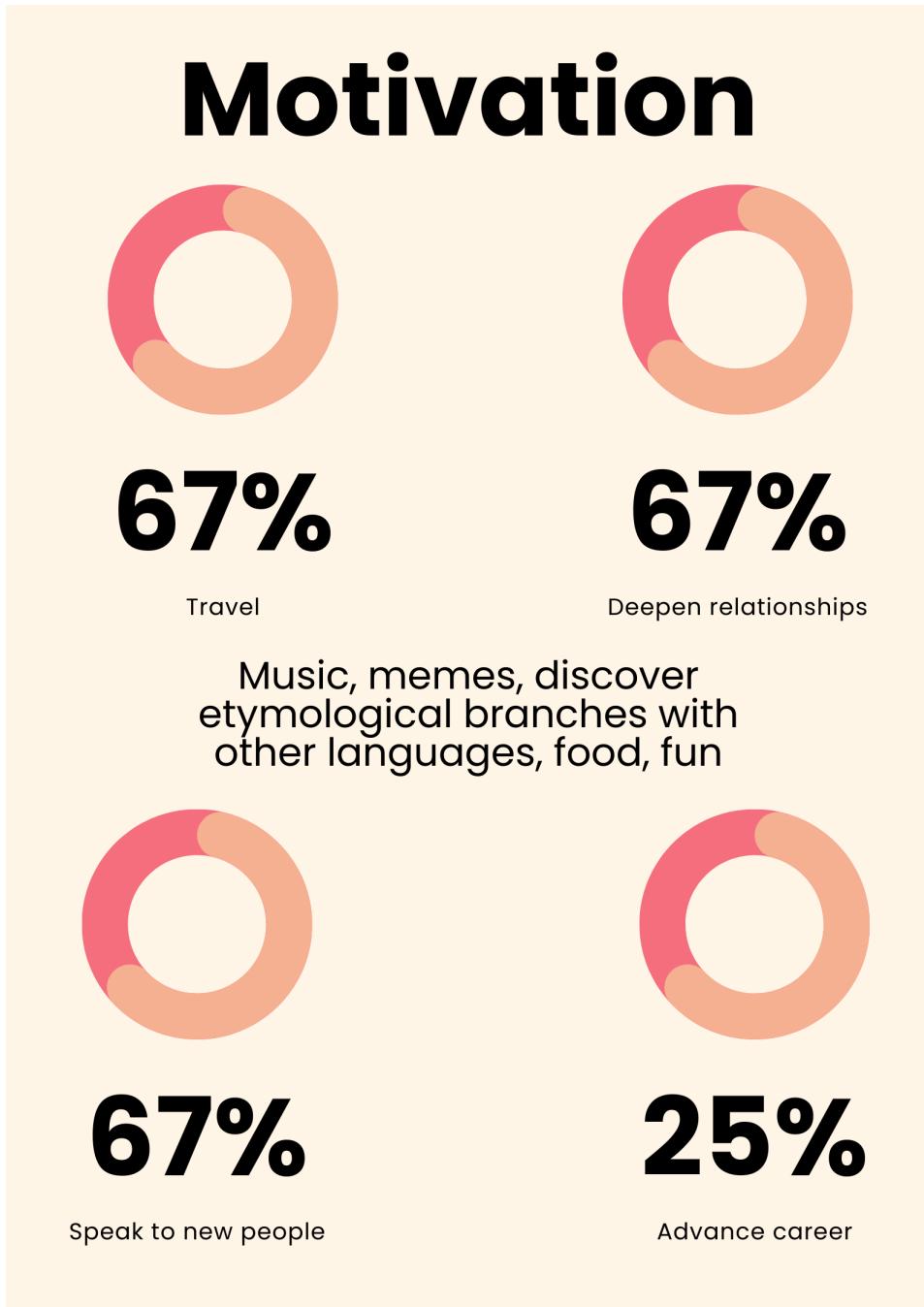


FIGURE 6. Language motivations

67% of the students are motivated by travel, speaking to new people and to deepen relationships. 33% went into ‘other’, and they expanded on this as music, meme culture and for general knowledge.

Current language apps do touch upon these topics, however they provide very general vocabulary. The topic ‘travel’ is expansive and thus it is impossible for an app to devise a curricula that would be relatable for every language learner. Mentioned in my literature

review section, cultivating stories that are personal to each person enables deeper thinking and memorisation. Therefore, learning words that have no personal value may seem ‘irrelevant’ and ‘random’, which are words used to describe the curriculum from my survey results.

The question “What do you want to improve the most in?”, also gave interesting results:



FIGURE 7. Language goals

Students were also given an opportunity to expand on this, being asked what features they wanted to see on this app that would help them progress in their language goals. In the time of reporting this survey, 3 responses were given:

1. Listening to words in a sentence. It's easy to just learn the words, but [not] how the words are used
2. Spaced repetition system
3. Drills, practice and games

In further questions, students emphasised how they wanted more flexibility with their listening tasks and being able to change the speech speed or be able to converse with the app and let it correct your pronunciation. The idea of having not enough real-speaking practice came up multiple times, which went hand-in-hand with how the sentences taught by the apps were irrelevant and the words they suggested them to learn did not identify with them. From this, we learn that when designing the app we should think about how we can make the content as personalised as possible to the user, instead of them following a syllabus written by somebody else.

In fact, one of my survey questions asked students what other resources they use in language learning.

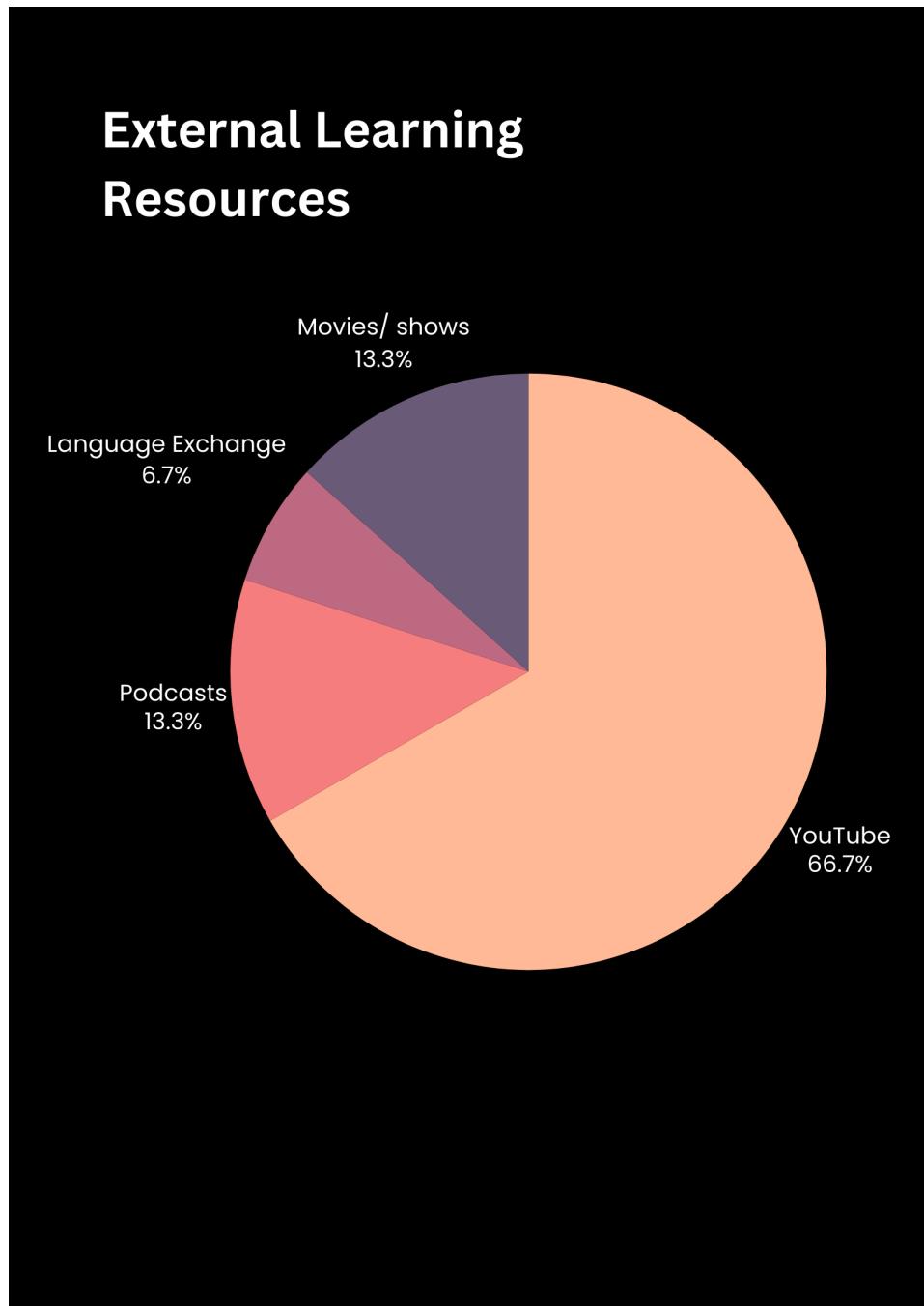


FIGURE 8. External resources

Improving speaking requires a foundational level of vocabulary in that certain topic; this may be the reason why app language learners struggle to achieve ‘fluency’, because the vocabulary taught by the app is not sufficient enough for their daily-life conversations or for them to understand the content they consume, which is unique to each and every person.

Duolingo's course follows the school system, which gives a limited set of vocabulary. For example, you are more likely to learn 'I play football', despite you being a basketballer. The survey results display that students learn from online resources and content rather than textbooks, where they have unlimited access to niche topics that are personalised to them. Therefore, creating an app that utilises these personalised content can make their learning more enjoyable, improving their language learning consistency and also help them achieve fluency by widening their vocabulary scope to more specialised words unique to them.

On the other hand, teachers were asked about what language apps could do better that can help students. Some suggestions include:

1. Being able to correct when one gets it wrong
2. Using free resources such as Google

While teachers focused on the functionalities, students who were consistent with language apps mentioned more UI-centric capabilities that they would like to see improved. This includes having an easy to navigate, minimally distractive UI (minimal colour usage, large, intuitive icons) and having the ability to customise flashcards.

Building on this, we can combine Duolingo's gamification techniques (short lessons and sense of progression) with Anki's spaced repetition system and custom sentences that can provide a more personalised learning experience to the user. To keep the user experience fun and motivational, which will assist in consistency, the content provided should be unique to each user and provide vocabulary that is relevant to them. Through using sources such as YouTube, students will be able to listen to the content through native users and also see how words are applied in relevant contexts.

Regarding teachers' comments on being able to self-correct, a feature should be included such that exercises get repeated if it has been previously wrong. The accuracy will be used to calculate a 'score' for the certain word, which will then be fed as input for the spaced repetition system.

The survey questions thus far have been biased to learning languages from apps, but this may not be the best approach. Therefore, I later on ask the user about their favourite learning methods.

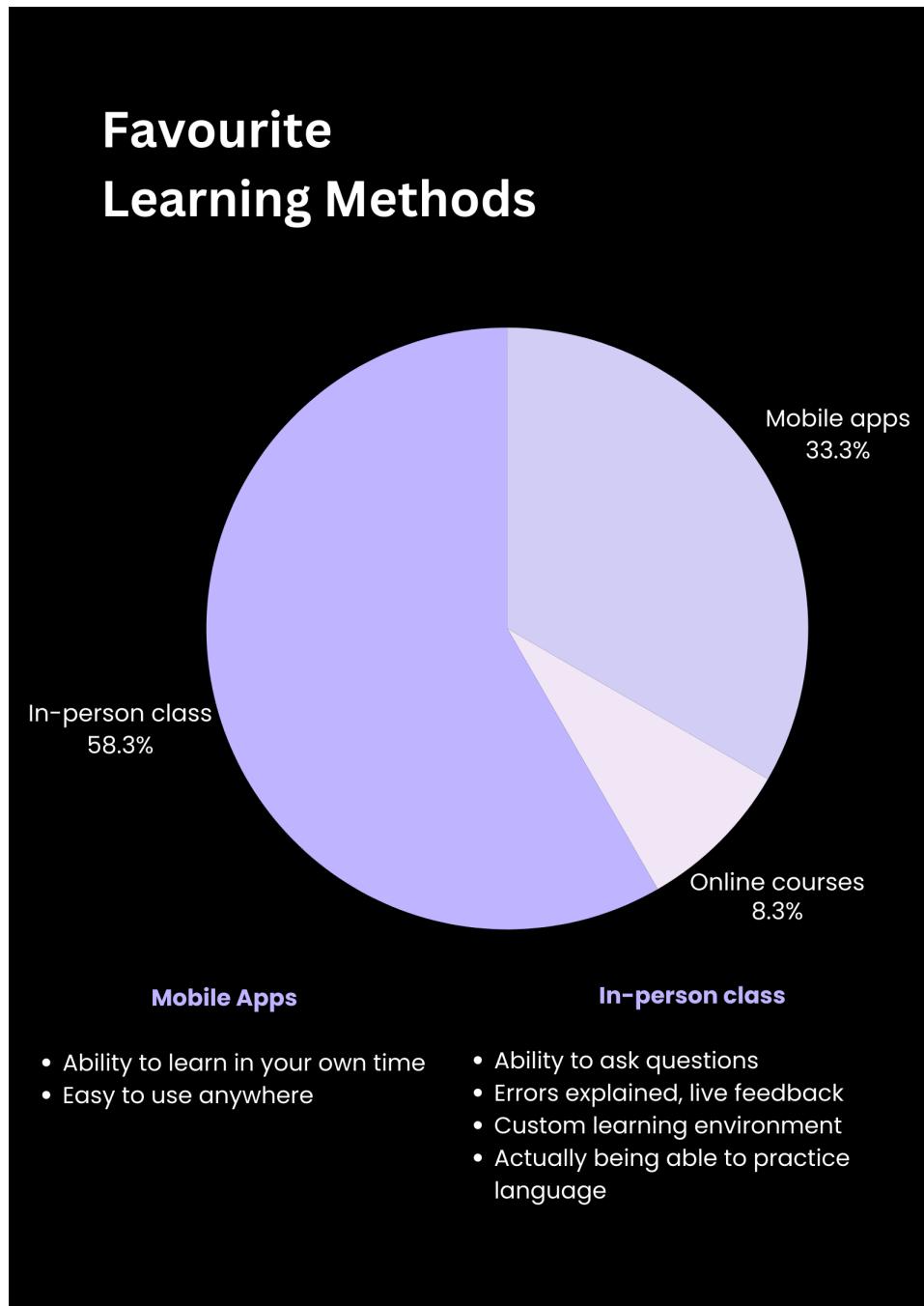


FIGURE 9. Best learning methods

By far, in-person classes are the most favourite language learning approach. The ability to ask questions, interact with others and get instant feedback (such as error explanations) directly from speaking the language in class is the most advantageous when learning languages. Unfortunately, many language apps fall flat with this, and so we see many platforms start to emerge where users can start question threads.

On the other hand, in-person classes can be costly and your curriculum is limited. The advantages of mobile apps is that you can learn in your own time and anywhere.

The question therefore is how can we merge the advantages of in-person classes to the app?

Looking back at previous responses, students emphasised their wish for pronunciation correction. Like most existing language learning apps, the app should have the functionality to listen to how words should be pronounced. It can further be expanded to also prompt the user to output in that language, and assess their pronunciation with an accuracy score. Unfortunately, this will not be the same as an in-person environment where an experienced teacher can correct the learner, but it gives instantaneous feedback. The app can also facilitate a custom-learning experience by providing relevant content and vocabulary to the user that is not restricted by a syllabus.

Issues that have not been highlighted by the survey takers also include the dangers of in-person learning. Students who do not contribute in class will not be able to practice their speaking muscle and thus will not reap the benefits stated above. Furthermore, students may pick up bad habits or mistakes from other students during interaction practices.

Overall, the survey has highlighted the importance of:

1. Gamification in learning with short lessons (improves motivation and consistency due to the feeling of progression)
2. Relevant content that does not just follow a general syllabus (improves autonomy and thus motivation and consistency)
3. Responsive UI that corrects users instantaneously, is easy to use and has a clean design
4. Listening exercises to improve pronunciation and speaking
5. Interaction with native speakers

While my app currently may not be able to achieve (5) Interaction with native speakers, further implementation of my app could include using chat bots such as Bing Chat or Chat-GPT to role-play as a language buddy.

10. IMPLEMENTATION (BACKEND)

Flask, a lightweight Python-based microframework, was chosen due to its simplicity and flexibility, its active community and updated documentation. Flask also utilises Python, which contains many useful libraries for word segmentation and other natural language processing (NLP) tasks.

Figure 10 is a UML diagram displaying the relationships between my Flask models. SQL database was used because SQL can be accessed with Flask through SQLAlchemy, a Python SQL toolkit and object relational mapper (ORM). Flask-SQLAlchemy provides ways to interact with and gain access to the database's SQL functionalities [37]. The ORM aspect allows for easy querying by using simple Python objects and methods rather than writing SQL statements.

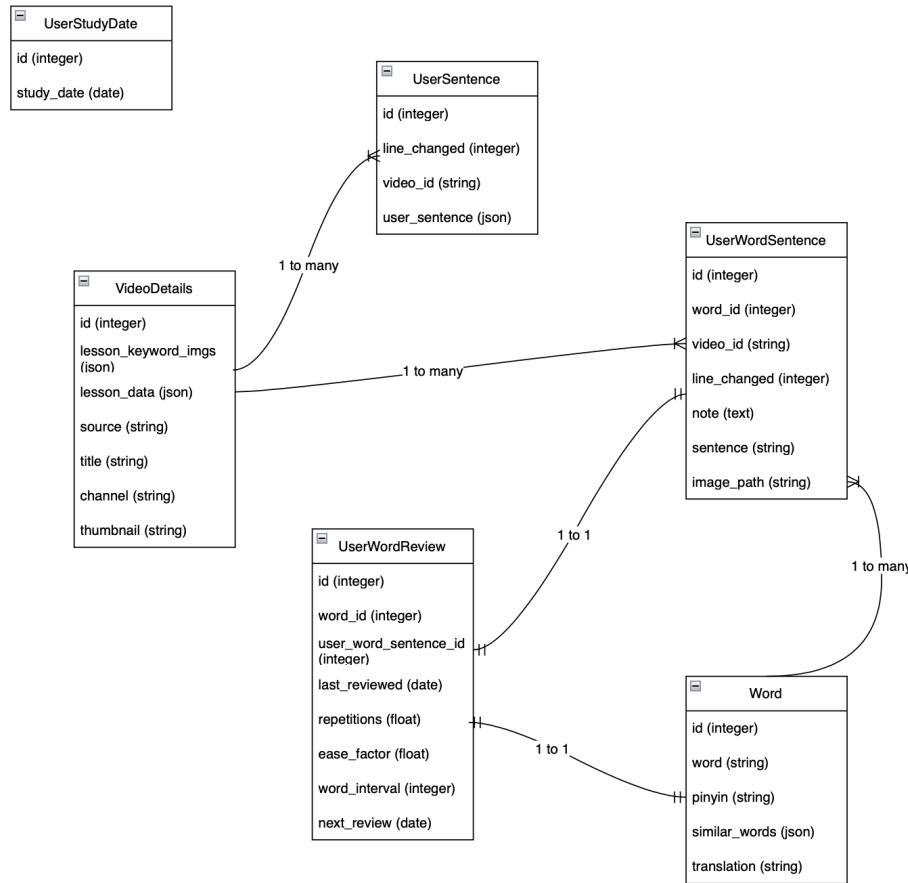


FIGURE 10. UML diagram

Figure 10 displays the relationships between these tables. The `UserStudyDate` is a table in charge of dealing with user streaks. The table gets updated whenever a user finishes a game lesson and a new `study_date` entry gets added.

The `VideoDetails` contains the video information from YouTube. The model saves the YouTube video id; a dictionary of the video's keywords and their respective images (the implementation of which is discussed below); the `lesson_data` consisting of the video's

transcript now segmented into chinese characters, their pronunciation, translations and similar sounding words; the source of the video (in this case, it is assumed to be YouTube, however if this app were to be expanded it could contain videos from other mediums); finally the video's title, channel and thumbnail.

Displayed beneath is an example JSON dictionary containing the 'keywords_img' as well as the 'lesson_data'. A video gets separated into different 'lessons' as video transcripts can be hours long if users want to transcribe long-form content such as podcasts, which Stanza cannot handle. Therefore, the transcripts get segmented into smaller chunks before processing and being appended into the 'lessons' array.

```
{
    "keywords_img": [
        {
            "img": <imgurl>,
            "keyword": "亚洲"
        },
        ...
    ],
    "lessons": [
        {
            "segment": {
                "duration": 1.291,
                "segment": "加州留学生的生活",
                "sentences": {
                    "entries": [
                        {
                            "pinyin": "jia zhou",
                            "similarounds": [
                                "甲胄",
                                ...
                            ],
                            "translation": [
                                [
                                    "加",
                                    [
                                        "to add",
                                        "plus",
                                        ...
                                    ]
                                ],
                                ...
                            ],
                            ...
                        },
                        ...
                    ],
                    "sentence": "加州留学生的生活"
                },
                "start": <starttime>
            }
        },
        ...
    ],
    "video_id": <videoid>,
    "source": "YouTube",
    "title": <title>,
}
```

```

    "thumbnail": <thumbnail>,
    "channel": <channel>
}
};

```

There is a one-to-many relationship from VideoDetails to UserSentence, as a video contains many sentences. This contains fields such as the sentence id which gets automatically incremented, the line number of this sentence in the context of the video, the id of the video that this sentence is related to, and finally the actual sentence, which again is a json containing the details of each word in the sentence, its translation, pronunciation, other similar sounding words and their POS.

```

{'sentence': '加州留学生的的生活',
 'entries': [
 {
   'word': '加州',
   'upos': 'PROPN',
   'pinyin': <pinyin>,
   'translation': <translation>,
   'similarwords': <otherwords>
 },
 ...
 {
   'word': '生活',
   'upos': 'NOUN',
   'pinyin': <pinyin>,
   'translation': <translation>,
   'similarwords': <otherwords>
 }
 ]
}

```

When a video gets downloaded, the sentences are processed using Stanza (this will be discussed more in detail below, under the section ‘word processing’), before being uploaded into the UserSentence table.

The UserWordSentence is used for the creation of flashcards and has a one-to-many relationship with a ‘Word’. A ‘Word’ is a character or set of characters in chinese that gets saved by the user to be tested later using a spaced-repetition algorithm (an algorithm that would resurface the word at optimal intervals to re-inforce learning). In this schema we auto-increment the UserWordSentence to uniquely identify each one, have a foreign-key relationship to the word being tested, the video that the sentence is part of, the line of the video the sentence being tested comes from, a personal note that would help with recall, the actual sentence string in order to keep the word’s context, and finally an image url that the user chooses from the frontend as the flashcard multimedia. There is a many-to-one relationship with Word, because a user can use the same sentence to test many different words (there are many words in a sentence).

The Word model simply contains strings for the actual chinese characters (word), its pronunciation (pinyin), a json list of similar sounding words (to help with pronunciation) and a json list of possible translations.

Finally, the UserWordReview model is utilised to store information for the spaced repetition algorithm.

This algorithm is inspired by Anki's own implementation, where a user ranks a certain flashcard's difficulty from 0-5, where 5 is a perfect response. In my implementation, this is calculated from how many of these exercises per word are wrong (seen later when discussing frontend, each word gets reviewed 5 times through 5 different exercises). A perfect 5/5 score would thus give a user a ranking of 5. The calculation also requires the number of previous repetitions of this flashcard, its previous ease factor (a floating point number generated by the last iteration of the spaced repetition algorithm to determine the number of days before the next review), and the previous interval that the user has seen the word. Additionally, I added a field called 'next_review' so that querying is easier. I simply have to query all reviews where next_review is less than or equal to today, which can then immediately be shown to the user.

The algorithm spits out a new interval (the number of days for the next review), increments the number of repetitions, and calculates the new ease factor that has been adjusted based on how well the flashcard was remembered. All of this information gets sent to the server after every 'lesson' gets completed.

10.1. Endpoints.

In this section we discuss the URL routes that the frontend application can query.

10.1.1. Processing a video.

The aim of this endpoint is to allow users to obtain the YouTube transcript from YouTube. This gets sent to a worker thread which will then do word processing, described in the next section.

This is a POST request to <http://projectvm05.cs.st-andrews.ac.uk:8080/vid> requiring the following fields:

```
{
    "video_id":<videoid>,
    "source": "YouTube",
    "forced":<booleantruefalse>,
    "title": <title>,
    "channel": <channelname>,
    "thumbnail":<thumbnailurl>
}
```

The 'forced' field is required if a user wants to re-download a video and overwrite the existing one in the database.

10.1.2. Obtain a video.

The aim of this endpoint is to allow users to see the json data for a particular video. This will query the VideoDetails table to obtain the relevant row with a particular video_id. At the same time it will also query the UserSentence table to get all the relevant sentences that are related to this video_id.

By combining these two queries, we obtain the mapping for the video's keywords and their image urls, as well as all the sentence data for the video, where each word contains information about their pronunciation, translation, POS and similar sounding words.

This is a GET request to http://projectvm05.cs.st-andrews.ac.uk:8080/getlesson/<video_id>.

10.1.3. *Add a study date.*

The aim of this endpoint is to update the UserStudyDate table so that we can later calculate the study streak of the user. Whenever this endpoint is called, the server will calculate the current time in Europe/London time, to maintain consistency. Then, it will check if the study_date already exists in the table; if not, it will add a new entry to the table.

This is a GET request to the endpoint `http://projectvm05.cs.st-andrews.ac.uk:8080/addstudydate`.

10.1.4. *Get study streak.*

The aim of this endpoint is to motivate a user by supplying the current study streak of the user. To achieve this, we first query all the unique study dates from the UserStudyDate table, and order them from descending from today.

In the case the user just opened the app, they would want to be shown the streak starting from yesterday. Thus, we start from yesterday's date and iterate through the study dates until there is a gap bigger than 1 (it is no longer consecutive). When this is done, we check whether there exists a study_date equal to today; if so, we add one to the current count.

This is a GET request to the endpoint `http://projectvm05.cs.st-andrews.ac.uk:8080/getstreak`.

10.1.5. *Get video library.*

The aim of this endpoint is to query all of the previously processed videos for the user. It is a simple query that obtains all videos from VideoDetails and returns this to the user.

This is a GET request to the endpoint `http://projectvm05.cs.st-andrews.ac.uk:8080/getlibrary`.

10.1.6. *Get cards to review today.*

The aim of this endpoint is to obtain all of the flashcards to be tested depending on the spaced-repetition algorithm (as previously discussed).

To achieve this, we join the UserWordReview and Word tables on word_id, and filter all reviews where the next_review field is less than or equal to today.

When this is done, we loop through the review and the word. Here, the word is isolated and does not come with the sentence it is part of, giving the user no context. Therefore, logic is required to also query the UserWordSentence table to obtain all the words with the specific word_id being tested, obtain a random sentence out of all of those options, then save the line changed (a unique identifier now that we have the video_id and the line in the video in question). This is then used to obtain the relevant UserSentence entry by querying the UserSentence with that combination of line_changed and video_id.

Now, we can obtain all relevant information to test the user with - the image related to that word, a sentence the word appears in, and the personal note aligned with that word. Along with this is the review information, such as the last_reviewed fields, repetitions (the number of times this word has been used to test the user), its ease factor and other details regarding the spaced-repetition algorithm.

This is a GET request to the endpoint `http://projectvm05.cs.st-andrews.ac.uk:8080/getcardstoday`.

10.1.7. *Update the spaced repetition (SRS) system.*

A user will have to update the review information of a card when they have completed a game lesson. Each lesson consists of 5 words; instead of sending 5 network requests to the server, once per word, it would be better do utilise batching, minimising overhead.

This is achieved by the server iterating through all of the words, obtaining their word_id, number of repetitions, the previous ease factor, the previous word interval and the quality of how well the user recalled the word, calculated by the frontend. Passing this to the function `update_user_word_review` in the ModelService class, these parameters are fed into the spaced repetition algorithm and each word obtains a new ease factor, number of repetitions, the interval for the next review as well as the next review date. Finally, this gets updated in the UserWordReview table.

This endpoint is called via a POST request to `http://projectvm05.cs.st-andrews.ac.uk:8080/batchupdatereviews` with the fields:

```
[  
  {  
    "word_id": <wordid>,  
    "last_repetitions": <lastrepetitions>,  
    "last_ease_factor": <lasteasefactor>,  
    "word_interval": <wordinterval>,  
    "quality": <quality>  
  },  
  ...  
]
```

where quality is a score from 1-5 based on how many of the exercises the user got correct.

10.1.8. *Creating flashcards.*

When creating a flashcard, a new record must be inserted into the Word table with its relevant pinyin, similar sounding words and translations. This is done after a check to see if the word does not already exist.

After this, we must create a new UserWordSentence where the word_id is equal to the id of the Word just created, and initialise the review information for this word with the default values of last_reviewed being the current date, repetitions as 0, ease_factor as 2.5 to follow the spaced repetition algorithm, word_interval as 1 and the next_review set to be the same day.

This is a POST request to `http://projectvm05.cs.st-andrews.ac.uk:8080/addnewreview` with the following fields:

```
{  
  "word": <word>,  
  "pinyin": <pinyin>,  
  "similar_words": <similar sounding words>,  
  "translation": <translation>,  
  "video_id": <videoid>,  
  "line_changed": <linechanged>,  
  "sentence": <sentence>,  
  "note": <personalnote>,
```

```

        "image_path": <imageurl>
    }

```

10.1.9. Updating flashcards.

There are two ways to update flashcards. The personal aspects of the flashcards are the image for the flashcard, as well as the note written by the user. These fields are updated by simple POST requests. For updating an image url, it is <http://projectvm05.cs.st-andrews.ac.uk:8080/updateimagepath>. Consequently, the endpoint for updating the note is <http://projectvm05.cs.st-andrews.ac.uk:8080/updatenote>.

The fields required for `updateimagepath` are as follows:

```

{
    "video_id": <videoid>,
    "word_id": <wordid>,
    "line_changed": <linenumber>,
    "image_path": <updatedimagepath>
}

```

The fields required for `updatenote` are as follows:

```

{
    "video_id": <videoid>,
    "word_id": <wordid>,
    "line_changed": <linenumber>,
    "note": <updatednote>
}

```

The fields ‘video_id’, ‘word_id’ and ‘line_changed’ are required to uniquely identify a row in the UserWordSentence table.

10.2. Worker threads.

An interesting aspect about Chinese is the fact there are no spaces between words. Word segmentation is thus difficult, as we cannot simply split sentences based on the whitespace character. Chinese characters additionally can have their own meaning by themselves, or be combined with other characters to form different words.

One example is given from an article on chinese word segmentation [38]. The phrase: “你们研究所有十个图书馆” can have multiple meanings depending on which characters you combine.

One interpretation is:

你们(“you”)/研究(“to study”)/所有(“all”)/十(“ten”)/个(classifier)/图书馆(“library”), meaning “you go study all the 10 libraries!”.

Another interpretation could be:

你们(“you”)/研究所(“institute”)/有(“to have”)/十(“ten”)/个(classifier)/图书馆(“library”), meaning “your institute has 10 libraries!”

Therefore, I decided to use a library for Chinese segmentation. In this process, I tried both Jieba and Stanza, however settled with Stanza due to the more advanced features Stanza offered, such as position of word (POS) tagging (categorizing a word as an adjective, adverb etc), lemmatization (finding the word’s root), as well as segmentation.

10.2.1. *Video processing.*

Incorporating Stanza [39] into the app was by creating a YouTubeHelper class with functions that initialized stanza; turned the youtube transcript into simplified chinese; processed each segmented word to obtain their POS, pinyin (pronunciation of the chinese word), their possible translations and similar sounding words; lastly, the main segmentation processing which would split the transcript into manageable, processable chunks for Stanza to compute.

Chinese characters can be written in two forms; traditional and simplified. The majority of chinese speakers use simplified characters, however some transcripts from YouTube are only available in traditional chinese, as seen in videos from Taiwanese speakers. Therefore, I used an API called HanziConv [40] for the specific purpose of converting all chinese characters between the two types. When the whole transcript is in simplified form, the phrases in the transcript are traversed and stanza is used to segment each word. At this time, the word gets put into a function called ‘process_words’ which would query an API called hanzidentifier [41] to check if this word is a valid chinese character, before calling a pinyin library [42] to obtain the word’s pronunciation and possible translations. Obtaining the similar sounding words is also done in an akin manner, where dimsim [43] is instead the library used. All of these libraries are readily available Python modules.

From the lens of scaling this app, it would be beneficial to use caching to prevent the repetitive calls for common words. Constantly calling words such as ‘the’ or ‘he/she’ introduces a lot of overhead. Thus, redis, an in-memory data structure store, was used for the purpose of caching the pinyin, translation and similar word requests to speed up processing.

Later on in the frontend we discuss the implementation of syncing the YouTube video to the captions and their respective translations and pinyin. This is prepared in the main logic of the YouTubeHelper class, which saves the time that phrase is spoken as well as its duration, which is supplied by the YouTube API itself.

Additionally, the YouTubeHelper class utilises additional APIs such as the TextRazor API [44] to get the keywords for the transcript, as well as the PyUnSplash API [45] to get corresponding images for these keywords. These keywords are displayed in the order of most frequent to the least frequently used in the transcript. Regarding the PyUnsplash API, the image URLs are saved with the rest of the transcript data, such that the frontend can look it up via a simple network request supplied by Flutter. To obtain the YouTube transcript itself, a YoutubeTranscriptApi [46] was used. Additional logic was added to ensure that only videos with chinese captions could be processed, to avoid any errors.

A downside of relying on these APIs are the limitations proposed by the data controllers. PyUnsplash, for example, limits image queries to 50 images per hour. Therefore, if the app were to scale to more users, an alternative API may have to be used, or costs will have to be involved for the best user experience. Otherwise, some videos displayed to the user will not contain images of the keywords for the transcript, which may hinder learning.

10.2.2. *Obtaining YouTube transcripts.*

The worker is also in charge of dealing with YouTube videos. When a user requests to process a new YouTube video, this is passed to Celery, a distributed task queue system of multiple workers and brokers to enable high availability and horizontal scaling [47]. This

architecture is shown in Figure 11. Celery was used due to the long processing time of Stanza, which requires asynchronous work outside of the usual HTTP request-response cycle which the rest of the Flask backend could handle.

Thus, when the backend route is called to process a video, this gets taken up by a celery worker which will do the video processing as explained in the above step.

Celery workers are also used for obtaining the keywords and their image urls from PyUnsplash, again due to the long waiting time. If a user were to wait for a response, the users would most likely quit the app due to a bad user experience. Both of these steps are achieved from the aforementioned ‘YouTubeHelper’ class.

Once both these steps are done, the data gets added to the VideoDetails table. Celery contains useful methods such as ‘group’ which allows tasks to be done in parallel, depending on the amount of worker threads available. In my system, I have provided 2 threads; for the purposes of the minimal-viable-product (MVP), only one user can use the app at a time, so the maximum number of threads open at a time would be 2 (one for obtaining the keywords and their images, another for the stanza word processing).

A ‘chord’ function, in-built in celery, is also used such that after these two tasks are done in parallel, the obtained data gets immediately added to the VideoDetails table.

Thus, the user can utilise the other features of the app as the video processing tasks run in the background.

10.3. Architecture & Hosting.

The backend architecture consists of different services: the main Flask backend, the SQL database, NGINX and the celery workers. One of the main issues of implementing the backend was realising how to combine all services together, such that they could speak to one another. Each celery worker had to be passed tasks from the Flask app and thus required their own instance of the Flask app context. Furthermore, each celery worker must also have their own instance of the SQL database so that they could add new videos into the VideoDetails table.

Therefore, the celery service contains some repetition of code from the Flask app service, such as the database models. This is a common downside to microservices architecture, however it is a necessary step because it allows decoupling of logic. Microservices allow for better scaling because compared to a monolithic application, if one service goes down, the rest of the services stay running [48].

The next step is to containerize the whole of the backend, so that from the point of view of the frontend, it only talks to one service. This is achieved through the orchestration tool, docker-compose, which allows us to run multi-container applications. In one command, all of the microservices can be created and started, just from one configuration file [49].

Docker enables the creation of a portable environment which means that your application can run in any server.

Finally, this backend must be hosted such that any frontend client can access the endpoints. Utilising University of St Andrews’ virtual machines, the docker-compose network was spun up. This means that any device connected to the University’s eduroam can connect to the endpoints discussed above.

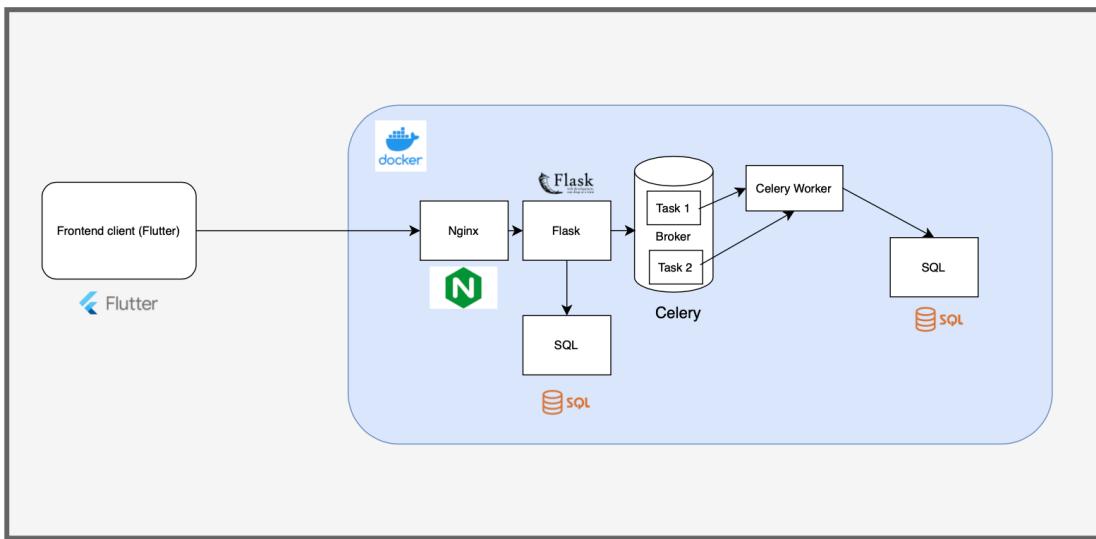


FIGURE 11. High-level architecture

11. IMPLEMENTATION (FRONTEND)

11.1. Flutter.

The decision to create a mobile app over a web application was chosen because of its accessibility. Although the backend will be hosted online (on a virtual machine supplied by the University), certain data will be cached locally on the mobile device itself. Whereas, a website requires constant WiFi connection and inhibits practicing a language on the go.

A paper on guiding teachers on how to use contextualised learning [50] discusses the four content factors that could inhibit a students' dedication in language learning: restricted curriculum content, lengthy content, inadequate content presentation and lack of affective engagement with content. To combat this, teachers can highlight potential linkages of a students' generic activity with the curriculum, perform activities in smaller word chunks (for example using gamification techniques like Duolingo), encourage users to learn words in certain real-world contexts (for example learning the stroke order for 'coffee' in a coffee shop), and direct students to connect even unemotional content to the world and real-life contexts to make the words more meaningful to them. For the last case, a student had connected the word 'determined' in a dialogue about family members to his own family situation.

Due to the portable nature of mobile phones, students can draw better connections; with the case of learning the word 'coffee' in a coffee shop, having a mobile app readily available at any location is very beneficial, helping to provide a deeper and more authentic learning experience.

In another case, Lu and her colleagues (2014) designed a mobile app based on the existing literature on the learning of Chinese characters and interviews with in-practice teachers, classroom observations as well as student show-and-tell [51]. This app presented Chinese characters along with pinyin (chinese pronunciation) and illustrations on the stroke order in writing Chinese characters. Additionally, games such as 'Pinyin Match' and 'Hearing and Match' were implemented, with gamification elements such as levelling up and competition.

Interviews were conducted with the students and teachers; the data showed that students positively engaged with the mobile app to practice and learn Chinese characters. Teachers also reported that the mobile app accommodated a variety of students' learning abilities. After the study, further recommendations for the app were recorded, such as providing animated hints on the correct stroke order as students wrote on the screen, offering instant feedback from the games and also archiving and organising learning artefacts as the students' learning portfolios.

These recommendations are interesting as it relates to the teachers' results from the initial survey conducted. Teachers thought that modern language apps today lacked the ability for students to self-correct which could be helped by providing animated hints on stroke order and instant feedback from games.

The same paper also mentioned that mobile apps enhanced students' learning in and outside the classroom, as mobile apps provided opportunities for learners to practice the language outside the classroom. One example is when students were tasked to take appropriate photos to interpret certain idioms - these students then reported that it enhanced their understanding of these Chinese idioms.

Through the initial surveys, the idea of gamification was stressed and thus my initial intention was to use Unity. Unity is a cross-platform game engine since 2005, and is popular with many mobile game app developers. Ideas of creating in game characters that the app user could talk to were proposed through utilising Large Language Models (LLM) models, however this idea was pushed to the backlog due to not being able to test the LLM's accuracy. A user may pick up something wrong from the LLM, which is detrimental to the user's learning. Instead, the learning in the app should be similar to Anki, where there is a set answer to check with. The learning overhead for Unity was also very big. Not only did art need to be involved, where you create your own models to put into your game, Unity is also quite cumbersome. It is also not a very friendly platform for customizability, for example adding extra packages that is beneficial to my language app.

Thus, I took a look at other app development platforms, such as Android Studio and XCode. Android Studio and XCode are native to platforms (android and iOS respectively), which means that scaling this application to a wide audience would be difficult. Luckily, I came across a cross-platform alternative, Flutter.

Flutter brings along many additional advantages. Flutter contains many readily available widgets that allows developers to focus more on the application logic rather than the user interface. These widgets are available on different OS versions and thus will bring fewer compatibility issues when distributing the app.

The active Flutter community means that packages are constantly being updated. As seen later in this paper, features such as tracking a user's stroke to learn a character's stroke order is an example of a pre-made package that developers can use, instead of creating the feature from the ground up. This allows for a faster and simpler development time.

11.2. Frontend architecture.

Before building Flutter apps, it is important to first decide how to structure it. A normal flutter app follows an architecture made up of four distinct layers; the presentation layer, application layer, domain layer and data layer.

Starting from the bottom up, the data layer represents the data sources, in our case all the json queried from the backend. The domain layer speaks to the data layer and converts this json into models that can be used by the rest of the frontend. This can be achieved by the use of repositories that deal with data serialization and data parsing. The application layer contains services that deal with the application logic and can access the many repositories, and finally the presentation layer consists of the widgets and controllers that deal with the interface.

This approach is great for very simplistic apps. When we begin to deal with larger applications, we need to take this architecture a step further and think about a feature-first or layer-first approach [52]. This is because scalable apps consists of a lot of different features. We can think of a feature as an action a user must take to achieve a goal.

A layer-first approach would look something like this:

```

src
  presentation
    feature1
    feature2
  application

```

```

        feature1
        feature2
domain
        feature1
        feature2
data
        feature1
        feature2

```

However one of the pitfalls of this approach is when adding a new feature3; we would have to make changes in each folder.

Instead, we can take a layer-first approach, as follows:

```

features
feature1
presentation
application
domain
data
feature2
presentation
application
domain
data

```

This is more logical because when adding a new feature we can focus on just one folder and it is easier to make changes to one feature.

The next step is therefore to decide how to split the app into the different features.

11.3. Frontend features.

Based on the user feedback and research as shown previously, we have identified the importance of context-based learning, using multimedia to reinforce understanding of words, the usefulness of spaced repetition and how gamification can increase a user's motivation and learning consistency.

To achieve context-based learning, obtaining YouTube videos for users to learn would be beneficial as users can understand and 'shadow' the native YouTuber in real-time.

Shadowing is a technique used by language learners to bridge the gap between listening and speaking. Whilst a learner listens to speech, they simultaneously repeat what they attended to.

Shadowing brings the benefits of bringing a learners' attention to the phonological aspects of what they hear, rather than the meanings, as there is very little time lag [53]. The same study showed that text-presented shadowing, where learners shadow together with a written script of a target passage, may improve reading skills and possibly pronunciation.

The disadvantage of shadowing is that a learner cannot hear themselves speak, as the attention is on listening to input and reproducing it orally. Thus, the paper emphasises the importance learners recording themselves for self-reflection. Finally, shadowing is the most effective when the content is learnt first.

Thus, providing YouTube transcripts that sync with the videos allow learners to practice shadowing. Users should be able to search for videos and save videos so that the learner

can re-visit the same video. Later on, we also touch upon self-reflection through recording the user's voice. This will be seen when we discuss the game aspects of the app.

Using multimedia combined with spaced-repetition is a combination mainly found with flashcard apps, such as Anki. Flashcards mainly contain a sentence or a keyword to be learned; when flipped, it contains the translation. For a flashcard to be fully utilised, images, sound and animations should be comprised in the flashcard. Therefore, my app will contain a user flow allowing for users to design their own flashcard by accessing images from online, be able to listen to the new words and also see animations of their stroke order.

Gamification has shown a direct correlation to a user's engagement to language learning, and thus their motivation and consistency. Learners should undergo a diverse set of exercises that uses as many senses as possible, such as visual, audio and kinetic simulation. My app will therefore contain exercises that will use all aspects of language (speech, writing, reading, translating), broken down into small, gamified lessons.

Lastly, learners mentioned their struggle with staying consistent with their learning. To mitigate this, the app should include features such as streaks and progress tracking of how many lessons they have completed that day.

Overall, the app would be split into 5 different features:

1. lessonoverview: this feature deals with obtaining all the videos you want to study from, requesting new YouTube videos and displaying the transcripts and keywords to the user.
2. makereviews: this feature deals with creating new flashcard and updating flashcard images and notes.
3. spacedrepetition: this feature deals with obtaining all the words to be reviewed that day, updating all the reviews and application logic dealing with the game exercises.
4. useroverview: this feature deals with calculating streaks and tracking a user's progress for that day.
5. youtubeintegration: this feature deals with showing the YouTube player and UI aspects for searching for YouTube videos.

Lesson overview feature example

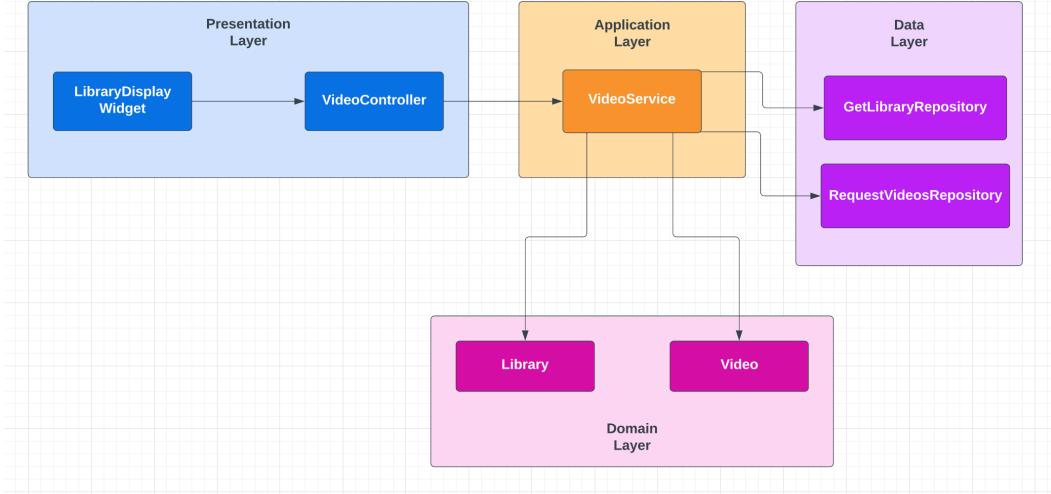


FIGURE 12. Example of lesson overview feature

Riverpod providers wrap around these services, which controllers in the presentation layer access. This is so that widgets in the presentation layer which use certain controllers can listen to state changes and automatically refresh the interface.

For example, the videoController accesses methods in the videoService to obtain the previously processed videos. When obtained, this gets put into a Library model (a list of all the videos they have previously processed), which Riverpod watches for any changes for. If any changes are detected, the widget using this controller will also be updated.

Riverpod is not only a state management framework, but also useful for performing reactive caching to easily update the UI and helps developers through catching programming errors at compile-time rather than at runtime [54].

11.4. MVP.

Now that the backend has been implemented, the next steps are to create an Minimal Viable Product (MVP) to use for user feedback. We can assess the MVP design using Nielson's 10 usability heuristics [55], which consists of:

1. Visibility of System status (the design should always keep the users informed of what is going on, through appropriate feedback)
2. Match between the system and the real world (words, phrases and concepts should be familiar to the user)
3. User control and freedom (users should have a clearly marked 'emergency exit' to leave unwanted action without hassle)
4. Consistency and standards (the app should follow platform and industry conventions)
5. Error prevention (best designs carefully prevent errors in the first place)

6. Recognition rather than recall (minimise user's memory load by making the elements and options visible. i.e. help in context, rather than giving a long tutorial)
7. Flexibility and efficiency of use (shortcuts may speed up the interaction for the expert user. Examples are keyboard shortcuts, touch gestures and customization)
8. Aesthetic and minimalist design (interfaces should not contain information that is irrelevant or rarely needed)
9. Help users recognise, diagnose and recover from errors (error messages should be expressed in plain language and constructively suggest a solution)
10. Help and documentation (perhaps provide some documentation to help users understand how to complete their tasks)

From Figure 13, the original MVP design we can already see the app lacking in many areas. Regarding heuristic (1), the home page with the animated gif holding a review sign is actually a pressable button to show a user's review lessons for that day. This is unlabelled and not immediately clear. The home page also does not contain a clear functionality that can instantly tell the user what they can do. This is also seen in the lesson overview page, where despite having a box with a camera icon and another text box to add a personal note, interviews have shown that users still get confused with the meaning of these boxes.

Original MVP

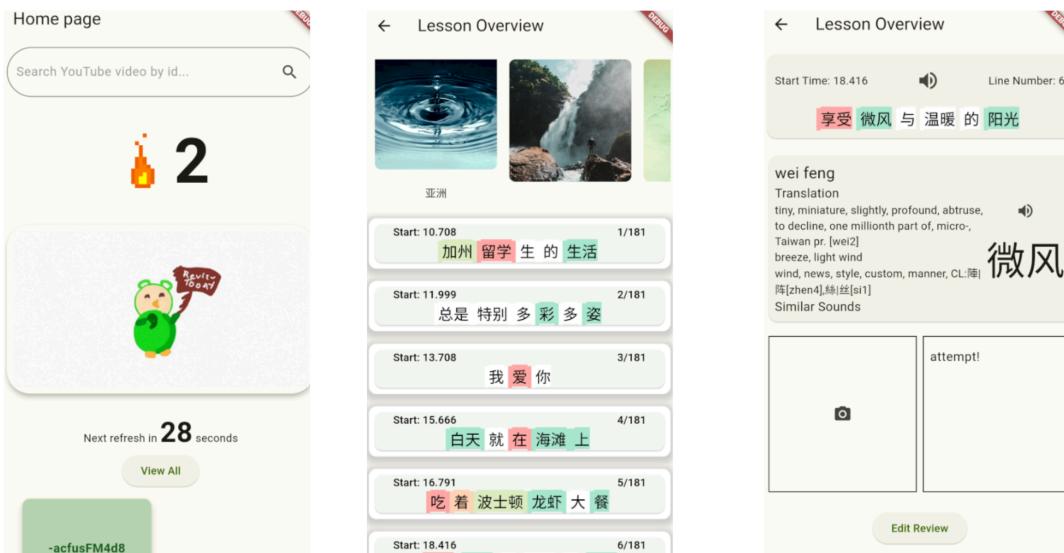


FIGURE 13. MVP design

Regarding the second heuristic, the words and phrases may be unfamiliar to the user. The main issue of the app is that it assumes that the user knows what to do. As an example, the rightmost page supplies the pinyin (pronunciation), translation and similar sounds to that word, but this is not clear due to the lack of labelling.

(3) is also a problem because there is no instantaneous escape route for a user when they accidentally follow a certain navigation path. To get back to the home screen, the user simply has to constantly press the back button. Sometimes, the back button in the app bar does not even exist. Thus, a navigation bar would be a suitable solution to this issue.

In the search bar widget (Figure 14) in the home page, (when searching for a new YouTube video to study from), the pop-up shows a widget with a YouTube thumbnail, name and channel.



FIGURE 14. Initial video search

However, the exit button is on the top left, which goes against convention (the exit button is normally seen on the top right). This design therefore goes against Nielson's 4th heuristic, which emphasises the importance of consistency and standards. Building on top of this, there is also a lack of exit buttons in general. This means that when a user hits an error, it is difficult to navigate away from this, leading to user frustration. Overall, this impacts Nielson's 5th, 9th and 10th heuristic.

Finally, for the 6th and 7th heuristic (minimising user's memory load by making options visible as well as introducing shortcuts to speed up user interaction), more icon buttons can be used. It is important that these icon buttons are big enough to be visible, but also fit the UI aesthetic (Nielson's 8th heuristic).

Taking this a step further, I also wanted to hear what other students had to say. With this MVP, I conducted semi-structured interviews and conversations.

Most of the responses mentioned the lack of an intuitive UI, such as certain actions not being clear, widgets being too clustered and the lack of a uniform structure and colour scheme. However, they enjoyed the game aspect and the ability to download transcripts from YouTube to study from, mentioning how in certain apps today there is an inability to learn from online articles and content.

something duolingo lacks is prob ability to learn and practice something u see on internet
Heart 1
 maybe a bar to copy and paste and then u revise off an article

FIGURE 15. Lack of utilisation of online resources

In the next iteration of the UI design, I drew from online inspirations and apps that I use personally and created inspiration boards. By using these ideas, I would further enhance my UI, re-iterateively conduct interviews and improve upon it. One example is shown below, where I used one interesting design to re-implement the creation of a flashcard page.

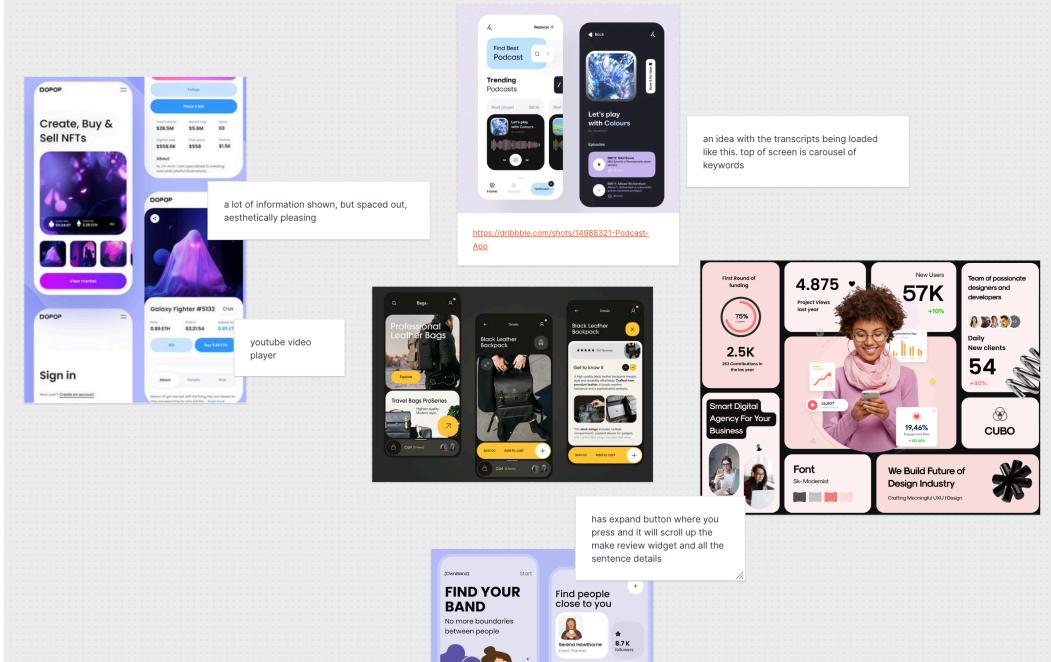


FIGURE 16. Inspiration board example

Make review page (old)

Lesson Overview

← Lesson Overview

Start Time: 18.416 Line Number: 6

享受 微风 与 温暖 的 阳光

wei feng
Translation
tiny, miniature, slightly, profound, abtruse,
to decline, one millionth part of, micro-,
Taiwan pr. [wei2]
breeze, light wind
wind, news, style, custom, manner, CL:陣
阵[zhen4],絲絲[si1]

Similar Sounds

attempt!

Edit Review

Make Review

白天 就 在 海滩 上

享受

Personal note
attempt!

Translation
old variant of 享[xiang3]
to enjoy, to live it up, pleasure, CL:
種[zhong3]
to receive, to accept, to suffer,
subjected to, to bear, to stand,
pleasant, (passive marker)

FIGURE 17. An iteration of make review page

Although the colour theme has improved, feedback included the lack of a focus on the page. The eye is not immediately attracted to any area of the screen, and it is not easy to know where to start to look. This also highlighted the importance of balancing usability and aesthetics.

Another critique was the lack of headers and instructions on the page. For example, on the left-most side is a list of similar sounding words, to help users with pronunciation (by identifying similar sounding words, users can be more aware with common pitfalls and mitigate further mistakes in pronunciation down the line). However, from a user perspective, this just looks like a list of random words. It would be best to label what this is exactly.

In the same interview, I asked them which app's design they liked the most, and why. They answered with Headspace's UI design (Headspace is a meditation app).

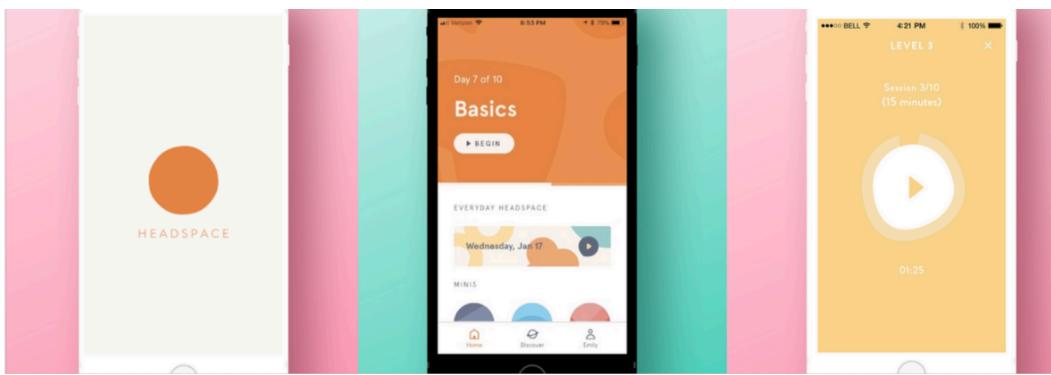


FIGURE 18. Headspace UI design

More specifically, the UI is spacious and calm to look at, which fit their branding. This can be seen in contrast to my initial home page design, where there were too many functionalities in one page. This creates a similar issue to Figure 17, where there is no particular focus on a page, leading to bad usability.

From this conversation, I concluded that each page should lead a user down a particular path through the app and be intuitive. It should follow common practices such as having the close button on the top right rather than the top left, as seen in Figure 14.

Home & Video page

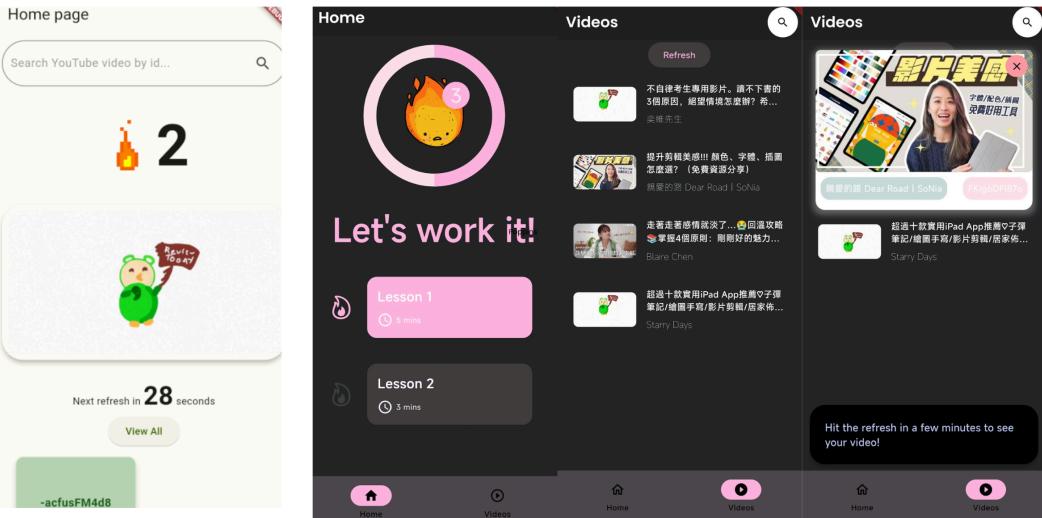


FIGURE 19. Home and Video pages

On the left hand side is the initial home page design. This consists of a search bar functionality, the streak number, a card widget for all the flashcards to review today, and finally the pre-downloaded transcripts of searched YouTube videos.

When the user searches a video and selects one they want to study, this will be shown on the home screen. In the first MVP, you may notice a countdown. Every 30 seconds, the frontend polls the server. It is implemented this way because obtaining the transcript of the YouTube video, running the Stanza NLP model on it, querying APIs to get the most critical words from the transcript and their respective image links, is not instantaneous. In the later iterations, this was changed for the user to manually press the refresh button only when they expect a new video to be downloaded, reducing the server load.

Additionally, the app has been revamped to contain navigations to a home page and video page, instead of cluttering all the information together. This separates out the different features of the app and allows each page to have a certain focus. From conducting interviews with users, it was suggested that the main focus should be the user's lessons to do that day, rather than all the videos in their library. Therefore, the home page now solely concentrates on a user's progress of lessons that day, their streak number, and all the exercises for them to complete.

Duolingo, as mentioned previously, utilises small, bite-sized lessons so that users can learn languages on the go and more conveniently. Inspired by this, each lesson shown on the home page only tests 5 new words, allowing users to do 5-minute lessons whenever they have time. Smaller chunks of learning has also proven to increase motivation and discipline. The large fire con at the top was also introduced in response to Nielson's 6th heuristic, giving the app a more decluttered look.

The right most image displays the new search widget after typing in the YouTube ID in the search bar on the video page. There is a larger thumbnail and the exit button is on the top right, following conventions and thus Nielson's 4th heuristic.

Transcript page

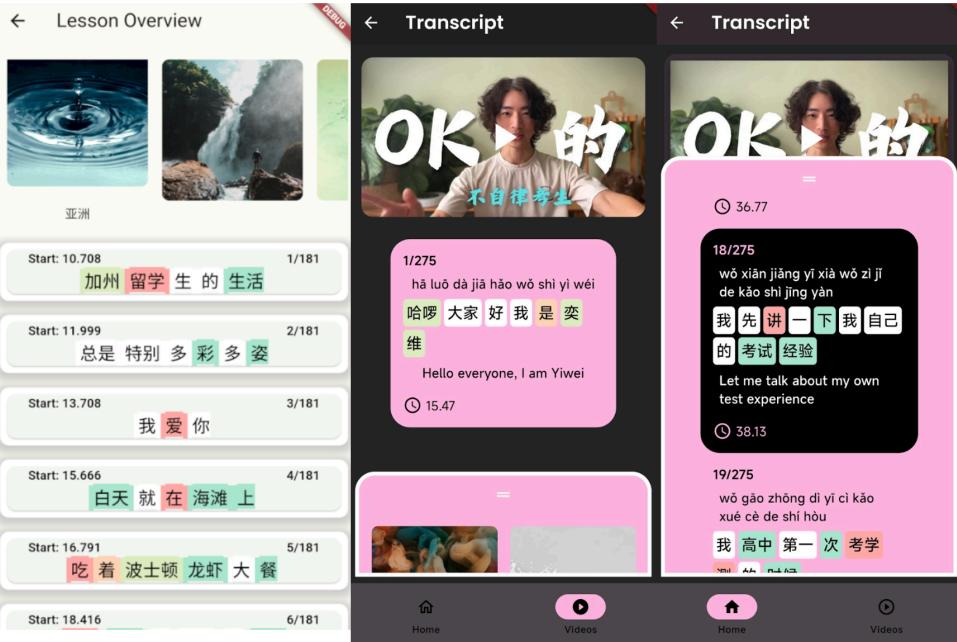


FIGURE 20. Transcript page

Figure 20 displays the full transcript of the video. Initially, this page just showed the keywords of the video with their respective images, then a scrollable list of all phrases from the video, with the times they are spoken (after ‘Start’) and the line number on the top right hand side. The highlighted words show their POS (parts of speech), such as whether it is a noun, verb, adjective etc.

Paper [56] discusses the approach that should be taken when developing course materials for technology-mediated Chinese language learning. Zhang Shenglan recommends that ‘for each chapter or unit, the learning objectives should be given at the beginning, so that students understand what is expected of them’. Since the app does not follow a course but the content of a YouTube video, this can be achieved through adding these keywords and their images.

By presenting these keywords before the transcript itself, it provides the most ‘pay-off value’ possible. These keywords can then be expanded upon in the transcript. At the same time, it provides context to the learner, depicting what the video is about, who are the characters in this video and who the video is for.

In the next few interviews, students discussed how it would be beneficial to also watch the YouTube video in real-time as they follow along the transcript. Students described how

they wanted more visual stimulation. In my literature review, it was discovered that people learn from body language, not just from the words themselves. Being able to draw from visual contexts to decipher new words has proven to be effective in learning.

Thus, in the new iteration of the app, a real-time listener has been implemented which matches the transcripts to the video as it plays (see Figure 20, middle image).

From adding in this feature, the app now consists of visual and audio simulation. Rather than using a robotic voice (used by Anki and other language apps), students can learn the intonation and speech styles of their favourite content creators. This makes the learning experience more enjoyable and also provides a method for users to learn more native ways of speaking. As seen from the surveys, language learners value learning from relevant content rather than mechanic textbook ways of speaking.

Along with this, a draggable scrollable sheet can also be seen peeking from the bottom. Exit buttons have also been incorporated into the app in case the user has navigated to this page accidentally, as well as gestures. By taking Nielson's 7th heuristic (adding shortcuts) into account, users can easily scroll up to see the draggable widgets. Otherwise, these widgets are hidden at the bottom of the screen, which gives the screen more space and improves its overall aesthetic. As well as the keywords of the image, it contains the rest of the transcript, allowing the user to have the whole script at their fingertips instead of having to wait for the video to play at a certain point before seeing a particular phrase of interest.

In later iterations, we can see that each phrase also contains the full pinyin (with their tones rather than just the romanji english characters) and a translation beneath. These add-on features are achieved through the Google Translate package and Pinyin package that Flutter offers.

Many YouTubers that teach mandarin online include the chinese subtitles, their pinyin and their direct translation in their videos. This has proved to be very beneficial to the community, as sometimes words in the sentence may be misheard and thus learned with the wrong pronunciation. With the pinyin shown immediately to the user, we can mitigate this risk. Furthermore, having a direct translation beneath the phrase is also extremely beneficial, as it strips away the need for the learner to navigate away from the app, translate the whole sentence, and come back on the app. Previously, each word in the sentence had to be translated independently, however this takes a lot of time if the whole sentence is made up of new words; users are more likely to be discouraged from learning mandarin and would quit the app.

Each of these phrases belong to pressable card widgets, enabling users to create their own flashcards.

Make review page (new)

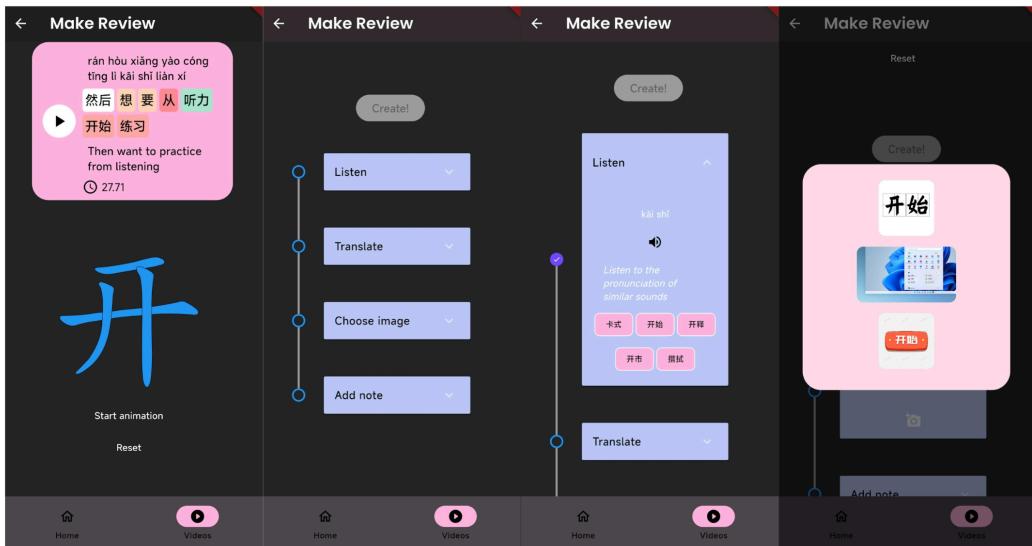


FIGURE 21. New review page

When one of these words get clicked, a user journey is created for a user to create a flashcard. This flashcard will save the word the user wants to review, as well as the sentence it is a part of, to keep its context information.

An improvement from the previous iteration includes the introduction of a stroke-order animation. This idea came from an interview with a beginner-learner of Chinese. Stroke-order is incredibly important in the Chinese language, but is easily overlooked. Adding animations to the UI also enhances the user experience by making it more fun.

In fact, the inclusion of multimedia has been shown to enhance learning [57]. Multimedia is a combination of more than one type of media such as text, symbols, images, pictures, audio, video and animations usually with the aid of technology for the purpose of enhancing understanding or memorisation. In the same paper, the use of multimedia was summarized to provide the following benefits:

1. Ability to turn abstract concepts into concrete concepts
2. Ability to present large volumes of information within a limited time with less effort
3. Ability to simulate students' interest in learning

The paper discusses the cognitive theory of multimedia learning, which consists of assumptions of dual-channel, limited capacity and active processing. In summary, these assumptions are that learners have many channels to separate visual and auditory information, and each channel has a limited load capacity. Thus, multimedia is beneficial as it separates the load from one channel, such that the learners are not overwhelmed from too much information.

From the semi-structured interviews conducted as well as the initial surveys, we can already see how impactful animations and listening to sound pronunciations are. These features stood out especially which, from my findings, can explain why Duolingo is much more popular than its competitor, Anki.

Furthermore, following Nielson's 8th heuristic (an aesthetic and minimalist design), I have improved the user journey when they create a flashcard (see Figure 21, 2nd image).

By making this information linear, users can easily identify their next steps to create a flashcard. There is no information overload and users can decide to open and close certain expandable widgets. A checkbox at the side also marks the user's progress so they can track which widgets they have seen already.

Previously, users were prompted to take their own images to represent a word. However, many interviewers discussed the overhead with this approach, as they would have to find a relevant photo from their own photo gallery. Furthermore, some words simply are difficult to find an image for. Therefore, a new API call to Google Images has been used, where the top 3 images are shown to the user instead (see Figure 21, 4th image).

The user simply has to press on their favourite image; this provides a much more seamless feel to the app. Teachers that took the initial survey also mentioned their desire to incorporate Google into the app - they emphasized how utilizing these free resources can be very beneficial, and many language apps today do not use its advantage. By adding these Google Images we can use free resources online submitted by native speakers of Chinese, which can strengthen the memory of words in learners.

An example is if we think about learning the word for cat. The British idea of a cat is very different to the image of a cat in the East. When learning English, we already associate 'cat' with a certain type of cat. However, when learning a new language, we should associate this new word with a language that aligns more with their culture, as it can provide more context to the learner, strengthening connections in the brain.

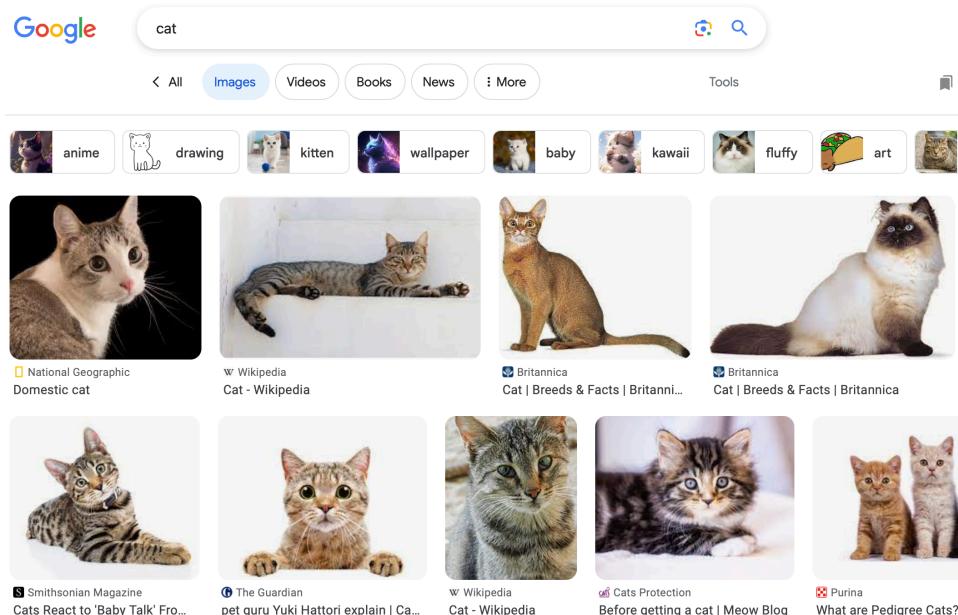


FIGURE 22. Cat (in english)

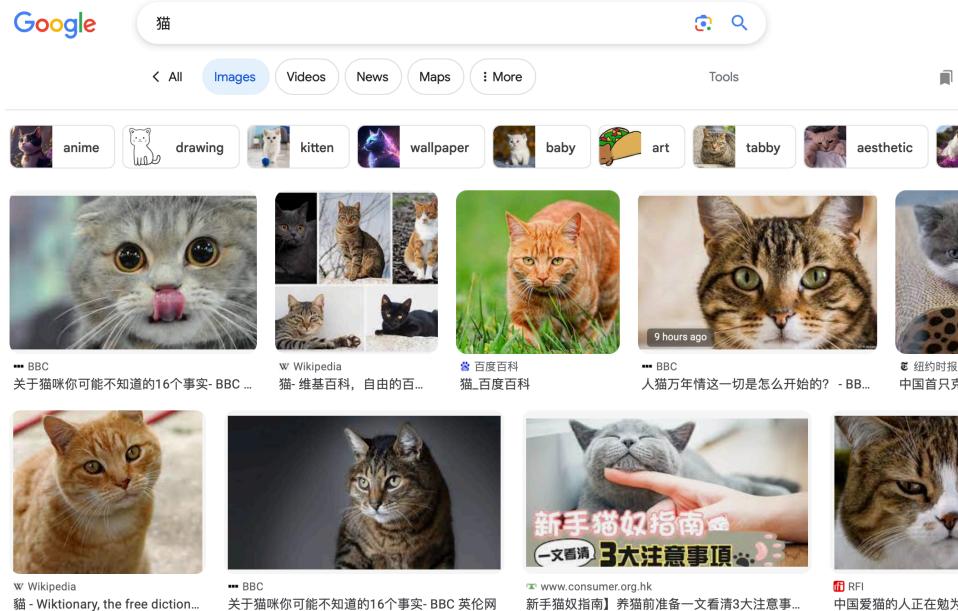


FIGURE 23. Cat (in chinese)

Although similar, we can already see the slight differences between the european cats and the cats when we search in chinese. Google Images also gives a much larger library of images that a user can choose from compared to their own personal photo gallery. Giving the learner the ability to choose their favourite image also means they spend more time thinking about that particular word, strengthening their connection with that word.

Lastly, a game functionality was added with five exercises:

1. Fill in the blank
2. Write the stroke order
3. Match the image
4. Translate the sentence
5. Speaking exercise

Game exercises

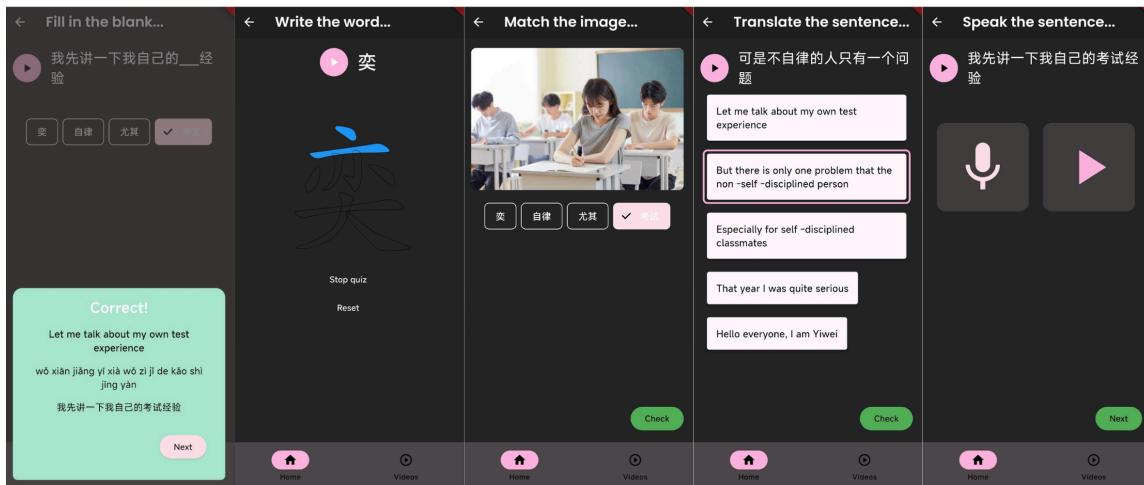


FIGURE 24. Games

Now that we have the ability to add a word, we must incorporate this into a spaced-repetition system.

According to Rigeney (1978) [58], learning strategies are the ‘actions, behaviours, steps, or techniques - such as seeking out target language conversation partners, or giving oneself encouragement to tackle a difficult language task - used by learners to enhance learning’. It encompasses the metacognitive (organisation and evaluation of learning), affective (handling the emotions of the learner), social (co-operation with others), cognitive (linking new information with pre-existing knowledge, analyzing the new knowledge and classifying it), memory (entering and retrieving knowledge) and compensation (guessing and using gestures to overcome deficiencies).

To make the learning of the vocabulary effective, we want to tap into as many of these categories as we can. For affectiveness, we can utilise previous research and design short, fun games for the learner that motivates and encourages them, even through mistakes. For cognitive, the exercises in the games will include using images and multimedia to help users link the information with pre-existing knowledge. The words will also be tested with sentences, to help users see the words in context and also help them analyze and classify these new vocabulary. With these techniques, these should also help with memory. Finally for compensation, the exercises will be challenging enough where learners are prompted to think critically before answering, for example by having translation and fill-in-the-blank exercises, where not all words are known by the learner.

The CoCAR model is also an interesting concept [59]. The paper on developing a training model for empowering the capacity of teachers teaching Chinese as a foreign language describes this model with three steps: cooperation-based cognition, action and reflection. Cooperation-based cognition refers to propositional knowledge of a teaching subject and

use of online tools. This is applied to situations such as designing teaching plans, providing feedback and deploying learning/ teaching strategies. For our case, this does not apply, as we are designing an app for students.

Action refers to using experience to enhance understanding. Jonnaert and Vander Borght (2003) defined competency as ‘the capacity to successfully manage an unknown situation’. Taking this a step further, deep understanding is distilled from reflection, where you mentally restructure experiences to obtain knowledge or insights.

When designing the games, we therefore need to create engaging exercises that allows students to manage unknown situations. Achieving this can be through using multiple ways of testing, such as through visuals, sound, kinetic (testing stroke order) and understanding (translations). For deep understanding of vocabulary, this is achieved from the ability of users to add images and personal notes to their flashcards, where users are prompted to think back to relevant experiences or images that remind them of that word.

Thus, I have distilled the learning aspect into 5 exercises. The first exercise is to fill in the sentence with the correct vocabulary; this exercise aims to teach the user how to use a certain word and where to put it in a sentence. In Figure 24, image 1, you can see the popup that shows when the user gets an exercise correct. This provides the user with pronunciation as well as the sentence’s meaning, giving the user extra information to aid with their learning.

Exercise 2, testing stroke order, is an interactive method for learners to learn how to write the characters. This idea was brought up by one of the interviewees learning Chinese. They mentioned how difficult stroke order was and how they enjoyed this aspect of the language the most. Adding additional multimedia reinforces learning. Knowing the stroke order also ensures that the learner does not simply recognise the character, which is a common pitfall many Chinese learners fall for. Furthermore, writing Chinese characters is very complex and can lead to a lack of motivation. Especially for new vocabulary, students may feel lost while writing a complicated character. Therefore, this app also provides stroke hints when a certain number of wrong strokes have been calculated, to keep the student’s morale high.

In a study conducted in an elementary school Chinese immersion language program, students were given iPads to encourage writing [60]. The second graders who were in the study were tasked to create story narratives in Chinese. The stories they would write in Chinese were developed using oral rehearsal in Chinese by using the in-built iPad’s voice recording, then they proceeded to input the Chinese story into a form of digital media, such as a book creator app.

Inputting Chinese were through the handwriting input method, allowing the students to improve their own Chinese writing ability. At the end of the study, the students showed a net positive attitude. The study concluded that integrating easy-to-use technology into stages of the writing process enhances how elementary students plan, write and create digital stories and these technologies should be used as transformative tools that can extend a student’s writing ability.

From our previous research, we already have seen the importance of creating stories to remember a certain vocabulary. This can be achieved by using the matching image to word exercise (Figure 24, 3rd exercise), where the image itself is a story of its own. The personal note that users put onto their flashcards also can help with memory retention.

Fourthly is translating a sentence, which allows a user to test their understanding. This is a technique seen in many flashcard applications, such as Anki.

Lastly is a speaking exercise. Apps such as Duolingo utilises AI to check the accuracy of a learner's pronunciation. When using this feature myself, I realised that Duolingo's AI allowed you to cheat to system, where you may pass the exercise despite pronouncing a few words wrong. Furthermore, the research we have conducted explains the importance of self-reflection in the language learning process. By recording your own self saying the words and comparing this recorded audio with the correct pronunciation, users can recognise their own mistakes themselves and they are less likely to make the same mistake again.

All these exercises utilises multimedia, which we have seen has proven to be effective for learning. In a study examining the use of multimedia on E-cards for students learning chinese as a foreign language [61], it was revealed that the more visual and verbal a flashcard is, the better the retention. Oxford (1990) recommended the use of word learning techniques through creating mental linkages (an example being grouping words by themes), applying images and sounds and finally employing an action to help learn words.

Traditional flashcards fall flat where audio cannot be integrated. Furthermore, it cannot access the internet and use visual media online. The optimal flashcard and way to be tested is therefore by testing with the sounds and images incorporated with that word. This is why we have such exercises as shown above.

12. EVALUATION

12.1. Critical appraisal.

12.2. Future work.

- Social connection (right now app only works for one person)

13. CONCLUSION

14. APPENDIX

Progress

Date	Log
27/9	<ul style="list-style-type: none"> - Read papers on LLMs and made notes - Set up git repository and initial folders for API part
30/9	<ul style="list-style-type: none"> - Trying to set up again, using ASP .NET core → APIs to bilibili - Using podcast api instead of bilibili! (turns out must pay for transcripts)
8/10	<ul style="list-style-type: none"> - Flask set up YouTube endpoints - pip install opencc, pinyin to transform unicode to simplified and get pinyin
15/ 10	<ul style="list-style-type: none"> - More pinyin, word segmentation - timestamps to start of sentence
16/10	<ul style="list-style-type: none"> - able to get the sentences and then the translations and pinyin - word segmentation works! - word segmentation takes a long time; need to do some caching and use rabbitMQ perhaps
18/10	<ul style="list-style-type: none"> - Looking at rabbitMQ for better scaling of processing transcripts - Studying how to deploy to heroku with multiple workers
28/10	Integrated Nginx and Docker. Finished Fluent Forever book for literature review
05/11	<ul style="list-style-type: none"> - Introduced to "celery" which integrates rabbitMQ with docker. - Still issues with stanza, because it's such a big module and the docker hub stanza is only for german. - Can use TextRazor to get the most important words from transcript
19/11	<ul style="list-style-type: none"> - Wrote more literature review. - Set up NGINX but issues with Celery. - Trying to add some images using google search... issues - Able to incorporate the words with similar pronunciation (similar sounding words)
11/12	<ul style="list-style-type: none"> - Celery memory issue.
24/12	<ul style="list-style-type: none"> - Rebuilt architecture so now app is cleaner and uses micro-services rather than monolithic - Backend routes work for spaced repetition (SRS), etc!

26/12	<ul style="list-style-type: none"> - app context working with celery! the issue was because the worker did not have access to the db. the contextTask in backend was able to set up celery, but each of the workers needed their own Flask app instance, each with their own instance of the db instances (that all connect to the same hosted db!). - now issues with the json and submitting the video data.
27/12	<ul style="list-style-type: none"> - Expanding to not just youtube videos - also able to overwrite previous videos (deleting all reviews etc). - polling does not work. user will have to manually refresh/ reload.
28/12	<ul style="list-style-type: none"> - Flutter set up... Just with emulator.
29/12	<ul style="list-style-type: none"> - Small change — added source to videos, know if it comes from YouTube or somewhere else. - Designing app on Figma so then we can create presentation, application, data layer diagram
02/01	<ul style="list-style-type: none"> - Been working on the domain and data repositories of the flutter app. - Update user sentence works. - Testing works.
08/01	<ul style="list-style-type: none"> - Working on service providers and services, controllers, application and presentation layers. - Got initial UI for obtaining sentences of the transcript, and you can now go onto make review page (can't make review yet) but you can tap on every word and it'll initialise new flash card for you
12/01/24	<ul style="list-style-type: none"> - Game logic (had some issues with the states, now fixed. And also, can batch update lessons now!). - Have to update the db to have a "loading" value in querying videos...
13/01/24	<ul style="list-style-type: none"> - Added timer that would periodically check if next video is ready!
14/01/24	<ul style="list-style-type: none"> - Did streaks! - Did the whole process of update the streak whenever lesson gets completed (checks local storage so not a lot of requests to server) when adding update date. - Merged to main branch, so main all updated now!
16/01/24	<ul style="list-style-type: none"> - YouTube search bar, it now can query youtube id! there were some hardships with using YouTube api.
18/01/24	<ul style="list-style-type: none"> - UI changes. - Failed attempt at trying to host onto Digital Ocean

21/01/24	<ul style="list-style-type: none"> - On the 19th, 20th, been struggling with hosting backend onto digital ocean. Many bugs and turmoil, have emailed <redacted> for help. - Working on improving UI, and writing up dissertation and get design feedback
25/01/24	<ul style="list-style-type: none"> - Working on writing the report the past few days. - Requested for a school VM to host. - Updated UI such that it can sync with YouTube video!!
26/01/24	<ul style="list-style-type: none"> - Can see stroke order animation now!
31/02/24	<ul style="list-style-type: none"> - Updating UI, improving the make review page (with timeline), conducted the 'semi-structured' interviews, been writing up the dissertation
04/02/24	<ul style="list-style-type: none"> - Got the obtaining images from google working! (issues with state management however) - Added the animated search bar and also the whole app navigation
07/02/24	<ul style="list-style-type: none"> - Can connect to the VM! - Phrase translations to the sentences and also their pinyin on top. - Many bugs with making review, updating review... fixed now.
08/02/24	<ul style="list-style-type: none"> - Revamped the home UI so that it shows streak and also a progress indicator showing how many lessons you got done that day!
09/02/24	<ul style="list-style-type: none"> - Improved search functionality (search widgets, also connect to backend to obtain videos!)
10/02/24	<ul style="list-style-type: none"> - New games! (and also progress bar works with it). - Can update SRS now. - Added the stroke order game, fill in blank and also match image to word
14/02/24	<ul style="list-style-type: none"> - Working on bugs like sorting the transcript properly. - Writing up report - Incorporated skipping through the video in lesson overview
17/02/24	<ul style="list-style-type: none"> - Streak bug (gets wrong streak) - Bug with navigation to home page after exercises completed
17/02/24	<ul style="list-style-type: none"> - Streak fixed! had to change backend to sort by unique descending, and also streaks should be calculated from the day before (in case not studied today), THEN we check if studied today and then we + 1.
26/02/24	<ul style="list-style-type: none"> - Exercise to record voice and hear back working!
28/02/24	<ul style="list-style-type: none"> - Translation exercises are all done now! Coding is finished :)

FIGURE 25. Progress log



Chinese Language App for Intermediate Learners [Survey I]

Yue Ning Law

Participant Information

What is the study about?

We invite you to participate in a research project to create a language learning app for intermediate Chinese learners. There are many beginner language apps available, but finding good apps for more advanced learners is challenging. I hope to use machine learning models and curated content from YouTube to motivate language learners and create engaging language ‘lessons’ for students.

This study is therefore a way to understand how students self-study Chinese at an intermediate level and draw parallels between a student’s study methods and language study research online.

Why have I been invited to take part?

You have been invited to take part because you are a student studying a language, or you are a language teacher. For students, I am interested to gain insights into the current study techniques you find most beneficial to you, and the pain points of language learning. For teachers, I want to use your expertise to learn about what makes a good language learner and any practises or study patterns you see from the top learners.

Do I have to take part?

This information sheet has been written to help you decide if you would like to take part. It is up to you and you alone whether you wish to take part. If you do decide to take part you will be free to withdraw at any time without providing a reason and with no negative consequences.

What would I be required to do?

A short, 15-minute survey on Qualtrics will be sent to your email. This form link will contain generic questions about your study techniques and your opinions on certain language apps. This will be entirely anonymous. At the end of the survey, you can contact the email address if you would like to take this discussion further, in an interview format.

Are there any risks associated with taking part?

All responses are anonymous. I will not know whose response belongs to whom.

Are there any benefits associated with taking part?

With taking part, I will be able to create an app that will be more beneficial to your language studies! The research will also enable future developers to make more helpful apps in the language learning space.

Informed consent

PIS_05/10/2023_1_CHINESELANGUAGEAPP

It is important that you can give your informed consent before taking part in this study. You will have the opportunity to ask questions about the research before you provide your consent.

Who is funding the research?

My research is not being funded.

Reward/compensation

There is no reward/compensation offered.

What information about me or recordings of me ('my data') will you be collecting?

I will be collecting your Qualtrics (anonymous) responses. Please note that when sharing data, all your responses will be anonymous and all data will be deleted 2 weeks after the submission of my dissertation.

Terms used to describe your data

In the next sections we will describe how your data will be stored, used, and shared. We will use these terms to describe what form your data will be in:

- Anonymised - means that parts of your data will be edited or deleted such that no-one, including the researchers, could use any reasonably available means to identify you from the data
- Pseudonymised – means that your data will be edited so that you are referred to by a unique reference such as a code number or different name, and the original data will be either deleted or only available to certain individuals. There will be a 'key' document, which will link your unique reference to your real identity. The key will be kept in a secure location, where only certain individuals will have access to it and be able to reconnect your data to you later. If this key is deleted your data becomes 'anonymised'.
- Fully identifiable - means that your data will be identifiable as yours.

How will my data be stored and who will have access to it?

Your Qualtrics data will be stored in an **anonymised** form. Your data will be stored in Qualtrics and only the researcher will be able to access it.

How will my data be used and in what form will it be shared further?

Your research data will be analysed as part of the research study. It may then be published in my dissertation. Data used in publications will be in **ANONYMISED** form.

Your data will also be made **publicly** available in **ANONYMISED** form by placing it in a data repository for the purpose of further research. All users, including the public, will have access.

When will my data be destroyed?

Data will be destroyed within 2 weeks after the dissertation submission, 05/04/2024.

International data transfers – Personal data

Your data may/will be stored and processed in St Andrews. No matter their physical location, researchers are required to store and make use of personal data as if they were in the UK; University requirements and the provisions of the data protection law apply at all times.

Will my participation be confidential?

Yes, your participation will only be known to the researcher.

Use of your personal data for research and your data protection rights

The University of St Andrews (the ‘Data Controller’) is bound by the UK 2018 Data Protection Act and the General Data Protection Regulation (GDPR), which require a lawful basis for all processing of personal data (in this case it is the ‘performance of a task carried out in the public interest’ – namely, for research purposes) and an additional lawful basis for processing personal data containing special characteristics (in this case it is ‘public interest research’). You have a range of rights under data protection legislation. For more information on data protection legislation and your rights visit <https://www.st-andrews.ac.uk/terms/data-protection/rights/>. For any queries, email dataprot@st-andrews.ac.uk.

Withdrawing your data

You can withdraw your data before 01/03/2024. If your data are anonymised, we will not be able to withdraw it, because we will not know which data is yours.

Ethics review

This research proposal has been scrutinised and subsequently granted ethical approval by the University of St Andrews Teaching and Research Ethics Committee.

Where can I find out about the results of the study?

When the dissertation gets submitted, I will email all participants a summary of my findings. I will also post this on webpages such as LinkedIn.

What should I do if I have concerns about this study?

In the first instance, you are encouraged to raise your concerns with the researcher. However, if you do not feel comfortable doing so, then you should contact Angela Miguel or the School Ethics Contact (contact details below). A full outline of the procedures governed by the University Teaching and Research Ethics Committee is available at <https://www.st-andrews.ac.uk/research/integrity-ethics/humans/ethical-guidance/complaints/>.

Contact details

Researcher

Yue Ning Law

arm14@st-andrews.ac.uk

Supervisor

Angela Miguel

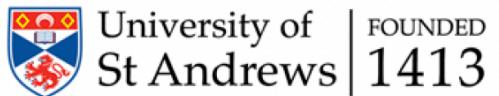
arm14@st-andrews.ac.uk

School ethics contact

Olexandr Konovalov

ethics-cs@st-andrews.ac.uk

FIGURE 26. Participant Information for surveys



School of Computer Science Ethics Committee

08 November 2023

Dear Yue Ning,

Thank you for submitting your ethical application which was considered by the School Ethics Committee.

The School of Computer Science Ethics Committee, acting on behalf of the University Teaching and Research Ethics Committee (UTREC), has approved this application:

Approval Code:	CS17314	Approved on:	08.11.23	Approval Expiry:	08.11.28
Project Title:	Chinese Language App for Intermediate Learners				
Researcher(s):	Yue Ning Law				
Supervisor(s):	Angela Miguel				

The following supporting documents are also acknowledged and approved:

1. Application Form
2. Participant Information Sheet
3. Participant Consent Form
4. Participant Advert
5. Sample Questions

Approval is awarded for 5 years, see the approval expiry date above.

If your project has not commenced within 2 years of approval, you must submit a new and updated ethical application to your School Ethics Committee.

If you are unable to complete your research by the approval expiry date you must request an extension to the approval period. You can write to your School Ethics Committee who may grant a discretionary extension of up to 6 months. For longer extensions, or for any other changes, you must submit an ethical amendment application.

You must report any serious adverse events, or significant changes not covered by this approval, related to this study immediately to the School Ethics Committee.

Approval is given on the following conditions:

- that you conduct your research in line with:
 - the details provided in your ethical application
 - the University's [Principles of Good Research Conduct](#)
 - the conditions of any funding associated with your work
- that you obtain all applicable additional documents (see the '[additional documents' webpage](#) for guidance) before research commences.

You should retain this approval letter with your study paperwork.

Yours sincerely,

Natasha Bazeley

SEC Administrator

School of Computer Science Ethics Committee

Dr Olexandr Konovalov/Convenor, Jack Cole Building, North Haugh, St Andrews, Fife, KY16 9SX

Telephone: 01334 463273 Email: ethics-cs@st-andrews.ac.uk

The University of St Andrews is a charity registered in Scotland: No SC013532

FIGURE 27. Ethics approval

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