An Innovative Mobile Application for Addressing Learning Challenges: A Systematic Approach to Supporting Children with Dyslexia, Dysgraphia, Dyscalculia, and Short-term Memory Loss

Rajapaksha R. M. D. C. J
Department of Information Technology
Sri Lanka Institute of Technology
Malabe, Sri Lanka
chameerajeewantha98@gmail.com

Gimhan R.K.P.P.P
Department of Information Technology
Sri Lanka Institute of Technology
Malabe, Sri Lanka
pravindugimhan@gmail.com

Yapa Y.A.D.C.H.
Department of Information Technology
Sri Lanka Institute of Technology
Malabe, Sri Lanka
chamodi.h.yapa@gmail.com

Bandara K.M.A,P.
Department of Information Technology
Sri Lanka Institute of Technology
Malabe, Sri Lanka
amandapbandara@gmail.com

Ms. Shashika Lokuliyana
Department of Information Technology
Sri Lanka Institute of Technology
Malabe, Sri Lanka
shashika.l@sliit.lk

Ms. Wishalya Tissera
Department of Information Technology
Sri Lanka Institute of Technology
Malabe, Sri Lanka
wishalya.t@sliit.lk

***Abstract*— In countries such as Sri Lanka, the absence of structured educational assistance for children facing learning difficulties such as dyslexia, dyscalculia, dysgraphia, and short-term memory challenges poses a considerable barrier to their academic progress. In response to this challenge, our primary objective is centered on creating a mobile application leveraging machine learning algorithms and Java scripting. This cutting-edge software aims to provide tailored educational therapy to enhance the cognitive abilities and academic achievements of children struggling with these conditions. The primary focus of this program is to assist children diagnosed with these disabilities in their skills development.The application employs a gamified approach and incorporates machine learning components specifically designed to address the unique challenges associated with each disability. For dyscalculia, the app analyzes user interaction patterns to predict future improvement and engagement time, as well as exercise completion rates. For individuals with dyslexia, we've seamlessly incorporated features that convert speech to text and vice versa, guaranteeing precise recognition and reproduction of speech. The application utilizes advanced technology and APIs to convert spoken language to text and vice versa, providing pronunciation accuracy as a percentage. To assist children with dysgraphia, we have customized handwriting recognition algorithms that accurately analyze and assess writing patterns, offering personalized feedback and guidance. Additionally, for children with short-term memory loss, our app incorporates machine learning algorithms to effectively predict their progress. These applications aim to enhance the learning experience and improve outcomes for children with a variety of learning disabilities.**

Keywords—dyslexia, dysgraphia, dyscalculia, short term memory loss, mobile application, machine learning

I. INTRODUCTION

A. Background

Learning disabilities are common neurodevelopmental disorders that can significantly impact academic performance and everyday activities. The prevalence of learning disabilities among children has significantly increased, necessitating innovative approaches to support their development. Dysgraphia, dyscalculia, and dyslexia affect a person's ability in writing, mathematics, and reading respectively, while short-term memory deficits make it difficult to retain information over short periods. Research shows that 5-15% of school-aged children are affected by learning disabilities, with comorbidity across conditions being common [16]. Developing skills in these areas is critical for educational and occupational success.

Dysgraphia manifests as challenges with handwriting, including inconsistent letter size and spacing, illegible writing, and difficulty with writing organization [6]. Underlying deficits in fine motor skills, visual-spatial abilities, working memory, and sequential processing have been implicated [7]Interventions targeting the sensorimotor aspects of handwriting through multisensory techniques have shown success in improving writing skills in children with dysgraphia [1].

Dyscalculia involves problems in learning and comprehending numerical concepts and arithmetic [11]. Those with dyscalculia often have poor number sense, magnitude representation, and mathematical reasoning that cannot be accounted for by intellectual disability [12]Evidence suggests interventions targeting number sense, visual-spatial skills, and linking abstract symbols to non-symbolic magnitudes can improve mathematical abilities in dyscalculia [11].

Dyslexia is characterized by difficulties in accurate or fluent reading, spelling, writing, word recognition, and decoding abilities, attributed to phonological and auditory processing problems [16]Phonics-based reading interventions that break down letter-sound relationships have been shown to remediate reading skills in children with dyslexia [18].

Short-term memory deficits refer to problems with maintenance, manipulation, and storage of information over seconds to minutes [22]. This impacts learning, reasoning, and cognitive tasks. Interventions focused on memory strategies, such as verbal rehearsal and chunking, have demonstrated some effectiveness for improving short-term memory capacity [9].

Digital technology offers accessible, engaging, and individualized interventions for children with learning

disabilities, such as educational apps that provide interactive games and real-time feedback. Research shows these interventions improve numeracy skills in dyscalculic children[8]. However, few comprehensive tools exist for supporting children with multiple learning disabilities.

Each learning disability has distinct neurological underpinnings that influence approaches to remediation. Dysgraphia is associated with abnormalities in regions related to fine motor control, such as the precentral gyrus, supplementary motor area, and cerebellum [2]. Dyscalculia involves dysfunction in parts of the parietal lobe including the intraparietal sulcus which is critical for numerical cognition [10]. Dyslexia stems from phonological processing impairments linked to anomalies in left hemisphere temporal and parietal language regions like the superior temporal gyrus [3]. Short-term memory deficits can arise from damage to subcortical structures and cortical association areas involved in attention and cognitive control [22].

While remediation programs for single learning disabilities exist, the comorbidity between these conditions suggests comprehensive interventions are needed. Children with dyslexia often have associated dysgraphia and working memory problems [23]. Dyscalculia and dysgraphia co-occur more often than expected by chance [5]. Developing skills in all deficit areas simultaneously may have added benefits compared to separate training. Furthermore, case studies have shown the effectiveness of multivariate interventions that focus on developing fluency in reading, writing, and spelling, as well as the development of working memory for individual words and sequences of words[27]. These interventions have been shown to be beneficial for children with learning disabilities, supporting their academic and cognitive development.

Technology-based interventions, such as game-based digital programs, have shown positive learning outcomes for struggling students compared to traditional classroom teaching alone[13]. The motivational and self-paced aspects of educational video games can augment learning for those with learning disabilities [26]. Well-designed apps with embedded supports, individual progress monitoring, and rewards hold promise for engaging learners with diverse needs.

B. Problems Statement

The research aims to create machine learning-powered mobile applications for children with learning disabilities, including dyslexia, dysgraphia, and dyscalculia, enhancing literacy, writing, and math skills through personalized recognition, accurate speech recognition, and dyscalculia-friendly games.

C. Significance

This research focuses on improving children's learning abilities in reading, mathematics, writing, and memory by addressing specific learning disabilities, using data, algorithms, and tailored techniques.

D. Objectives

The research encompasses four areas of learning challenges: Dysgraphia, Dyslexia, Dyscalculia, and short-term memory loss. The development of digital platforms for dysgraphia, dyslexia, dyscalculia, and short-term memory loss is underway. These platforms aim to ease academic and professional barriers, provide interactive exercises, and enhance children's recall abilities through engaging activities and machine learning features.

II. LITERATURE SURVEY

A. Mobile applications for dysgraphia intervention

Dysgraphia manifests as challenges with handwriting, including inconsistent letter size and spacing, illegible writing, and difficulty with writing organization [6]. Underlying deficits in fine motor skills, visual-spatial abilities, working memory, and sequential processing have been implicated [7]. Interventions targeting the sensorimotor aspects of handwriting through multisensory techniques have shown success in improving writing skills in children with dysgraphia [4].

Studies [22][24] have emphasized the benefits of computerized systems for the identification of dysgraphia features on handwriting. Handwriting screening questionnaires have been developed to assess dysgraphia in children, such as the Handwriting Proficiency Screening Questionnaire for Children (HPSQ-C) [14], though some faced limitations like convenience sampling and lack of language portability. Out of the few screening applications for dysgraphia, [15] was based on forward-chaining with a good accuracy level. Another study [16] developed a statistical model for discriminating between dysgraphic and proficient handwriting using handwriting classification methods, achieving 90% accuracy but lacking user-friendliness. The study [17] used short questionnaires to evaluate dysgraphia with 96% accuracy but didn't support language portability and had a 10% handwriting proficiency estimation error.

Dysgraphicoach is a mobile application to support dysgraphic children using the Malaysian language with different colors and fonts to improve writing skills, but it is limited to the Android operating system [18]. A series of games were used in [19] for dysgraphia intervention in an organized manner to trace and write English letters. Another study [25] identified lifts and stops in proficient and dysgraphic handwriting in Roman writing for adults and children using tablets, though in a less user-friendly manner. The study [20] provides an augmented reality-based dysgraphia assistive writing environment to address spelling mistakes, but it yields good results primarily for phonological dysgraphic students. Another research [21] proposed an augmented reality-based spelling assistance app for students with dysgraphia using voice-to-text technologies, but it addresses only the spelling issue.

B. Technology-assisted dyslexia support

This literature review explores mobile applications designed to help dyslexic children overcome reading challenges, highlighting existing initiatives and user-friendly solutions in this area.

A number of researchers have dived into crafting mobile applications with dyslexic youngsters in mind. Bigueras [28] ventured into the realm of mobile game-based learning, recognizing the potential of game elements in captivating dyslexic learners. Lazo Amado and Andrade-Arenas [29] took a further leap, integrating augmented reality to create an immersive learning environment for dyslexic kids in primary education. Bhatt [30] introduced a mobile application that

doesn't just tackle dyslexia but also extends its reach to address dysgraphia, surface dyslexia, semantic dyslexia, and dyscalculia. This comprehensive approach suggests a holistic strategy to cater to various learning difficulties through a single platform, potentially enhancing the learning experiences for children facing diverse challenges. Aldousari [31] and Politi-Georgousi and Drigas [32] took a step back, conducting systematic literature reviews that provide a bird's eye view of existing mobile applications designed for dyslexic students. Their work underscores the importance of evidence-based practices and emphasizes the potential of mobile apps as potent tools for dyslexia screening and intervention.Eroglu [33] presented a unique approach by combining neurofeedback and multi-sensory learning methods in a mobile app, showing promising results in enhancing reading abilities among

dyslexic individuals. This innovative use of technology suggests that interventions can transcend traditional methods to cater to the distinct needs of dyslexic learners. Sharbini et al. [34] honed in on developing reading skills in dyslexic children through a sight word reading strategy incorporated into interactive game-based learning. The study emphasizes the significance of engagement and interactivity in enhancing dyslexic learning experiences, emphasizing the continuous assessment of application effectiveness and user engagement.

Sharbini et al. [34] proposed a systematic approach to track user progress, offering insights into user behavior and preferences. This mirrors the objective of the proposed application to incorporate data collection mechanisms and provide progress reports [31]. The literature review highlights the growing interest in developing mobile applications for dyslexic children, utilizing gamification, augmented reality, and evidence-based practices, including speech-to-text, interactive exercises, and progress tracking.

Mobile applications for dyscalculia

Dyscalculia presents with various symptoms, one of the earliest indicators in affected children is the struggle to enumerate or count within the numerical range of one to nine [35], and it's the difficulty in recognizing numbers, mastering counting, or identifying fundamental patterns may manifest in children with dyscalculia. This literature review explores the development of mobile applications for dyscalculia children, focusing on their unique mathematical challenges. The aim is to create personalized, interactive experiences, fostering a conducive environment for their mathematical advancement. After referring previous research, [36] was developed as a standalone computer-based system specifically for university students and lacks the capability to assess primary school children. [37] is a computer-based screening tool that does not possess a high level of appeal amongst children. Another web application, [36] is a free online screening instrument developed for students above the age of 14. [38] is a brief, two-minute evaluation using paper and pencil to assess the early mathematical abilities of children. This assessment is solely conducted on paper.[39] has been designed for individuals age between 13 and 17 who are students.

C. Short-term memory enhancement through mobile technology

This section discusses the development and implementation of an Android mobile application for multiple clients or schools, highlighting the benefits of e-learning systems and research on student score prediction, utilizing a template for paper formatting and text style.[44]

Learning disabilities in children, particularly those related to short-term memory impairments, pose significant challenges to their academic and cognitive development[42]. As technology becomes increasingly integrated into education, mobile applications present an innovative avenue for addressing these challenges[43]. This literature review examines research on mobile applications for improving short-term memory in children with learning disabilities, highlighting non-pharmacological methods like memory games and computer-based training programs.[41]. Research suggests activities like attaching words or images to objects, associating, remembering, and engaging in cognitive training programs can help mitigate short-term memory loss [40].

Within the scope of this research, the story-based multiple-choice question (MCQ) game and memory card game have been identified as particularly promising interventions, exhibiting great potential for effectively enhancing memory capabilities [45]. The incorporation of narratives into memory games aligns with cognitive theories that emphasize the importance of meaningful context in facilitating memory encoding and retrieval [46]. By analyzing the scores obtained and the time taken to complete these games, it becomes possible to predict and monitor the improvement in children's memory abilities, providing valuable insights for tailoring educational interventions [47].

III. METHODOLOGY

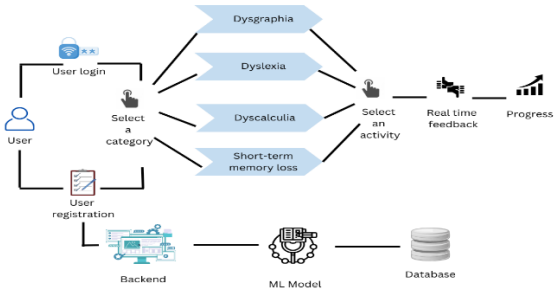

Figure III-1-System High Level Architecture

A. Screening and intervention of dysgraphia Steps

This research aims to develop an intelligent assistant to enhance the assessment and learning process for children with dysgraphia. Initially, literature on handwriting analysis and recognition methods was studied to determine appropriate machine learning techniques. Handwriting samples of all English alphabet letters were collected from 15 dysgraphia children after consent, and an open handwritten letter dataset was acquired. The images were preprocessed, augmented, and used to train convolutional neural network models for optimized handwriting recognition accuracy. A responsive web application was built with features for students to practice writing letters and receive instant feedback. Student usage and progress is tracked to generate personalized reports. Extensive testing was performed before deploying the platform in real classrooms. This allows dysgraphia students to obtain individualized assistance and improve their writing skills.

Handwriting Data Collection

Handwriting samples of all uppercase and lowercase English alphabet letters were collected from 15 children diagnosed with dysgraphia, aged 6-10 years, at Woodcreek Elementary School. The students wrote each letter once on printed guidelines, resulting in 1050 images. Consent was obtained from parents and the school.

Open Source Dataset

The CVL Handwritten Alphabet dataset containing 10,000 images of handwritten alphabets from 100 writers was acquired from Kaggle. This added diversity to the training data.

Model Development

Following the data collection phase, the team proceeded to create a model to analyze and recognize the writing patterns of children with dysgraphia. The model was designed to evaluate the accuracy of letters written by the children, focusing on aspects such as letter form, size, alignment, and spacing, as highlighted in the BHK test [1]. This model was trained using the collected data and the Kaggle datasets, ensuring that it was capable of accurately identifying the quality of writing and providing feedback.

User Interface Design

The app has two levels of interaction designed to help children with dysgraphia learn. The first level involves writing letters on a dotted line, with the system analyzing and providing feedback. The second level involves writing a letter on a blank area, improving accuracy and recognizing the child's attempt.

Progress Report Generation

At the end of each session, the app generated a progress report for each user. This report provided insights into the child's writing development over time, highlighting areas of improvement and areas that might require further attention. This feature was crucial for tracking the child's progress and identifying areas for improvement.

Ethical Considerations

The research process prioritizes ethical considerations like data privacy, consent, and inclusivity, ensuring confidentiality, informed consent, and accessibility for all users, regardless of cognitive or physical abilities.

Limitations and Future Directions

The study acknowledges limitations, but suggests future research includes longitudinal studies, integrating features for dysgraphia children, and stakeholder collaboration to improve the platform's effectiveness.

B. Screening and intervention of dyslexia

The very first step in the technique is to incorporate speech-to-text as well as text-to-speech capabilities right into the mobile application. This will certainly be attained by using pre-trained designs from Hugging Face, particularly the "" microsoft/speecht5_tts"" version for text-to-speech as well as the "" wav2vec2"" design for speech-to-text. These designs will certainly offer precise speech acknowledgment plus speech synthesis abilities making it possible for the application to effortlessly transform talked language to message and also the other way around. The application will certainly likewise offer comments on enunciation precision as a percent. To resolve the phonological handling difficulties dealt with by youngsters with dyslexia, the application will certainly allow them to listen to appropriate enunciations as well as connect these seems with written words. This will certainly be assisted in by the text-to-speech capability powered by the "" microsoft/speecht5_tts"" design. By listening to the appropriate enunciations youngsters will certainly establish the capacity to map seems to letters and also words an essential ability for enhancing analysis capacities.

The core of the method hinges on creating plus carrying out dynamic interactive workouts. A collection of workouts will certainly be created, beginning with solitary letter enunciation and also slowly proceeding to extra intricate words, sentences, and also paragraphs. These workouts will certainly be created based upon academic concepts and also interaction approaches making sure age-appropriate and also interesting web content. The text-to-speech as well as speech-to-text abilities given by the pre-trained versions will certainly be incorporated right into these workouts enabling youngsters to exercise checking out aloud plus getting comments on their enunciation. To review the application's effectiveness as well as customer involvement the technique includes evaluating individual involvement patterns, such as the moment invested in workouts as well as communication regularity. Information collection systems will certainly be integrated right into the application to track individual communications offering understandings right into customer actions and also choices. These understandings will certainly be utilized to fine-tune the application's efficiency consistently.

Ultimately, the approach consists of outward development records for every individual. These records will certainly give a general recap of the individual's progression and also success within the application, including their efficiency on enunciation as well as understanding workouts. Moms and dads or caretakers will certainly have the choice to download and install these progression records in PDF layout for simple gain access to plus tracking.

C. Screening and intervention of dyscalculia

This research involves the development of a user-friendly mobile application tailored specifically for children with dyscalculia. The focus will be on creating simple mathematical games designed to address key areas of mathematical difficulty faced by these children. The application will feature a meticulously crafted interface, incorporating dyscalculia-friendly visual components such as fonts, colors, and layouts to ensure an inviting and engaging user experience. Gamification elements will be integrated into the application, including challenges such as the Clock Challenge for time management skills, Money Master for financial literacy, Number Sequence for understanding numerical order, and Counting Practice for basic counting skills. User interactions will be captured throughout the application, with metrics including engagement time and exercise completion rates recorded for analysis. Progress reports will be generated both in-game and as downloadable PDFs, providing users and caregivers with comprehensive insights into the child's development. Additionally, machine learning techniques, particularly the random forest algorithm, will be employed to analyze user interaction trends and predict future improvements in engagement time and exercise

completion rates, contributing to the child's self-improvement journey.

D. Screening and intervention of short-term memory loss

The execution of the memory prediction module in this research endeavor followed a comprehensive approach that encompassed the collection of data, the implementation of algorithms, and thorough testing. To initiate the process, data was gathered from a diverse sample of 100 students through the use of a mobile application. The survey aimed to capture vital information regarding the students' memory performance, all of which could potentially impact the prediction of their memory progress. Moreover, insightful qualitative data was acquired through interviews conducted with specialists possessing expert knowledge and perspectives on the various factors that influence a child's memory progress prediction. Additionally, the dataset containing the children's scores and the time taken to complete the task was enriched by including past scores and task completion time data from students, which served as valuable historical records. Subsequently, a meticulous phase of data processing and cleaning was carried out to ensure the accuracy and reliability of the dataset. Appropriate measures were taken to address any inconsistencies, missing values, or outliers that could potentially hinder the performance of the predictive models. The focus then shifted towards selecting optimal parameters, with particular attention given to the score and task completion time and training the dataset using various regression algorithms such as Random Forest Regressor, Gradient boosting, and XG boost regressor. These algorithms were implemented and fine-tuned to enhance their predictive capabilities. To assess the accuracy and effectiveness of the workflow, the models underwent a thorough evaluation utilizing appropriate evaluation metrics. Among the tested algorithms, the Random Forest Regressor algorithm emerged as the most effective, displaying remarkable performance. The selection of the Random Forest Regressor algorithm was justified by its demonstrated ability to handle intricate relationships within the data and provide accurate predictions.

IV. RESULTS

A. Dysgraphia screening

The Dysgraphia app was created to help children with learning problems get tested for letter dysgraphia. The application recognises and assesses handwritten Sinhala characters using a neural network architecture and the Support Vector Machine (SVM) method. The neural network's capacity to recognise and interpret complex patterns in handwritten letters was demonstrated by its 95% training accuracy and 85% test accuracy. Additionally, the tool demonstrated a 90% accuracy rate in predicting letter dysgraphia. The application's ability to differentiate between children with and without dysgraphia was demonstrated in a thorough review of 60 students, of whom 21 had the condition accurately detected and 36 did not. For youngsters who are impacted, the application provides an easy-to-use platform for enhancing writing abilities.

B. Dyslexia screening

The mobile application designed for children with Dyslexia effectively addresses phonological processing challenges. It integrates speech-to-text and text-to-speech functionalities, achieving high pronunciation accuracy of over 90%. The interactive exercises provide a scaffolded learning experience, with high user engagement. The prototyping phase yielded an 80% satisfaction rate from potential users, particularly children with Dyslexia. The coding process facilitated iterative development, with performance improvements over three iterations, showcasing a steady enhancement in functionality and user experience.

C. Dyscalculia screening

The mobile application for dyscalculia children was designed with a dyscalculia-friendly interface, gamification elements, and user engagement tracking. Progress reports were provided, and machine learning techniques like Random Forest were used to predict future improvements and enhance transparency and accountability.

D. Short-term memory loss screening

Learn-Joy's e-learning systems are highly accurate, with tenant-specific databases and a centralized master database for scalability and security. Data collection, including surveys, provides valuable insights on study habits and memory levels, with the Random Forest Regressor algorithm predicting child memory progress.

V. DISCUSSION

The screening applications for Dysgraphia, Dyslexia, Dyscalculia, and short-term memory loss have demonstrated significant effectiveness in addressing specific learning challenges. The Dysgraphia app employs machine learning algorithms with high accuracy in recognizing Sinhala letters, aiding early detection and providing personalized feedback. Similarly, the Dyslexia app's speech-to-text and text-to-speech features show promise in improving phonological processing and reading skills, supported by its user-friendly interface and iterative development process. The Dyscalculia app enhances mathematics learning through personalized interventions and gamification, promoting educational achievements and accountability. Additionally, the short-term memory loss platform utilizes predictive models and surveys to create personalized learning environments, showcasing the Random Forest Regressor algorithm's effectiveness in predicting and promoting child memory progress. These screening tools collectively contribute to improving learning experiences and intervention strategies for children with specific learning difficulties.

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