

**Auriva: Adaptive Learning Platform for English Language
Development in Autistic Children in Sri Lanka**

**Motor-Informed Adaptive Handwriting Learning
Module**

R26-IT-006

Project Proposal Report

Liluksha R.S - IT22216700

B.Sc. (Hons) Degree in Information Technology Specialized in
Information Technology

Department of Information Technology

Sri Lanka Institute of Information Technology Sri Lanka

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DECLARATION

I declare that this is my own work, and this proposal does not knowingly incorporate any material previously submitted for a degree or diploma at any other university or higher education institution, nor does it contain any material that has been previously published or written by another person apart from where proper acknowledgment is given in the text.

Name	Student ID	Signature
Liluksha R.S	IT22216700	<i>R S. Liluksha</i>

The above candidate is conducting research for their undergraduate dissertation under my supervision.

Name	Date	Signature
Ms. Manori Gamage	20/03/2026	<i>me.</i>

ABSTRACT

Handwriting is a crucial skill in early education. However, children with Autism Spectrum Disorder often face challenges in this area, mainly because of difficulties with fine motor skills, motor planning, and visuomotor coordination. These difficulties can lead to problems such as poor letter formation, inconsistent spacing, and reduced overall writing ability. Although many educational apps let children practice handwriting through tracing and repeating letters, they often don't address the underlying motor problems or adjust to each child's specific needs. Because of this, children with ASD often miss out on the personalized support they need to improve their handwriting. To address this, our research introduces a Motor-Informed Adaptive Handwriting Learning System. The component uses a tablet and stylus to collect handwriting data like stroke path, speed, and accuracy. It uses a rule-based scoring model to measure performance and groups students by motor ability. With this information, the system creates custom learning paths, starting with letters and moving to words and more complex writing. It updates motor scores and adjusts activities to help children improve accuracy, consistency, and spacing. Teachers receive clear progress reports to track and support students. The system uses React Native for the frontend, Node.js and FastAPI for backend processing, PostgreSQL for data storage, and Chart.js for visualizations. We believe this adaptive, data-driven environment will help children with ASD build motor skills and improve their writing. The system also supports inclusive education and aims to close learning gaps. It can be used in schools, special education centers, and therapy settings as a scalable educational technology solution.

Keywords: Autism Spectrum Disorder, Adaptive Learning, Handwriting Analysis, Motor Skill Assessment, Assistive Educational Technology

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LIST OF ABBREVIATIONS

ASD	Autism Spectrum Disorder
DSR	Design Science Research
XAI	Explainable AI
HCI	Human-Computer Interaction
API	Application Programming Interface
KPI	Key Performance Indicator
UI	User Interface
DB	Database

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1 INTRODUCTION

1.1 Background and Context

Describe the real-world problem

Handwriting is an essential skill in early childhood education and plays an important role in literacy development, academic participation, and cognitive learning. It requires coordination between fine motor control, visual perception, and motor planning. However, many children with Autism Spectrum Disorder (ASD) experience difficulties in these motor coordination processes, which often result in poor letter formation, unstable stroke movements, irregular spacing, and slow writing speed. Research shows that these handwriting difficulties are closely related to deficits in fine motor control and visuomotor coordination, and studies have found that children with ASD demonstrate lower handwriting quality and weaker motor control compared to typically developing children [1], [2]. In the Sri Lankan school context, handwriting is still a key part of early education and classroom activities, making these challenges more noticeable for children with ASD. Although some educational applications provide letter tracing and basic writing practice, they rarely analyze the motor aspects of handwriting. Therefore, there is a need for a system that can evaluate handwriting motor performance and provide adaptive learning support based on each child's motor abilities.

Who is affected and why it is important

ASD affects millions of children worldwide and is associated with developmental challenges such as communication difficulties, social interaction impairments, and motor skill deficits. Many children with ASD experience fine motor skill difficulties, which directly affect handwriting ability and writing performance in school environments [3]. Students with ASD often struggle to control writing tools, maintain consistent letter sizes, and regulate writing speed. Research shows that more than half of school-aged children with autism require occupational therapy to address fine motor problems that influence handwriting tasks [4]. If not addressed early, these difficulties may continue into later stages of life. Since handwriting is an important communication and academic skill, improving handwriting abilities in children with ASD is essential for supporting their academic development and overall well-being.

Statistical evidence (local/global)

ASD is increasingly prevalent worldwide, with approximately 1 in 127 children globally diagnosed with the condition, according to the World Health Organization [5]. A large proportion of these children experience difficulties with fine motor coordination and handwriting, which affects their ability to produce legible letters and maintain proper writing patterns. Research indicates that 50-80% of children with ASD show handwriting impairments, including poor letter formation, inconsistent spacing, and slow writing speed [1]. In the Sri Lankan context, autism prevalence has been reported as approximately 1 in 93 children in regions such as the Colombo district, highlighting the growing need for educational and technological interventions to support children with developmental and learning difficulties [7].

Analysis of Existing Solutions and their limitations

Several technological and educational solutions have been proposed to support learning for children with autism, including adaptive learning systems, digital learning platforms, and assistive writing technologies. For example, adaptive learning systems have been developed to personalize educational content based on students' cognitive profiles and learning behaviors [8]. These systems aim to improve engagement and learning outcomes by dynamically adjusting instructional materials and learning pace.

Similarly, other research has explored the use of technology to support writing development in students with ASD. Software tools such as writing assistance platforms and digital writing environments have shown potential in improving writing performance and student engagement [9]. In addition, multisensory writing applications have been designed to help children with learning disabilities practice letter writing using interactive digital interfaces [10].

Despite these advancements, several limitations remain. First, many existing systems primarily focus on improving engagement or general learning performance rather than addressing the underlying motor difficulties associated with handwriting in children with ASD. Second, most systems do not analyze handwriting movements or motor performance in detail, which limits their ability to provide personalized handwriting interventions. Third, existing tools often lack adaptive mechanisms that adjust handwriting practice based on a child's individual motor abilities and progress over time.

These limitations highlight the need for a more specialized system that can analyze handwriting motor performance and provide adaptive learning support tailored to the unique needs of children with ASD.

Ideas for the proposed solution and its parts

To address the identified limitations, this research proposes a **Motor-Informed Adaptive Handwriting Learning System for Children with ASD**. The proposed system aims to improve handwriting skills by analyzing the motor performance of children during writing tasks and providing adaptive learning support based on their individual abilities.

The system will utilize a tablet-based interface to capture handwriting data, including stroke trajectories, writing speed, and letter formation patterns. These data will be analyzed to extract motor performance features related to handwriting quality and control. Based on these features, a rule-based motor scoring mechanism will evaluate the child's handwriting performance and identify specific motor difficulties that affect writing tasks.

Using the identified motor profile, the system will generate personalized handwriting exercises and adaptive letter learning sequences tailored to the child's needs. Additionally, the system will provide feedback to students and generate progress reports for teachers and therapists, enabling continuous monitoring of handwriting development. By combining motor analysis and adaptive learning strategies, the proposed solution aims to provide a more effective approach for supporting handwriting development in children with ASD.

Relevant SDG alignment

The research is relevant to several of the United Nations Sustainable Development Goals. The first is the **SDG 4: Quality Education**. The Sustainable Development Goals highlight the importance of quality education for all children, including those who require special attention in learning. The Motor-Informed Adaptive Handwriting Learning System can contribute to this goal by offering a quality and adaptive learning environment for children who require special attention in learning how to write. The study is also relevant to **SDG 10: Reduced Inequalities**. The Motor-Informed Adaptive Handwriting Learning System can help reduce inequalities between autistic and non-autistic children by offering a personalized learning environment for children based on their capabilities. The Motor-Informed Adaptive Handwriting Learning System is also relevant to **SDG 3: Good Health and Well-Being**. The system can contribute to this goal by offering a friendly learning environment for children who suffer from Autism Spectrum Disorder during their learning how to write.

Research cluster alignment

The proposed system for an educational assistive technology aims to assist children with ASD to improve their handwriting skills by incorporating the ideas of educational technology and adapting learning methodologies. The system is based on the **Technology Integration & Management (TIM)** research cluster, which covers specific aspects like Human-Computer Interaction (HCI), Usability Analytics (UA), and Requirements Engineering (RE). The system also focuses on user-centered design and usability, considering the needs of children with ASD, teachers, or therapists to design an appropriate learning environment for the target group.

1.2 Literature Review

1.2.1 Discuss existing research approaches

Handwriting Motor Analysis Studies

Several research studies have investigated handwriting difficulties and motor impairments in children with ASD. One of the earliest studies by Fuentes et al.[1] analyzed handwriting samples of children with ASD using the Minnesota Handwriting Assessment. The study found that children with autism demonstrated significantly poorer letter formation quality compared to typically developing children, highlighting the influence of motor control difficulties on handwriting performance.

Johnson et al.[2] conducted a kinematic evaluation of handwriting movements to examine whether children with autism have difficulty controlling handwriting size. Their findings showed that children with ASD often struggle with maintaining consistent letter size and writing patterns due to deficits in motor coordination and movement control.

While these studies provide important insights into handwriting motor impairments, they mainly focus on identifying handwriting problems rather than developing learning systems to address them. Most of the studies analyze handwriting samples for assessment purposes but do not propose adaptive training methods to improve handwriting skills.

Motor Coordination and Fine Motor Skill Research

Research has also explored the relationship between motor coordination and developmental skills in individuals with ASD. Talkar et al.[3] investigated motor coordination patterns in children with ASD using time-series analysis of speech and handwriting signals. The research demonstrated that differences in motor coordination can significantly affect handwriting performance and writing consistency in autistic children.

Similarly, Taverna et al.[4] explored the relationship between fine motor skills and developmental abilities in individuals with autism. Their study showed that fine motor skill impairments are strongly associated with difficulties in communication and daily functional activities, including handwriting tasks.

Research on Handwriting Evaluation Techniques

A review study conducted by Handle et al.[5] examined multiple experimental approaches used to analyze handwriting in individuals with ASD. The review identified key handwriting variables such as

writing speed, stroke quality, and spatial consistency as important indicators of handwriting performance in autistic individuals.

Furthermore, Muthusamy et al.[6] investigated the impact of sensory processing dysfunction on fine motor skills in children with ASD. Their findings revealed a strong correlation between sensory processing deficits and reduced fine motor performance, suggesting that sensory integration plays an important role in handwriting development.

Digital Handwriting Analysis and Sensor-Based Approaches

Recent studies have adopted sensor-based and tablet-based data collection methods to capture detailed handwriting features. Murnani et al. [7] highlight the use of spatiotemporal signals such as stroke trajectory, velocity, and pressure for identifying handwriting difficulties. These datasets are typically collected using digital tablets or stylus devices.[8]

These studies collectively highlight that motor coordination, sensory processing, and fine motor control are major factors influencing handwriting difficulties in children with autism.

1.3 Discuss existing products/services

Several mobile applications have been developed to support learning and skill development for children with ASD. Applications such as Otismo, MITA, AutiSpark, Writing Wizard, and LetterSchool provide interactive learning environments that help children practice alphabet recognition, tracing, cognitive skills, and basic educational activities. These applications use visual guidance, audio feedback, and game-based learning to improve engagement and support early childhood learning.

For example, Writing Wizard and LetterSchool provide guided tracing exercises that help children practice correct letter formation through visual instructions and animations. On the other hand, applications such as Otismo, MITA, and AutiSpark focus on cognitive development, communication skills, and educational games specifically designed for children with autism. Although these applications provide engaging learning environments, most of them focus primarily on alphabet tracing, cognitive learning, or communication skills rather than identifying handwriting-related motor difficulties. In addition, these systems generally use fixed learning sequences and do not adapt handwriting training based on a child's motor abilities or writing performance. As a result, they cannot provide personalized handwriting learning tailored to individual motor challenges, highlighting the need for an adaptive handwriting learning system designed specifically for children with ASD.

Table 1- Comparison of existing products

Feature	Otismo	MITA	AutiSpark	Writing Wizard	LetterSchool	Proposed System
Designed for autism learning	✓	✓	✓	✗	✗	✓
Alphabet tracing practice	✓	✗	✗	✓	✓	✓
Cognitive learning activities	✓	✓	✓	✗	✗	✓
Interactive visual learning	✓	✓	✓	✓	✓	✓

Handwriting motor performance analysis	X	X	X	X	X	✓
Motor difficulty identification	X	X	X	X	X	✓
Adaptive letter learning sequence	X	X	X	X	X	✓
Personalized handwriting training	X	X	X	X	X	✓
Teacher progress reports	✓	X	X	✓	X	✓

1.4 Highlight limitations of existing systems

Although educational technologies and assistive learning systems for children with ASD have improved, several limitations still exist. Many studies mainly analyze handwriting performance or motor difficulties rather than providing practical systems to improve handwriting skills. In addition, most adaptive learning platforms focus on engagement or general learning content instead of handwriting development, while assistive writing tools mainly support writing composition rather than handwriting motor skills. Furthermore, many existing applications lack personalized handwriting training that adapts activities based on a child's motor ability. These limitations highlight the need for a specialized system that can analyze handwriting motor performance and provide adaptive, personalized handwriting learning for children with ASD.

Several mobile applications have been developed to support learning for children with ASD such as Otismo, MITA, and AutiSpark. These applications provide interactive activities to improve cognitive skills, communication, and basic learning through visual guidance and game-based tasks. However, these apps mainly focus on general learning and engagement rather than handwriting skill development. In addition, they do not analyze handwriting movements or motor performance, and they lack adaptive handwriting training based on a child's individual motor abilities.

Table 2 - Highlighting existing systems

Limitations	Otismo	MITA	AutiSpark
Focus of learning activities	Mainly focuses on cognitive and communication skills, not handwriting practice	Focuses on puzzles and cognitive skills rather than handwriting learning	Focuses on early learning and cognitive development, not handwriting training
Handwriting support	Very limited handwriting practice	No handwriting learning activities	Limited handwriting-related activities
Motor skill analysis	Not present	Not present	Not present
Adaptive learning for handwriting	Not present; activities adapt generally but not for handwriting	Not present	Limited; difficulty adapts but not handwriting skills
Letter learning sequence	Predefined activities, not based on motor ability	Not focused on letter learning	Predefined learning path

Progress monitoring for handwriting skills	Limited; mainly tracks activity completion	Limited; tracks puzzle progress only	Limited; focuses on activity progress
Support for ASD motor difficulties	Not specifically designed for handwriting motor challenges	Not designed for handwriting motor training	Designed for autism learning but not handwriting motor analysis
Curriculum alignment	Not aligned with specific national curricula	Not aligned with school curricula	Not aligned with school curricula

1.5 Research Gap

Although several studies and educational applications have explored handwriting learning and motor skill development in children with ASD, important limitations still exist in current research and practical solutions.

First, many existing research studies focus mainly on analyzing handwriting difficulties rather than providing practical learning systems that help children improve their handwriting skills. For example, previous studies have examined handwriting performance using assessment tools and kinematic analysis to identify issues such as poor letter formation, inconsistent stroke patterns, and difficulty controlling handwriting size in children with ASD [1], [2]. While these studies provide valuable insights into handwriting impairments, they primarily concentrate on evaluation and analysis and do not propose interactive learning systems that adapt handwriting training based on the identified motor difficulties.

Second, existing research on motor coordination and handwriting movements has demonstrated that children with ASD often experience deficits in motor planning, stroke control, and visuomotor coordination [3]. However, most of these studies analyze motor patterns using experimental methods and laboratory-based evaluations. As a result, there is limited integration between motor performance analysis and real educational tools that can be used in classrooms to support handwriting learning.

Third, several mobile applications and educational software tools have been developed to support handwriting learning and autism education. Applications such as Writing Wizard, LetterSchool, and ABC Kids provide interactive tracing exercises that help children practice letter formation through visual guidance and repetition. Similarly, autism-focused learning applications such as Otsimo, MITA, and AutiSpark provide interactive activities designed to support cognitive and language development. Although these applications improve engagement and provide basic handwriting practice, they primarily rely on fixed tracing activities and predefined learning sequences.

A key limitation of these applications is that they do not analyze the underlying motor performance of the child during handwriting activities. Most systems treat all learners in a similar way and do not adapt learning tasks based on individual motor abilities. As a result, children with different motor difficulties may receive the same handwriting exercises even though their learning needs are different.

Furthermore, existing applications generally do not provide teacher-oriented monitoring tools or detailed progress reports that help educators track handwriting development over time. Teachers often

rely on manual observation to evaluate student progress, which may not provide objective insights into motor performance or handwriting improvement.

Therefore, a clear research gap exists in the development of a handwriting learning system that integrates motor performance analysis with adaptive handwriting instruction. Current research provides analytical insights into handwriting difficulties, while existing educational applications provide handwriting practice activities. However, there is a lack of systems that combine these two approaches.

The proposed research aims to bridge this gap by introducing a Motor-Informed Adaptive Handwriting Learning System that analyses handwriting stroke trajectories, assesses motor performance using a rule-based scoring model, and creates tailored handwriting learning activities tailored to each child's motor capabilities. This method consolidates motor performance analysis, clustering-based motor ability classification, and adaptive letter sequencing into a unified framework, distinguishing it from current solutions. The suggested approach integrates these components with special education teacher progress monitoring and elucidative feedback, thereby offering a more efficient, data-informed, and tailored handwriting learning environment for children with ASD.

2 OBJECTIVE

2.1 Main Objective

To design and implement a motor-informed adaptive handwriting learning system that identifies handwriting motor difficulties and provides personalized handwriting training for children with ASD using rule-based motor score evaluation and adaptive letter sequencing aligned with the Sri Lankan curriculum.

This objective addresses the limitations of existing handwriting learning applications that provide letter tracing activities but do not analyze motor performance or personalize learning based on handwriting difficulties in children with ASD.

2.2 Specific Objectives

Objective 1

To design a handwriting data capture mechanism that is able to capture the trajectory of the stroke, the order of the stroke, the writing speed, and the spatial accuracy while the child is engaged in handwriting activities via the tablet interface. This objective will allow the system to capture handwriting motor data, which is essential for assessing the child's handwriting performance and the difficulties that may arise from motor coordination problems associated with ASD.

Objective 2

To design a rule-based motor score calculation model that evaluates handwriting performance using motor features such as line control, curve accuracy, and stroke consistency. The motor score model will quantify handwriting quality and identify specific motor difficulties that affect handwriting performance.

Objective 3

To categorize the handwriting motor difficulties based on the calculated motor scores, and categorize the letters based on their motor complexity. This objective is important as it will assist in the identification of motor skill difficulties and enable the system to recommend the appropriate handwriting exercises to the child.

Objective 4

To design an adaptive letter sequencing mechanism that will allow the selection of handwriting exercises based on the motor ability of each child. This mechanism will provide personalized handwriting training by presenting letters and writing activities that match the child's current motor skill level. The adaptive mechanism will assist the child in the personalized handwriting process.

Objective 5

To design a progress monitoring and reporting module that assists special education teachers in analyzing the child's handwriting performance, generating progress reports, and providing explainable insights on detected motor difficulties and recommended handwriting activities.

3 METHODOLOGY

3.1 Research approach

This research adopts a Design Science Research (DSR) approach, which focuses on designing, implementing, and evaluating a technological artifact to address a real-world problem. The objective of this study is to develop a Motor-Informed Adaptive Handwriting Learning System to support handwriting skill development for children with ASD.

The research follows a system development and evaluation process consisting of four stages:

- Problem identification - which examines handwriting challenges in children with ASD.
- Design and development - where adaptive learning mechanisms and the suggested handwriting learning system are implemented into practice.
- Demonstration - in which the system generates adaptive learning tasks and evaluates handwriting motor performance.
- Evaluation - which uses both quantitative and qualitative metrics to determine the effectiveness of the system.

The system analyses handwriting stroke data collected from tablet-based writing tasks and evaluates motor difficulty based on motor scoring. Based on that score, the system generates an adaptive letter-writing sequence tailored to each child's motor abilities.

3.2 Technical methods and algorithms

The proposed component employs a tablet and stylus to gather handwriting data throughout preliminary motor assessment exercises, encompassing the drawing of lines, curves, and shapes. It documents stroke paths as X-Y coordinates across a temporal scale, subsequently extracting crucial spatiotemporal characteristics. These include stroke smoothness, writing speed, pause frequency, spatial accuracy, and stroke consistency. These extracted features enable the analysis of motor control and aid in the identification of handwriting challenges.

All extracted features are normalized to a common scale to ensure consistency. A rule-based motor scoring model calculates a Motor Score using weighted features, including accuracy, smoothness, and consistency. This method provides interpretability and transparency, which are advantageous in educational settings.

A clustering(K-Means) algorithm categorizes children into different groups based on their motor ability, using the features or scores that have been extracted. This process identifies patterns in motor skills and facilitates more personalized interventions.

Based on both the rule-based scores and clustering results, the system identifies specific motor difficulties (e.g: poor curve control, inconsistent spacing) and groups handwriting tasks into stroke-based categories such as straight, curved, and zigzag patterns. Category-level analysis helps to understand a child's motor skills, identifying both strengths and weaknesses.

The component also classifies handwriting tasks into stroke types, including straight, curved, and zigzag patterns. Analysis of these categories enables assessment of each child's motor strengths and weaknesses. An adaptive letter sequencing algorithm selects handwriting tasks according to each child's motor ability profile. Letters are introduced in order of motor complexity, starting with simpler stroke patterns and progressing to more complex ones. This strategy provides a more personalized and efficient method compared to a fixed alphabetical sequence.

The system delivers explainable feedback and progress reports for special education teachers, including motor performance summaries, identified difficulties, cluster-based motor levels, and recommended learning activities. It integrates handwriting analysis, rule-based scoring, clustering, motor classification, and adaptive learning to provide a personalized and transparent handwriting solution for children with ASD.

3.3 Tools and platforms with justification

Frontend Technology: React Native

React Native is used as the frontend framework because it supports cross-platform mobile development, allowing the system to run on both Android and iOS tablets used in educational settings. It efficiently handles touch and stylus input, which is important for capturing handwriting on tablets. React Native also enables code reuse across platforms, reducing development time. Native Android (Java/Kotlin) and Flutter were considered, but React Native was chosen due to its larger ecosystem and easier integration with JavaScript-based backend services.

Backend Technology: Node.js and FastAPI

The backend uses Node.js and FastAPI. Node.js has been chosen for its event-driven programming paradigm, which efficiently processes multiple requests from teachers and students. FastAPI has been chosen for processing handwriting data and calculating rule-based motor scores due to its high-performance capabilities for data-intensive operations. Django framework has not been used as it would only add complexity to the APIs. Spring Boot framework has also not been used as it would demand more resources to set up.

Database Technology: PostgreSQL

PostgreSQL was chosen due to its ability to store structured data, such as student data, handwriting data, motor data, and progress reports. It also excels in data integrity, making it perfect for dealing with related data, like students, teachers, and activities. MongoDB was not chosen because the system uses structured data, not unstructured data. Firebase was not chosen because it does not offer the kind of query functionality that is required to generate progress reports.

Other Tools and Technologies:

Chart.js would be used to create a graphical representation of the handwriting performance analytics and progress reports, and this would enable the teachers to better understand the progress of the students and the point at which the motor difficulties occur. While D3.js was also considered, Chart.js proved to be more effective for the project as it works better with web and mobile applications.

Explainable AI (XAI) techniques are used in the reporting module to give information that can be understood about how the child is learning to write letters and words. The system explains how that initial motor test results affect the choices about how to arrange the letters. For instance, if the child's initial assessment shows that they are better at controlling straight-line strokes than curved strokes, the system will start by teaching them letters that use mostly straight strokes and then slowly move on to letters that require more complex motor skills. Special education teachers can better understand why the system suggests the adaptive learning sequence it does with this description.

3.4 Data collection and ethical considerations

Data Collection

The system gathers handwriting data from children with ASD as they use a tablet for writing activities. These sessions take place in a classroom setting and are supervised by special education teachers.

The system records different types of handwriting performance data, such as:

- Stroke trajectory coordinates (X and Y points) generated during writing tasks
- Stroke order and direction during handwriting movements
- Writing speed and timing details
- Accuracy of letter formation
- Motor performance indicators like line stability, curve control, and spatial consistency

These data points help assess handwriting motor skills and are used to calculate motor scores for the adaptive learning system. The data comes from children in special education classrooms during handwriting sessions. In each session, students use a stylus and tablet to practice shapes, letters, and simple words. The system stores this data securely and uses it to assess handwriting and create progress reports for teachers. It only collects information about handwriting performance, not sensitive medical details.

3.5 Data Sources and Ethical Considerations

The data utilized in the system will be obtained from the following sources:

- Handwriting interaction data generated directly from children through the use of the tablet application.
- Student profile information provided by teachers, including student identification numbers and learning levels.
- Activity performance records collected during handwriting practice sessions.

The dataset for handwriting performance evaluation is anticipated to include multiple writing samples per student, collected over several learning sessions. This repeated data collection enables the system to monitor changes in handwriting performance and assess improvements over time.

As this research involves children with ASD, strict ethical guidelines will be followed during data collection and experimentation. Informed consent will be obtained from parents or legal guardians, and participation will be voluntary. Parents will be informed about the purpose of the research objectives and the types of data collected. All data will be anonymized using unique identification codes to protect student identities. Student performance data will be securely stored and accessible only to authorized personnel, thereby ensuring safe and appropriate learning activities for children with ASD.

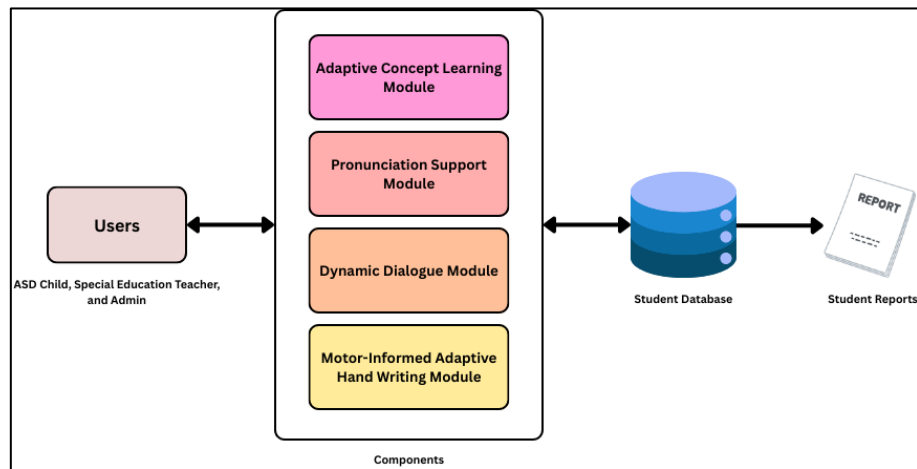
Validation strategy and performance metrics

The effectiveness of the handwriting learning system will be measured by determining the extent to which it enables children with ASD to improve their writing skills. As children participate in writing activities, the system will collect stroke information based on accuracy, stability, and speed. These will be used to compute motor scores. The key performance indicators will include the accuracy with which children write letters, improvements in motor scores, the time it takes to finish writing, and the consistency with which they write letters. Additionally, usability input will be obtained from special education teachers to evaluate how easily the system can be used and determine its effectiveness.

4 HIGH-LEVEL SYSTEM ARCHITECTURE

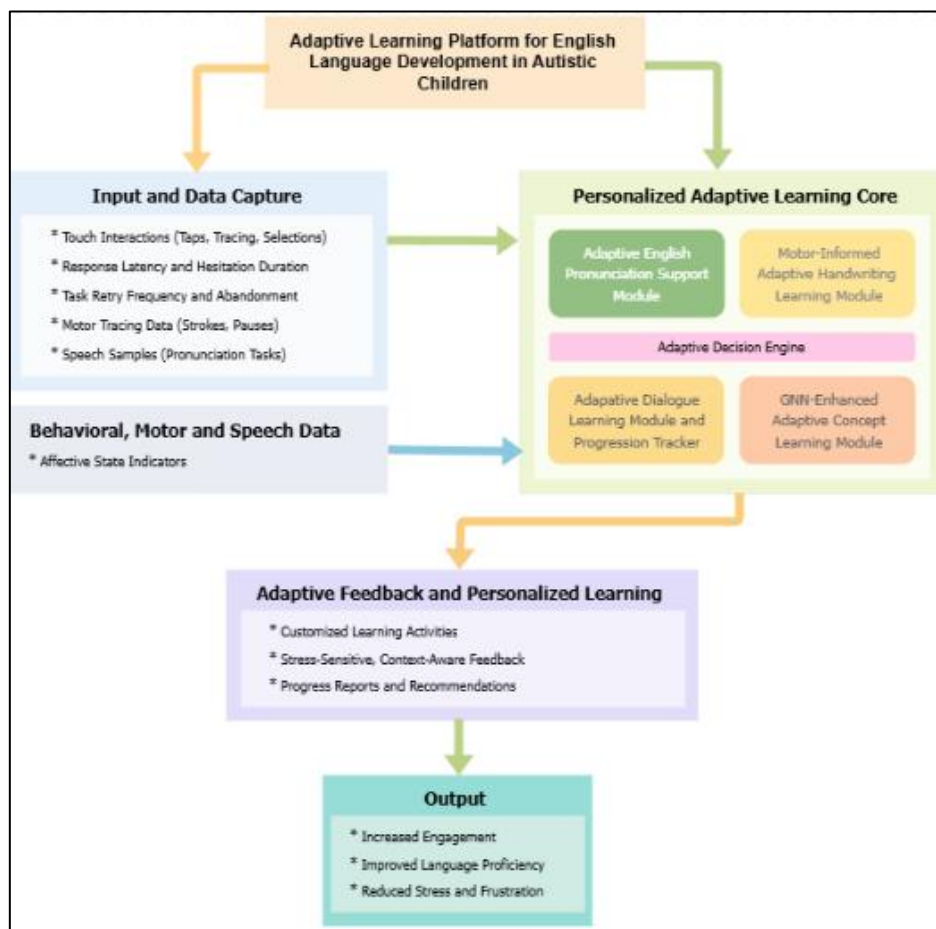
4.1 Overview of proposed solution and its components

Figure 4-1- Overview of proposed system



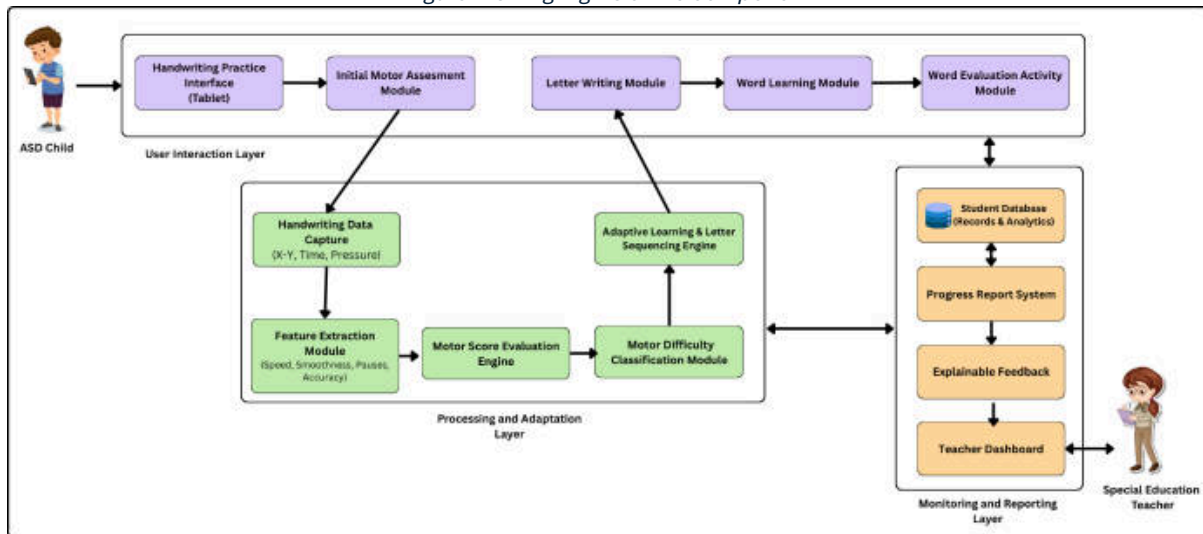
4.2 System diagram of components

Figure 4-2- system Diagram of components



4.3 Highlight the individual component and its parts

Figure 4-3- Highlights of the component



4.4 Data flow explanation

When the child writes on a tablet with a stylus, the proposed system starts by gathering real-time spatiotemporal handwriting data, such as stroke trajectory (X–Y coordinates), stroke order, writing speed, and spatial accuracy. This information is sent to the back end, where feature extraction is done to find important motor attributes including precision, smoothness, speed consistency, and how often the motor stops. These elements are standardised and utilised to calculate a Motor Score using a rule-based weighted scoring model, guaranteeing a straightforward and comprehensible assessment.

At the same time, a clustering algorithm sorts children into categories based on their motor skills (like low, medium, or high), which makes it easier to personalise. The approach uses the rule-based scores and clustering results to figure out the child's motor skill profile and any specific motor problems they may have.

The learning process is organised: initially, you learn lowercase letters, then uppercase letters, and lastly writing at the word level. There are three attempts for each letter: Attempt 01 (animated stroke demonstration to enhance motor memory), Attempt 02 (guided practice with arrows to strengthen stroke sequence and control), and Attempt 03 (independent writing to test full motor recall). The system checks how well you did on each attempt by looking at things like deviation, pause count, stroke correctness, and completion time. It then decides whether to move on or try again. The Adaptive Learning and Letter Sequencing Engine uses this information to choose handwriting assignments that are right for each person's motor skills, starting with easy stroke patterns and moving on to more difficult ones.

After learning how to write letters, the system moves on to writing words (beginning with easy ones), evaluating and uses the same motor analysis, rule-based grading, and clustering methods to check performance. The algorithm keeps updating motor scores, improving clustering, and changing the learning content as needed throughout all stages. Finally, all performance data is saved so that teachers can make progress reports for each kid that contain motor scores, highlighted problems, improvement trends, and feedback that can be understood. This lets teachers keep an eye on and help children with ASD in a way that works for them.

5 USER REQUIREMENTS

5.1 Stakeholder identification

The system's stakeholders include end users, proxy users, decision makers, and regulatory or policy bodies. Each group interacts with the system differently, which affects how it is executed.

Users

End User

The primary end users of the system are children with ASD who directly interact with the handwriting learning app. They work on a tablet to trace letters, draw shapes, and write simple words. The system records their handwriting strokes and analyzes features such as stroke path, line steadiness, and writing accuracy. Using this information, it offers handwriting activities that fit each child's motor skills. The goal is to help children improve their handwriting skills through structured learning activities that align with their motor coordination and learning pace, thereby supporting their participation in classroom learning and academic development.

Proxy User

The proxy users of the system are special education teachers who use the system to support and guide children during handwriting lessons. Because children with ASD often need supervision when using educational technology, teachers serve as a link between the system and the child. They create and manage student profiles, assign handwriting activities, and monitor how students perform during writing sessions. Teachers also review motor analysis results and progress reports from the system. These reports help them see how students' handwriting skills are improving and adjust their teaching methods as needed. Teachers can also use the system to prepare regular progress reports to share with parents and therapists, helping everyone support the child's learning and development.

Stakeholders

System Administrator

In the proposed Motor-Informed Adaptive Handwriting Learning System, the school principal acts as the system administrator and manages the system within the school. The principal does not use the learning content directly, but is responsible for creating and managing teacher accounts, assigning students to special education teachers, and making sure the system follows school policies. The administrator also ensures the system meets educational guidelines and data privacy rules set by education authorities.

Decision-Makers

Decision makers are people who influence a child's learning and development. This group includes parents or guardians, therapists, and school administrators. Parents and therapists use system reports and teacher feedback to review a child's progress and decide if more learning support or therapy is needed. The school principal oversees how the system is used and makes sure it helps with teaching and monitoring in the special education program.

Regulatory and Policy Bodies

Regulatory and policy bodies make sure educational technologies meet national education standards and support inclusive education. In Sri Lanka, these groups include education authorities, curriculum developers, and special education policymakers. They check that the proposed system matches the Sri Lankan primary education curriculum and helps include children with special needs.

5.2 Functional requirements

• Functional Requirements for End User (Child with ASD)

01. The system shall allow children to practice handwriting using a tablet-based interactive interface.
02. The system shall provide guided tracing activities for alphabet letters aligned with the up to Grade 3 Sri Lankan curriculum.
03. The system shall capture handwriting stroke data such as stroke trajectory, direction, and writing speed during writing exercises.
04. The system shall evaluate the child's handwriting performance based on motor features such as line accuracy, curve control, and stroke consistency.
05. The system shall categorize alphabet letters based on stroke patterns such as straight strokes, curved strokes, and mixed strokes.
06. The system shall provide visual and audio feedback to guide the child during handwriting practice.
08. The system shall allow the child to attempt writing each letter multiple times before evaluating mastery.
09. The system shall assign an initial letter learning sequence based on the child's motor assessment results.
10. The system shall present word writing activities after the child demonstrates sufficient letter writing proficiency.
11. The system shall record the child's writing performance data for further analysis and progress tracking.
12. The system shall evaluate the child's handwriting performance through activity-based assessments using previously learned letters and words.
13. The system shall monitor session duration and automatically end the learning session when a predefined time limit or fatigue threshold is reached.

• Functional Requirements for Special Education Teacher

14. The system shall allow teachers to create and manage student profiles.
15. The system shall allow teachers to assign handwriting learning sessions to students.
16. The system shall allow teachers to monitor real-time handwriting performance during learning activities.
17. The system shall generate individual student progress reports based on handwriting performance data.
18. The system shall allow teachers to review historical performance data and learning progress over time.
19. The system shall support generation of periodic progress reports (e.g., every 6 months) for evaluation purposes.
20. The system shall allow teachers to export or share progress reports with parents and therapists.

21. The system shall provide performance summaries highlighting motor difficulties and improvement trends.

5.3 Non-functional requirements

- **Usability Requirements**

The system interface shall be simple, visually clear, and suitable for children with ASD. It shall use calm colours, clear icons, and minimal visual clutter to reduce sensory overload. The system shall provide visual cues, animations, and audio guidance to help children understand handwriting tasks. It shall also support touch and stylus interaction on tablet devices.

- **Performance Requirements**

The system shall provide real-time handwriting feedback during writing activities. It shall process handwriting input and generate evaluation results within a few seconds. The system shall also support multiple student profiles without performance degradation.

- **Security Requirements**

The system shall ensure secure storage of student data and performance records. Access to student progress reports shall be restricted to authorized users such as special education teachers and administrators. The system shall also protect sensitive student information according to educational data privacy standards.

- **Accessibility Requirements**

The system shall support multiple forms of learning assistance such as visual instructions, audio guidance, and replay options to accommodate different learning needs of children with ASD. All instructions shall be easy to understand and consistently presented.

- **Reliability Requirements**

The system shall ensure stable operation during learning sessions without unexpected interruptions. It shall maintain data integrity when storing handwriting performance data and progress reports.

- **Compatibility Requirements**

The system shall be compatible with tablet devices used in educational environments. It shall also support integration with reporting tools used by schools for student progress evaluation.

- **Scalability Requirements**

The system shall support multiple teacher–student interactions simultaneously without affecting system performance or response time.

- **Maintainability Requirements**

The system shall allow updates to letter categories, learning activities, and curriculum content without requiring major changes to the system architecture.

6 COMMERCIALIZATION PLAN

6.1 Target market and customer persona

The primary users of the proposed system are special education schools, inclusive education units, and therapy centers supporting children with ASD. In Sri Lanka, it is suitable for government schools with special education units, private special education centers, and autism therapy clinics that follow the local curriculum.

The primary customer persona is school administrators and principals responsible for adopting educational technologies. Special education teachers serve as proxy users, utilizing the system in classrooms for handwriting training and student progress monitoring. Parents are not direct users, as the system is intended for teacher use during school sessions.

6.2 Value proposition

This brings something new to the table by providing a combination of motor performance knowledge, adaptive handwriting practice, and tracking in one place. Instead of providing simple letter tracing games like most conventional apps, it attempts to go deeper into the actual motor problems that affect handwriting. It attempts to do this by analyzing stroke paths and motor scores to come up with personalized handwriting practice plans for each child. It also provides teachers with valuable progress reports to track how well each child in the class is performing. All this contributes to better handwriting training for kids with ASD.

6.3 Revenue model

The system will operate on a Software as a Service subscription model, with an annual license fee charged per institution rather than per student. This structure will make budgeting predictable for schools operating under fixed government allocations.

Three subscription tiers are proposed, as outlined in the table below:

Figure 6-1- Subscription tiers

Tier	Student Capacity	Target Segment
Tier 1	Up to 30 students	Small special education units
Tier 2	0 - 120 students	Mid-scale schools and larger special education units
Tier 3	120+ students or multi-campus institutions	Large institutions with expanded administrative needs

In addition to the paid tiers, a freemium pilot license could be made available, to allow schools to evaluate the platform before committing to a subscription, which aligns with how procurement decisions are typically made in Sri Lankan public education, where trial evidence is often required prior to budget approval.

6.4 Cost estimation

The primary cost components of the system are software development for the mobile application and backend services, cloud infrastructure for hosting databases and application servers, ongoing system maintenance and updates to improve functionality and security, and teacher training and onboarding for participating institutions. Because of its digital platform design, operational costs remain relatively low after the initial development phase, supporting scalable deployment across multiple educational institutions.

6.5 Pricing strategy

A tiered pricing strategy can be implemented to accommodate different types of educational institutions. Possible pricing models include:

- Basic package - Access to handwriting learning modules and student management features.
- Standard package - Includes adaptive learning mechanisms and teacher dashboards.
- Premium package - Includes advanced analytics, progress reporting, and institutional performance monitoring.

This approach allows smaller institutions to adopt the system at lower costs while offering additional features for larger organizations.

6.6 Competitive advantage

The proposed system offers several competitive advantages compared to existing handwriting learning applications. First, most existing applications focus primarily on alphabet tracing and handwriting practice, whereas the proposed system analyzes motor performance and stroke trajectory data to identify handwriting difficulties. Second, the system introduces adaptive letter sequencing based on motor abilities, enabling personalized learning pathways for each child. Third, the system provides teacher-monitoring tools and progress reports that support educational assessment and therapy planning.

These features create a comprehensive educational solution that integrates learning, analysis, and reporting, making it more effective than traditional handwriting learning tools.

6.7 Intellectual property considerations

The proposed system includes several innovative components that may qualify for intellectual property protection. These include the rule-based motor scoring mechanism, the adaptive letter sequencing algorithm, and the integration of motor trajectory analysis with handwriting learning activities. Intellectual property protection can be pursued through:

- Software copyright protection for the developed system.
- Patent applications for unique algorithmic methods used in motor score evaluation and adaptive learning.
- Trademarks for the system name and branding.

Protecting these intellectual assets ensures that the developed technology can be commercialized while safeguarding the originality of the research contribution.

7 BUDGET AND JUSTIFICATION

The proposed budget includes the hardware, software tools, cloud services, and operational resources required to design, develop, test, and evaluate the Motor-Informed Adaptive Handwriting Learning System during the research project period.

Figure 7-1- Budget Estimation

Description	Estimated Cost (LKR)
Tablet device for handwriting data collection and testing	25,000
Stylus pen for handwriting input	3,000
Cloud VPS server hosting (backend API and database – 6 months)	10,000
Mobile app development tools / plugins	5,000
Database hosting and storage services	5,000
Transport cost for visiting special education schools for testing	8,000
Documentation, printing, and report preparation	1,000
Miscellaneous development expenses	5,000
Total Estimated Budget	62,000

Hardware Costs

A tablet and a stylus pen are required to capture children's handwriting input during learning sessions. These devices allow the system to record stroke trajectory data such as writing direction, speed, and shape accuracy.

Software Licenses

Some development tools, plugins, and UI components may require small license costs to support handwriting input processing and mobile application development.

Cloud Services

Cloud hosting is required to store student handwriting data, motor scores, and progress reports. It also supports the backend system that processes handwriting data and generates learning activities.

Human Effort Cost

The development of the system requires time for system design, algorithm implementation, testing, and evaluation. This cost represents the development effort involved in building the research prototype.

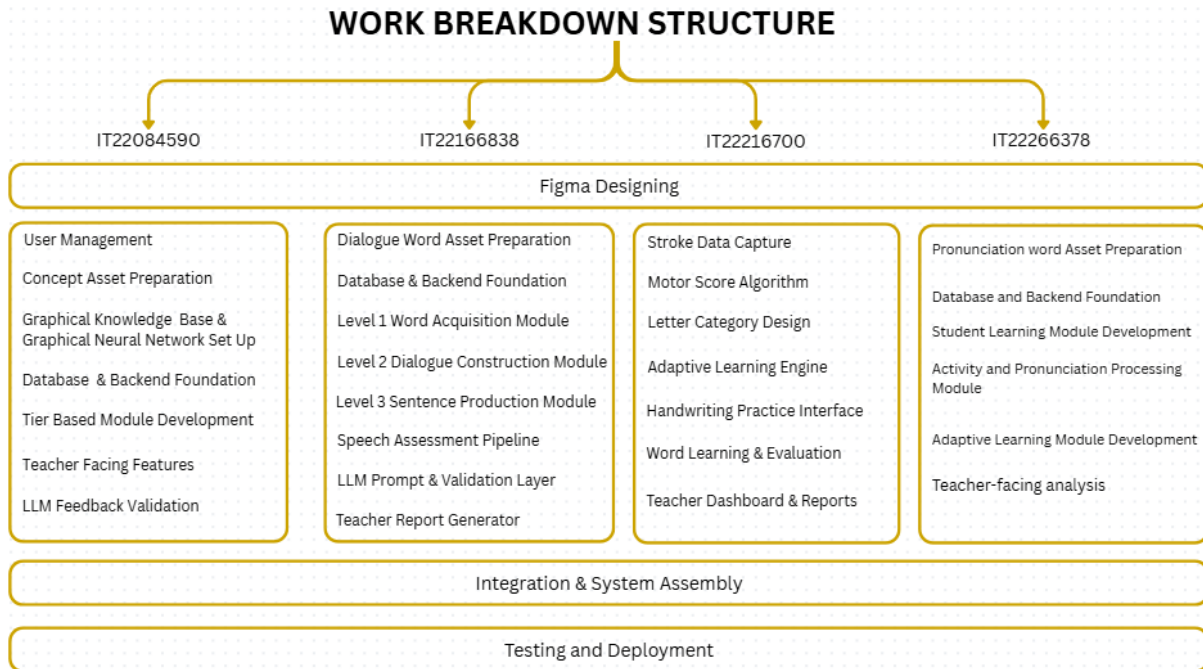
Operational and Testing Costs

Internet access and transportation costs are required for system development, testing, and visiting special education schools for requirement gathering and evaluation.

8 WORK BREAKDOWN STRUCTURE (WBS)

- Task breakdown per member

Figure 8-1- Task breakdown per member



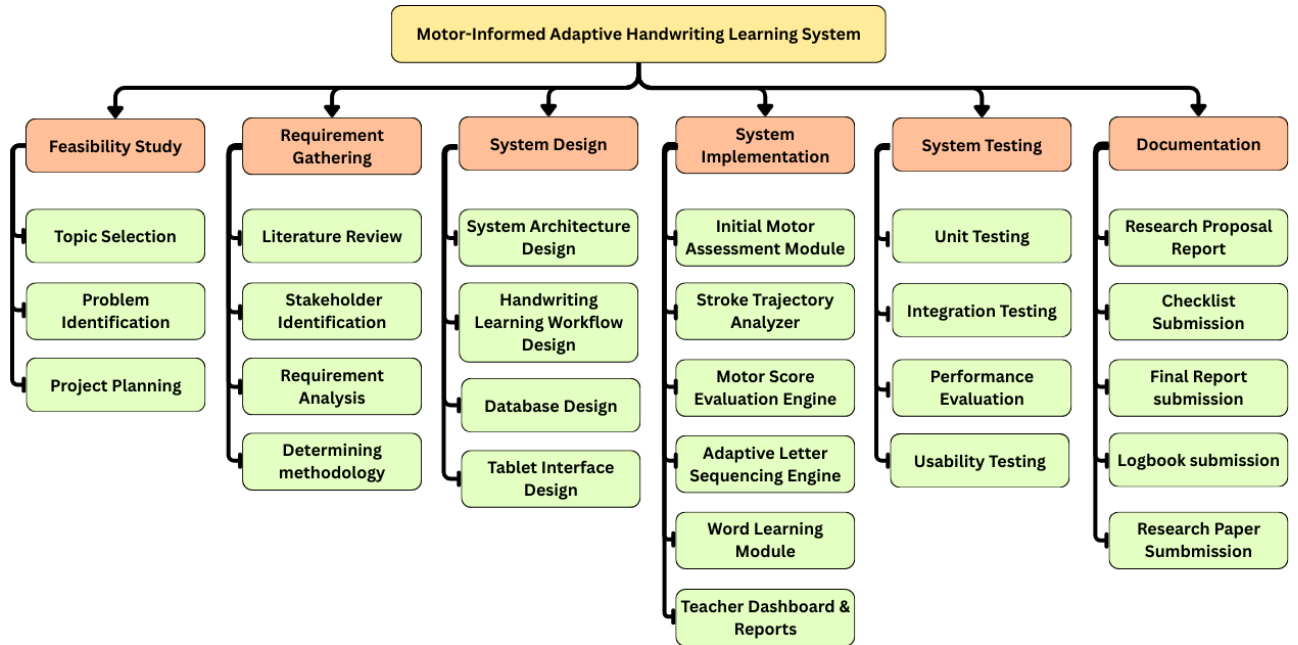
- Timeline alignment

Table 3 - Activities with timelines

Phase	Activities	Duration
Phase 1	Literature review, problem identification, and proposal preparation	Month 1 - Month 3
Phase 2	System design and architecture planning	Month 3
Phase 3	Dataset preparation, requirement validation with teachers, and interface design	Month 4
Phase 4	Development of individual system components	Month 5 - Month 7
Phase 5	Integration of all four components into the unified learning platform	Month 8
Phase 6	System testing, usability evaluation, and performance assessment	Month 9
Phase 7	System improvement, bug fixing, and optimization	Month 10
Phase 8	Final report writing, documentation, and project presentation	Month 10 – Month 11

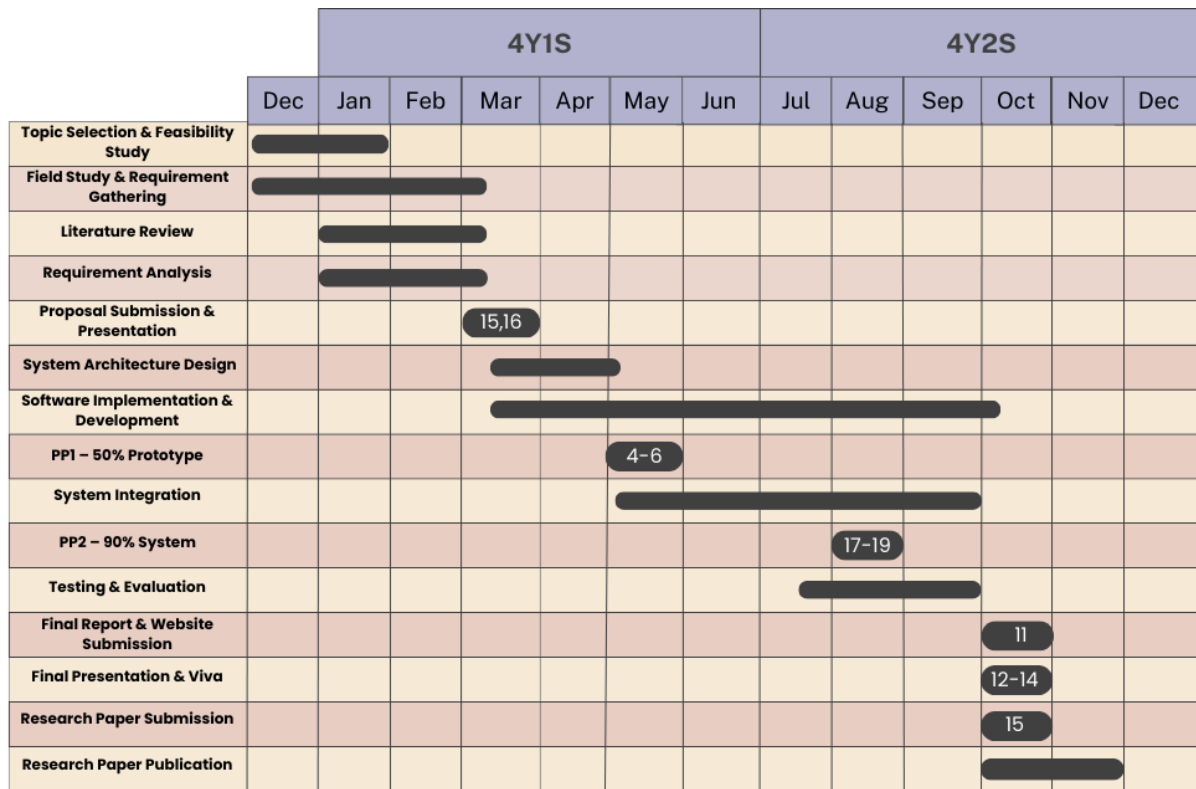
- Individual Component WBS

Figure 8-2 - Work Breakdown Structure



9 GANTT CHART

Figure 9-1- Gantt chart



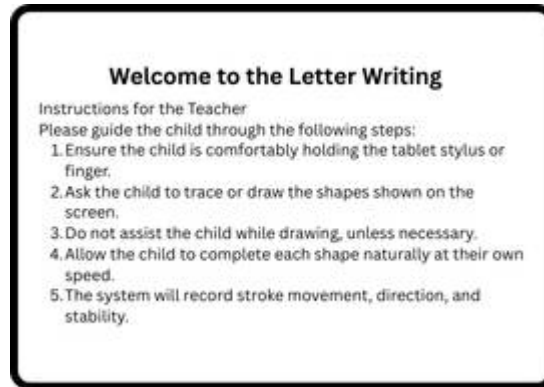
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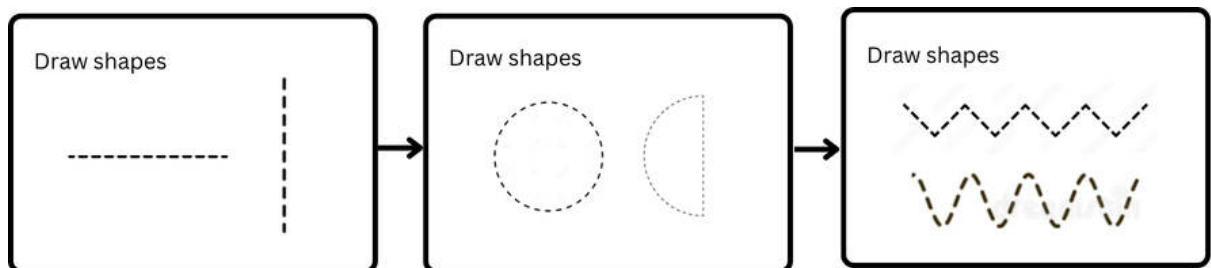
11 APPENDICES

- Preliminary UI mockups

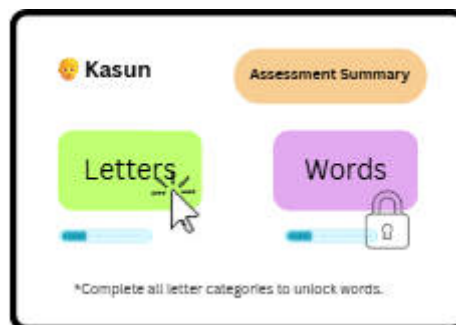
Appendices 1-Instruction for teachers about initial assessment



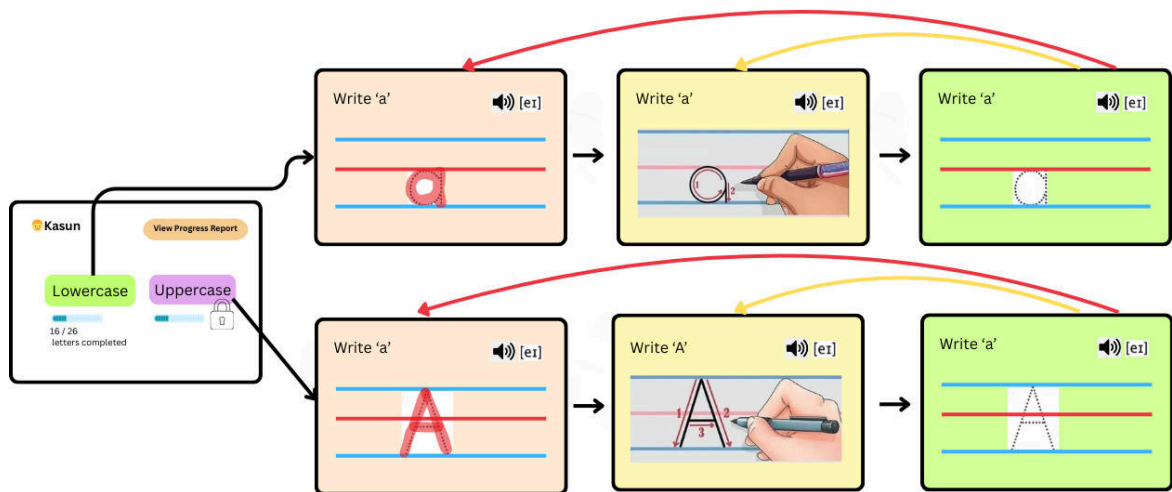
Appendices 2 - Initial assessments



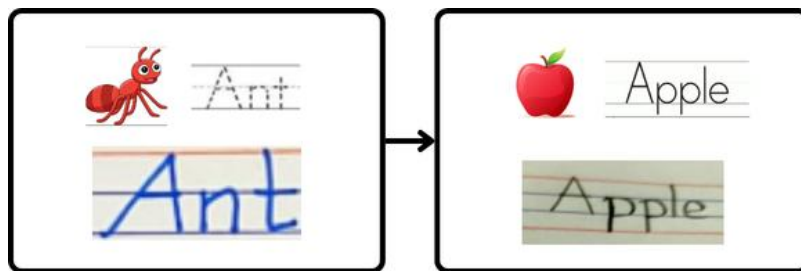
Appendices 3 - Letter and Word Learning Interface



Appendices 4 - Letter writing activities



Appendices 5 - Word learning activities



Appendices 6 - Word evaluation assessments

