Enhancing Sinhala Writing Skills in Dyslexic Students through Personalized and Gamified Learning

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Declaration

I certify that this dissertation does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any university and to the best of my knowledge and belief, it does not contain any material previously published or written by another person or myself except where due reference is made in the text. I also hereby give consent for my dissertation, if accepted, be made available for photocopying and for interlibrary loans, and for the title and abstract to be made available to outside organizations.

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under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

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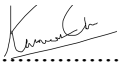

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Abstract

Dyslexia, a learning disability affecting 15–20 percent of the global population, significantly impairs reading, writing, and comprehension. In Sinhala, a language with a complex script and phonetic system, these challenges are particularly severe, especially in handling modifiers and constructing sentences. Conventional teaching methods often fail to meet the individual needs of dyslexic students, leading to reduced engagement and low self-esteem. While research on game-based and personalized learning strategies shows potential, existing studies primarily address reading and writing skills in languages like English and Malay, leaving a gap in approaches for improving Sinhala writing skills. Initial data collection process revealed significant struggles with the correct placement of modifiers, spelling errors, and sentence coherence among dyslexic students. Students also exhibited slower writing speeds and greater difficulty in dictation compared to copying tasks as well as frustration and a lack of confidence in writing. To address these challenges, we designed and implemented an application with a personalized and gamified learning framework, iterating through the Design Science Research (DSR) methodology. We designed the focused exercises based on six selected letters ග (Ga), ල(La), ය(Ya), ට(Ta), ක(Ka), and ප(Pa) from Sinhala alphabet. For the evaluation, a group of 10 dyslexic students was divided equally into a control group and a treatment group using stratified sampling. Application was evaluated using a pretest/posttest design after giving the application for 14 days to the treatment group. The results demonstrated improved average letter accuracy in nearly 21% and reduced average writing time by nearly 2 minutes in the treatment group achieving the research aim. Additionally, the qualitative feedback highlighted overall positive responses toward the application, which features a personalized and gamified learning framework.

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Chapter 1

Introduction

Dyslexia is one of the most common learning disabilities, affecting approximately 15 to 20 percent of the global population, as reported by the International Dyslexia Association (IDA) [1]. This condition primarily impairs reading abilities due to difficulty correlating speech sounds with their respective letters. These challenges often extend beyond reading, adversely impacting writing skills, oral communication, comprehension, and short-term memory. Additionally, there are prevalent misconceptions that individuals with dyslexia lack intelligence, despite evidence showing that their IQ levels are typically equivalent to or even higher than those without the condition. The underlying cause of dyslexia is linked to variations in the brain region responsible for language processing, called ‘occipito-temporal cortex [2].

In many developed countries, learning disabilities like dyslexia receive significant attention, and as a result, both parents and teachers are often well-informed about the condition and its impact on children. However, in the Sri Lankan context, there is still a lack of awareness and understanding of dyslexia among most parents and educators. Additionally, only a limited number of specialized centers provide treatment, which are primarily located in major cities, making it difficult for children in rural areas to access proper diagnosis and support. Our research focuses to address that issue by exploring effective intervention strategies for dyslexia by leveraging technology to receive treatment regardless of the geographic location.

1.1 Background of the Problem

Language is the most sophisticated form of human communication. It is central to reading, writing, speaking, thinking, and many other cognitive abilities. While all animals have ways of communicating, human communication is far more advanced due to the complexity of the human brain.

Writing is a fundamental skill that is essential for learning, communication, and self-expression. It is a vital tool in both academic and everyday contexts because it enables people to express thoughts, ideas, and feelings with clarity and accuracy. By improving creativity, organization, and critical thinking, writing promotes cognitive development. By the age of four or five, most children begin learning to write with the guidance of parents or pre-school teachers. Early development of good writing skills in children, in particular, sets the stage for success in academics and beyond, enabling them to express themselves with confidence and engage in the world in a meaningful way. It is the process of representing spoken sounds using symbols, and the alphabet is the system of symbols used to capture the sounds of language. As children learn the alphabet and written language, they gradually develop the ability to read. This shows a clear connection between writing and reading.

Brain development plays a crucial role in acquiring writing and reading skills. By around the age of ten, most children can recognize all the letters of their mother tongue and understand basic written patterns. They continue to improve in speed and fluency. After this age, most children are capable of learning additional languages with relative ease [3].

It is often assumed that any child without mental or physical disabilities can easily learn to read and write. However, this is not always the case. Many children face challenges in developing reading and writing skills. Several factors can influence a child's ability to learn these skills effectively. Common factors include a lack of motivation or interest in learning, slow developmental progress, low educational background of parents, financial difficulties, and certain medical conditions that can impact those reading and writing abilities [4]

1.2 Problem Statement

Dyslexia can be identified as one of the most common medical conditions that mainly affects the reading skills of a person. Due to the direct connection between reading and writing, it will impact one's writing skills as well. Untreated dyslexia can significantly impact a child's communication abilities, education, mental health, and other areas of development. Evidence shows that untreated dyslexia often results in poor academic performance, which, when prolonged, can contribute to feelings of low self-esteem and elevate the risk of anxiety and depression [5]. Therefore, early detection and intervention in cases of dyslexia can yield substantial therapeutic benefits. Primary school-aged students are an ideal population for such interventions, as early support can help address and mitigate learning challenges before they intensify.

In Sri Lanka, where Sinhala is the primary language, both the health and education sectors currently provide limited support for specific learning disorders such as dyslexia. Furthermore, there is a shortage of trained staff within the school system to support dyslexic students effectively. A study on teachers' knowledge of dyslexia revealed that only special education teachers received training on this condition [6]. Dyslexic students struggling academically may also compare themselves with their non-dyslexic peers, making school environments especially challenging and creating a need for alternative support options.

A review of existing literature reveals that there are assistive technologies associated with gamification and personalization that have been mainly used to support dyslexic students' learning in English and other foreign languages, like Malay. And also it reveals the lack of assistive technologies available to address the challenges faced by students learning in Sinhala, more towards the writing challenge, with comparison to reading challenges. This gap requires us to do more in-depth analysis on how we can associate gamification and personalization with an assistive technology to enhance the writing skills of dyslexic students learning in Sinhala.

1.3 Motivation

Recognizing these challenges, this research is motivated to address these challenges by introducing effective and interactive learning interventions that aim to boost motivation,

confidence, and cognitive development. Furthermore, while extensive research exists for dyslexic learners in languages such as English, there is a notable lack of studies tailored to students learning in Sinhala. By focusing on this undiscovered area, the study intends to bridge a critical gap, offering insights into how personalized and gamified approaches can support Sinhala-speaking dyslexic students and contribute meaningfully to inclusive educational practices.

1.4 Research Aim and Objectives

The main aim of this research is to explore effective strategies to improve the Sinhala language writing skills of dyslexic students using a personalized game-based learning platform.

To achieve this aim, it is broken down into sub-objectives.

- To identify the key features of writing difficulties in Sinhala among primary school-aged dyslexic students.
- To design personalized learning within a gamified environment that targets the unique writing challenges of dyslexic students in Sinhala.
- To assess the effectiveness of a personalized and gamified learning environment in improving the writing proficiency of dyslexic students in Sinhala.

The research questions are listed below.

1. What are the key features of writing difficulties experienced by primary school-aged dyslexic students learning in Sinhala?
2. How to personalize within a gamified learning environment to effectively address the writing challenges faced by dyslexic students in Sinhala?
3. What gamified elements can be used to address the Sinhala writing challenges of dyslexic students, and how do these elements impact the motivation and learning outcomes?
4. How do personalized and gamified learning environments affect the writing proficiency of dyslexic students in Sinhala?

1.5 Scope of the Project

Early intervention has been largely considered as one of the secrets to effective intervention for dyslexic children. It enables to reduction of the learning gap between the dyslexic students and non-dyslexic students at early stages before widening that gap. With that consideration, the scope of this research has been carefully defined to ensure that it remains manageable and achievable within the allocated timeframe.

1.5.1 In-Scope

- This research specifically focuses on students diagnosed with dyslexia who face challenges in Sinhala writing skills.
- This research targets children aged eight (8) to ten (10) who are actively engaged in academic learning.
- The scope includes 6 letters we selected according to the research findings and different activities with simple letters, two word letters, letters with modifiers, and two letter words with modifiers.

1.5.2 Out-Scope

- This research does not focus on other co-existing conditions, such as learning disabilities such as autism or ADHD, including
- The scope is limited to the Sinhala language and does not consider other linguistic contexts.
- The study does not address the development of other skills, such as reading or short-term memory.

1.5.3 Assumptions

- It is assumed that the handwritten recognition model might be over-fitted to the sample population.
- It is assumed that the teaching content provided during the intervention phase remained consistent across all participants.

- It is also assumed that external factors, such as environmental distractions, did not significantly affect the research outcomes.

Chapter 2

Literature Review

This chapter reviews existing literature relevant to dyslexia, with a particular emphasis on writing difficulties. Section 2.2 introduces the concept of dyslexia, including medical aspects, common learning difficulties, and the limitations of traditional interventions. Section 2.3 investigates various educational interventions, focusing on phonological and assistive technology-based methods, and further examines strategies such as gamification, personalization, UI/UX, and multisensory approaches. Sections 2.4 to 2.6 offer deeper insights into how gamified learning, personalized learning, UI/UX and multisensory techniques have been applied to support both reading and writing difficulties. Section 2.7 highlights the relatively limited focus on writing difficulties and outlines the related works relevant to the Sri Lankan context. Section 2.8 presents the related work in a structured tabular format. Finally, Section 2.9 identifies the key research gaps that this study aims to address.

2.1 What is Dyslexia

The International Dyslexia Association [7] defines dyslexia as a specific learning disability of neurobiological origin, characterized by difficulties in accurate and/or fluent word recognition, along with poor spelling and decoding abilities. The concept of dyslexia has been the subject of ongoing debate, with a variety of theories providing distinctive explanations based on their respective perspectives. According to Developmental Dyslexia [8], three prominent theories have been extensively discussed in the literature:

1. **Phonological Deficit Theory** - This theory proposes that dyslexia arises from a specifiimpairmentnt in phonological processing, which affects the ability to represent and

manipulate the sounds of language skills that are essential for learning to read.

2. **Magnocellular Theory** - According to this view, dyslexia is linked to a dysfunction in the magnocellular pathways of the brain, which are involved in processing rapid sensory information. This can result in visual and auditory deficits that impact reading acquisition and fluency.

3. **Cerebellar Deficit Theory** - This theory attributes dyslexia to abnormal functioning of the cerebellum, a brain region responsible for motor coordination and skill automization. It suggests that cerebellar deficits may interfere with the automatic execution of reading related processes and phonological tasks.

According to Cleveland Clinic [5], students with dyslexia often face difficulties, including trouble spelling basic words, confusion between letters with similar shapes, mixing up positions of sounds within words, and showing reluctance to read aloud in class. Another study, Roitsch et al. [9] further outlines a range of difficulties associated with dyslexia. These include:

- Difficulty with the development of phonological awareness and phonological processing skills.
- Difficulty in accurately decoding nonsense or unfamiliar words.
- Difficulty in reading single words in isolation.
- Inaccurate and labored oral reading.
- Lack of reading fluency.
- Challenges in learning the names of letters and their associated sounds.
- Difficulty with learning to spell.
- Trouble with word finding and rapid naming.
- Variable difficulty with aspects of written composition.
- Variable degrees of difficulty with reading comprehension.

Traditional one-size-fits-all educational approaches present significant limitations for these students. In such methods, teachers deliver the same content to all students at the same pace, which can result in issues related to pacing, memory retention, comprehension, and engagement. These approaches often fail to address individual learning needs and may negatively affect the self-esteem of dyslexic learners. These limitations have led to the development of various educational interventions specifically designed for dyslexic students.

2.2 Educational Interventions for Dyslexia

The literature on supporting students with dyslexia can generally be divided into two main categories: assistive technology-based interventions and phonologically based interventions. Phonological based interventions are focused on creating designs to improve the learning abilities of dyslexic students that are more theoretical, which requires more human resources to execute. Assistive technology-based interventions are the ones that help to improve the learning abilities of dyslexic students with the use of a technology-based tool. This section reviews several phonological based interventions to gain insights into the tactics used.

An intervention which spanned across one year of using Orton Orton Gillingham approach among Singaporean students with dyslexia to improve their reading and spelling skills is discussed in Lim et al. [10]. The Orton Gillingham approach is a multisensory, direct, explicit and sequential way of teaching the literacy for dyslexic students. Students had been administered 80 hours of Orton Gillingham instructions to the small groups of 4 students over the year twice a week. A single-subject pre-test/post-test design was used to evaluate the intervention by psychologists at the Dyslexia Association of Singapore. And The study reported a significant impact in reading and spelling standard scores of dyslexic students using a multi sensory learning strategy like Orton Gillingham. And also this paper highlights the fact that the age at which students began the intervention was inversely related to their gains in reading and spelling.

Lee [11] examines the design and development of a Malay word recognition intervention program. The intervention targeted students with dyslexia from grade one to three. Three objectives such as teaching the full alphabet, word building and word reading were aimed to achieve. To fulfil this aim while making the learning content more interesting and en-

gaging they used game based learning techniques as well as multisensory learning. Bingo games and flash cards were examples for that. Students' improvement was assessed in word recognition and reading by giving sets of 10-word probes before and after the intervention and analysing those marks for each objective.

Nourbakhsh et al. [12] explores the effects of multisensory method and cognitive skills training on perceptual performance and reading ability among dyslexic students in Tehran-Iran. The researchers divided 60 dyslexic students into 3 groups and conducted 16 sessions per week. Multisensory learning approach was administered on one group while another group was administered on cognitive skills training and the other group worked as the control group. They had been focused on three modalities such as visual, auditory and tactile as for the multisensory approach. Improvement in reading and memory tests were the learning outcomes expected out of this research study. The study used sets of tests such as Reading and Dyslexia Test (RDT), Bender Visual Motor Gestalt Test (BVMGT), and Rey-Osterrieth Complex Figure test (ROCF) to assess the learning outcomes. The results indicated that the multisensory developmental intervention was more effective than the cognitive skills training. Furthermore the study showed that the multisensory method significantly improved the performance of dyslexic students on reading, visual-motor, and memory tests compared to the control group.

Wridy [13] is a mobile application designed to support children with learning disabilities such as dyslexia. It offers activities focused on practicing the writing of the English alphabet. This application uses multisensory learning techniques such as 3D models and colour-changing feedbacks for the visual aspect, tracing alphabet on touch screen for the tactile aspect and components in Wridy for sensory aspect to imrprove the engagement and learning outcomes of students. This application showed the mean system usability score of 60 based on the responses from six participants, placing Wridy in the 15th to 34th percentile, indicating a grade D with an acceptable adjective rating.

The iLearnRW Game [14] was created to help dyslexic students at home and in the classroom. It uses game-based learning strategies to increase motivation and engagement and personalization learning strategies to assist students in improving their literacy abilities regardless of whether a teacher is present using adaptation mechanisms. In order to make sure the game fits the unique demands of its audience, the design approach used partici-

patory design techniques, which allowed end users and dyslexia specialists to contribute. In contrast to conventional games with a predetermined plot, iLearnRW centers on distinct characters, each of whom represents a distinct category of language challenges. In the end, this friend list serves as a graphic representation of the student's educational path, highlighting the difficulties they have faced and possibly completed while making the learning more engaging and interesting.

Abdul Hamid et al. [15] examines a computer based learning model for students with dyslexia. It consists of six main components which are exercise model, behaviour processing model, student model, teaching model, expert model and domain knowledge model. It addresses the different cognitive difficulties such as spelling, reading and writing. This model uses personalization techniques to cater for the specific needs of each individual using the behavior processing model.

After referring phonological based and assitive technology based interventions, multisensory learning and game-based learning approaches are found to be common, while personalized learning emerging as a significant component within technology-supported interventions.

Multisensory learning, an educational approach engaging multiple senses (sight, sound, touch, and movement), aids in improving information absorption and retention among students. Gamified learning, which incorporates game elements such as points, rewards, challenges, and levels into educational activities, is frequently used to enhance engagement and motivation. Personalized learning, which customizes educational content to meet individual needs, is notably applied in technology-based interventions, as it is often impractical to manually adjust content for each participant in non-technology-based settings.

Moreover, game-based learning can integrate multisensory learning components, enhancing its effectiveness. With advancements in technology, current interventions increasingly incorporate assistive technology to support dyslexic students more effectively, as noted by Lim and Oei [10]. While these approaches have been widely applied to reading interventions, their application to writing support requires further examination. This literature review aims to examine existing research on interventions designed to support dyslexic students, with particular emphasis on writing support tools. Our analysis focuses on the ef-

fectiveness of personalized learning, the impact of gamification on educational outcomes, UI/UX and multisensory approaches, work related to writing interventions, and the context of Sri Lanka. Furthermore, this literature review identifies existing gaps in the literature.

2.3 Gamified Learning Approaches for Dyslexic Students

Gamification, or the integration of game elements into educational settings, serves to boost motivation and engagement. Research has shown that dyslexic students frequently encounter negative emotions such as anxiety, low self-esteem, and frustration, which traditional teaching methods often fail to address effectively. In response, researchers have explored various support techniques, with digital game-based learning and gamification showing significant positive impacts on the learning outcomes of dyslexic students. Games transform learning into an engaging, interactive experience, particularly suited for students with dyslexia.

Essential gaming elements such as storylines, reward systems, goal setting, level progression, feedback, and achievement tracking are identified as critical motivators for student engagement by Bigueras [16]. The role of character customization, unlockable rewards, and competitive elements (e.g., leaderboards) in sustaining engagement is further emphasized by Dymora and Niemiec [17]. Multiple studies investigate how different gamification components impact motivation and learning outcomes among dyslexic students. For example, The gamification platform" ClassDojo," which employs badges and a reward system to motivate dyslexic students, is analyzed by Gooch et al. [18]. This platform allows teachers to creatively customize badges while enabling dyslexic students to personalize their badges, which reflect their unique strengths and challenges. An experimental study using ClassDojo revealed that students react differently to negative and positive badges, providing insights into how specific gamification elements can enhance motivation and engagement.

Similarly, The influence of features such as leaderboards and badges on intrinsic motivation and learning outcomes is examined by Hanus and Fox [19]. However, Mekler et al. [20] caution that certain elements, like points and leaderboards, may negatively impact dyslexic students if not carefully implemented. Bigueras [16] emphasizes that storytelling is particularly engaging for children, who are drawn to game narratives and are motivated to progress to uncover what happens next. Level-based progression, as discussed by Sarah Abu Bakar

et al. [21], plays a vital role in organizing gameplay, fostering a sense of achievement, and enhancing self-confidence.

Several applications exemplify gamified learning tailored to dyslexic students. Lexipal [22] and Larolexia [16] concentrate on improving reading skills through game-based learning environments. The application iLearnRW [23] demonstrated improvements in literacy skills, including segmentation and sentence completion, while boosting engagement and motivation in dyslexic students learning both at home and in school settings. The game features multiple characters with diverse, rich narratives.

In Sri Lanka, Helply [24] is a mobile application designed for primary school students with dyslexia, offering mini games to develop various skills. Arunalu [2], another Sinhala language-based intervention, was developed to address reading challenges in dyslexic students through a game-like environment, incorporating four screening and intervention methods. Additionally, Rupasinghe et al. [25] gamifies the teaching of five commonly confused Sinhala alphabet letters, making the learning process both engaging and effective for dyslexic learners.

2.4 Personalized Learning Approaches for Dyslexic Students

Personalization is essential in addressing learning disabilities, as each individual with a learning disability exhibits a unique profile of strengths and challenges. It is emphasized by Martinez Marrero [26] that technology-based instructional design should be learner centered and tailored to specific learning disabilities. Below are some interventions that effectively integrate personalization.

A mobile application for dyslexic people utilizing artificial intelligence and machine learning concepts is discussed by Rajapakse et al. [1]. This application is designed to deal with the reading difficulties faced by the dyslexic people in their day-to-day activities. ALEXZA can capture real-time feeds, identifying text within images using image processing techniques. The application recognizes complex words unfamiliar to the user and, leveraging a learning algorithm, replaces these with simpler alternatives from its database. Feedback

and preliminary prototype testing indicated the success of this personalized approach.

A tailored educational resource system was presented by Banik et al. [27] to support children with unique needs, such as those with autism, dyslexia, ADC, and ADHD. There are four primary parts to the system: an intelligent interface for tailoring educational materials according to user profiles; web mining to gather diverse multimodal learning materials matched to user interests; IoT sensor integration to adapt content in real time based on factors like mobility and speech; and machine learning to identify and categorize users based on individual characteristics, enabling tailored content delivery. The study involved participants across age groups, with a focus on 30 children with disabilities in Bangladesh. Data collected included age, gender, location, disability type, mobility, and learning level. The effectiveness of the system was evaluated using personalized search results and user satisfaction feedback, demonstrating its potential to enhance learning for children with diverse needs through adaptive, technology-driven solutions.

Another intervention is a writing tool specifically designed for dyslexic students, comprising four modules, as discussed by Gupta [28]. The final module, Testing and Learning, utilizes an adaptive learning model to generate new writing exercises based on the student's performance in previous levels. Here, performance is assessed by the number of errors in each exercise.

Hope [29] is an interactive mobile solution aimed at addressing dyslexia-related challenges in writing, reading, and speaking. The application first assesses the user's skill level in each area, and based on this assessment, recommends targeted therapies. These therapies are dynamically organized according to the user's performance on aptitude tests, providing a highly personalized experience. Integrating personalization techniques into educational interventions for dyslexic learners seeks to reduce dependence on supervisors or specialized educators.

Another intervention is an application was created by Sik-Lányi et al. [30] to help dyslexic kids under the age of five with their writing. The Learn module and the Test module are the two primary components of the application. While the Test module contains exercises designed to help kids remember and reinforce what they have learned, the Learn module offers activities centered around arithmetic numbers, mathematical symbols, and alphabets (both

upper and lower case). Performance in learning and testing tasks is evaluated via an integrated evaluation module. A learning algorithm with three primary parts—representation, evaluation, and optimization—is at the heart of the system. To guarantee thorough learning coverage, the algorithm in the representation component chooses character sets according to preset parameters. The evaluation component measures the learner's performance, logs their progress, and uses graphical displays to visualize the results. The optimization component maximizes knowledge retention by promoting relearning and practice-based learning. By regularly assessing each learner's development and acknowledging their accomplishments, it also encourages self-motivation.

A classification model to tailor tools and strategies for improving reading based on individual needs is proposed by Zingoni et al. [31]. Another adaptive learning model uses machine learning and consists of five core components: Exercise Model, Behavior Processing Model, Student Model, Expert Model, and Teaching Model is discussed by Abdul Hamid et al. [15]. This model targets improvements in phonology, spelling, reading, and writing skills. Notably, the Behavior Processing Model monitors student engagement with the content and dynamically adjusts activities to maintain the student's interest and enhance engagement.

2.5 UI/UX and Multisensory Approaches

Rocha et al. [32] employ a user-centered design approach to create an interactive learning tool. It also mentions that the game design's simplicity is the user interaction's main feature. Furthermore, this research paper emphasizes that the interface should have an appealing color design to make the children interested in the game. In this study, two methods of usability evaluation were used to find out the results of the experimental design and to enhance the system further to make it comfortable for dyslexic learners. Several research studies have shown several methods to have an effective result from the game. Human-computer interaction (HCI) strategies such as using audio and sound, minimizing text, using high quality computer graphics and images, and including dyslexia friendly design features show great promise for improving educational games for dyslexic students.

According to research, dyslexic individuals frequently feel visual discomfort when exposed to white backgrounds, suggesting the usage of basic and light-colored backgrounds, elimi-

nating white, to solve these concerns. Pastel colors are very good at reducing visual stress, while dark-colored text improves readability. Furthermore, using dyslexia-friendly fonts such as OpenDyslexic can enhance the gaming interface's efficacy. Ronimus et al. [33] also highlight the importance of using simple layout design and user interface design, while Arunalu [2] emphasize features such as short text and font size 12 pt and 14 pt to improve accessibility and ease of understanding for dyslexic students.

By combining these HCI driven design concepts into educational games, developers may build effective and engaging learning experiences suited to dyslexic students' requirements, resulting in better learning outcomes and satisfaction for users. The observational study on the game iLearnRW [23] highlights how it was designed using a participatory design model, involving both end users and dyslexia experts in the development process. This collaborative approach contributed to unique game features not commonly found in other interventions for dyslexic students. This participatory design has a significant impact on improving the user interface (UI) and User experience of the game.

Multisensory learning means the use of multiple senses simultaneously in the learning process. Many researchers have their interest focused on using multisensory approaches in learning. Shams and Seitz [34] highlight that Multisensory training protocols those combining visual stimuli and auditory stimuli are more effective than unisensory training in enhancing learning processes. These protocols contribute significantly to improvements in perceptual skills, memory, and recognition. Kast et al. [35] conducted a study on computer-based multisensory learning in children with dyslexia, revealing that both dyslexic and non-dyslexic participants significantly improved their writing abilities. This finding emphasizes the potential of Multisensory approaches to improve grapheme and phoneme processing, as indicated by the improved perception and memory observed.

Ohene-Djan and Begum [36] provide evidence that multisensory games specifically designed for dyslexic children support the effectiveness of multisensory teaching methods in reducing learning challenges, particularly among dyslexic individuals. These games use a variety of sensory modalities, such as high-quality visuals, rich colors, physical items, and visual representations, to provide an interactive and interesting learning experience. For example, the Dyslexia Activity System (DAS), a unique online learning tool, uses interactive gaming approaches to help students acquire skills in reading, writing, arithmetic, numer-

acy, word construction, memory, and sequencing. Multisensory teaching approaches aim to encourage a positive learning attitude and overall skill development by using dyslexic children's natural strengths, such as increased creativity and sensory responsiveness. The fundamental goal of methods like the DAS is to help dyslexic children discover and correct mistakes in math and reading activities to improve academic performance and self-confidence. As demonstrated by Kast et al. [35], the multisensory approach enhances educational outcomes and fosters a more engaging and interesting learning environment for students with dyslexia. However, further studies need to investigate the long-term benefits and scalability of the Multisensory approach in various educational contexts. The next intervention is a mobile application described by Tariq and Latif [37], designed to improve the writing difficulties in dyslexic children aged 5 or under. They have developed a custom designed algorithm called "Writers Learning Algorithm" based on a computational model of learning, with components for re-learning, evaluation, and reinforcement. In incorporates character recognition algorithms and multisensory learning. another intervention is called "Wridy" [13] which is made for writing for kids with learning disabilities including dyslexia. For the intervention they have used 3D uppercase English alphabet tracing, a scoring system that provides feedback to the user with multisensory learning.

While a significant number of research and interventions have been developed to help dyslexic students who struggle with reading, far less focus has been placed on problems related to writing. In Sri Lanka, the dyslexia-focused studies have primarily addressed reading difficulties. In contrast, there is lack of study and resources on writing. The following section highlights the existing worrk in this area, with a particular emphasis on Sinhala writing skill improvement.

2.6 Sinhala Language and Writing

Hamid et al. [38] highlights that most of the interventions for dyslexic students are developed in English, with limited resources available in other languages, including Malay, Mandarin, and Arabic. While dyslexia exhibits universal features across all languages, it also manifests language-specific characteristics that vary depending on the linguistic context. The observational study by Lokubalasuriya et al. [39] offers significant insights into the unique language-specific characteristics of dyslexia among Sinhala-speaking children aged 5 to 7 years. Unlike dyslexia in alphabetic languages, where letter reversals are a com-

mon feature, this study reveals that such reversals are less prominent in Sinhala. Instead, the frequent omission and substitution of modifiers, which are integral components that alter the sound and meaning of Sinhala letters, emerge as distinguishing features. These findings emphasize the necessity of developing educational tools and interventions specifically designed to address the complexities of Sinhala's alpha-syllabic opaque orthographic structure. Such tools must account for the unique linguistic challenges faced by dyslexic learners in this context, ensuring more effective support and learning outcomes.

In Sinhala, applications such as Arunalu [2], Pubudu [40], and Walipilla [41] are dedicated to screening for dyslexia and addressing reading challenges among dyslexic students. These interventions employ machine learning techniques, including deep neural networks, to enhance effectiveness. Additionally, other Sinhala-based interventions focus on teaching the alphabet to dyslexic students, underscoring the utility of game-based and personalized learning strategies in these contexts. However, the smaller number of resources specifically designed for dyslexic students learning in Sinhala is evident, particularly in tools aimed at improving writing skills. Research in this area remains underexplored, highlighting a clear gap that necessitates further investigation. This study aims to address this gap by designing, implementing, and evaluating an application that integrates game-based learning and personalized strategies to support and enhance the writing skills of dyslexic students learning in Sinhala.

2.7 Summary of Existing Work

To evaluate the effectiveness and design methodologies of current instructional tools for dyslexic learners, particularly in Sinhala, the table 2.1 summarizes numerous important factors from significant research and implementations. Every row in the table signifies a research or application. The Research paper column provides citation references. The Description field summarizes the application's purpose and emphasis. Techniques highlight the particular technical or educational strategies used. Learning skills refers to the targeted improvement of cognitive or academic abilities, such as reading and writing. Target Age denotes the intended user age group, and Platform specifies the technological medium (e.g., mobile or online). The Evaluation Method outlines the assessment of effectiveness. The results summarize the findings from the evaluation, and the limitations outline any constraints, such as language focus, operating system, or scope of learning addressed.

Research paper	Description	techniques	Learning skills	Target Age	Platform	Evaluation Method	Results	Limitations
[2]	Address reading disabilities in Sinhala-speaking dyslexic children. Developed as a multisensory approach.	• Voice recognition • Progress tracking system • Game narratives and story-building • Rewarding system • 4 screening interventions	Reading skills and letter identifi-cation	5-6 years old	Mobile	A pre-test and post-test were given to the control and treatment groups then compared the results.	72 percent accuracy in the CNN model 85 percent accuracy using a Support Vector Machine.	• Only focus on the reading improvement. • Only developed for the Android OS. • Only focus on the Sinhala
[22]	This learning model is used to improve the motivation and engagement of dyslexic students.	• Game narratives • Levels • Challenges • Points and Rewards • Feedback • Goals	Motivate dyslexic students to improve reading skills	8-5 years old,	Mobile	Qualitative and quantitative evaluation with 40 students.	Improve engagement and motivation of dyslexic children	• The age category of this app targets a problem with children's learning because some levels in the game can be hard for them, according to the research paper.

Research paper	Description	Techniques	Learning skills	Target Age	Platform	Evaluation Method	Results	Limitations
[18]	Motivating dyslexic students while learning. It has two components, an awarding system and a reporting system.	• Badges • Awards • Levels	Motivate dyslexic students for learning	8-12 years old	Tablet	The 12-week study involved 2 teachers and 7 dyslexic students, with pre-study and post-study interviews conducted with teachers, parents, and students.	Significant improvement in reading performance	• Only use the reward or Achievement system game element for the learning game.
[16]	Mobile Game-based learning for Filipino children. Has an achievement system to motivate dyslexic children.	• Game narratives • Levels • Challenges • Points and Rewards • Feedback • Goals	Reading performance of dyslexic children	8-12 years old	Mobile	Evaluation done using 12 dyslexic students, and parents selected the study type.	Reading performance in the Reading Letter Category and Word Category	• Only focus on the reading improvement of the dyslexic children. • Only one Language which is Filipino
[13]	Multisensory mobile application, was developed to support kids with learning disabilities like dyslexia in learning to write alphabets.	• Multisensory approach • Augmented reality • 3D alphabet models with stroke order indicators • Visual and audio feedback during alphabet tracing	Writing skills of dyslexic students	Unser 12 years old	Mobile	The application was sent to a target sample of 6 dyslexic children under 12 years old for a system usability test using a 5-point Likert scale.	The results showed a mean SUS score of 60 out of 100,which corresponds to a grade of D and an ”OK” adjective rating.	• Small sample size. • Need for more reliable testing and data collection methods • Lack of certain features in the application.
[29]	This design helps people with dyslexia overcome their weaknesses in writing, reading, and speaking.	• Artificial Intelligence, Virtual Reality, Image Processing, Voice Recognition, Handwriting Recognition, Support Vector Machine algorithms, and Speech Recognition.	overcome dyslexic students' weaknesses in writing, reading, and speaking.	Under 12 years old	Mobile	Application was sent to the target sample for the system usability scale with a 5-point Likert scale.	The researchers tested the application's ability to detect the stage of dyslexia using an SVM algorithm and found it to be 100 percent accurate.	• The application is currently limited to Android devices. • The application is currently limited to the English language.

Table 2.1: Existing Literature

2.7.1 Research Gap

- Research on game-based and personalized learning for dyslexic students has mostly concentrated on languages like English, with little focus on Sinhala. Specifically, there is a lack of research that addresses the challenges faced by Sinhala-speaking dyslexic students in improving writing skills.

- Many studies have explored game-based educational platforms to improve reading skills in dyslexic students. However, there is a notable gap in effective strategies to enhance their writing skills. Writing, especially letter formation and letter-sound correspondence, is frequently underrepresented in the educational technology interventions that are currently available.

Chapter 3

Methodology

We employed the Design Science Research (DSR) methodology to provide an effective educational framework that not only improves the writing proficiency of dyslexic students but also enhances their motivation and self-confidence through gamification and personalized learning. The DSR is a methodology that follows an iterative design and evaluation to address real-world problems through innovative artifacts [42]. Our approach involves progressing through the key phases of DSR, including problem identification and motivation, defining the objectives of the solution, design and development, and evaluation. Each phase allows for refinement and validation, ensuring that the framework effectively meets the needs of dyslexic students.

DSR was particularly aligned with our research due to several significant reasons. Firstly, our research aimed at creating a technological artifact (the assistive writing application) that had to go through several cycles of development and revision according to user feedback. Each phase of our research produced artifacts, from initial rough sketches and conceptual models to Figma prototypes to the final working application. Secondly, DSR's emphasis on solving real-world problems aligns perfectly with our goal of addressing the specific educational challenges faced by dyslexic students in their attempt to write in Sinhala. In addition, DSR's highly interactive and user-centered nature played a critical role in creating an efficient solution for dyslexic students, whose requirements are varied and tend to be poorly understood. The image 3.1 shows the DSR phases that we customized for our research.

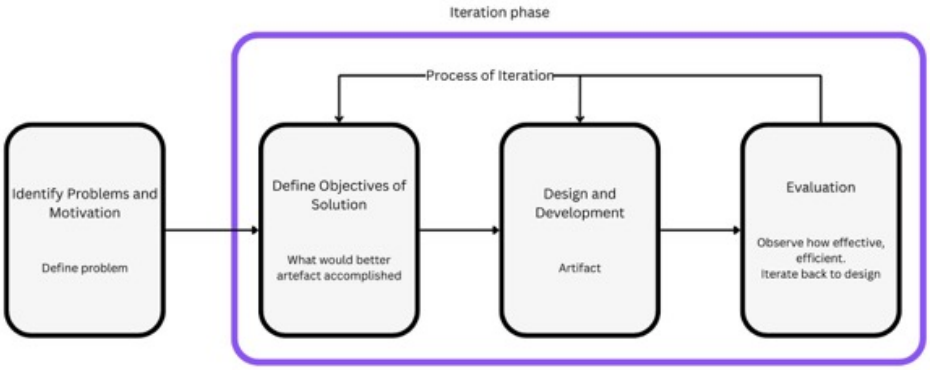

Figure 3.1: Customized Design Science Research Methodology

3.1 Problem Identification and Motivation

We conducted a preliminary study, iterating through the design science research framework to identify the specific writing challenges faced by dyslexic students when writing in Sinhala.

To define the problem, we conducted a study with students, reviewed relevant books[43], and held discussions with specialists in the domain. The primary objectives of this study included:

- Identifying specific writing challenges, such as difficulty with modifiers, sentence structuring, and time-constrained accuracy.
- Gaining insights into emotional and motivational barriers affecting dyslexic students' learning in Sinhala.

To get a better understanding of the writing difficulties of dyslexic students, a study was conducted with a sample of 10 dyslexic students aged 8 to 10 years. This age group was chosen because early detection and intervention are critical in managing dyslexia. All participants were native Sinhala speakers with basic literacy skills and were formally diagnosed with

dyslexia by a qualified professional. Parental or guardian consent was obtained before the study. Throughout the research process, we collaborated with primary school teachers and special education experts to leverage their knowledge and ensure effective teaching methods for the study. Their involvement provided valuable insights into dyslexia management strategies within the local educational environment.

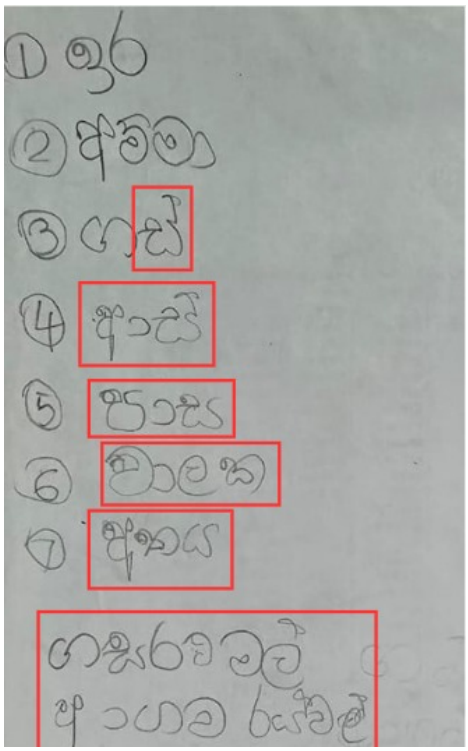

Figure 3.2: Sample Data in Preliminary Study

The samples collected from dyslexic students revealed several notable challenges in their ability to write accurately in Sinhala. Such as :

- Inability to form complete simple words. Approximately 20 percent of the dyslexic students demonstrated a profound difficulty in writing whole words, suggesting challenges not only with individual letters but also with the ability to conceptualize and reproduce words as cohesive units. This indicates potential issues with cognitive processes related to sequencing and phonological representation.
- Difficulties with modifiers (”Pillam”) Approximately 67 percent of the students exhibited challenges in writing letters with modifiers, which led to difficulty in forming accurate word structures in the Sinhala language.

- Longer completion times.

The core of the design science research method lies in the iterative process of designing, developing, and evaluating the artifacts. This iterative process enables continuous improvement and learning based on feedback and insights at each phase. The process has several iterations, and each builds on the data gained in the previous one. We will undertake three primary prototyping iterations using papers and Figma, followed by the developed system. To evaluate each iteration phase, we used different sample sizes.

3.2 First Iteration Phase

3.2.1 Base Design

In the initial iteration phase, we designed data from written ideas, and rough sketches were created to depict potential features and user interactions for a Sinhala language writing tool for students with dyslexia. Initial design models were to create activities using the first 6-10 letters of the Sinhala alphabet. It involved activities focused on creating simple 2 - 3 letter words while considering the use of modifiers. This design approach attempted to demonstrate how learning letters might be broken down to manageable segments, incorporate multisensory learning techniques, and propose engaging activities.

3.2.2 Base Design Evaluation

To validate our design process, we discussed it with primary school teachers and special education teachers, all of whom are experienced in working with dyslexic students. These discussions provide us with key findings, the importance of multisensory integration(particularly visual and auditory features), the effectiveness of visual guidance to facilitate memorization, the follow of systematic letter teaching order, and the need for a personalization feature to address each student's unique challenges.

The special education teachers also provided valuable insights regarding user interface design concerns. They emphasized that students with dyslexia often experience visual discomfort and distraction if subjected to complex or high contrast designs. Based on their expertise and existing literature, we learned that pastel colors create a more comfortable visual

experience and that using a light background with far colored text is better for readability. Their recommendation is to maintain simplicity in the overall design and emphasizes that simplicity is crucial for dyslexic students to minimize distraction and help students focus on learning content. With this insightful feedback provided by special education teachers regarding visual design, we also examined the potential for introducing gamification elements to facilitate student engagement. In particular, we investigated the potential for including elements such as levels, evaluative feedback systems, rewards, challenges, and leaderboard within the user interface design. The special education teachers emphasized the possible benefit in utilizing levels, feedback, rewards, and challenges to help keep students engaged and motivated; they advised against including a leaderboard. They were concerned that a leaderboard would put too much pressure on individuals and would be intimidating or discouraging for dyslexic users.

Another significant observation from our discussion was significant longer times dyslexic students require to learn letter recognition and formation than their peers. Special education teachers emphasized that dyslexic students may have more improvement from a more focused and sequential approach with fewer letters. This led to our decision to limit our initial design to six letters rather than attempt to work with a broader range. Based on these findings, we developed a strategy to address the identified challenges by designing and creating a personalized and gamified learning framework and six Sinhala letters ග(Ga), ල(La), ය(Ya), ට(Ta), ක(Ka), and ප(Pa) were selected to focus on the exercises. These letters were chosen considering the following factors:

- The need for varying levels of complexity to ensure a progression from simpler to more advanced forms because of the diverse writing abilities among primary school students (ages 8-10) with dyslexia. This approach acknowledges that students enter the learning process with different baseline abilities, ranging from those who possess basic writing skills to those who struggle with fundamental letter recognition.
- Frequently used letters in the Sinhala language according to the Grade 1 Teachers' Guidebook, as well as from the previously referred previous work [25].
- Expert recommendations on the cognitive capacity and time required for dyslexic students to learn effectively.

3.3 Second Iteration Phase

3.3.1 Application Design

In designing our intervention, we implemented a series of activities addressing all the findings found on the prior iteration. Pre-writing activities were introduced first, providing dyslexic students with a foundational step before advancing to complex levels. This approach then progresses to letter identification activities, followed by tracing and freehand writing activities.

The flow chart 3.3 shows the structure of activities:

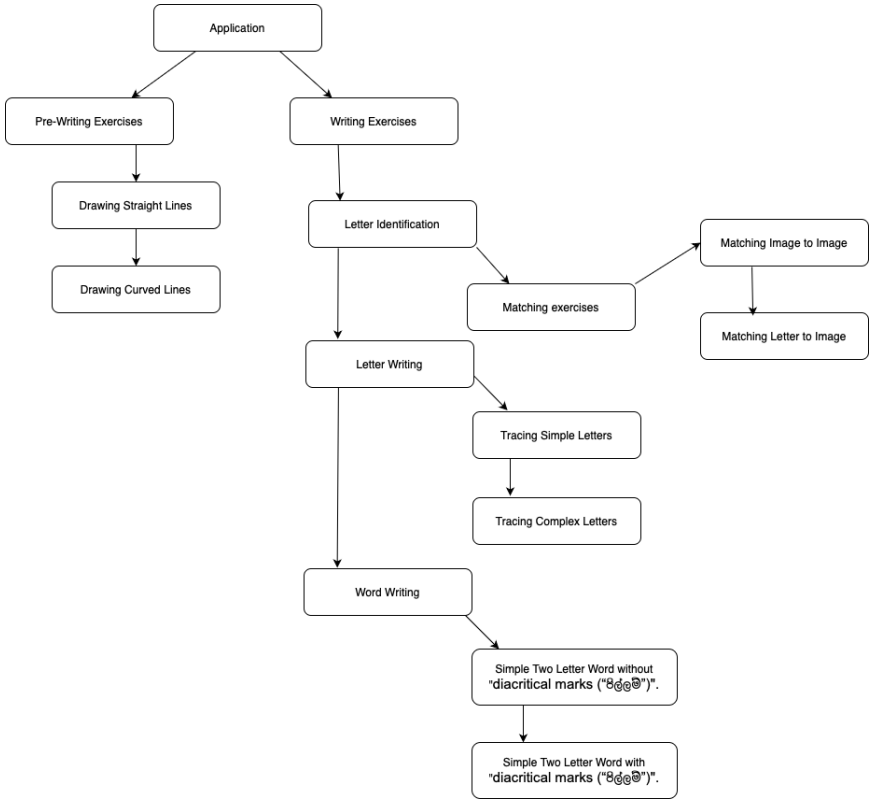

Figure 3.3: Activity Structure

Based on these activities, we designed the detailed Figma prototypes. The design incorporates a carefully considered pastel color palette, utilizing simple and clear visuals to minimize cognitive load and visual discomfort of dyslexic students. We designed the Figma prototypes using images suitable for dyslexic students. Audio cues and sounds were used

to support multisensory learning, guidance, and the final product. Each activity incorporated game elements such as levels, progress tracking, feedback, and a reward system to enhance the students' engagement and motivation. Additionally, these activities contain two levels to address students' unique difficulties and facilitate gradual skill development. The font used throughout the design was "Hodi Potha", a type of font that students are familiar with in the local educational context. Figure 3.3 displays the game map we designed using Figma.

Figure 3.4: Game Map

Pre-Writing Activities Design

During the pre-writing design phase, foundational tracing activities were designed to facilitate the formation of Sinhala letters. These activities include both straight line and curved line tracing, which serve as basic components required for the letter construction. A soft pastel color scheme is used across backgrounds and interface elements, as it helps reduce visual stress and supports better focus for dyslexic students. The interactive interface presents a clean tracing space with visual cues such as dotted lines and directional arrows, subtly guiding the stroke order. Encouraging and corrective sound effects are used to provide immediate feedback during tracing, helping learners recognize and correct their tracing. A celebratory animation with sound is triggered upon activity completion, offering a motivating sense of achievement. To enhance user experience, interactive elements such as an eraser tool for removing traces and a progress bar indicating completion status were incorporated. Additionally, each level includes repeated tracing of the shape to reinforce learning and support the gradual development of fine motor skills needed for Sinhala letter formation. Figure 3.4 shows some of the pre-writing activities we designed for dyslexic students.

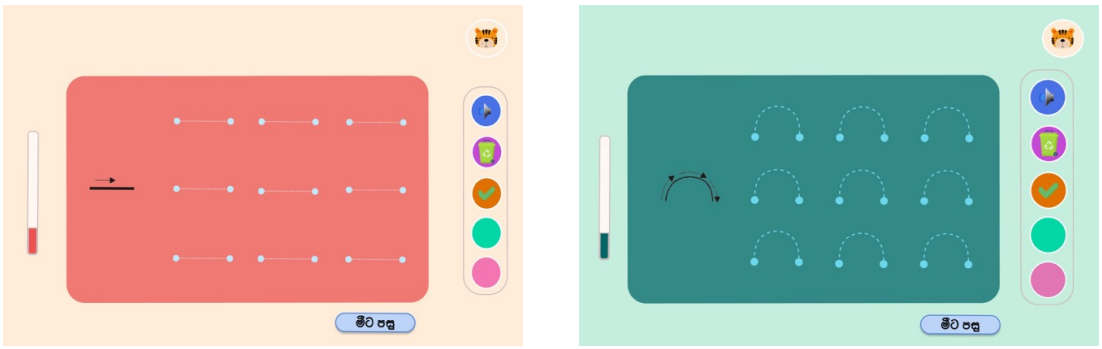

Figure 3.5: Figma Design - Pre-Writing Activities

Post-Writing Activities Design

Building upon these fundamentals, the Post-writing module included more advanced sub-levels for letter identification, guided tracing practice, and freehand writing. This structured approach was extended to increasingly complex challenges, including two-letter words, letters with modifiers, and finally two-letter words with modifiers.

Letter Identification

Letter Identification activities were designed with two levels. In the first level, students were given the six letters with a flip card mini game, these cards are designed with the letter and picture on each side, which helps students to identify the letter. A pastel pink color card background and black letter color were used to increase the readability. The design included a progress bar to help students track their progress through the activity, as in the figure 3.5

Figure 3.6: Letter Identification Level One

The second level was designed with a letter-to-image match mini-match game which students match the letters with the image according to the prior level and draw a line. The interface is designed with a light greenish blue pastel color to minimize visual stress, and feedback is given by changing the border colors as in figure 3.7.

Figure 3.7: Letter Identification Level Two

Tracing Activities

When designing the user interfaces for the tracing activities, we mainly focused on the findings we got through the discussion with domain experts and existing literature. The interface design incorporates minimalist design principles and recommended pastel color schemes, which have been shown to reduce the visual discomfort of dyslexic students and increase readability. Interactive elements are integrated into the design to enhance engagement through positive feedback, such as celebratory confetti animations when levels are completed. To facilitate mistake identification, the pre-drawn outline changes to red when

a mistake occurs by providing immediate visual feedback. Our design prioritizes accessibility through navigation features, including a game map for progress tracking. We also designed to offer customization options such as pen colors and the selection of eraser tools. According to the level of the activities, we provide visual and auditory guidance to dyslexic students. We also adhere to HCI principles like consistency, visibility, error prevention and recovery, feedback, and simplicity. These elements collectively create a supportive learning environment for dyslexic students by maintaining an engaging and adaptive user experience.3.8 figures show some of the pre-writing activities we designed for dyslexic students.

Figure 3.8: Figma Design - Post-writing Activities(Tracing)

Freehand Writing Activities

In freehand writing exercises similar to tracing exercises, we used a simple design with recommended pastel colors adhering to HCI principles. In here, there is a lined area to write the letter or the words as in Figure 3.9. Interactive elements are integrated into the design to enhance engagement through positive feedback, such as celebratory confetti animations when levels are completed. We used popups to give different feedback about the status of the activity to enhance the user experience as in figure 3.10.

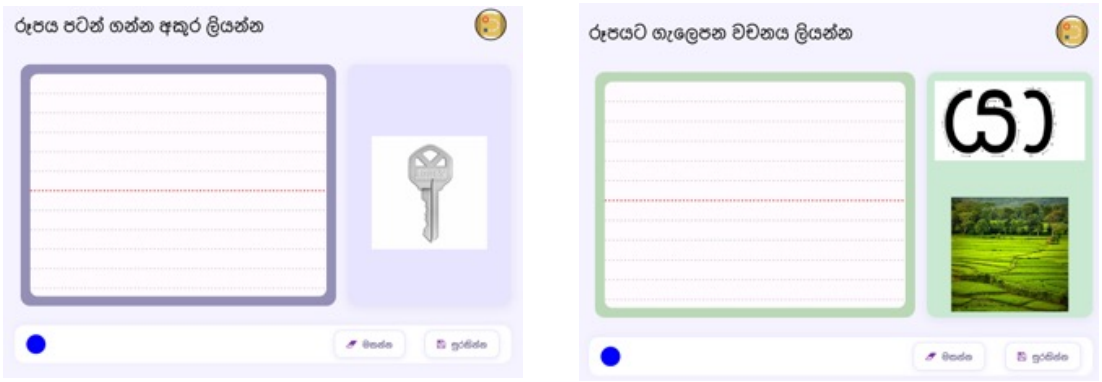

Figure 3.9: Figma Design - Post-Writing Activities (Freehand Writing)

Figure 3.10: Figma Design - Interactive Elements(Freehand Writing)

3.3.2 Prototype Evaluation

To validate our design decisions, we presented the Figma prototypes to 6 dyslexic students and 3 teachers to get their feedback. Their feedback confirmed that our color palette was effectively utilized to enable interactions like tracing without visual distraction. The user interface's simplicity and clarity effectively reduced visual confusion, and the images chosen were effective in enabling letter recognition and recall. The "Hodi Potha" font had good readability for the students. Participating students also conveyed that they found it easy to navigate between the Pre-Writing and Post-Writing modules, and their respective sub-levels. Most notably, the activities we had chosen, ranging from simple line practice to letter identification, tracing, freehand writing, and initial word formation, were assessed as appropriately challenging and useful for dyslexic students. These valuable findings were systematically incorporated into the development of our final system.

3.4 Third Iteration Phase

3.4.1 Game Design

The observations and findings obtained from our Figma prototypes, we designed and developed working mobile applications that were specifically designed for dyslexic students. Our application had logic and algorithms that were designed to detect writing errors that are most often encountered by dyslexic students and offer personalized assistance in their learning process.

Our development process focused on developing a user-friendly interface to address the unique needs of dyslexic users while embedding our error detection mechanisms. To address the personalization requirements, we developed an algorithm that could dynamically adjust exercise difficulty levels based on individual student performance in prior exercises, such that each student would have an experience that was personalized to be challenging enough.

We specifically focused on developing the interaction model of the user for the stylus and tablet to enable effortless handwriting recognition with precise visual feedback. The application was built on cross-platform technology to maintain compatibility with a variety of devices. Key functionality encompassed handwriting recognition and analysis, variable difficulty level, visual and auditory feedback mechanisms, and a coherent game-based learning path.

3.4.2 Evaluation of Game Design

To validate our application and meet our objectives, we conducted testing with around 6 dyslexic students and over 10 non-dyslexic students in a primary school setting. Having both a mixed group of participants allowed us to analyze the target user experience while providing baseline comparisons. The test confirmed that our algorithms and logic worked as expected, but they required additional tuning to become more precise. This comparison of responses from dyslexic and non-dyslexic participants enabled us to establish appropriate threshold levels for detection algorithms. The data sample collected during the evaluation phase and the finalized threshold value determined through our analysis are presented in the table 3.1:

Task	Average Completion Times - (In Seconds)	Average Accuracy Scores - (Out of 100)
Letter Tracing	38.34	92.40
Letter Freehand Writing	32.01	75.71
Word Tracing	49.34	74.86
Word Freehand Writing	44.24	66.39
Letter with Modifier Tracing	43.88	75.65
Letter with Modifier Freehand Writing	35.11	65.69
Word with Modifier Tracing	53.15	72.21
Word with Modifier Freehand Writing	48.68	60.98

Table 3.1: Performance Summary Across Post-writing Levels

We also collected qualitative feedback from six dyslexic students with the help of teachers. A majority of the participants preferred writing with a stylus over a finger when writing on tablets, especially pointing out that writing with a stylus felt more natural. Students were interested in writing on tablets, perceiving the tablet environment as more motivating than ordinary paper books. The assessment also showed a fundamental usability problem: participants reported too much transition time between freehand writing activities, disrupting their flow of engagement.

The supervising teachers provided additional valuable insights, commenting that students can become disengaged due to a lack of visual diversity in the app. This brought to light the necessity to include more diverse visual elements, alternative color combinations, and interactive elements to sustain interest, especially among children suffering from dyslexia who are likely to have problems with attention. These discoveries were meticulously noted to guide the ultimate enhancements of our app and thereby ensure that it would effectively tackle the individual writing issues affecting students with dyslexia.

3.5 Project Management Process

For our research project, we employed a specialized project management approach that balanced academic research rigor and efficient software development.

- GitHub Version Control: We utilized GitHub for source codes, feature branches, and code review management, so that research algorithms and software implementations were synchronized
- Google Drive Documentation: All research documents, meeting notes, and non-code artifacts were stored in a Google Drive repository, providing centralized access to all team members
- Trello Task Management: We utilized Trello boards to track individual tasks, research milestones, and development progress through separate workflow stages.
- Regular team meetings: conducted bi-weekly team meetings to monitor progress, address problems, a nd reprioritize needed.

Chapter 4

Implementation

The technical aspects of the development process for our personalized and gamified learning application are covered in this section. The system is built with a strong focus on supporting early dyslexic learners through a structured, gamified, and adaptive learning experience. Pre-writing, post-writing, and a personalization framework are its three primary components, each of which is intended to focus on a distinct facet of the process of developing writing skills. The solution makes use of modern mobile technologies, machine learning techniques, and cloud-based services to ensure accessibility and scalability. The system's high-level architecture, technological stack, use case diagrams, user narratives, a description of the underlying mechanisms of each key component in the application and the rationale behind them are also provided.

4.1 User Centered Design Approach

As mentioned in the Methodology section, we have collaborated with primary school teachers, special education teachers and children in order to get continuous feedback for our prototypes and finalized on a design which fulfills all the user requirements while maintaining a dyslexia-friendly, age-appropriate user environment. This section consists of all the user narratives and the use case diagram, which was designed based on the user narratives.

4.1.1 Use Case Narratives

Use Case Name	Register User.
Summary	The system should be able to register new users.
Actors	Student
Preconditions	The user has not already been registered to the system.
Description	The user should be able to provide relevant details at registration and create a new account.
Exceptions	If the user is unable to provide the necessary details, the registration process won't be successful, and an error message will appear.
Post conditions	A new user account will be created by the system, and the user will be redirected to the login page.

Table 4.1: Use Case Narrative – Registration

Use Case Name	User login to the system.
Summary	Users can log into the system using their username and password.
Actors	Student
Preconditions	The user must be registered to the system.
Description	The user navigates to the login page and enters their credentials. The system then verifies the credentials, and if they are correct, the user is granted access to the system.
Exceptions	Invalid credentials result in an error message, and the user remains on the login page.
Postconditions	The user is logged into the system and has access to their dashboard.

Table 4.2: Use Case Narrative – Login

Use Case Name	Allows users to log out from their account securely.
Summary	The system should allow users to log out from their accounts securely.
Actors	Student
Preconditions	The user must have a valid registered account and should log in to the system.
Description	After using the system, the user selects the ”Logout” option. The system terminates the session, ensures no data is cached or stored locally, and redirects the user to the login page.
Exceptions	If there is an issue logging out (e.g., network issue), the system will prompt the user to try again or display an error message.
Post conditions	The user logs out of the system and is redirected to the login page.

Table 4.3: Use Case Narrative – Logout

Use Case Name	View pre-writing exercises.
Summary	The user should be able to view and complete the pre-writing exercises.
Actors	Student
Preconditions	Users must be logged in to the system and at an appropriate level to view the pre-writing exercises.
Description	The user should be able to complete pre-writing exercises, which are personalized in a game-based environment.
Exceptions	If the student fails to complete the exercise, the activity may need to be repeated.
Postconditions	• The system evaluates the completed exercise and gives a score. • The system updates the student's progress and gives rewards based on the provided answer. • The system loads new content based on the user's performance.

Table 4.4: Use Case Narrative – View pre-writing exercises

Use Case Name	View letter Identification exercises.
Summary	Users are given letter Identification exercises to help them identify different letters.
Actors	Student
Preconditions	The student is logged in and is at an appropriate level, which can view the letter identification exercises.
Description	The system assigns letter identification exercises to the student, prompting them to identify specific letters. Visual aids and prompts are used to support recognition, and the system tracks the student's responses. The exercises include matching image-to-image, letter-to-letter, and letter-to-image tasks.
Exceptions	If the student fails to complete the exercise, they may need to repeat the exercise.
Postconditions	• The system evaluates the completed exercise and gives a score. • The system updates the student's progress and gives rewards based on the provided answer. • The system loads new content based on the user's performance.

Table 4.5: Use Case Narrative – View letter identification exercises

Use Case Name	View letter writing exercises.
Summary	Users are given exercises to write letters using six selected letters, either without or with diacritical marks, in a personalized game-based environment.
Actors	Student
Preconditions	The student is logged in and is at an appropriate level, which can view letter writing exercises.
Description	The user is given exercises related to letter writing with and without diacritical marks in a personalized game-based environment.
Exceptions	If the student fails to complete the exercise, they may need to repeat the exercise.
Postconditions	• The system evaluates the completed exercise and gives a score. • The system updates the student's progress and gives rewards based on the provided answer. • The system loads new content based on the user's performance.

Table 4.6: Use Case Narrative – View letter writing exercises

Use Case Name	View two-letter word writing exercises.
Summary	Users are given exercises to write two-letter words using six selected letters, either without or with diacritical marks, in a personalized game-based environment.
Actors	Student
Preconditions	The student is logged in and is at an appropriate level, which can view two letter word writing exercises.
Description	The user is given exercises related to two-letter word writing with and without diacritical marks in a personalized game-based environment.
Exceptions	If the student fails to complete the exercise, they may need to repeat the exercise.
Postconditions	• The system evaluates the completed exercise and gives a score. • The system updates the student's progress and gives rewards based on the provided answer. • The system loads new content based on the user's performance.

Table 4.7: Use Case Narrative – View two-letter word writing exercises

Use Case Name	Give users badges for certain milestones.
Summary	The system rewards users with badges upon completing specific milestones (e.g. completing 10 activities, and reaching learning goals).
Actors	Student
Preconditions	The student has completed milestones that qualify for badge rewards.
Description	When the student completes a predefined milestone (e.g., completing a set number of challenges, or learning specific letters), the system checks their achievement status. If the milestone is met, the system automatically awards the appropriate badge and notifies the student.
Exceptions	If there is an error calculating the student's progress or an incomplete activity, no badge is awarded.
Postconditions	The badge is added to the student's profile, contributing to their overall progress and motivating continued engagement.

Table 4.8: Use Case Narrative – Give Badges

Use Case Name	View progress.
Summary	The users should be able to view their progress.
Actors	Student
Preconditions	The user must be logged in to the system.
Description	The user should be able to go to the specific interface after selecting the view progress option.
Exceptions	-
Postconditions	The user should be able to view the progress and the mistakes that they have made in exercises.

Table 4.9: Use Case Narrative – View Progress

Based on the use case narratives that are mentioned above in Table 4.1 to 4.9, the use case diagram was drawn. It is shown below as Figure 4.1.

4.1.2 Use Case Diagram

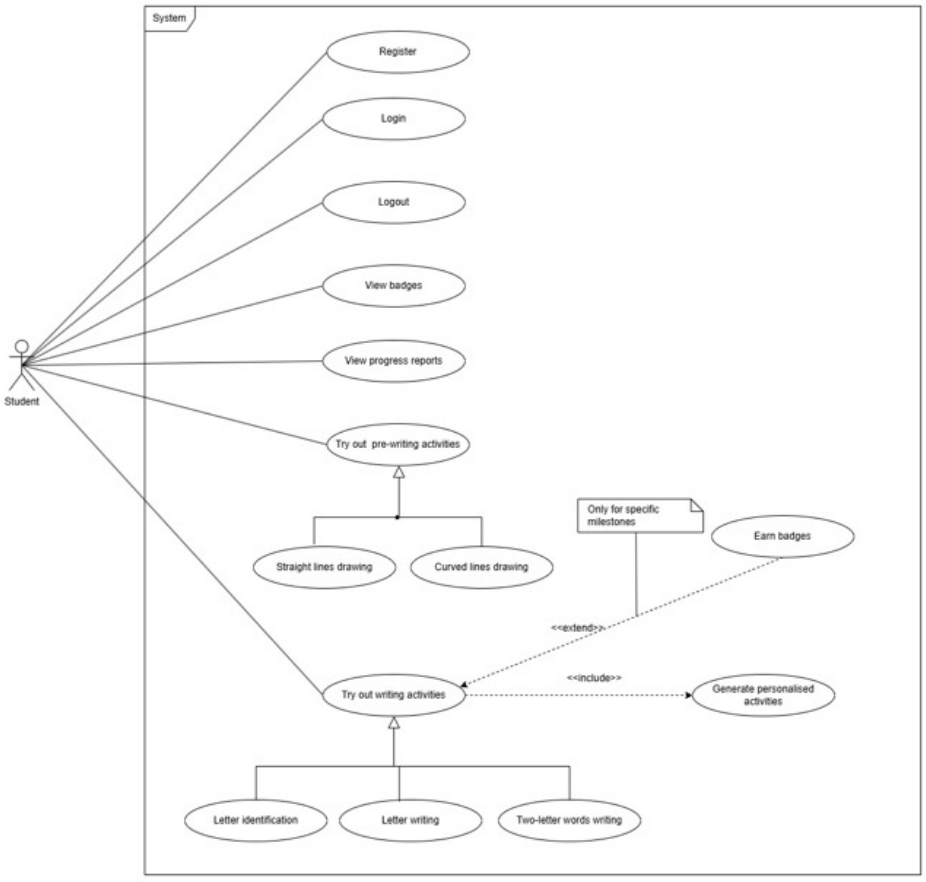

Figure 4.1: Use Case Diagram

4.1.3 System Architecture

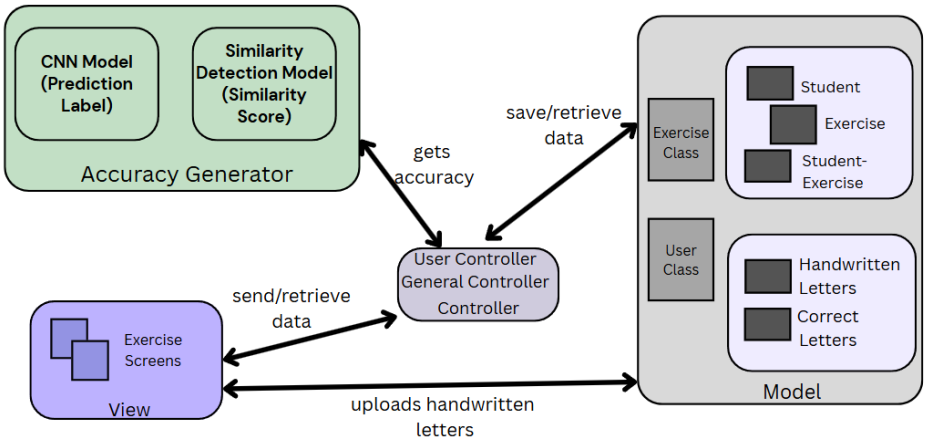

Figure 4.2: High-Level Architecture

The system uses Model–View–Controller architecture as shown in figure 4.2, to cater for the separation of concerns, for scalability benefits and maintenance ease. We can modularize the application using this architectural design, which naturally fits with our objectives of interactive learning, personalization, and service integration.

View component comprises interactive exercise screens related to pre-writing and post-writing that are visible for end users. Model component is responsible for maintaining the data related to exercises, students, student attempts of the exercises and also storing handwritten letter images. Apart from that model component has an exercise class and a user class, which handle the business logic of the application. Controller component works as the mediator between the model and the view component. It is responsible for handling the user requests and sending responses according to them. The user controller and the general controller have been used to achieve that task.

Apart from these components, there is another module called the accuracy generator, which is responsible for predicting the handwritten letters and generating accuracy scores.

4.2 Technology Justification

This section provides the justifications for selecting various kinds of technologies that have been used through out the research.

React Native

React Native was chosen for the frontend due to its architecture of reusable components, which enables effective development while maintaining a consistent user interface across the application. The use of a virtual DOM helps in achieving performance gains by limiting direct changes to the real DOM, thus making the application faster and more responsive. In addition, React's relatively lower learning curve, especially for developers with a JavaScript background, shortens the overall development process. Apart from that, React Native cross-platform capability enables the app to perform flawlessly on both Android and iOS using a single codebase, which saves time and gives greater exposure to the users.

Node JS

Node.js was chosen as the backend technology because it can efficiently handle API requests in a non-blocking, event-driven way, making it particularly suitable for real-time applications such as ours. Node.js also enables developers to use JavaScript for frontend and backend development, thereby maintaining consistency in the development stack. The presence of a diverse ecosystem of libraries, coupled with robust community backing, accelerates the development process and facilitates the integration of external services, including Firebase and various cloud APIs.

Cloud Firestore And Firebase Storage

Firebase Cloud Firestore and Firebase Storage were selected due to their easy compatibility with React Native and real-time features that are vital to applications' requirements. Cloud Firestore offers a NoSQL database with scalability features, allowing the structured storage of user-generated data such as progress, performance metrics, and personalization profiles. Firebase Storage is explicitly tailored to handle large binary files, like handwritten sample images. The platform allows for the safe and effective storage of these images. Both services exhibit simplicity in integration, affordability, and support from Google's solid infrastructure, which ensures reliability, scalability, and strict access control.

Python

Python is a preferred language for the machine learning aspect of this project since it is equipped with a lot of libraries and frameworks such as Numpy, Keras...etc. Since there are a large number of Python machine learning communities, issues arising during machine learning activities can easily be resolved quickly with support from the community.

Keras

Keras is characterized by its ease of use and user-friendliness. It effectively abstracts many aspects of the lower-level TensorFlow. complexity. Prototyping of neural networks is simplified and quick.

Jupyter Notebook

Jupyter Notebook provides an interactive coding environment that facilitates machine learning experimentation and quick prototyping. jupyter notebook cells can be executed independently and in any order which aids in viewing real-time intermediary outputs. This is useful to create machine learning workflows easily allowing quick experimentation with code.

Google Cloud Run, Docker and FastAPI

Hosting and maintaining the accuracy generator service using Google Cloud Run, Docker and FastAPI creates a cost efficient and scalable option which is very easy to maintain. And it allows secure HTTPS endpoints for the exposed API.

4.3 Main Components of the System

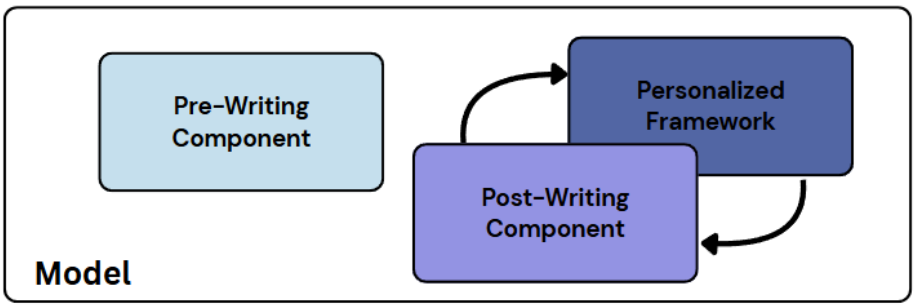

Figure 4.3: Main Components of the System

As shown in the figure 4.3, the proposed model consists of three main components, which are the pre-writing component, the post-writing component and the personalized framework. The post-writing component is interconnected with the personalized framework.

4.3.1 Pre-Writing Component

The Pre-writing module corresponds to the first main level in the learning structure of the application. Through the mastery of basic shapes, including straight and curved lines, the pre-writing Module aims to assist students in developing the essential abilities needed to write letters. These forms work as building blocks for creating whole Sinhala letters.

The application compares the student's traced SVG path and the target SVG path. And it checks for path alignment and the path length when assessing the accuracy of the student tracings. The attempt is considered incorrect if the traced length differs much, either by being too long or too short. The system uses Euclidean distance for the straight lines and uses Cubic Bézier formula to calculate the path length.

When assessing the path alignment, the traced path divides into smaller points called gesture points and then each point maps to the closest segment of the original SVG path. The system considered the tracing as a valid attempt if all the gesture points fall within the acceptable predefined distance threshold.

4.3.2 Post-Writing Component and the Personalization Framework

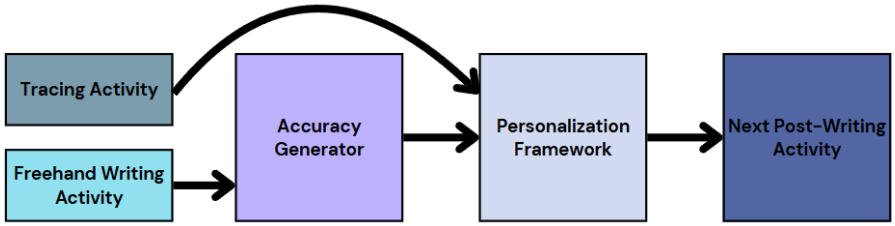

Figure 4.4: Structural Flow

Post writing component and the personalization framework are interconnected. Figure 4.4 depicts the structural flow of how these components work together.

Before progressing to writing exercises, the dyslexic student gets to know the letters first and that is called the letter identification module. Through these exercises, children are taught to identify Sinhala letters and associate them with well-known items. Students tap on cards featuring Sinhala letters in the Letter Matching exercise. When the card is tapped, an image of an object that begins with that letter is revealed. The goal of the picture matching exercise is to match the appropriate image from a collection of images with the relevant Sinhala character. These visually exciting, engaging games increase letter recognition accuracy and memory retention.

Apart from the letter identification module, each main level has a set of sub levels. And these sublevels represent tracing activities and freehand writing activities of the selected letters or words. They will be accessible to the user after completing all the pre-writing tasks and the letter identification module.

Tracing Activity

The tracing activity is a guided writing exercise designed to help dyslexic students develop proper letter formation and fine motor skills. Completion time and tracing accuracy will be measured as the performance metrics. Completion time will be counted from the start of the exercise to the end of the task until the user saves the exercise. Same mechanism that has been used in the pre-writing component to measure the accuracy of the tracing activities will be used here.

Freehand Writing Activity

Students are prompted to write a given Sinhala letter or word freely on a blank canvas using the stylus on the tablet. This type of exercises aim to improve the independent letter formation skills. Completion time and tracing accuracy will be measured as the performance metrics. As in the tracing activities, completion time will be counted from the start of the exercise to the end of the task until the user saves the exercise. Accuracy generator will be used to measure the accuracy of the handwritten letter or word.

Accuracy Generation

Three methods for evaluating handwriting accuracy were investigated in order to find out the most effective way.

1. **Image Similarity Technique**
   This technique compares the handwritten letter with the correct letter and generates a similarity score based on its structure. We have used SSIM(Structural Similarity Index Measure) as the algorithm for it. But we only managed to achieve 60-70% as the similarity score for nearly matched images. This technique was very sensitive to small changes in alignment or rotation.

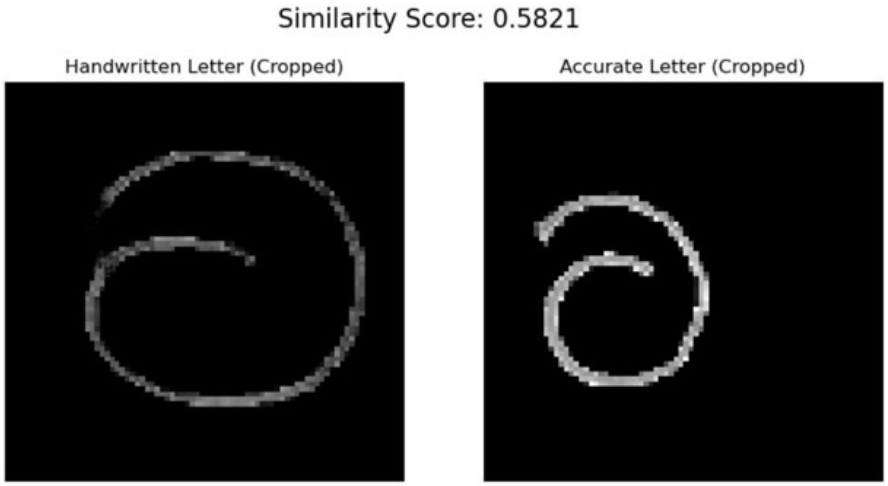

Figure 4.5: Image Similarity Technique

Figure 4.5 shows an attempt to compare a handwritten letter with an accurate picture

of the same letter. Even if the handwritten letter is mostly accurate, these similarity scores were unable to produce good accuracy.

2. **CNN Model Classification Technique**
   A Convolutional Neural Network (CNN) model was built from scratch to classify Sinhala letters written by students and generate an accuracy based on its confidence percentage of the prediction. We have used this method in order to mitigate the issue that we had in the previous technique. The CNN model consists of two convolutional blocks followed by fully connected layers. The first block starts with a 2D convolutional layer with 32 filters of size 3×3 and ReLU activation, followed by a 2×2 max pooling layer and a dropout layer with a rate of 0.25 to prevent overfitting. The second block mirrors this pattern with 64 filters in the convolutional layer, again followed by max pooling and dropout. The output is then flattened and passed through a dense (fully connected) layer with 128 neurons and ReLU activation, followed by another dropout layer with a rate of 0.5. Finally, the model ends with a softmax output layer.

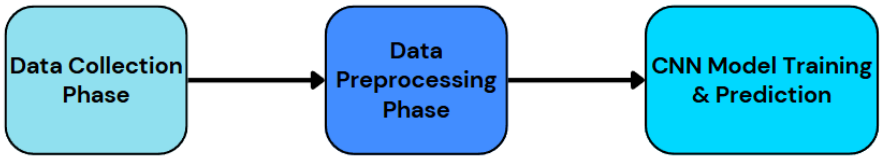

Figure 4.6: CNN Model

Three phases were used to prepare the CNN model for the prediction as shown in the figure 4.6.

- **Data Collection Phase**

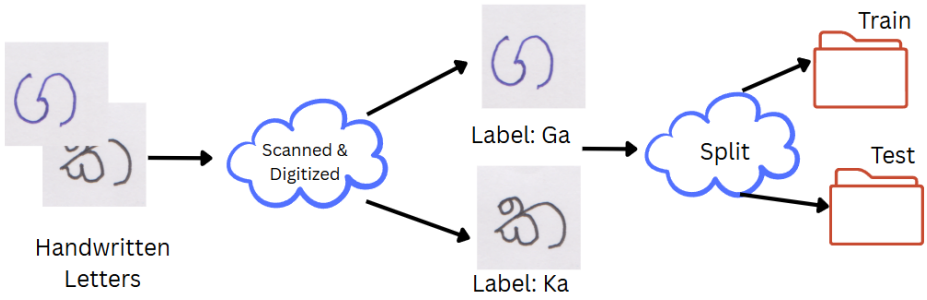

Figure 4.7: Data Collection Phase

We were able to collect about 6200 correct handwritten letters from about 20 non-dyslexic students at the primary school for the six selected letters with and without modifiers. Then they were scanned and made available digitally and labelled by the letter name as shown in the figure 4.7. And then they were divided into train and test folders 80% to 20% ratio.

- **Data Preprocessing Phase**

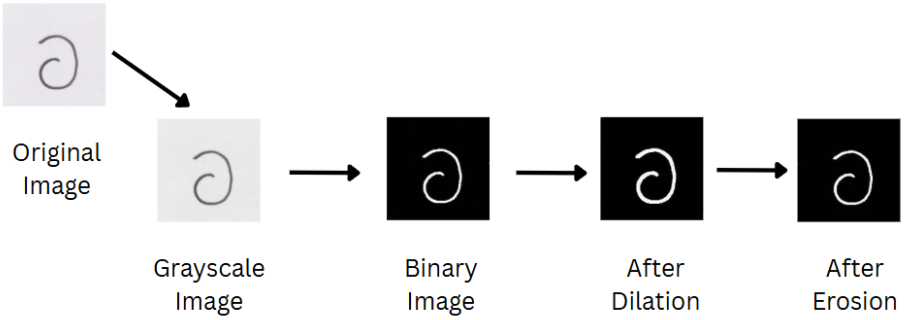

Figure 4.8: Data Preprocessing Phase

Images were preprocessed before inputting them to the model. The whole process is shown in the figure 4.8. First, the original images were converted into grayscale to ease the processing. Then we have used the adaptive threshold technique to make the images binary and inverse. This technique was specifically used to address the varying light conditions of the grayscale image. And then images have gone through a process called dilation, where if there are any disconnected parts of the stroke of the letter, it will thicken the stroke to connect them and make it into a single line of stroke. And then in the erosion phase letter

stroke would reduce the stroke width to normal size. After going through this phase, images have been fed into the model.

- **CNN Model Training & Prediction**
  CNN model has achieved 99.01% training accuracy while validation accuracy was 94.29%. But this method also had a drawback. Even if the model can identify the handwritten letters and generate an accuracy score for them, there might be cases where the prediction is wrong. If the prediction is wrong, the accuracy that is going to be generated from the model will also be wrong. So that led to consideration of an alternative option, which is the third option.

3. **Hybrid Model - Accuracy Generator**
   Accuracy generator is a combination of a CNN model and a similarity detection model, which has been proposed to mitigate the drawbacks of earlier proposed solutions, as shown in the figure 4.9.

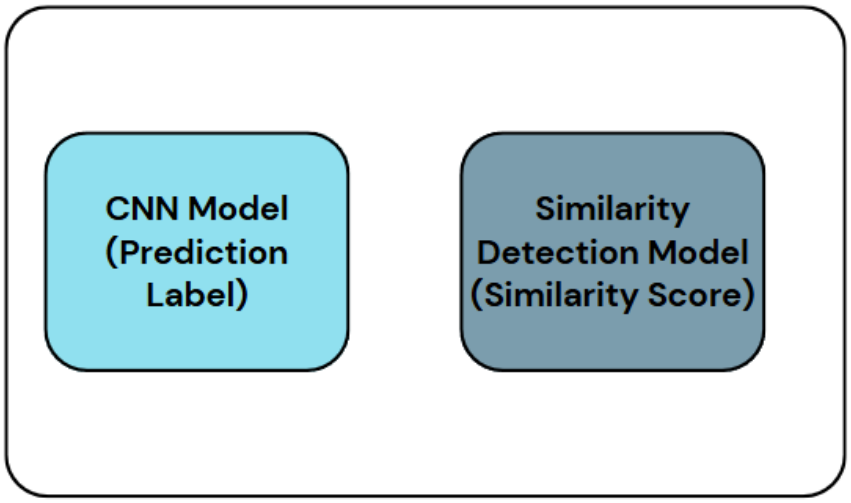

Figure 4.9: Accuracy Generator

- **CNN Model Prediction**
  We have used the earlier model that we have been used as the second option to predict a label and generate a confidence score for the handwritten letter.
- **Similarity Detection Model**

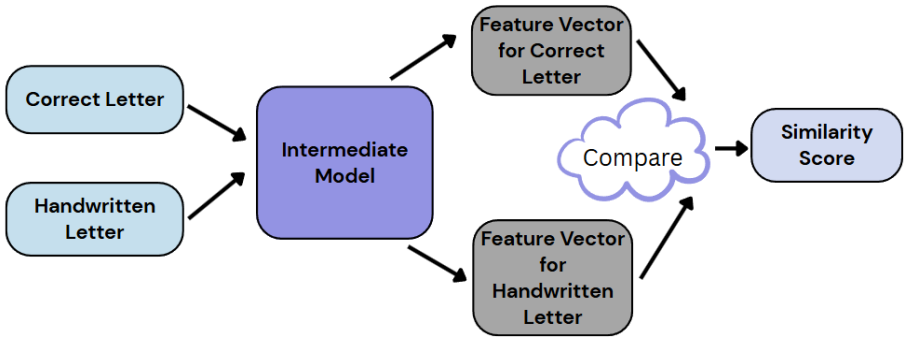

Figure 4.10: Similarity Detection Model

For the similarity detection model, we made an intermediate model which was created from the previous model's input and set its output to the penultimate layer, which stores the feature embeddings. And the correct version of the letter and the handwritten letter are fed into the model and it generates two feature vectors for the correct letter and for the handwritten letter. These two vectors are compared using the cosine similarity and generate a similarity score based on them as shown in the figure 4.10.

In this technique, if the prediction is wrong, we can heavily rely on the similarity score; if the prediction is correct, we can heavily rely on that score.

Personalization Framework

Personalization framework is responsible for loading the next exercise in the post-writing component based on the student's competency. It can identify individuals' weaknesses and propose exercises based on them. It follows the over-teaching method to improve memory retention, which is currently used in special education centers.

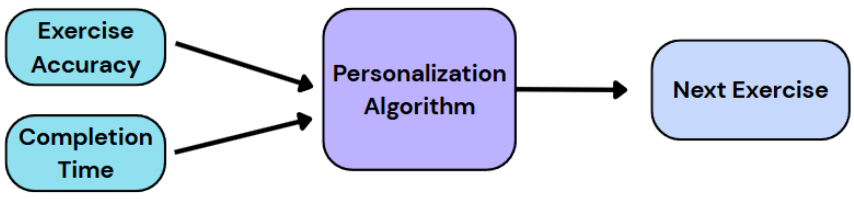

Figure 4.11: Personalization Framework

As shown in figure 4.11, exercise accuracy and the completion time measured in tracing activities and freehand writing activities are fed into the prediction model to predict the next exercise.

Chapter 5

Results and Analysis

The methodology of the study involved selecting participants for the experiment, conducting a pre-test to assess the current writing abilities of the dyslexic children, implementing the intervention (treatment phase), administering a post-test, and evaluating the outcomes based on the results that were taken from the test results as well as data collected from the application when students doing exercises. Visual representations and comparative data are used to analyse the results and helps to come to a conclusion whether the application really has a positive role or a negative role in the learning of Sinhala writing skills among the dyslexic students.

5.1 Evaluation

A sample of 10 dyslexic students who struggled with writing, aged from 8-10 was selected from a primary school. The 8-10 age group was selected here because studies have shown that early detection and intervention in cases of dyslexia can yield substantial therapeutic benefits. So Primary school-aged students are an ideal population for interventions like this. 10 students were divided into two groups, which are control group and treatment group. Before participating to the study, the guardians/parents of the students were informed about this research as well as got consent from them to participate their children to the research study. After getting the proper approvals, pretest was given. The pretest consisted of the letters and words that were given in the mobile application as exercises. And accuracy of the letters and words of the pre test were marked by a primary school teacher. Apart from getting the accuracy of the letters, the time that it takes to complete the pretest was also collected for better evaluation accuracy.

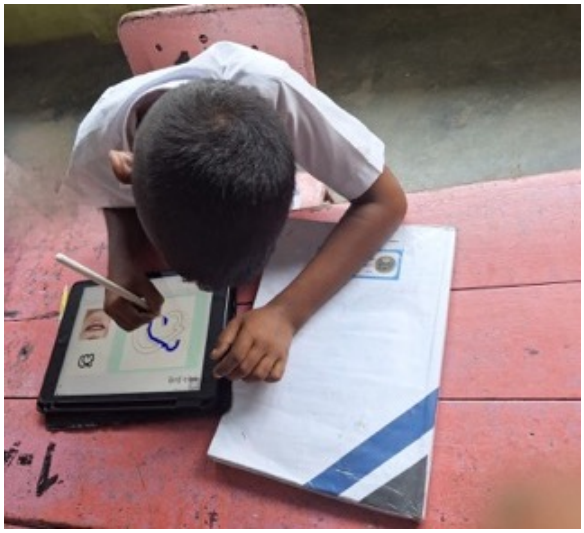

Figure 5.1: A Student During a Session

Five students which were in the treatment group participated in 20 minutes session per day spanned across fourteen days to do the activities of the writing application while continuing their usual learning activities at school. Figure 5.1 was a photo that was captured during the intervention phase. Students in the control group were also continued their usual learning activities at school but they didn't get the writing application. At the end of the treatment phase both the control group and the treatment group were given the post test which also included the letters and words that were given in the application as the exercises. Completion times and the marks that were given by the primary school teacher for the post test were collected. At the end of these phases the marks and the completion times that were collected from both the pre-test and post-test were compared and analysed.

The marks obtained from the pre-test and the post-test for the treatment group are shown in Table 5.1 below.

The figure 5.2 below shows the comparison of the marks between the pre test marks and the post test marks taken by the treatment group.

Student	Pre Test Marks (Out of 13)	Post Test Marks (Out of 13)
Student 1	10	12
Student 2	7	10
Student 3	10	11
Student 4	7	9
Student 5	9	10

Table 5.1: Pre Test Marks and Post Test Marks - Treatment Group

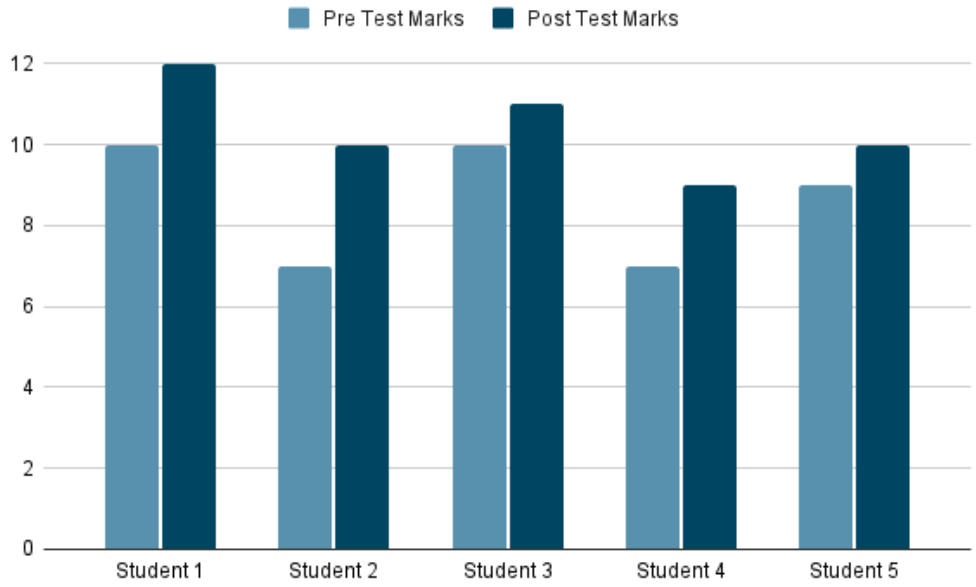

Figure 5.2: Pre Test Marks and Post Test Marks - Treatment Group

The marks obtained from the pre-test and post-test for the control group are shown in Table 5.2 below.

The figure 5.3 below shows the comparison of the marks between the pre test marks and the post test marks taken by the control group.

Student	Pre Test Marks (Out of 13)	Post Test Marks (Out of 13)
Student 6	9	9
Student 7	9	9
Student 8	7	7
Student 9	6	7
Student 10	6	6

Table 5.2: Pre Test Marks and Post Test Marks - Control Group

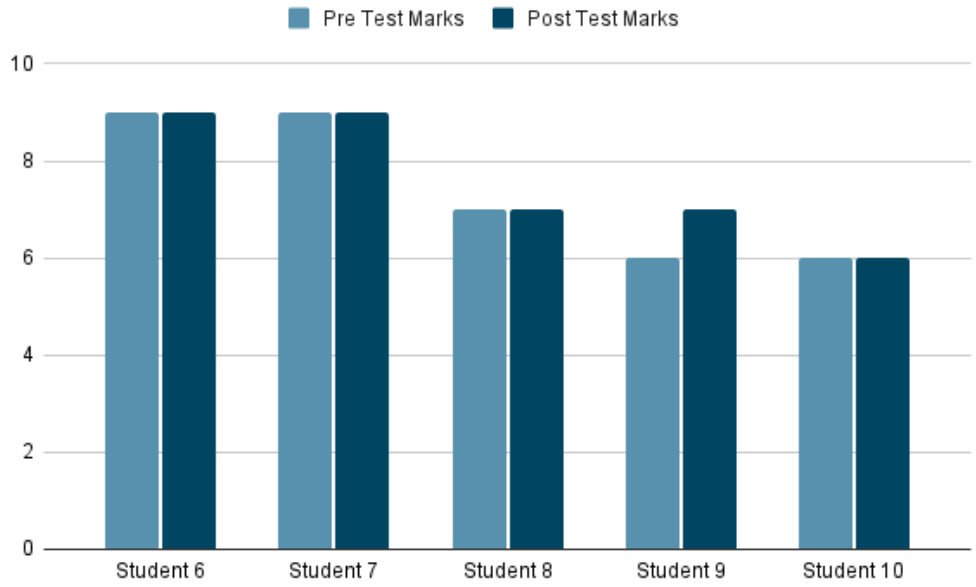

Figure 5.3: Pre Test Marks and Post Test Marks - Control Group

After analysing the two graphs created from the two tables we can see that all students in the treatment group showed improvement in writing skills. The average increase in marks is 1.8 when comparing the students' average marks for the post test and the average marks for the pre test, indicating that all the students have learnt at least one letter/word after using the intervention. In the control group 80% of the students are showing no improvement while only 1 student has shown an improvement of correcting one letter/word than the pre test.

The next comparison can be done considering the pre test and the post test score of the same group. It is called a paired T-test which generates a P value based on the data and if

that P-value is less than 0.05($p<0.05$), it is believed that there is a significant improvement associated with that intervention statistically. The data has to be normally distributed in order to do the paired T-test. To check whether the data set is normally distributed, Shapiro-Wilk test is done. And it generates a p value and it has to be greater than 0.05 ($p>0.05$).

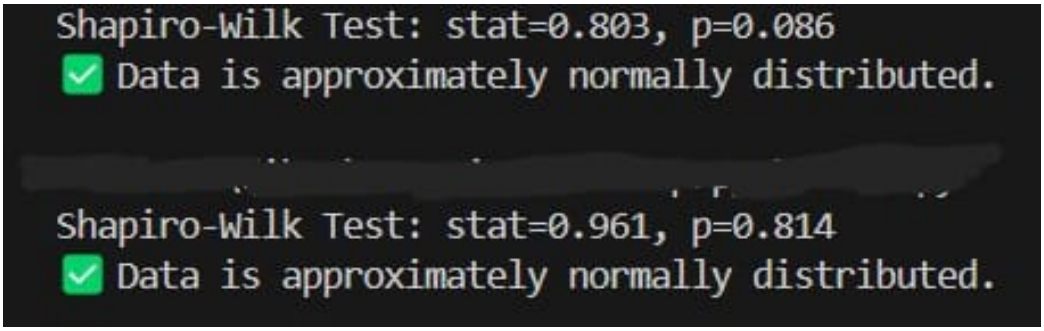

Figure 5.4: Normal Distribution - Pre and Post Test Marks$_T$

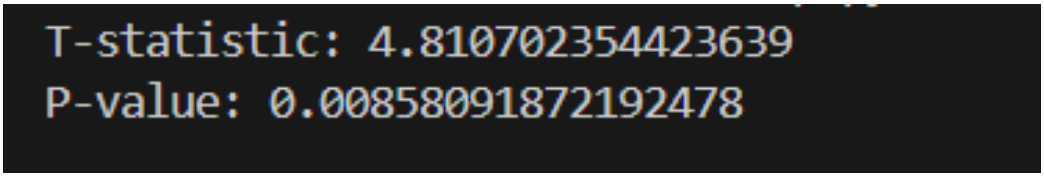

Figure 5.5: P value - Treatment Group

After testing the pre test marks and the post marks of the treatment group, they generated p=0.086 and p=0.814 accordingly as figure 5.4, qualifying to do the paired T test. After generating a p value for paired T-test using the pre test marks and post test marks it generated 0.0085 shown in figure 5.5 which is 0.0085< p shown in the indicating that there is a significance in the intervention.

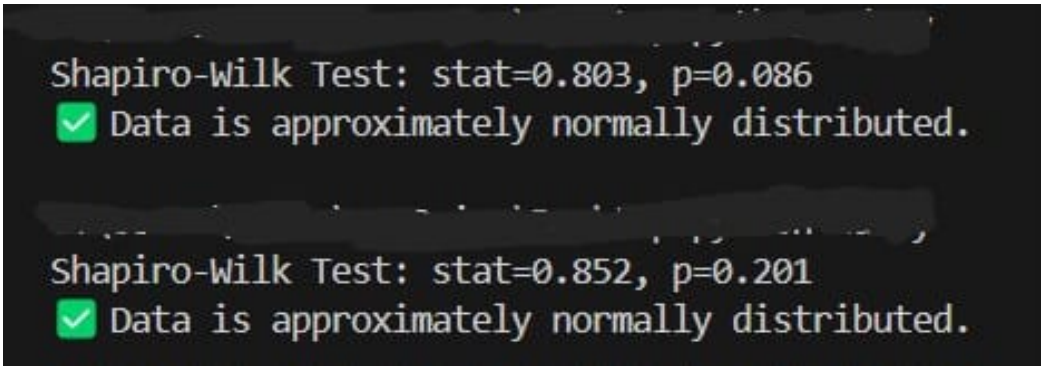

Figure 5.6: Normal Distribution - Pre and Post Test Marks$_C$

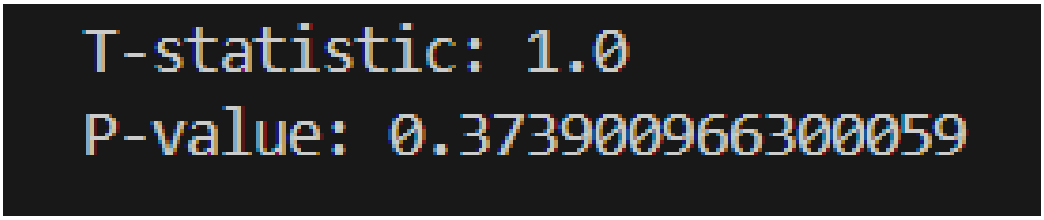

Figure 5.7: P value - Control Group

If we consider the pre test marks and the post test marks of the control group, both of the marks are normally distributed according to the Shapiro-Wilk test as shown in figure 5.6 When we tested the two scores for paired T-test it generated p value of 0.373 shown in figure 5.7 which is $p<0.373$. And it is not significant enough according to the paired T-test. So we can deduce that our writing application has made some kind of a good impact on the dyslexic children which is statistically provable.

The time that it took to complete the pre-test and post-test for the treatment group are shown in Table 5.3 below.

Figure 5.8 below are represented based on the completion times that it takes to finish the pre test and post test by the treatment group.

Student	Completion Time - Pre Test (In Seconds)	Completion Time - Post Test (In Seconds)
Student 1	264	137
Student 2	345	164
Student 3	234	127
Student 4	302	185
Student 5	215	148

Table 5.3: Pre Test and Post Test Completion Times - Treatment Group

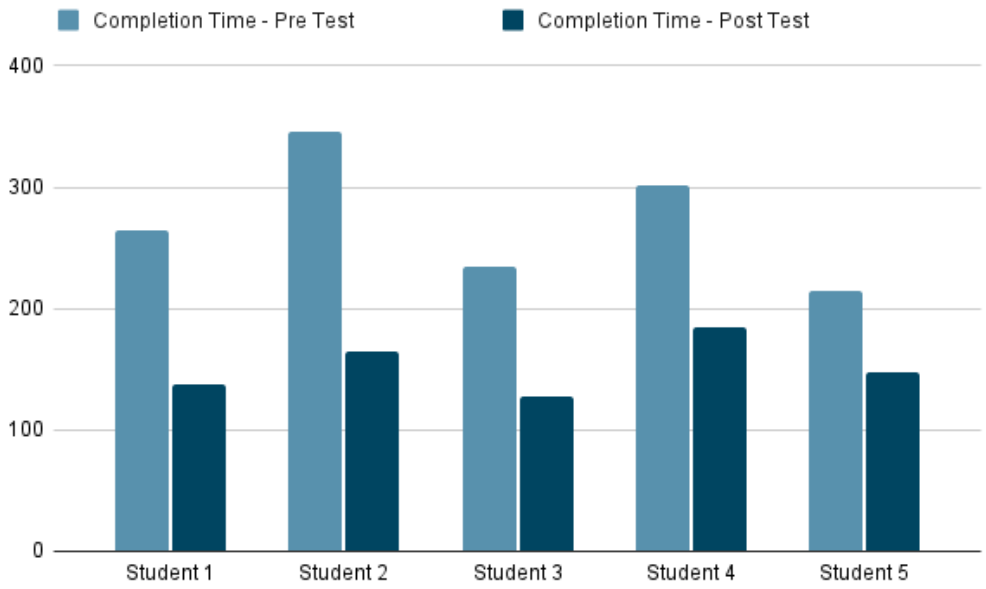

Figure 5.8: Pre Test and Post Test Completion Times - Treatment Group

The time that it took to complete the pre-test and post-test for the control group are shown in Table 5.4 below.

The figure 5.9 depicts the completion times that it took to finish the pre-test and post-test by the control group.

Student	Completion Time - Pre Test (In Seconds)	Completion Time - Post Test (In Seconds)
Student 6	251	243
Student 7	208	216
Student 8	318	309
Student 9	297	268
Student 10	247	255

Table 5.4: Pre Test and Post Test Completion Times - Control Group

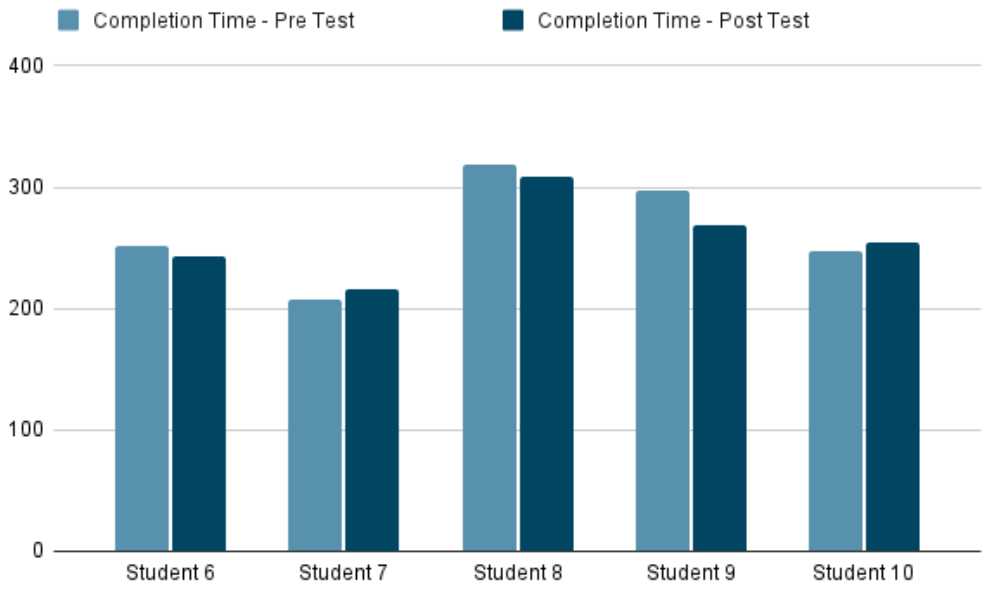

Figure 5.9: Pre Test and Post Test Completion Times - Control Group

All students in the treatment group completed the post test faster than the pre test. The average completion time between the post test and the pre test was reduced nearly by 2 minutes, indicating improved confidence and fluency in writing. Control group's minimal improvement is seen. Two students had taken more time in the post test than the pre test, while three students managed to complete the post test with less time compared to the pre test. Out of those 3 students, there is only one student took substantial less time.

Apart from the pre-test and post-test evaluation, we have generated table 5.5, based on the

accuracy scores of the exercises that the treatment group has done using the application. Students have tried out all the exercises in the application twice within the two weeks. The table below shows the results of the accuracy of the two attempts. Accuracy scores are calculated out of 100.

Average Accuracy	**Student 1**	**Student 2**	**Student 3**	**Student 4**	**Student 5**
Avg Accuracy 1st Time - Letter Writing	74.68	77.26	82.88	91.49	79.42
Avg Accuracy 2nd Time - Letter Writing	90.11	76.49	98.71	87.42	78.87
Avg Accuracy 1st Time - Word Writing	67.67	53.34	71.13	70.50	73.22
Avg Accuracy 2nd Time - Word Writing	72.50	67.30	77.20	69.50	79.17
Avg Accuracy 1st Time - Letter Writing with Modifiers	52.10	63.48	56.37	72.53	41.14
Avg Accuracy 2nd Time - Letter Writing with Modifiers	60.69	74.03	74.01	69.28	52.77
Avg Accuracy 1st Time - Word Writing with Modifiers	63.89	62.83	64.52	55.53	62.50
Avg Accuracy 2nd Time - Word Writing with Modifiers	75.64	61.59	72.89	62.50	77.96

Table 5.5: Average Accuracy Comparison of the Two Attempts

The figure 5.10 below shows the data based on table 5.5 above.

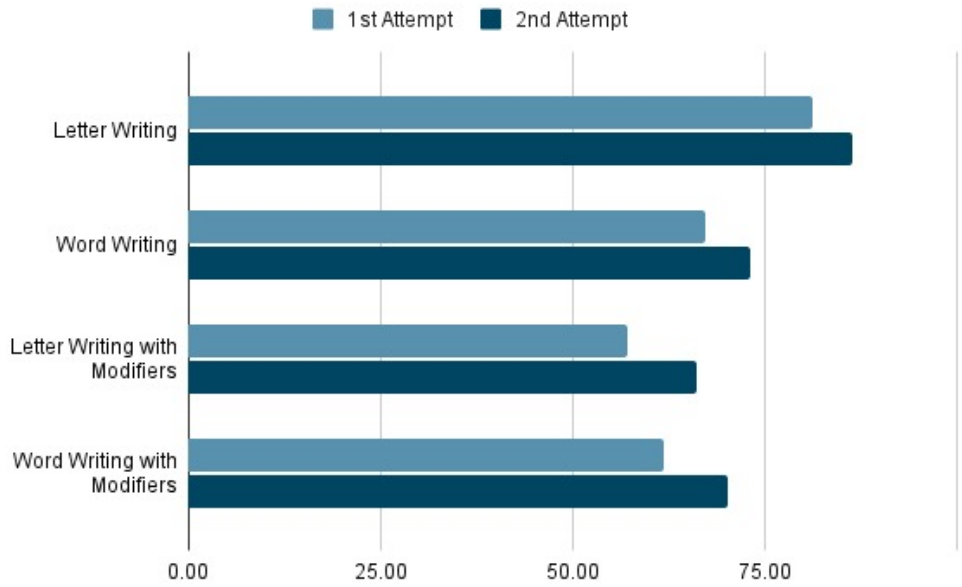

Figure 5.10: Average Accuracy Comparison of the Two Attempts

When comparing the two attempts of four main levels, all the four levels showed improvement in the second attempt than the first attempt following +5.17, +5.96, +9.03, and +8.26 average change comparing the two attempts. The highest improvement was seen in letter writing with modifiers and word writing with modifiers main levels recording 9.03 and 8.26 average positive change. This suggests that repetition and exposure through personalized, gamified exercises significantly helped students tackle even the complex language components, such as modifiers in Sinhala writing.

In addition to the experimental evaluation, we conducted a survey to gather feedback from special educators, speech therapists and primary school teachers. A structured questionnaire was provided to them as a google form, which included a series of statements and two open-ended questions to capture their opinions regarding the mobile application. For the list of statements, respondents were asked to indicate their level of agreement using a Likert scale, as outlined below.

1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree

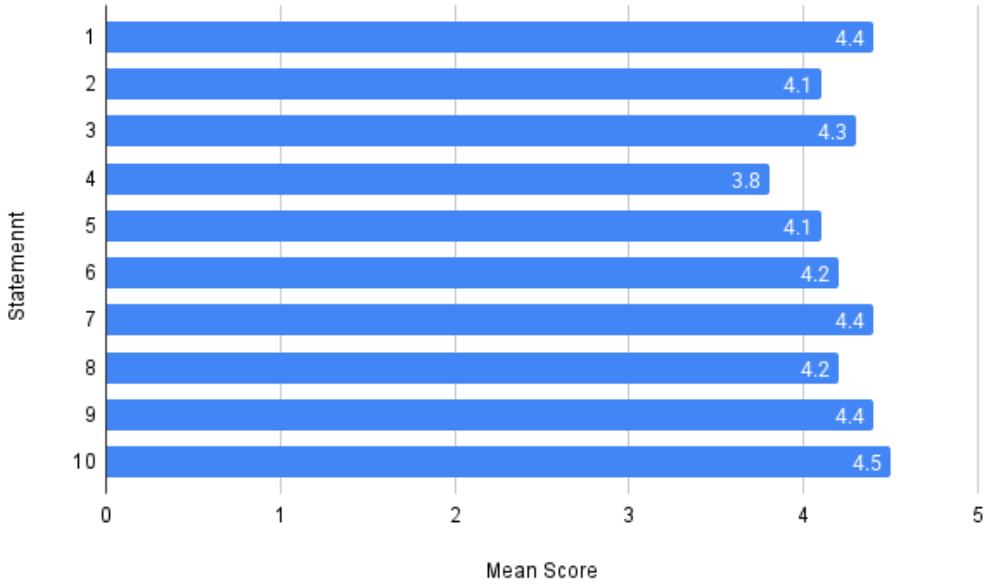

Figure 5.11: Quantitative analysis of feedbacks from domain experts

The figure 5.11 shows the average scores for the 10 statements that the medical practitioners have answered to. 4.5, highest mean score is achieved for the statement 10 which is ”I recommend this game for dyslexic students as a supporting tool/assistive technology.” 4.5 indicates respondents are between agreeing or strongly agreeing to the statement 10. Apart from that, there are three statements that got the second highest mean score. Statement 1, statement 7 and statement 9 has got 4.4 mean score and those statements are mentioned below.

- ”The application effectively addresses the writing challenges faced by dyslexic students.”
- ”The application includes effective assessments to measure improvements in writing skills among dyslexic students.”
- ”I recommend this game for dyslexic students to improve their writing skills as a supporting tool/assistive technology.”

Apart from these statements, there are two open ended questions in the google form. These are the feedback that the respondents had given.
Question: What is your overall impression regarding the gaming application for students with dyslexia?

- ”This gaming application is an innovative and encouraging step forward in supporting students with dyslexia. It makes learning more interactive and enjoyable while addressing their unique challenges in a thoughtful and empowering way.”
- ”Accessibility is quite good.”
- ”Very Useful application for students with dyslexia.”
- ”Good application”
- ”Excellent application. It’s inspiring to see technology being used to make learning more accessible. This app has great potential to transform how students with dyslexia experience education.Good application”
- ”It’s truly inspiring to see such an engaging and thoughtful tool designed to support dyslexic students. The concept is not only inclusive but also promotes confidence and enjoyment in learning, which is so important. It’s clear that a lot of care has gone into making the experience user-friendly and accessible. I really believe this has great potential as an effective assistive technology, and I’m excited to see how it continues to make a difference for learners who need that extra support.”
- ”Excellent effort”
- ”A truly creative approach to inclusive education! This app not only supports students with dyslexia but also helps boost their confidence through fun and engaging way.”

Question: What are your suggestions to improve this game application for dyslexic students as a supporting tool/ assistive technology?

- ”Make available as an mobile application for all platform”
- ”Make this available in google play store & App Store for both Android and IOS users”
- ”Make it available in google playstore for free of charge.”

Chapter 6

Discussion and Conclusion

Dyslexia is one of the most common learning disabilities, affecting approximately 15 to 20 percent of the global population, as reported by the International Dyslexia Association (IDA). This condition primarily impairs reading abilities due to difficulty correlating speech sounds with their respective letters. These challenges often extend beyond reading, adversely impacting writing skills, oral communication, comprehension, and short-term memory. Each dyslexic student is different from one another, and conventional teaching approaches such as ”One Size Fits All” are unable to address the individual needs. Overall, they are having a negative impact on their self-esteem. Because of these reasons, researchers have found effective learning interventions that cater to dyslexic students' needs. We can divide the interventions mainly into two sections. One is an assistive technology-based interventions and the other is not. Assistive technology-based one is the use of technologies like mobile phones, tablets, etc. to teach and improve the literacy skills of the dyslexic students with less interaction with therapists, special educators, etc. Other interventions are programs that are being conducted to improve the literacy skills of dyslexic students with the presence of a therapist, special educator, etc. Three effective learning strategies are mainly used under those interventions, namely multi-sensory learning, game-based learning, and personalized learning. This research proposed to explore the combination of game-based learning environments and personalized learning to enhance the writing skills of dyslexic students in the Sinhala language. By investigating these technologies, the study hoped to uncover new methods to provide a more engaging, personalized, and effective educational experience for students with dyslexia. Through this exploration, we were able to contribute to the development of improved educational strategies that address the diverse needs of dyslexic students learning the Sinhala language, fostering their academic

growth and emotional well-being.

6.1 Discussion

The objective of our study was to create an effective intervention for dyslexic students who have difficulties with Sinhala writing through a Design Science Research approach. The study resulted in the creation of a mobile application with game-based design incorporating personalization, multisensory features, and visually appealing user interfaces, design elements determined through the literature review as being key to enhancing success rates in assistive technologies.

The results of the evaluation showed that the students who used our application had higher writing accuracy compared to students who didn't use the application. A key element of our design was the integration of specific game elements that significantly enhanced student engagement. Our level system provided a structured progression model that accommodated the transition from basic pre-writing activities to more complex letter and word creation exercises. This increasingly demanding progression contained an appropriate amount of challenge while also giving the students a sense of achievement. By completing exercises, the students were rewarded with badges, which gave them positive reinforcement and a tangible sense of achievement that particularly motivated dyslexic students who struggle with the traditional teaching approach.

Our research objectives directed the development and evaluation processes, respectively, leading to significant outcomes for each objective under consideration. By consulting domain experts and teachers, we successfully identified key writing challenges specific to Sinhala language faced by dyslexic students, which directly affect the design of our application. Our personalized learning space effectively targeted individual writing challenges through an adaptive algorithm that changed levels of difficulty according to user performance. The incorporation of gamified elements such as levels, rewards, systems, and game characters enhanced student focus and interest, as confirmed by special educators' feedback. Most significantly, our study found that the integration of personalization and gamification techniques effectively enhanced writing ability in Sinhala dyslexic students, thereby fulfilling our primary research goal.

The design of personalized learning experiences within the gamified environment has had a significant impact on addressing the unique Sinhala writing difficulties faced by the dyslexic students. We observed that tailoring activities to address each student's specific writing challenges provided targeted support to students that a traditional, one-size-fits-all approach could not provide. This adaptability, with the system dynamically adjusting the difficulty and focus of exercises based on a student's real-time performance, helped the students to mitigate their weaknesses through repetition without a disinterest in the exercises.

6.2 Limitations

Sample size limitation

The evaluation was conducted with only ten dyslexic students, which limits the generalization of findings. Resource limitations and the difficulties in finding and recruiting volunteers with a diagnosis of dyslexia contributed to this small sample size.

Technical limitation

Throughout the development process, we encountered a few technical challenges:

- There were compatibility issues with the machine learning model that was used to check the accuracy of the handwritten letters written by dyslexic students across various operating systems. Certain libraries and packages performed inconsistently between Windows and macOS.
- There were some compatibility issues with React Native with IOS, where some react native components, like picker, do not work well with IOS devices.

6.3 Conclusion

In comparing our solution to existing approaches, our application addresses a significant gap in the literature: a lack of writing support tools for dyslexic students in Sinhala language. Whereas numerous applications are available for mainstream languages like English, our work is one of the initial attempts at developing expert writing assistance for

dyslexic students in the setting of the Sinhala language. The smooth blending of personalization features, particularly crafted to cater to the unique performance of each student, sets our solution apart from more conventional solutions that fail to consider the diverse difficulties faced by dyslexic students in writing.

6.4 Future Work

Future work include

- Increase the performance of the application, especially game-level saving and loading features.
- Development of the game to cover all the letters of the Sinhala language through level game design.
- Development of the game to write more letter words and sentences.
- Include features that allow therapists/teachers to change the content.
- Evaluation of the model using a good sample representation.

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Chapter 7

Appendices

7.1 Annexure I: Participant Information Sheet

PARTICIPANT INFORMATION SHEET

A Study on Developing and Evaluating a Mobile Application to Enhance Sinhala Writing Skills in Dyslexic Students: Focusing on Letter Formation and Letter-Sound Correspondence through Personalized and Gamified Learning

I am Dr. L N C De Silva, attached to the University of Colombo School of Computing. My current designation is Senior Lecturer. I would like to invite you to take part in the research project titled "Enhancing Sinhala Writing Skills in Dyslexic Students through Personalized and Gamified Learning" conducted by D.G.D.H. De Silva, K.M.G.S.Kulasekara , S.Pranavan at University of Colombo School of Computing.

1. Purpose of the study

The purpose of this research project is to explore and develop effective strategies for designing personalized game-based learning platform to improve the Sinhala language writing skills of dyslexic students.

2. Voluntary participation

Your participation in this study is voluntary. You are free not to participate at all or to withdraw from the study at any time despite consenting to take part earlier. There will be no loss of medical care or any other available treatment for your illness or condition to which you are otherwise entitled. If you decide not to participate or withdraw from the study you may do so at any time.

3. Participant Selection

A student diagnosed with dyslexia and aged between 8 and 10 years, who also exhibits difficulties in Sinhala writing.

4. Initial Contact and Recruitment

Participants will be recruited from an age range of 8 to 10 years and must be dyslexic students facing writing difficulties. Additionally, students should not have other diagnosed conditions affecting intelligence or learning and must possess a basic knowledge of using a device. The recruitment of participants will be conducted under the supervision of teachers at a primary school in Kurunegala with consideration of above criteria.

5. Duration, procedures of the study and participant's responsibilities

a) The procedure/s to be carried out is/are ;

- **Initial Assessment**: At the start of the study, an initial assessment will be conducted to establish baseline writing skills. This will involve evaluating participants' current writing abilities to provide a reference point for measuring improvement.
- **Final Assessment**: At the end of the study, a final assessment will be performed to evaluate the effectiveness of the application. This assessment will compare participants' progress and writing skills against the initial baseline to determine the impact of the intervention.
- **Data collection** : Participants' writing outputs will be collected. This includes recording and analyzing the content of their written responses. This data will be included in the dataset, allowing for personalization of the learning experience.

b) Participants will undergo a series of procedures over a 2-week period, with sessions lasting 20 minutes per day.

c) No biological material is collected.

6. Potential benefits Participation in this study

Potential benefits for participants are benefit in improvement in writing skills and motivate participants to engage in study sessions.

7. Risks, hazards and discomforts

The primary potential risk associated with this study is the use of the application. Participants may experience mild discomfort from extended screen time, including eye strain or fatigue, particularly if they are not accustomed to regular use of digital devices.

8. Reimbursements

There will be no monetary compensation provided for participation in this research project. The study is self-funded by undergraduate students and aims to contribute to academic knowledge and practical applications in the field.

9. Confidentiality.

Confidentiality of all records is guaranteed and no information by which you can be identified will be released and only anonymous data will be published. These data will never be used in such a way that you could be identified in any way in any public presentation or publication without your express permission. Data without identification information may be shared with other researchers as many journals expect the authors to make their data available to other researchers.

10. Sharing the Results

Participants will have the opportunity to view their progress and results through the application's built-in features. The app will provide detailed analytical reports that track individual improvement over time, allowing participants to see their achievements and areas for further development

11. Termination of study participation

You may withdraw your consent to participate in this study at any time, with no penalty or effect on medical care or loss of benefits. Please notify the investigator as soon as you decide to withdraw your consent.

12. Clarification

If you have questions about any of the tests / procedures or information please feel free to ask any of the persons listed below.

1. Name : D.G.D.H. De Silva
   Contact : 076-3226646
   Email:2020cs038@stu.ucsc.cmb.ac.lk

2. Name: K.M.G.S. Kulasekara
   Contact : 071- 6694654
   Email: 2020cs098@stu.ucsc.cmb.ac.lk

3. Name : S. Pranavan
   Contact: 077-13193339
   Email: 2020cs138@stu.ucsc.cmb.ac.lk

Figure 7.1: Participation Information Sheet - English

7.2 Annexure II: Participant Information Sheet - Sinhala

සහභාගිවන්නන්ගේ තොරතුරු පත්‍රිකාව

ඩිස්ලෙක්සියා ඇති සිසුන්ගේ සිංහල ලිවීමේ කුසලතා පෞද්ගලීකරණය කළ සහ ක්‍රීඩාකරණය කළ ඉගෙනුම් ක්‍රම හරහා වැඩිදියුණු කිරීම

"Enhancing Sinhala Writing Skills in Dyslexic Students through Personalized and Gamified Learning"

මම කොළඹ විශ්වවිද්‍යාලයේ පරිගණක විද්‍යාලයට අනුයුක්තව ජ්‍යෙෂ්ඨ කථිකාචාර්ය ලෙස සේවය කරන ආචාර්ය එල් එන් සී ද සිල්වා වෙමි.කොළඹ විශ්වවිද්‍යාලයේ පරිගණක විද්‍යාලයේ D.G.D.H ද සිල්වා,K.M.G.S.කුලසේකර,S .ප්‍රනවන් යන අවසන් වසෙරේ උපාධි අපේක්ෂකයින් විසින් පවත්වනු ලබන "ඩිස්ලෙක්සික් සිසුන්ගේ සිංහල ලිවීමේ කුසලතා වැඩි දියුණු කිරීම සඳහා ජංගම යෙදුමක් සංවර්ධනය කිරීම සහ ඇගයීම පිළිබඳ අධ්‍යයනයක්: පුද්ගලීකරණය කළ සහ ක්‍රීඩා පාදක ඉගෙනීම හරහා අකුරු සෑදීම සහ අකුරු-ශබ්ද කෙරෙහි අවධානය යොමු කිරීම" නම් පර්යේෂණ ව්‍යාපෘතියට සහභාගී වන ලෙස මම ඔබට ආරාධනා කිරීමට කැමැත්තෙමි.

1. අධ්‍යයනයේ අරමුණ

මෙම පර්යේෂණ ව්‍යාපෘතියේ අරමුණ වන්නේ ඩිස්ලෙක්සික් සිසුන්ගේ සිංහල භාෂා ලිවීමේ කුසලතා වැඩි දියුණු කිරීම සඳහා පුද්ගලාරෝපිත ක්‍රීඩා පාදක ඉගෙනුම් වේදිකාවක් සැලසුම් කිරීම සඳහා ඵලදායී උපාය මාර්ග ගවේෂණය කිරීම සහ සංවර්ධනය කිරීමයි.

2. ස්වේච්ඡා සහභාගීත්වය

මෙම අධ්‍යයනයට ඔබේ සහභාගීත්වය ස්වේච්ඡාවෙන් සිදු වේ. කලින් සහභාගී වීමට කැමැත්ත පළ කර තිබියදීත්, කිසිසේත්ම සහභාගී නොවීමට හෝ ඕනෑම අවස්ථාවක අධ්‍යයනයෙන් ඉවත් වීමට ඔබට නිදහස ඇත. ඔබට වෙනත් ආකාරයකින් හිමිවන ඔබේ අසනීප තත්ත්වය හෝ තත්ත්වය සඳහා වෛද්‍ය ප්‍රතිකාර හෝ පවතින වෙනත් ප්‍රතිකාර අහිමිවීමක් සිදු නොවේ. ඔබ අධ්‍යයනයට

සහභාගී නොවීමට හෝ ඉවත් වීමට තීරණය කරන්නේ නම්, ඔබට ඕනෑම අවස්ථාවක එය කළ හැක.

3. සහභාගීත්වය තෝරාගැනීම

පර්යේෂණයට පදනම් වී ඇත්තේ අවුරුදු 8vත් 10ත් අතර වයසේ පසුවන ඩිස්ලෙක්සියා රෝගය වැළඳී ඇති , සිංහල ලිවීමේ අපහසුතා ද පෙන්නුම් කරන දරුවන්ය.

4. මූලික සම්බන්ධතා සහ බඳවා ගැනීම්

සහභාගිවන්නන් වයස අවුරුදු 8 සිට 10 දක්වා වයස් පරාසයක සිට බඳවා ගනු ලබන අතර ලිවීමේ දුෂ්කරතා වලට මුහුණ දෙන ඩිස්ලෙක්සික් සිසුන් විය යුතුය. මීට අමතරව, සිසුන්ට බුද්ධියට හෝ ඉගෙනීමට බලපාන වෙනත් රෝග විනිශ්චය කළ තත්වයන් නොතිබිය යුතු අතර උපාංගයක් භාවිතා කිරීමේ මූලික දැනුමක් තිබිය යුතුය.

5. කාලසීමාව, අධ්‍යයනයේ ක්‍රියාපටිපාටි සහ සහභාගිවන්නාගේ වගකීම්

අ) ක්‍රියාත්මක කළ යුතු ක්‍රියාපටිපාටිය/එනම් ;

මූලික තක්සේරුව (Initial assessment): අධ්‍යයනය ආරම්භයේදී, මූලික ලිවීමේ කුසලතා තහවුරු කිරීම සඳහා මූලික තක්සේරුවක් සිදු කරනු ලැබේ. වැඩිදියුණු කිරීම මැනීම සඳහා යොමු ලක්ෂ්‍යයක් සැපයීම සඳහා සහභාගිවන්නන්ගේ වර්තමාන ලිවීමේ හැකියාවන් ඇගයීම මෙයට ඇතුළත් වේ.

අවසාන තක්සේරුව(Final assessment): අධ්‍යයනය අවසානයේ, යෙදුමේ සඵලතාවය ඇගයීම සඳහා අවසාන තක්සේරුවක් සිදු කරනු ලැබේ. මෙම

ඇගයුම මගින් සහභාගිවන්නන්ගේ ප්‍රගතිය සහ ලිවීමේ කුසලතා මූලික පදනමට එරෙහිව සංසන්දනය කරනු ඇත.

දත්ත රැස් කිරීම (Data collection) : සහභාගිවන්නන්ගේ ලිවීමේ ප්‍රතිදානයන් එකතු කරනු ලැබේ. මෙයට ඔවුන්ගේ ලිඛිත ප්‍රතිචාරවල අන්තර්ගතය පටිගත

කිරීම සහ විශ්ලේෂණය කිරීම ඇතුළත් වේ. මෙම දත්ත දත්ත කට්ටලයට ඇතුළත් කර, ඉගෙනීමේ අත්දැකීම පුද්ගලීකරණය කිරීමට ඉඩ සලසයි.

ආ) සහභාගිවන්නන් සති 2 ක කාලයක් තුළ ක්‍රියාපටිපාටි මාලාවකට මුහුණ දෙනු ඇත, සැසිවාර දිනකට විනාඩි 15-20 ක් පවතී.

ඇ) ජීව විද්‍යාත්මක ද්‍රව්‍ය එකතු කරනු නොලැබේ.

6. විභව ප්‍රතිලාභ

සහභාගිවන්නන් සඳහා ඇති විය හැකි ප්‍රතිලාභ නම් ලිවීමේ කුසලතා වැඩිදියුණු කිරීමේ ප්‍රතිලාභ සහ අධ්‍යයන සැසිවල නිරත වීමට සහභාගිවන්නන් පෙළඹවීමයි.

7. අවදානම්, උපද්‍රව සහ අපහසුතා

මෙම අධ්‍යයනය හා සම්බන්ධ මූලික විභව අවදානම වන්නේ යෙදුම භාවිතා කිරීමයි. සහභාගිවන්නන්ට අක්ෂි ආතතිය හෝ තෙහෙට්ටුව ඇතුළුව දිගු තිර කාලය හේතුවෙන් මෘදු අපහසුතාවයක් අත්විඳිය හැකිය, විශේෂයෙන් ඔවුන් ඩිජිටල් උපාංග නිතිපතා භාවිතා කිරීමට පුරුදු වී නොමැති නම්.

8. ප්‍රතිපරෑණය

පර්යේෂණ ව්‍යපෘතිය සඳහා දත්ත රැස් කිරීම සමඟ කිසිදු ගෙවීමක් සැලසුම් කර නොමැති අතර එය උපාධි අපේක්සකයින් විසින් ස්වයං අරමුදල් යොදා ගනිමින් කරනු ලබන ව්‍යපෘතියක් වේ.

9. රහස්‍යභාවය

සියලුම වාර්තා වල රහස්‍යභාවය සහතික කෙරෙන අතර ඔබව හඳුනාගත හැකි කිසිදු තොරතුරක් නිකුත් නොකරන අතර නිර්නාමික දත්ත පමණක් ප්‍රකාශයට

පත් කෙරේ. ඔබේ ප්‍රකාශිත අවසරයකින් තොරව ඕනෑම පොදු ඉදිරිපත් කිරීමකදී හෝ ප්‍රකාශනයකදී ඔබව කිසිම ආකාරයකින් හඳුනා ගත හැකි ආකාරයෙන් මෙම දත්ත කිසිවිටෙක භාවිතා නොකෙරේ. බොහෝ සඟරා කතුවරුන් තම දත්ත

වෙනත් පර්යේෂකයන්ට ලබා දීමට අපේක්ෂා කරන බැවින් හඳුනාගැනීමේ තොරතුරු නොමැති දත්ත වෙනත් පර්යේෂකයන් සමඟ බෙදා ගත හැකිය.

10. ප්‍රතිඵල බෙදාගැනීම

සහභාගීවනනනට ඔවුන්ගේ ප්‍රගතිය සහ ප්‍රතිඵල යෙදුමේ අන්තර්ගත විශේෂාංග හරහා බැලීමට අවස්ථාව ලැබේ. යෙදුම කාලයත් සමඟ පුද්ගල වැඩිදියුණු කිරීම් නිරීක්ෂණය කරන සවිස්තරාත්මක විශ්ලේෂණ වාර්තා සපයනු ඇත, සහභාගිවන්නන්ට ඔවුන්ගේ ජයග්‍රහණ සහ වැඩිදුර සංවර්ධනය සඳහා වන ක්ෂේත්‍ර බැලීමට ඉඩ සලසයි.

11. අධ්‍යයන සහභාගීත්වය අවසන් කිරීම

වෛද්‍ය ප්‍රතිකාර සඳහා කිසිදු දඬුවමක් හෝ බලපෑමක් හෝ ප්‍රතිලාභ අහිමි වීමකින් තොරව, ඔබට ඕනෑම වේලාවක මෙම අධ්‍යයනයට සහභාගී වීමට ඔබේ කැමැත්ත ඉල්ලා අස්කර ගත හැකිය. ඔබ ඔබේ කැමැත්ත ඉල්ලා අස්කර ගැනීමට තීරණය කළ වහාම විමර්ශකයාට දන්වන්න.

12. පැහැදිලි කිරීම

ඔබට කිසියම් පරීක්ෂණයක් / ක්‍රියා පටිපාටි හෝ තොරතුරු පිළිබඳ ප්‍රශ්න ඇත්නම් කරුණාකර පහත ලැයිස්තුගත කර ඇති ඕනෑම අයෙකුගෙන් විමසීමට කාරුණික වන්න.

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Figure 7.2: Participation Information Sheet - Sinhala

7.3 Annexure III: Informed Consent Form

INFORMED CONSENT FORM

A Study on Developing and Evaluating a Mobile Application to Enhance Sinhala Writing Skills in Dyslexic Students. Focusing on Letter Formation and Letter-Sound Correspondence through Personalized and Gamified Learning

Principal Investigator: Dr. L N C De Silva

- Introduction:

You are being invited to participate in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please read the following information carefully and feel free to ask any questions.

- Purpose of the Study:

The purpose of this research project is to explore and develop effective strategies for designing personalized game-based learning platforms to improve the Sinhala language writing skills of dyslexic students.

- Consent:

I have read and understood the information provided above. I have had the chance to ask questions and received satisfactory answers. By signing this form, I freely consent to participate in the study described above.

To be completed by the participant.

1. Have you read the information sheet? (Please keep a copy for yourself) YES/NO

2. Have you had an opportunity to discuss this study and ask any questions? YES/NO
3. Have you had satisfactory answers to all your questions? YES/NO

4. Have you received enough information about the study? YES/NO

5. Who explained the study to you? .....
6. Do you understand that you have the right to not to participate in this study? YES/NO

7. Do you understand that you are free to withdraw from the study at any time, without having to give a reason and without affecting your future medical care? YES/NO

8. Sections of your medical notes, including those held by the investigators relating to your participation in this study may be examined by other research assistants. All personal details will be treated as strictly Confidential. Do you give your permission for these individuals to have access to your records? YES/NO

9. Have you had sufficient time to come to your decision? YES/NO
10. Do you agree to take part in this study? YES/NO

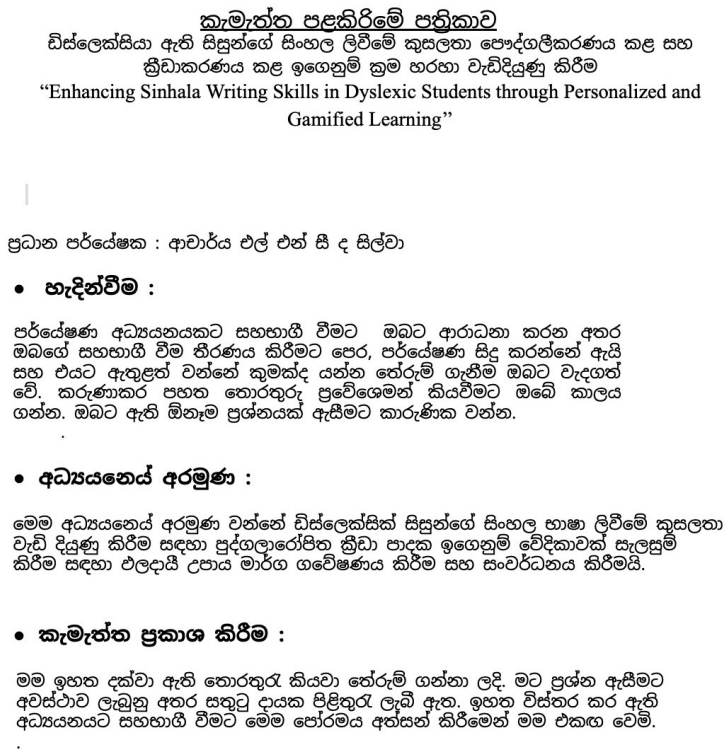
Participant's signature..... Date.....
Name (BLOCK CAPITALS) .....

To be completed by the investigator/ person obtaining consent
I have explained the study to the above volunteer and he/ she has indicated her willingness to take part.

Participant's signature..... Date.....
Name (BLOCK CAPITALS) .....

Figure 7.3: Informed Consent Form - English

7.4 Annexure IV: Informed Consent Form- Sinhala



කැමැත්ත පළකිරීමේ පත්‍රිකාව

ඩිස්ලෙක්සියා ඇති සිසුන්ගේ සිංහල ලිවීමේ කුසලතා පෞද්ගලීකරණය කළ සහ ක්‍රීඩාකරණය කළ ඉගෙනුම් ක්‍රම හරහා වැඩිදියුණු කිරීම

"Enhancing Sinhala Writing Skills in Dyslexic Students through Personalized and Gamified Learning"

ප්‍රධාන පර්යේෂක : ආචාර්ය එල් එන් සී ද සිල්වා

- **හැදින්වීම :**

පර්යේෂණ අධ්‍යයනයකට සහභාගී වීමට ඔබට ආරාධනා කරන අතර ඔබගේ සහභාගී වීම තීරණය කිරීමට පෙර, පර්යේෂණ සිදු කරන්නේ ඇයි සහ එයට ඇතුළත් වන්නේ කුමක්ද යන්න තේරුම් ගැනීම ඔබට වැදගත් වේ. කරුණාකර පහත තොරතුරු ප්‍රවේශෙමන් කියවීමට ඔබේ කාලය ගන්න. ඔබට ඇති ඕනෑම ප්‍රශ්නයක් ඇසීමට කාරුණික වන්න.

- **අධ්‍යයනයේ අරමුණ :**

මෙම අධ්‍යයනයේ අරමුණ වන්නේ ඩිස්ලෙක්සික් සිසුන්ගේ සිංහල භාෂා ලිවීමේ කුසලතා වැඩි දියුණු කිරීම සඳහා පුද්ගලාරෝපිත ක්‍රීඩා පාදක ඉගෙනුම් වේදිකාවක් සැලසුම් කිරීම සඳහා ඵලදායී උපාය මාර්ග ගවේෂණය කිරීම සහ සංවර්ධනය කිරීමයි.

- **කැමැත්ත ප්‍රකාශ කිරීම :**

මම ඉහත දක්වා ඇති තොරතුරු කියවා තේරුම් ගන්නා ලදි. මට ප්‍රශ්න ඇසීමට අවස්ථාව ලැබුනු අතර සතුටු දායක පිළිතුරු ලැබී ඇත. ඉහත විස්තර කර ඇති අධ්‍යයනයට සහභාගී වීමට මෙම පෝරමය අත්සන් කිරීමෙන් මම එකඟ වෙමි.

Figure 7.4: Informed Consent Form - Sinhala

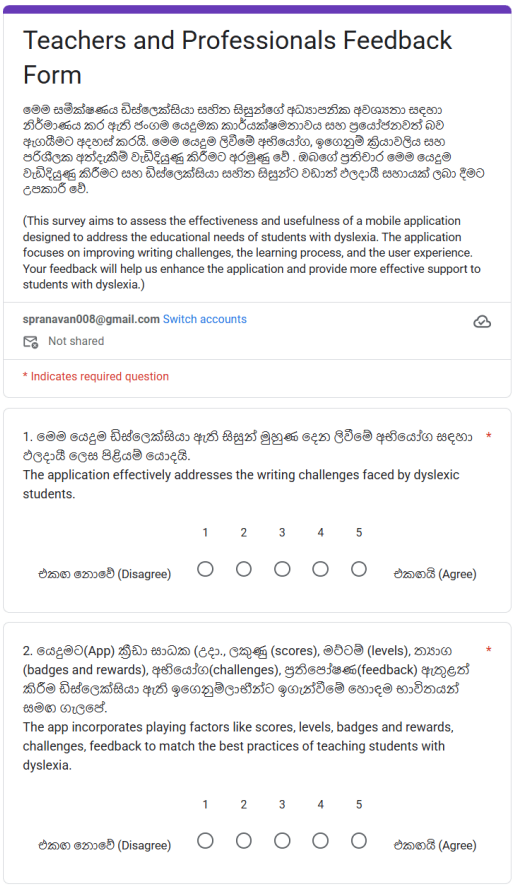
7.5 Annexure V: Pre-Test/Post-Test

පූර්ව පරීක්ෂණය සහ පශ්චාත් පරීක්ෂණය (Pre-Test and Post-Test)
අසා ලිවීම - පහත වචන අධීක්ෂක විසින් කියවනු ලබන අතර ශිෂයයා එම වචනවලට සවන් දීමෙන් පසු එම වචන ලිවිය යුතුය.

1.ක
2.ට
3.ග
4.ල
5.ප
6.ය
7.ගා
8.යා
9.කට
10. ගල
11. පය
12. ගාල
13. යාය

Figure 7.5: Pre-Test/Post-Test

7.6 Annexure VI: Feedback Form



Teachers and Professionals Feedback Form

මෙම සමීක්ෂණය ඩිස්ලෙක්සියා සහිත සිසුන්ගේ අධ්‍යාපනික අවශ්‍යතා සඳහා නිර්මාණය කර ඇති ජංගම යෙදුමක කාර්යක්ෂමතාවය සහ ප්‍රයෝජනවත් බව ඇගයීමට අදහස් කරයි. මෙම යෙදුම ලිවීමේ අභියෝග, ඉගෙනුම් ක්‍රියාවලිය සහ පරිශීලක අත්දැකීම් වැඩිදියුණු කිරීමට අරමුණු වේ . ඔබගේ ප්‍රතිචාර මෙම යෙදුම වැඩිදියුණු කිරීමට සහ ඩිස්ලෙක්සියා සහිත සිසුන්ට වඩාත් ඵලදායී සහායක් ලබා දීමට උපකාරී වේ.

(This survey aims to assess the effectiveness and usefulness of a mobile application designed to address the educational needs of students with dyslexia. The application focuses on improving writing challenges, the learning process, and the user experience. Your feedback will help us enhance the application and provide more effective support to students with dyslexia.)

spranavan008@gmail.com Switch accounts

Not shared

* Indicates required question

1. මෙම යෙදුම ඩිස්ලෙක්සියා ඇති සිසුන් මුහුණ දෙන ලිවීමේ අභියෝග සඳහා ඵලදායී ලෙස පිළියම් යොදයි. *
The application effectively addresses the writing challenges faced by dyslexic students.

	1	2	3	4	5	
එකඟ නොවේ (Disagree)	○	○	○	○	○	එකඟයි (Agree)

2. යෙදුමට(App) ක්‍රීඩා සාධක (උදා., ලකුණු (scores), මට්ටම් (levels), ත්‍යාග (badges and rewards), අභියෝග(challenges), ප්‍රතිපෝෂණ(feedback) ඇතුළත් කිරීම ඩිස්ලෙක්සියා ඇති ඉගෙනුම්ලාභීන්ට ඉගැන්වීමේ හොඳම භාවිතයන් සමඟ ගැලපේ. *
The app incorporates playing factors like scores, levels, badges and rewards, challenges, feedback to match the best practices of teaching students with dyslexia.

	1	2	3	4	5	
එකඟ නොවේ (Disagree)	○	○	○	○	○	එකඟයි (Agree)

3. යෙදුමට(App) ක්‍රීඩා සාධක (උදා., ලකුණු (scores), මට්ටම් (levels), ත්‍යාග (badges and rewards), අභියෝග(challenges), ප්‍රතිපෝෂණ(feedback) ඇතුළත් කිරීම ඩිස්ලෙක්සියා ඇති සිසුන්ගේ සහභාගීත්වය සහ අභිප්‍රේරණය වැඩි දියුණු කරයි. *
Gamification elements in the application (e.g. scores, levels, badges and rewards, challenges, feedback) enhance student engagement and motivation.

	1	2	3	4	5	
එකඟ නොවේ (Disagree)	○	○	○	○	○	එකඟයි (Agree)

4. යෙදුම(App) ඩිස්ලෙක්සියා ඇති සිසුන්ට ප්‍රවේශ විය හැකි පරිශීලක-හිතකාමී (user-friendly interface) අතුරුමුහුණතක් සපයයි. *
The application provides a user-friendly interface that is accessible for dyslexic students.

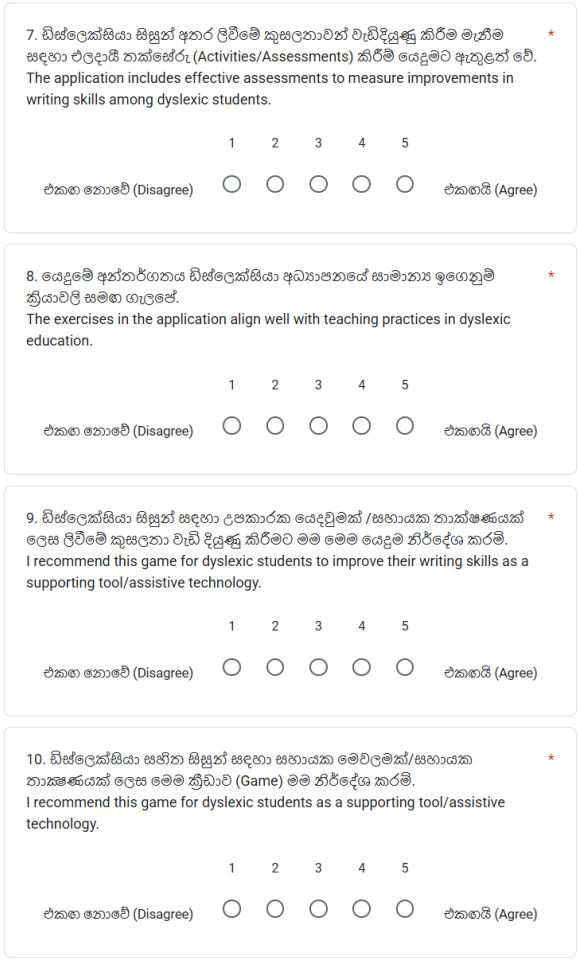
	1	2	3	4	
එකඟ නොවේ (Disagree)	○	○	○	○	එකඟයි (Agree)

5. යෙදුමේ(App) සැලසුම (වර්ණ, අකුරු, දෘශ්‍ය ආධාරක ඇතුළුව) ඩිස්ලෙක්සියා ඇති සිසුන්ට සුදුසු වන අතර දෘශ්‍ය වෙහෙස අඩු කරයි. *
The application design (including colors, fonts, and visuals) is suitable for students with dyslexia and reduces visual strain.

	1	2	3	4	5	
එකඟ නොවේ (Disagree)	○	○	○	○	○	එකඟයි (Agree)

6. යෙදුම ඩිස්ලෙක්සියා ඇති සිසුන් අතර විවිධ කුසලතා මට්ටම් සහ ඉගෙනුම් වේගයන්ට අනුවර්තනය කළ හැකිය. *
The application is adaptable to various skill levels and learning paces among dyslexic students.

	1	2	3	4	5	
එකඟ නොවේ (Disagree)	○	○	○	○	○	එකඟයි (Agree)



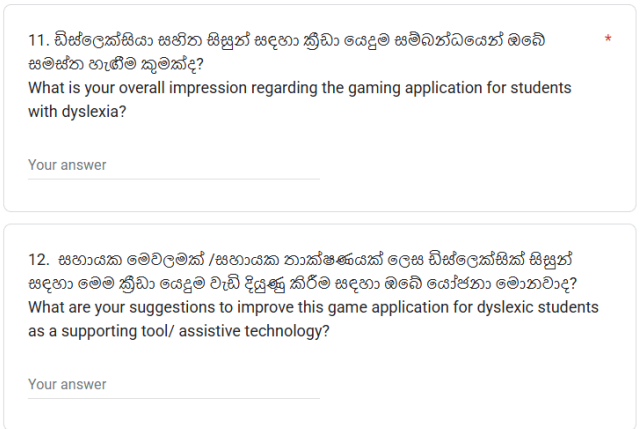


Figure 7.6: Feedback Form