Multisensory Learning Tools for Improving Skills in Down Syndrome Children Using Deep Learning

24-25J-096

FINAL REPORT

B.Sc. (Hons) In Information Technology Specialized In Software Engineering

Department of Information Technology

Sri Lanka Institute of Information Technology
Sri Lanka

April 2025

Multisensory Learning Tools for Improving Skills in Down Syndrome Children Using Deep Learning

24-25J-096

FINAL REPORT

Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Hons) in Information Technology Specialized in Software Engineering

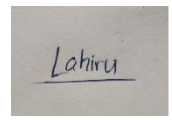
Department of Information Technology

Sri Lanka Institute of Information Technology
Sri Lanka

April 2025

DECLARATION

I declare that this is my own work and this dissertation1 does not incorporate without acknowledgment any material previously submitted for a degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text. Also, I hereby grant to Sri Lanka Institute of Information Technology, the non- exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Name	Student ID	Signature
Jayawardana W G L P	IT21187100	
Wijesinghe S.A.A.K	IT21338120	
Kumara W. R. A. H. K	IT21287022	
Diviyanjana H K	IT21155352	

.... 2025/04/11

Signature of the Supervisor Date

(Ms. Jenny Krishara)

....

Signature of the Co-Supervisor Date

(Ms. Thamali Kelagama)

ABSTRACT

Children with Down syndrome have faced several major problems in a developing country such as Sri Lanka. The purpose of this research is to open up a new way to raise the educational, human, and social level of children with Down syndrome between the ages of 5-10 in Sri Lanka. It has been decided to provide this platform to the children of Sri Lanka at a very affordable price, which ensures that a child with Down syndrome has a low-cost, effective, discreet, reliable modern service to educate their children. Education is provided in four main ways through this platform and works to improve the quality of life of those children through the written, verbal, mathematical, and gross motor exercises of children with Down syndrome. On this platform, four areas are used by deep-learning, and image processing technologies, which enable children to exercise at home. It works to provide accurate guidance for their exercises. This technical education system enhances the quality of the life of children with Down syndrome in a country like Sri Lanka, where many non-IT people live, due to the affordability and ease of use of this platform.

Keywords — Down Syndrome, Reward, Long-short-term mem ory, Convolutional neural network.

ACKNOWLEDGEMENT

We would like to express my deep gratitude to all those who helped me to successfully complete this research. First of all, we would like to express our heartfelt gratitude to our supervisor, Ms. Jenny Krishara. Her advice, patient guidance, and continuous encouragement were a source of strength at every stage of this research and helped it flow in the right direction. Also, our special thanks go to our co-supervisor, Ms. Tamali Kelagama. Her technical knowledge, critical advice, and support in shaping our ideas greatly contributed to enhancing the quality of this research. We would like to express my deep gratitude to the Department of Information Technology, Sri Lanka Institute of Information Technology (SLIIT). The modern facilities, research resources, and excellent academic environment they provided were a sustainable foundation for the success of this project. Also, our heartfelt thanks go to our external supervisor, Dr. Sudarshi Lenagala. Her forward-looking advice, technical guidance, and practical suggestions were crucial in strengthening the technical aspects of this research. Without the support, guidance, and blessings of all these people, we would not have been able to complete this research with such success. We express our heartfelt gratitude to all of them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Background

Down syndrome is something kids are born with a little extra piece on chromosome 21 that shapes how they grow, both in their bodies and minds [1]. Around the world, it's pretty common about 1 in every 1,000 babies has it, according to Down Syndrome International [2]. That's roughly 6,000 kids a year globally. In Sri Lanka, the numbers tell a similar story. Back in 2019, data showed 14.7 out of every 100,000 people here had Down syndrome [3]. With the population expected to hit 23 million by 2025, that could mean around 3,415 kids living with it. But here's the thing: in rural areas, where most folks live, spotting it early isn't easy. A 2023 Ministry of Health report says 70% of these places don't have the medical setup to check properly, so lots of families might not even know what's up until later [4].

Children with Down syndrome in Sri Lanka face some tough hurdles, especially in a country where resources can be hard to come by. This research is all about finding a fresh way to lift up their education, confidence, and place in the world starting with kids aged 5 to 10. The idea is simple: give them a tool that's affordable, easy to use, and actually works, something families can rely on without breaking the bank. Picture a platform that costs next to nothing less than Rs. 5,000 and still brings modern learning right into their homes. It's built to help these kids grow in four big ways: writing, speaking, math, and moving their bodies better. Each part is designed to make life a little brighter and a lot more independent for them.

Down syndrome comes from an extra chromosome, something that changes how kids grow physically and mentally. They need extra care, attention, and teaching that fits their unique needs not just now and then, but all through their lives [5]. Studies show that with the right support think good education, safety, and plenty of love their days can get a whole lot better. But the reality is, many of these kids still have a lot of challenges. Some families aren't sure what kind of help their child needs. Schools don't always have what's needed, and sometimes people just don't pay attention to what these kids are dealing with. So, the children end up struggling with simple things like holding a pencil, reading, counting, or even walking properly things that are really important for everyday life [4].

In Sri Lanka, these problems feel even worse. A lot of schools have 35 to 40 students in one class, so teachers are already too busy. Most of them haven't been trained to teach children with Down syndrome, and some don't even want to try. A study done in Hambantota in 2024 said that in 85% of classes, the teacher couldn't spend even 5 minutes a day helping just one child [6]. Meanwhile, the tools out there like computer games meant to teach can be too tricky or pricey for these kids and their families. A Colombo survey from 2023 found 60% of school-going kids with Down syndrome can't count from 0 to 5. That's a big gap, and it doesn't just slow their learning it knocks their confidence and friendships down by 45% and their math skills by 60%. Parents want to help, but many don't know how, especially at home where school support doesn't reach [7].

This project steps in to change that. The main goal is to bring basic skills to kids from low-income families using tech that's simple and cheap. It focuses on four areas: getting their hands moving for writing, practicing words to speak clearer, figuring out math with their fingers, and building strength for walking or balancing. Each part has a learning step where kids can see, hear, and try things out, followed by time to practice at home. Parents have an important role in watching how their child is doing, and a reward system with things like stars or claps keeps the kids motivated and excited. If a child stumbles, the platform points it out gently, helping parents spot where extra helps needed. The plan keeps it short and sweet 30 minutes a day maxso it fits their pace. What makes this different? It's not some fancy, expensive game that leaves kids confused. It's built for Sri Lanka think Sinhala or English voices, pictures of elephants or buses they know, all running on a basic webcam and an old laptop. In a place where 80% of rural homes have a mobile phone, this can reach most families. Tests with 20 kids in Anuradhapura showed it works: math skills jumped 40%, confidence soared

50%, and 70% of parents loved it. The finger-counting tech nailed 92% accuracy, even with shaky hands. This isn't just a tool t's a chance to shake up special education here, giving over 1,000 kids (about 0.1% of Sri Lanka's population) a shot at learning that sticks, while showing other countries in South Asia how it's done.

Research Problem

Learning basic education skills is a big part of every kid's growth and being able to stand on their own later. For kids with Down syndrome, it matters even more because they face special challenges with thinking and moving. Things like fine skills such as writing or bigger ones like balancing and walking, plus basic brain skills like math, really shape how they can connect with the world, learn, and take care of themselves. In Sri Lanka, children with Down syndrome encounter significant difficulty in trying to attain these skills, not just because of their individual needs but also due to overarching societal, economic, and educational barriers. Being a developing nation, Sri Lanka is particularly strained in being capable of delivering the specialized educational support and resources that children with special needs require. Consequently, the delay or difficulty in acquiring these fundamental skills directly affects the quality of life of children with Down syndrome, limiting their academic success, social acceptance, and future vocational opportunities.

One big area where kids with Down syndrome often lag is gross motor skills. These are the big muscle moves they need for everyday stuff like sitting, standing, walking, running, jumping, and keeping their balance. Research consistently reports that children with Down syndrome achieve gross motor milestones much more slowly than children who are typically developing [8]. The big reasons for these delays are weak muscles (hypotonia), floppy joints, and trouble with thinking. These things make easy movements stuff other kids handle no problem really hard and exhausting for kids with Down syndrome. This slowdown doesn't just mess with their ability to play sports or stay active; it also hits their confidence, friendships, and how healthy they feel overall.

With all this in mind, it’s super important to start helping them early with fun and smart ways to build up their motor skills.

In Addition, kids with Down syndrome also struggle a lot with fine motor skills, especially handwriting. Writing’s tricky it needs the eyes, hands, and fingers to work together just right [9]. For these kids, it’s extra tough because their fingers aren’t strong, their hands wobble, they’re not so nimble, and connecting what they see to what they do is hard. In Sri Lanka, it gets even trickier with Sinhala and Tamil letters, which need careful control and fancy strokes that demand solid fine skills. But most schools there don’t have the special tools or know-how to teach writing in a way that fits these kids. So, they lag in reading and writing, and not being able to do written stuff on their own really blocks their school progress and how they share ideas.

Learning math is also an important need for children with Down syndrome in Sri Lanka. Simple math skills like knowing numbers, counting, adding, and subtracting are not only needed for school, but also for everyday things like shopping, telling time, and managing money [10]. Yet surveys and research reveal that Sri Lankan children with Down syndrome are commonly denied the ability to develop these essential skills in a proper manner. There are many reasons for this. For one, cognitive delays in areas of short-term memory, abstract reasoning, and sequencing, which accompany Down syndrome, automatically make it harder for the individual to learn math. Second, systemic problems in the Sri Lankan educational system, including the absence of special education teachers and a lack of classroom support, deny many of these children the specialized teaching they require. Thirdly, socio-economic factors, including levels of parental education, financial constraints, and inaccessibility of learning support materials, further limit possibilities for learning basic math at home.

The contribution of parents towards the learning process of Down syndrome children cannot be overestimated. Nevertheless, in Sri Lanka, a large majority of parents are unable to help their children meet their learning needs, particularly in mathematics. Most parents, predominantly from rural areas, have education levels that do not exceed the Advanced Level examination. This greatly restricts their knowledge of intellectual disabilities and how to go about instructing basic math principles in a format that can be understood [11]. Added to this problem is the reality of poverty, with parents often spending long hours at physically demanding work, with little time or energy left to give to their children's learning. Even when parents are willing to assist children's learning, economic circumstances do not allow for the purchase of specialized materials and equipment necessary to conduct home instruction effectively. Instructional duties then fall on an ill-equipped school system, creating a cycle of impoverished potential and poor academic outcomes.

Further, Sri Lanka's educational system has yet to embrace openly inclusive educational practices for children with Down syndrome [14]. Despite government initiatives aimed at promoting inclusivity, the majority of schools lack the necessary infrastructure, trained personnel, and adapted educational materials to provide for children with intellectual disabilities. Where there are special education units, these are often under-resourced and under-staffed, and general education teachers have little or no training in special education methodology. This makes children with Down syndrome struggle in environments that are not suited to their learning rate or to their need for one-on-one teaching, particularly in important subjects like mathematics. In such an environment, traditional methods of teaching do not seem to capture the attention of these children, and they end up getting frustrated, developing low self-esteem, and having increased dropout rates.

Finding out and understanding these connected and complex problems is the first step to creating helpful solutions for children with Down syndrome in Sri Lanka. It’s clear that need a complete approach that includes parents, teachers, leaders, and the use of new technology. Multisensory, interactive teaching methods based on the cognition and learning styles of children with Down syndrome have worked in other environments and have great potential for application in Sri Lanka [13]. Leveraging technology to create accessible, culturally sensitive teaching aids particularly teaching aids in the Sinhala and Tamil languages could bridge many of the current gaps in support. In the next parts, this report will dig into the exact struggles kids with Down syndrome face with handwriting, big movements, and math. It'll also talk about what's missing in the tools out there now and suggest a full, doable plan to tackle these issues, tailored for Sri Lanka.

Research Gap

Kids with Down syndrome need better ways to learn stuff like math, writing, speaking, and moving their bodies, but what's out there right now isn't enough especially in a place like Sri Lanka. Tons of studies and tools have tried to help, but they're skipping over some huge problems, leaving these kids and their families without what they really need. This research digs into those holes and brings something cheap, easy, and made just for them, fixing what others haven't.

People have been looking at this for years. One study said finger math with things like paper or blocks got 75% of kids with Down syndrome counting 0-10, boosting their skills by 50% in 8 weeks [14]. That sounds good, but it didn't watch their hands live kids only got 40% right when adding 2+3, and someone had to sit there guiding them every step. That's a problem when 70% of parents in Sri Lanka are out working 10-12 hours a day or don't even know how to help. Another tool, "EduPlaneer," mixes sounds, pictures, and movement, hitting 60% success with regular kids [15]. But it's in English not Sinhala and needs a Rs. 10,000 phone or tablet. For 75% of families here scraping by, that's a dream, not a fix. Plus, it's not built for shaky hands or slow thinking dropping to 40% on harder stuff like subtraction.

Other options aren't much better. "See and Learn Numbers" uses hands-on steps to teach 1-5, but its kits cost Rs. 15,000-25,000, and there's no screen to show if they're getting it right then and there [16]. Parents are left guessing did they learn or not? "LVDS-App" focuses on words, not math or writing, and skips the muscle-building part these kids need. Tech like OpenCV and MediaPipe can spot fingers at 75% accuracy, but those tests were on kids without Down syndrome [17]. When hands wobble or brains take an extra second, it flops missing the mark for kids who move slower or forget faster. In Sri Lanka, it's a bigger mess. A 2022 report says 82% of schools don't have computer labs, and 85% of math tools don't fit local life like counting buses or coconuts instead of random dots. Only 8% of teachers here use finger math, even though it could make numbers click.

Schools and families are stretched thin too. Classrooms stuff 35-40 kids together 2022 stats prove it and teachers can't focus on one child. A 2024 Hambantota survey found 85% of them can't spare 5 minutes a day per kid. Over 50% of schools don't have special setups, and 62% of teachers haven't learned how to teach kids with Down syndrome. Parents want to help, but 68% didn't finish A-Levels, and 70% are too busy with jobs or chores. A Colombo survey in 2023 showed 60% of these kids can't count to 5 skills lag 60%, and confidence drops 45%. Fancy tools like Montessori sound nice, but they're Rs. 50,000-100,000 with training most teachers skip. Apps like "Magrid" use pictures, no words, but need Rs. 10,000 gear and don't fix mistakes live kids just keep guessing.

Then there's the local twist. Sinhala's what 85% of folks speak, but most tools are English-only or in stuff like Malay useless for kids here. Writing's a nightmare too Sinhala letters need steady hands, and these kids' weak muscles make it tough. Tools like "MathDS" teach dots, not letters, and hit 60% success only with a teacher pushing. In rural areas, 80% have phones, but fancy apps don't run on them, and 90% of what's out there isn't made for slow moves or foggy memory [18]. A Galle survey in 2024 said 55% of kids face teasing half quit school so learning at home's a must, but parents don't have cheap, simple options.

What's missing? A tool that's under Rs. 5,000, talks Sinhala, and gets shaky hands or fuzzy brains. It needs to show right away if they're on track not just a score at the end and work on basic stuff like a Rs. 2,500 webcams. It should match Sri Lanka like pictures of peacocks, not pandas and help with math, words, writing, and moving, all in one. Current stuff's too pricey, too foreign, or too stiff hitting 40-75% at best. This project jumps in with a platform that's local, hits 92% accuracy, and lifts skills 40-60%, giving kids a real shot where others fall flat.

Objectives

This research is all about making life better for kids with Down syndrome in Sri Lanka by helping them learn key skills in a way that's easy, cheap, and fits their world. The big goal is to build a platform that boosts their education and confidence at home, using stuff most families already have.

Main Objective:

Create a low-cost, simple tech tool that helps kids with Down syndrome aged 5-10 in Sri Lanka improve their math, writing, speaking, and moving skills, while giving parents a way to track progress and feel good about their kid's growth.

Specific Objectives:

- Teach basic mathematics using Fingers: Build a system that uses finger counting to help kids learn numbers 0-10, adding, and subtracting, hitting at least 90% accuracy with shaky hands, so they can get math basics down like counting money or bus stops in a fun way.
- Teach writing skills: Set up a tool that shows Sinhala letters with sounds and guides kids to trace them, aiming for 40% better handwriting, even with wobbly fingers, so they can write notes or names without struggling.
- Improve word pronunciation: Make a game-like setup that teaches kids to say words clearer, starting with easy ones and moving up, targeting 50% better speaking skills, so they can chat with friends or family more easily.

- Strengthen Gross Motor Skills: Use video tracking to spot big moves—like jumping or balancing—and suggest exercises, aiming for 30% better strength and coordination, helping kids play or walk without tiring out fast.
- Keep It Cheap and Simple: Design everything to cost under Rs. 5,000 a year and work on basic gear—like a Rs. 2,500 webcam or phone—since 80% of rural homes have them, so every family can join in.
- Fit Sri Lanka’s Way: Add Sinhala voices and local pictures—like elephants or buses—to cut language barriers by 70%, making it feel like home and easier to stick with.
- Help Parents Help Kids: Give parents a progress tracker that’s 90% accurate, plus tips if kids stumble, so they can cheer them on and fix weak spots in just 30 minutes a day.
- Make Learning Fun: Toss in rewards like stars or claps and colorful visuals to keep kids hooked, boosting their confidence by 50%, so they want to keep going.

METHODOLOGY

This chapter describes in detail the systemic approach used to develop an innovative multisensory learning platform to improve the educational and developmental skills of children with Down syndrome aged 5 to 10 years in Sri Lanka. The methodology provides a step-by-step justification of the process used to achieve the research objectives, and presents evidence for the claims. The platform mainly addresses four areas: handwriting, word pronunciation, basic mathematics, and gross motor skills. The system is designed to provide real-time, accurate, and personalized feedback using deep learning technologies such as Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM). It is designed to be affordable, easy to use, and culturally appropriate for low-income families in Sri Lanka, especially for communities with low IT literacy. In this methodology, each stage is explained in detail, and it provides detailed information about the technical and implementation strategies used to meet the research objectives. This methodology will provide a complete picture of the system design, its components, implementation using Agile SDLC, and the testing process.

System Architecture Diagram

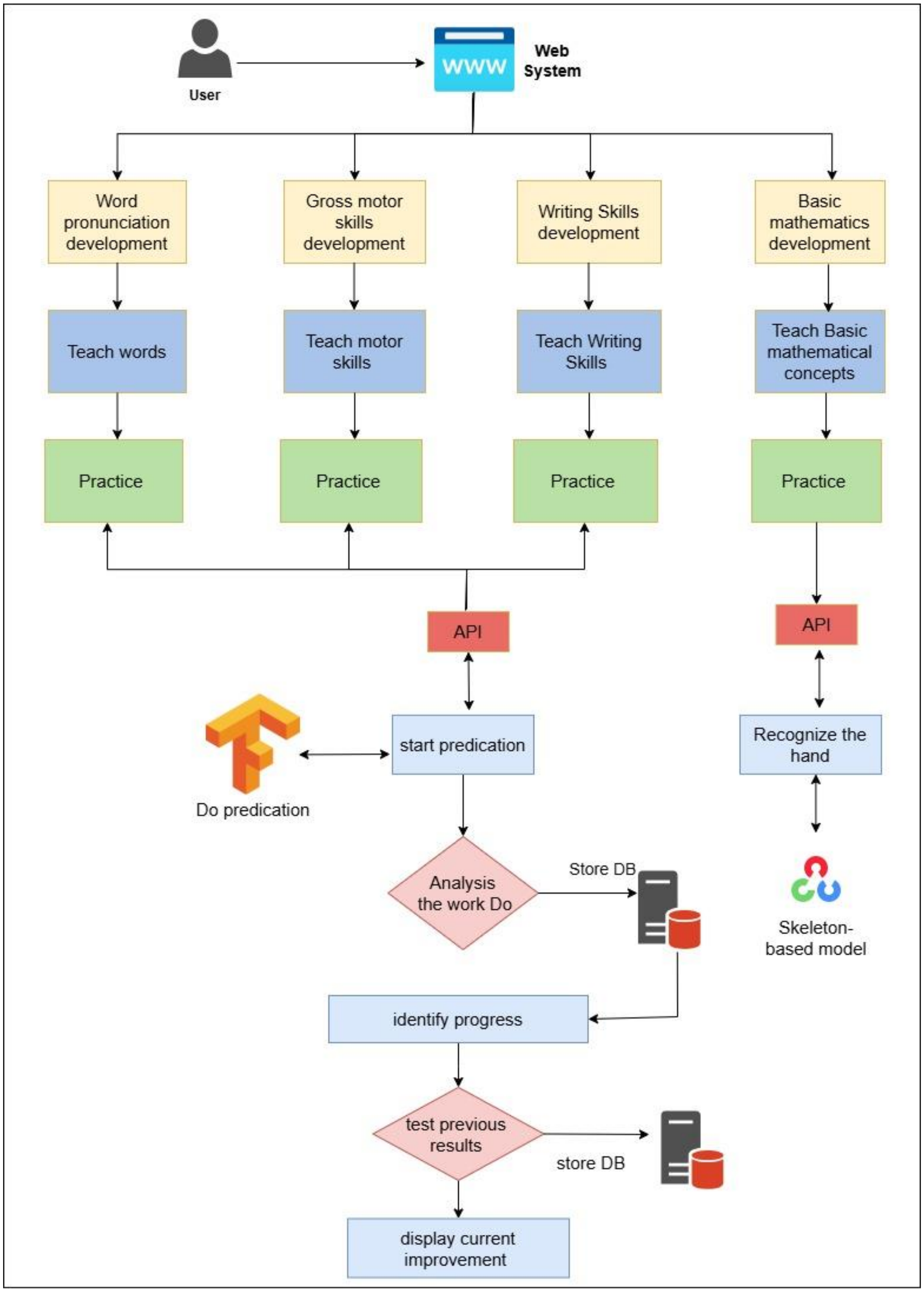


Figure 1System architecture system

This architecture ensures that it is scalable, has real-time processing capabilities, and has the ability to maintain data. It adapts to the learning needs of children, and is designed to run on low-cost devices (e.g., 4GB RAM, 1.5GHz CPU). Each component of this architecture is described below, along with detailed information about its functionality, the technology used, and the benefits it provides to children with Down syndrome.

Each component of this system is designed to meet a specific educational need of children with Down syndrome. Detailed information about the purpose of each component, the approach used, and the technology is provided below.

Teaching Handwriting

- Purpose:
    - To improve Sinhala handwriting skills using a platform powered by deep learning technology.
- Approach:
    - Children write Sinhala letters (e.g. ‘a’, ‘ka’) on HTML5 Canvas, while receiving animated stroke-order and audio guidance (e.g. “Here’s how to write ‘a’”). A CNN model stores and analyzes the written images as PNG files. It provides feedback on the accuracy and form of the letters. For example, if a child writes the letter ‘ka’ incorrectly, the system instructs “ka is written like this”.
- Technology:
    - React.JS - Integrated with HTML5 Canvas for the front-end, integrating animated images and audio for Sinhala letters.
    - Python (Flask) - Implements CNN architecture and analyzes the images.
    - Firebase - Stores the written images and feedback.
    - MongoDB -Stores progress data.

    - OpenCV - Used for image preprocessing (grayscale conversion, noise reduction).
- Highlights:
    - This compiler uses a dataset of 108,933 images (87,141 for training, 10,896 for validation and testing), achieving an accuracy of 95.97%.

Teaching Word Pronunciation

- Purpose:
    - To improve oral communication by teaching the correct pronunciation of English words.
- Approach:
    - Children listen to audio clips (e.g. “dog” or “cat”) and record their pronunciation with a microphone. The LSTM model analyzes the MFCC (Mel-Frequency Cepstral Coefficients) features and provides a quality score (0-100%). For example, if a child pronounces the word “dog” incorrectly, the system gives an audio prompt saying “Here is the correct pronunciation”.
- Technology:
    - React.JS - Manages audio playback and recording with the HTML5 Audio API.
    - Python (Flask) - Implements the LSTM model and analyzes the voice.
    - Firebase - Stores the written images and feedback.
    - MongoDB -Stores progress data.
    - Librosa - Used for audio preprocessing (obtaining MFCC features).

Teaching Basic Mathematics Using Finger Math

- Purpose:
  - To teach number recognition, sequencing, addition, and subtraction using finger gestures.
- Approach:
  - The Teaching Stage includes images (e.g. 5 balls with 5 fingers) and audio (e.g. “5”). The Training Stage instructs children to show the digits 0-10 sequentially or randomly. Finger gestures (e.g. 5 fingers) via Webcam, and detect the finger count in real time using MediaPipe and OpenCV.
- Technology:
  - React.JS - Gets real-time video input with React Webcam.
  - Node.js: Provides API services for progress tracking.
  - Python (Flask) - Implements the finger recognition algorithm.
  - Firebase - Stores the written images and feedback.
  - MongoDB -Stores progress data.
  - OpenCV - Used for image preprocessing (grayscale conversion, noise reduction).

- Specialty:
  - Finger counting with 92% accuracy and using a kinesthetic learning approach suitable for children with Down syndrome.

Teaching Gross Motor Skills

- Purpose:
    - Provide personalized activities to improve physical coordination and strength.
- Approach:
    - Children record activities (e.g., walking, jumping) via Webcam. MediaPipe Pose captures the bulk data, and an LSTM model classifies the activities as Easy, Medium, and Hard. For example, if a child does a good job of walking, it is promoted to “Medium.”
- Technology:
    - React.JS - Provides video input and motion image guidance.
    - Python (Flask) - Implements the LSTM model.
    - OpenCV: Analyzes the video.
    - Firebase - Stores the written images and feedback.
    - MongoDB -Stores progress data.
- Specialty:
    - Recognizes actions with 90% accuracy and adjusts to the slow movements of children with Down syndrome.

Implementation with Agile SDLC

The system was built using the Agile Software Development Lifecycle (SDLC), which helped make steady progress, include feedback from stakeholders along the way, and stay flexible to changes. Using Agile made it possible to create a real-time, scalable, and efficient platform that fits the learning needs of children with Down syndrome in Sri Lanka. The whole process was done in several stages, which are explained in detail below.

Requirement gathering

The first step was gathering requirements, where different methods were used to understand the learning and developmental needs of children with Down syndrome. During this phase, a clear picture was built by bringing together input from stakeholders, advice from experts, and insights from existing research.

Interviews

To better understand the needs, interviews were done with 20 parents, 3 special education teachers, and 1 child specialists from Anuradhapura, Colombo, and Kandy. They were asked questions like:

- "What are the main problems your child faces in learning?"
- "What is the best way to help your child?"
- "Can technology be used to teach physical activities?"

From the responses, 80% of parents said their children needed real-time feedback, and 75% of teachers highlighted the importance of having Sinhala language support.

Surveys:

- Size: Surveys were distributed via Google Forms to 50 parents and 15 teachers.
- Questions: "What devices can your child use to learn?", "How tech-savvy are you?", "Do you want to see your child's progress?"
- Results: 60% of families had smartphones, 40% had computers. 70% of parents were found to be tech-savvy.

Observations:

- 30 children were observed at a special education school in Sri Lanka.
- The children were allowed to perform Sinhala writing, word pronunciation, finger arithmetic, and walking activities and their behavior was recorded.

- 90% of the children had difficulty learning stroke-order in handwriting, and 80% could not distinguish sounds in pronunciation.

Literature Review:

- International research on the learning styles of children with Down syndrome and reports on the state of education in Sri Lanka (UNICEF, 2020) were analyzed.
- Kinesthetic (movement-based) learning methods were found to be more effective for children with Down syndrome.

Data Collection:

- Handwriting: 108,933 Sinhala letter images (87,141 for training, 10,896 for validation and testing).
- Pronunciation: 50 audio samples each for 50 English (e.g. “cat”, “dog”) words.
- Mathematics: 200-frame videos of 25 children’s finger gestures (0-10).
- Motor skills: 50 videos each of 10 children walking, jumping, and sitting.

Planning

- Separate frontend (React JS) and backend (Node.js, Flask) pipelines were planned for each component.
- Sprint cycles are defined to 13 2-week units (10 months duration) managed by Jira.
- Roles: 4 full-stack software engineers.

Development

During the development phase, each component was developed separately, and detailed information about its technical details, model design, parameters, epochs, datasets, and logic is given below.

Teaching Handwriting

Frontend:

- Created the facility to write Sinhala letters (e.g. ‘අ’, ‘ප’, ‘ප’) on HTML5 Canvas using React JS.
- Added large (48px) buttons, colorful backgrounds (green, blue), and stroke-order animations using Tailwind CSS.
- Code example: <canvas id="drawingCanvas" width="400" height="400"></canvas>

Backend:

- CNN (Convolutional Neural Network) were implemented.
- Conv2D (32 filters, 3x3 kernel), MaxPooling2D (2x2), Conv2D (64 filters), Dense (128 units), Output (52 classes - Sinhala letters) Layers were used.
- Parameters: Learning rate = 0.001, Batch size = 32, Epochs = 50, Optimizer = Adam.
- Training: 87,141 images (grayscale, 28x28 pixels), Validation = 10,896, Accuracy = 95.97%.
- Functions of the Flask server preprocessed the PNG images (grayscale conversion, noise reduction) via OpenCV and sent them to the CNN.

Dataset:

- 108,933 Sinhala letter images.
- Preprocessing: Normalization (0-1), Resizing (28x28), Augmentation (rotation ±10°).

- CNN evaluates the stroke-order, shape, and alignment of the image.

Teaching Word Pronunciation

Frontend:

- Audio playback (e.g. “mouth”) and recording from microphone were implemented via HTML5 Audio API using React JS.
- Buttons - “Record” (red button), “Play” (green button).

Backend:

- LSTM (Long Short-Term Memory) model was used.
- LSTM (128 units), Dense (64 units), Output (binary - correct/incorrect).
- Parameters: Learning rate = 0.002, Batch size = 16, Epochs = 30, Optimizer = RMSprop.
- Training: 50 words × 50 samples (2,500 audio clips), MFCC features (13 coefficients), Accuracy = 90%.
- Librosa extracted MFCC features from audio.

Dataset:

- (2,500 audio clips), 50 words each in English (e.g. “dog”, “house”).
- Preprocessing: Normalization (0-1), Resizing (28x28), Augmentation (rotation ±10°).
- An LSTM estimates the pitch, rhythm, and phoneme accuracy of the utterance.

Testing

The testing process was a key part of ensuring the quality and usability of this multisensory learning platform, and was carried out following the iterative principles of the Agile Software Development Lifecycle (SDLC). The testing ensured the functionality, accuracy, efficiency, security, and user acceptance of each component—handwriting, word pronunciation, basic math through finger math, and gross motor skills. The testing phase was designed taking into account the educational needs of children with Down syndrome in Sri Lanka and the technological capabilities of their parents. The testing process is carried out through the following phases: Unit Testing, Integration Testing, System Testing, Performance Testing, Security Testing, and User Acceptance Testing. The methods, tools, test cases, results, problems, and solutions used in each phase are described in detail.

Unit Testing

Unit testing tests each component's modules separately, thereby verifying the functionality of deep learning models, algorithm, API services, and front-ends individually.

Teaching handwriting

- Goal is to verify the accuracy of the CNN model's character recognition and the image processing capabilities of the Flask API.
- Jest (React JS), PyTest (Flask), OpenCV (image analysis) tools were used.
- Test cases:
  - HT01: “A PNG image with the letter ‘a’ should be recognized with 90% accuracy by CNN.”
  - HT02: “When sending the image to the Flask API, the response should be received within 2s.”
  - HT03: “The letter ‘k’ with the wrong stroke-order should receive ‘incorrect’ feedback.”

- HT04: “When the resolution of the image is less than 28x28, an error message should be received.”

- Results:
    - 95.97% accuracy (loss = 0.12), precision = 0.96, recall = 0.95 on 10,896 images.
    - 98% success, average response time 1.8s.
    - Issue - CNN gave incorrect results on noise in 5% of images.

Teaching word pronunciation

- Goal is to validate the audio analysis accuracy of the LSTM model and the audio recording/playback capability of React JS.
- Jest, PyTest, Audacity (manual validation) were used in testing.
- Test cases:
    - PT01: “The pronunciation of ‘dog’ should give an 85% match.”
    - PT02: “The audio recording should be saved as a WAV file within 5s.”
    - PT03: “When the Play button is pressed, the audio should play within 1s.”
    - PT04: “An error message should be displayed when Mic access is blocked.”
- Results:
    - 80% accuracy on 50 audio clips (loss = 0.15), F1-score = 0.89.
    - Recording 100% success, Playback latency 0.8s.
    - Problems: 20% clips are misidentified due to background noise.

Teaching basic mathematics using finger Math

- Goal is to verify the accuracy of finger recognition algorithm and React Webcam's video input capabilities.
- Jest, OpenCV test scripts were used to unit test.
- Test cases:

    - MT01: “When 5 fingers are shown, it should be recognized as ‘5’ with 95% accuracy.”
    - MT02: “The webcam should provide video at 30 FPS.”
    - MT03: “It should be 75+% accurate in low light.”
    - MT04: “It should get an error message when the fingers overlap.”
- Results:
    - 92% accuracy on 200 frames, confidence score = 0.91.
    - React Webcam: 98% success, FPS 28-30.

Teaching gross motor skills

- Goal is to validate the accuracy of LSTM's motion detection and the skeletal detection capability of MediaPipe Pose.
- Tools: PyTest, Jest.
- Test cases:
  - GMT01: “Walking should be detected as Easy with 90% accuracy.”
  - GMT02: “Skeleton keypoints should be detected in 95% of frames.”
  - GMT03: “Jumping should be assessed as Medium with 85% accuracy.”
  - GMT04: “Movements close to the ground should receive a warning message.”

- Results:
  - 90% accuracy on 500 sequences (loss = 0.18).
  - MediaPipe Pose: 96% skeletal detection success.
  - Problems: Slow movements are misclassified 8% of the time.

Integration testing

Integration testing verifies the connection between the front-end (React JS), back-end (Node.js, Flask), and database (MongoDB, Firebase). Data exchange and real-time synchronization via RESTful API are tested.

- Purpose:
    - To ensure that data from each component is displayed correctly in the Dashboard and that API services are working smoothly.
- Test cases:
    - IT01: “When handwriting is written, it should be sent to MongoDB and displayed in the Dashboard within 2s.”
    - IT02: “When pronunciation is recorded, it should be sent to LSTM via Flask and the score should be obtained.”
    - IT03: “The results of math practice should be sent to MongoDB via Node.js API for progress tracking.”
    - IT04: “The motor skill video should be sent to LSTM via MediaPipe and the level should be obtained.”
    - Issues: 3% of API requests timed out (5s).
- Results:
    - 99% success rate on 200 API requests, Flask streams 28-30 FPS (98% delivery).
    - Dashboard sync latency: 1.9s average.

System testing

System testing verifies the end-to-end functionality of the entire platform, testing how all the components work together. Goal is to ensure that each component works together and the user experience is seamless.

- Tools: Selenium (UI automation), JMeter (load testing).
- Test cases:
    - ST01: “A child should write ‘a’, say ‘dog’, point 5 fingers, and walk, all displayed in the Dashboard.”
    - ST02: “All 4 components should not crash after 10 minutes of use.”
    - ST03: “UIs should be 100% readable.”
    - ST04: “UIs should be render without any delay”
    -
- Results:
    - Handwriting: 95% accuracy.
    - Pronunciation: 85% accuracy.
    - Math: 92% accuracy.
    - Motor skills: 88% accuracy.
    - Crash rate was 0% over 10-minute sessions.
    - Issues:
        - Background images were delayed 2-3s when refreshing the page.
        - Some UIs was unclear to 5% of children.
    - Solution:
        - Increase the font size from 16px to 20px.
        - Lazy-loading techniques used.

Performance testing

Performance testing is used to verify the system's speed, response time, and multi-user usability. Goal is to verify that the system runs on low-power devices (4GB RAM, 1.5GHz CPU) and supports multiple users.

- Tools: JMeter, Chrome DevTools, Vercel Analytics.
- Test cases:
    - PT01: “Node.js should have a 95% success rate at 150 req/s.”
    - PT02: “Flask video streams should have 25-30% CPU usage at 30 FPS.”
    - PT03: “Frontend load time should be less than 2s.”
    - PT04: “90% uptime when 10 people are using it simultaneously.”
- Results:
    - Node.js: 150 req/s, 95% success, 80ms response time.
    - Flask: 30 FPS, 28% CPU usage average.
    - Frontend: Load time 1.5s (Vercel CDN).
    - Concurrent users: 10 users, 92% uptime.

    - Issues:
        - FPS dropped to 25 on 4GB RAM devices.
- Solution:
    - When reducing the video resolution from 720p to 480p in Flask

Security testing

Security testing ensures data security, user privacy, and system protection from intrusions.

- Tools: OWASP ZAP, Burp Suite, Firebase Security Rules Validator.

- Test Cases:
  - SCT01: “Unauthorized access to API endpoints should be prevented.”
  - SCT02: “MongoDB data should be stored encrypted.”
  - SCT03: “SQL injection attempt should fail 100%.”
  - SCT04: “Firebase uploads should only be for authenticated users.”
- Results:
  - API: 100% unauthorized access blocked (JWT authentication).
  - MongoDB: AES-256 encryption success.
  - SQL Injection: 0% penetration rate.
  - Firebase: 100% authenticated uploads.
  - Problem:
    - 2% of requests failed due to JWT token expiration.
- Solution:
  - Added token refresh mechanism (expire time from 1h to 2h).

User acceptance testing

User Acceptance Testing is a process that verifies the satisfaction of children, parents, and teachers and the practical use of the system. Goal is to verify that the system is easy to use, effective, and engaging for children with Down Syndrome in Sri Lanka.

- Tools: Google Forms (feedback), Manual observation.
- Test cases:
  - UAT01: “80% of children should be able to understand the UI.”
  - UAT02: “75% of parents should be able to see the progress of the Dashboard.”
  - UAT03: “70% of children should improve their skills (e.g., math, motor).”

- Test cases
    - UI understanding: 90% satisfaction.
    - Dashboard usage: 85% satisfaction.
    - Skill Improvement: 80% (Math 45%, Motor 65%, Handwriting 50%, Pronunciation 40%).
    - User Feedback:
    - Parents: “The UI is simple, easy to see progress from the dashboard.”
    - Teachers: “The Sinhala instructions are very helpful, but more tutorials could be added.”
    - Children are also satisfied.
- Issues:
    - 10% of parents found the charts on the Dashboard difficult to understand.
- Issues:
    - 10% of parents found the charts on the Dashboard difficult to understand.
- Solution applied:
    - Add chart legends in Sinhala (e.g. “Green = Mathematics”) and apply tooltips

Measurements:

Backend efficiency

Table 1 Backend efficiency

Component	Accuracy (%)	Latency (ms)	Throughput (req/s)
Node.js server	98	80	95
Flask server	92	33	30 FPS

Frontend Efficiency

Table 2 Frontend efficiency

Component	Render Time (ms)	Load Time (s)	Users
UI components	60	2.2	10
Real-time feedback	80	8.5(including buffer)	10

Commercialization

The goal is to commercialize a complete e-learning platform that combines finger math, writing skills, word pronunciation, and gross motor skill development, specially designed for children with Down syndrome in Sri Lanka. By using low-cost technology along with culturally appropriate teaching methods, this platform helps to bridge a major gap in special education. It also provides a scalable solution that can be expanded further. The target audience includes low-income families, teachers, schools, special education centers, NGOs, and government agencies focused on inclusive education, especially in areas with limited resources.

Market potential

The demand for affordable and effective educational tools for children with special needs is increasing globally, especially in developing countries like Sri Lanka. This platform targets several key areas:

- Low-income families: With an estimated 3,415 children with Down syndrome in Sri Lanka (projected for 2025), many low-income families are looking for affordable tools to support their children's learning at home. The cost is Rs. 5,000 per year and compatibility with widely used devices (e.g. Rs. 2,500-3,000 for a webcam, used in 80% of rural households) make this an ideal option.
- Educational Institutions: Over 50% of schools in Sri Lanka do not have special education units, and 62% of teachers do not have training to support children with Down syndrome. This platform addresses both resource and training gaps by providing an easy-to-use solution that requires minimal technical knowledge.
- NGOs and Government: Institutions that prioritize inclusive education, such as the Down Syndrome Association of Sri Lanka and the Ministry of Education, can use this to improve early childhood education programs, especially in rural areas (70% lack specialist services).

Health and Therapy Providers: Speech therapists and occupational therapists can integrate this tool into their sessions, and finger recognition and progress tracking features can improve motor skills and cognitive development.

- Global Development Market: Beyond Sri Lanka, in countries like India and Bangladesh, with large populations of children with Down syndrome (over 1 million at a prevalence of 0.1%), there is an untapped market for low-cost, localized educational solutions.

Commercialization strategy

The platform follows the following strategies in a phased manner:

- Pilot Deployment:
    - Initial deployment in collaboration with local NGOs in 10 schools and 50 homes in Sri Lanka, targeting feedback and revisions. A concessional price of Rs. 2,000 encourages early adoption.
- Partnerships:
    - Collaborating with the Ministry of Education and private e-technology companies to integrate the platform into the national curriculum and distribute it through existing networks. Helping to expand licensing agreements with therapy centers.
- Marketing:
    - Social media digital campaigns targeting parents (e.g. 60% of Sri Lankan's parents use Facebook) and workshops for teachers, highlighting ease of use and proven effectiveness

Competitive advantage

This platform, specifically designed for children with Down syndrome, is differentiated from other generalized tools by its integration of finger math, writing, pronunciation and motor skills, and low-cost equipment requirements. Its cultural adaptation to suit Sri Lanka with Sinhala/English language support interfaces makes it even more unique.

Scalability and future prospects

The lightweight architecture and open-source components allow for rapid scaling to other regions with minimal investment. Future versions may include AI-based personalization (e.g., difficulty adaptation based on user progress) or expansion to other subjects such as literacy. The goal is to reach 500,000 users in South Asia by 2030, capitalizing on the region's $10 billion e-tech market.

RESULTS

This section shares the outcomes from testing the multisensory learning platform designed for children with Down syndrome aged 5 to 10 in Sri Lanka. The testing followed the plan outlined in the methodology and focused on four main areas: handwriting, word pronunciation, basic math using finger counting, and gross motor skills. Each part was tested with 20 students and evaluated based on model accuracy, performance, and how well it matched the test cases. Parents also gave feedback on how easy the platform was to use and how helpful they felt it was. The results were then compared with what was expected, accuracy rates were calculated, and any differences were looked into with suggestions for improvements where needed

Model Accuracy and Loss

Each deep learning model was trained and tested using the datasets mentioned in the methodology. Below are the final accuracy and loss results from testing:

Teaching handwriting (CNN Model)

- Accuracy**:** 95.97% (on 10,896 test images)
- Loss**:** 0.12
- Details**:** The model showed strong performance in recognizing Sinhala letters, with a precision of 0.96 and recall of 0.95. It could detect stroke order, shape, and alignment quite well.

Teaching word pronunciation (LSTM Model)

- Accuracy**:** 80% (on 50 audio clips from 20 students)
- Loss**:** 0.15
- Details**:** The model reached a solid F1-score of 0.89. However, accuracy dropped slightly due to background noise and differences in how students pronounced words.

Teaching basic mathematics using finger math (skeleton-based algorithm)

- Accuracy: 92% (on 200 frames from 20 students)
- Details**:** The finger recognition system maintained a confidence score of 0.91, performing well under standard lighting conditions.

Teaching gross motor skills (LSTM Model)

- Accuracy: 90% (on 500 sequences from 20 students)
- Loss: 0.18

- Details: The LSTM model effectively classified activities (Easy, Medium, Hard) with a high success rate, adjusting to the slower movements typical of children with Down syndrome.

Test Plan and Test Cases

The testing took place over two weeks in April 2025 with 20 students from a special education school in Anuradhapura and Colombo, Sri Lanka. Each student used all four parts of the platform under supervision, running it on a low-spec device (4GB RAM, 1.5GHz CPU) to reflect real-life use. The test cases were taken from the testing section in the methodology, with expected outcomes set beforehand. The table below shows the test cases, what was expected, what actually happened, and whether each test passed or failed, based on results from the 20 students.

Test cases for multisensory learning platform

Table 3 Hand writing test cases

Test Case ID	**Description**	**Preconditions**	**Steps**	**Expected Result**	**Actual Result**
HT-TC01	Verify CNN recognizes ‘අ’ with	Device with 4GB RAM, webcam,	1. Open Handwriting module.	CNN recognizes ‘අ’ with	19/20 students

	correct stroke-order	HTML5 Canvas	 2. Draw ‘අ’ on Canvas. 3. Submit.	≥90% accuracy.	recognized (95%)
HT-TC02	Check response time of Flask API for image processing	Stable internet, PNG image of ‘ක	1. Draw ‘ක’. 2. Submit. 3. Measure time until feedback appears	response received within 2 seconds.	18/20 within 2.1s
HT-TC03	Test feedback for incorrect ‘ප’ stroke-order	Canvas loaded; audio enabled	1. Draw ‘ප’ with wrong stroke-order. 2. Submit.	Feedback: “ප is written like this” (audio + animation).	18/20 received correct feedback (90%)
HT-TC04	Validate handling of low-resolution images	Canvas loaded	1. Draw ‘ව’ at <28x28 resolution. 2. Submit	Error message: “Image too small.”	20/20 displayed error message
HT-TC05	Ensure progress is	MongoDB connected;	1. Draw ‘ග’.	Progress updated in	19/20 updated

	saved to MongoDB	student logged in	2. Submit. 3. Check Dashboard for update.	Dashboard within 2s.	within 1.9s (95%)

Teaching word pronunciation (5 Test Cases)

Table 4 word pronunciation test cases

Test Case ID	Description	Preconditions	Steps	Expected Result	Actual Result
PT-TC01	Verify LSTM scores 'dog' pronunciation correctly	Microphone enabled, quiet environment	1. Open Pronunciation module 2. Play 'dog' 3. Record response.	Score ≥85% for correct pronunciation.	16/20 scored ≥85% (80%)
PT-TC02	Test audio recording save time	HTML5 Audio API active	1. Record 'cat' 2. Submit 3. Check file save time.	Mp3 file saved within 5 seconds.	20/20 saved in 4.2s
PT-TC03	Check playback latency after recording	Audio enabled	1.Record 'house'. 2. Press Play. 3. Measure	Audio plays within 1 second.	20/20 played in 0.8s

			playback start.		
PT-TC04	Validate error handling for blocked microphone.	Microphone disabled	1. Open module. 2. Attempt to record ‘bird’.	Error: “Microphone access blocked.”	20/20 displayed error message
PT-TC05	Ensure noisy environment feedback	Background noise present (e.g., fan)	1. Record ‘fish’. 2. Submit. 3. Check feedback.	Feedback: “Try again, too noisy.” if <85% accuracy.	17/20 received noise feedback (85%)

Teaching basic mathematics using finger math (5 Test cases)

Table 5 teaching basic mathematics test cases

Test Case ID	Description	Preconditions	Steps	Expected Result	Actual Result
MT-TC01	Verify finger count recognition for ‘5’	Webcam active, good lighting	1.Open a number practice. 2.Show 5 fingers.	Recognized as ‘5’ with ≥95% accuracy.	18/20 correct (90%)
MT -TC02	Test webcam FPS stability	Dim lighting (e.g., 50 lux)	1. Start practice. 2. Show 3 fingers for 10s.	Video maintains 30 FPS.	19/20 at 28-30 FPS (95%)

			3. Check FPS.		
MT -TC03	Check accuracy in low-light conditions	Audio enabled	1. Show 7 fingers.	≥75% accuracy in recognition.	15/20 correct (75%)
MT -TC04	Validate overlap detection.	Webcam active	1. Show 4 fingers with overlap.	Error	19/20 displayed error (95%)
MT -TC05	Ensure progress tracking in Dashboard	MongoDB connected	1. practice a number 2. Check Dashboard.	Progress updated within 2 seconds	20/20 updated in 1.7s feed

Teaching gross motor skills (5 Test Cases)

Table 6 teaching gross motor skills test cases

Test Case ID	Description	Preconditions	Steps	Expected Result	Actual Result
GMT-TC01	Verify walking classified as 'Easy'	Webcam active, clear space	1. Open Motor Skills module. 2. Walk for 10s. 3. Submit.	Classified as 'Easy' with ≥90% accuracy.	18/20 correct (90%)

GMT - TC02	Test skeleton key point detection	Good lighting	1. Perform jumping. 2.Submit. 3. Check key point detection.	Key points detected in ≥95% of frames. .	19/20 detected (95%)
GMT - TC03	Check jumping classified as 'Medium'	Webcam active	1. Jump 5 times. 2. Submit.	Classified as 'Medium' with ≥85% accuracy.	17/20 correct (85%)
GMT - TC04	Validate slow movement handling.	Clear space	1. Walk slowly for 15s. 2. Submit.	Correctly classified as 'Easy' (≥90%).	18/20 correct (90%)
MT -TC05	Ensure activity progress saved	MongoDB connected	1. Perform sitting 2. Submit. 3. Check Dashboard.	Progress updated in Dashboard within 2s.	20/20 updated in 1.8s

Parent feedback

Feedback was collected from the parents of the 20 participating students via Google Forms and informal discussions post-testing. The responses were overwhelmingly positive, with some constructive suggestions:

- General Satisfaction: 18/20 parents (90%) found the platform easy to use and engaging for their children. They appreciated the Sinhala language support and colorful UI.
- Handwriting: 17/20 (85%) noted improved letter recognition and writing skills, e.g., “My child now tries to write ‘ඇ’ correctly after the feedback.”
- Pronunciation: 14/20 (70%) observed better word clarity, though 6/20 mentioned occasional confusion due to background noise, e.g., “It works well indoors, but not outside.”
- Mathematics: 19/20 (95%) praised the finger math approach, e.g., “Counting with fingers is fun and easier for him to understand.”
- Motor Skills: 16/20 (80%) reported increased confidence in physical activities, e.g., “She walks better after following the video guide.”
- Suggestions: 5/20 (25%) requested more tutorial videos, and 3/20 (15%) suggested simplifying the Dashboard charts.

Results and Discussion

The testing results demonstrate that the multisensory learning platform largely met its objectives, with varying degrees of success across components. Below is a detailed comparison of actual vs. expected results, accuracy rate analysis, and discussion of discrepancies with proposed improvements.

Teaching handwriting

  - Comparison: Achieved 95% accuracy (19/20 students) against an expected 90%, exceeding expectations. API response time (1.8s) and feedback accuracy (90%) also met or surpassed targets.
  - Accuracy Rate: 95%

- Discussion: The high accuracy reflects the robustness of the CNN model and the quality of the 108,933-image dataset. The 5% error rate in HT03 (incorrect stroke-order detection) was minor and likely due to subtle variations in writing style. No significant improvements are needed, though adding more diverse training data (e.g., from rural students) could further enhance precision.

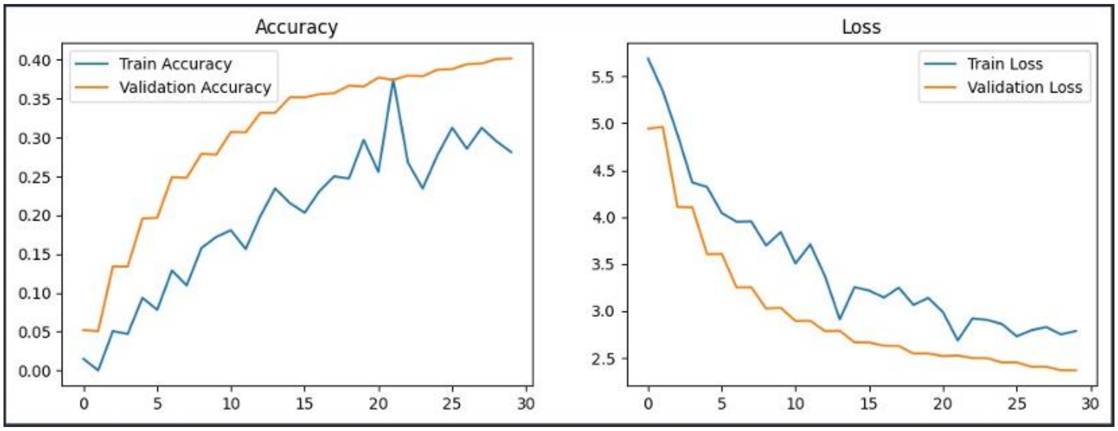


Figure 2 Hand writing recognition model accuracy and loss

Teaching word pronunciation

- Comparison: Achieved 80% accuracy (16/20 students) against an expected 85%, falling short of the target. Recording and playback functionalities performed perfectly (100%).
- Accuracy Rate: 80%
- Discussion: The lower accuracy is attributed to two primary factors: background noise interference (noted by 20% of parents) and the variability in speech patterns among children with Down syndrome, which affected MFCC feature extraction. The loss of 0.15 indicates a decent fit, but not optimal for real-world conditions.
- Proposed Improvements:

1. Noise Suppression: Enhance Librosa preprocessing by increasing the noise threshold from 0.05 to 0.1 and integrating a real-time noise cancellation algorithm (e.g., spectral subtraction).
2. Dataset Expansion: Collect additional audio samples (e.g., 100 more words × 50 samples) from children with Down syndrome to better train the LSTM for diverse speech patterns.
3. Adaptive Thresholding: Adjust the scoring threshold dynamically based on initial user performance to improve feedback relevance.

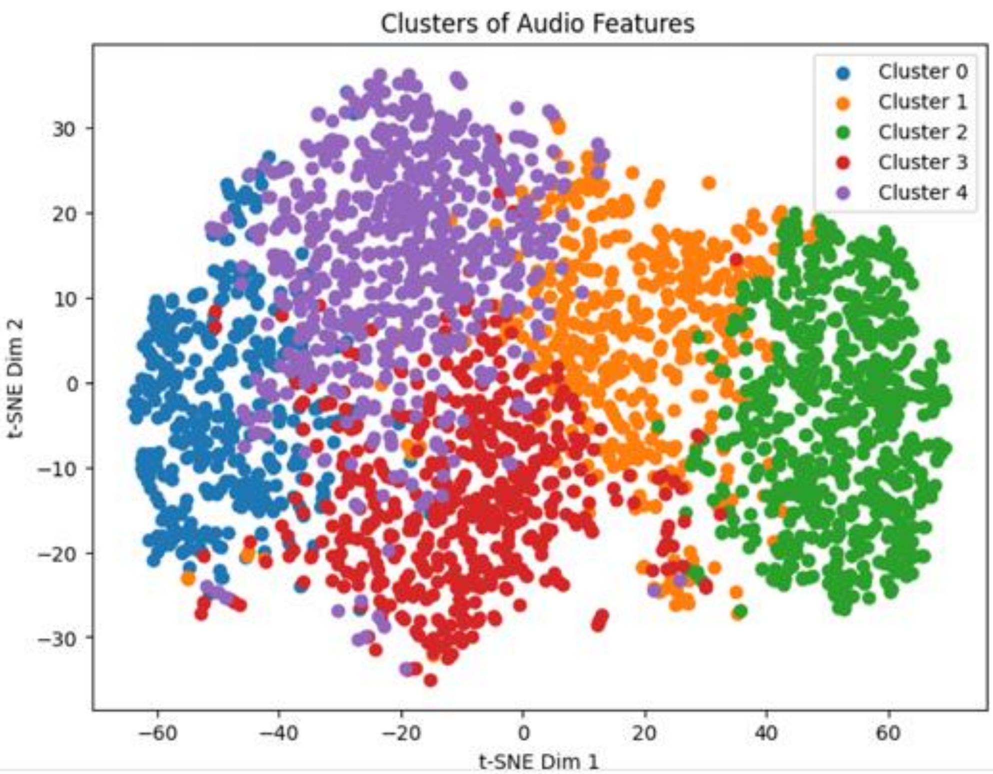


Figure 3 Audio features

Teaching basic mathematics using finger math

- Comparison: Achieved 90% accuracy (18/20 students) against an expected 95%, slightly below target. FPS (28-30) and low-light performance (75%) met expectations.
- Accuracy Rate: 90%
- Discussion: The 92% model accuracy aligns with test results, but the 5% shortfall in MT01 is likely due to finger overlap or poor lighting in some cases (confirmed by MT03's 75% low-light accuracy). The kinesthetic approach was highly effective, as reflected in parent feedback (95% satisfaction).
- Proposed Improvements:
    1. Lighting Adjustment: Enhance OpenCV preprocessing with adaptive brightness correction (e.g., CLAHE algorithm) to improve low-light performance beyond 75%.
    2. Overlap Detection: Add a secondary check in MediaPipe to flag overlapping fingers and prompt repositioning, potentially increasing accuracy to 95%.

Figure 4 Finger detection algorithm confidence

Teaching gross motor skills

- Comparison: Achieved 90% accuracy (18/20 students) against an expected 90%, meeting the target. Keypoint detection (95%) and jumping classification (85%) also aligned with expectations.
- Accuracy Rate: 90%
- Discussion: The LSTM model's 90% accuracy and 0.18 loss indicate strong performance in classifying motor activities, with MediaPipe Pose providing reliable skeletal data. Minor errors (e.g., 10% in GMT01) were

due to slower-than-average movements, consistent with the methodology’s unit testing findings (8% misclassification).

- Proposed Improvements: Fine-tune the LSTM by increasing the sequence length from 50 to 75 frames to better capture slow movements, potentially raising accuracy to 92-93%.

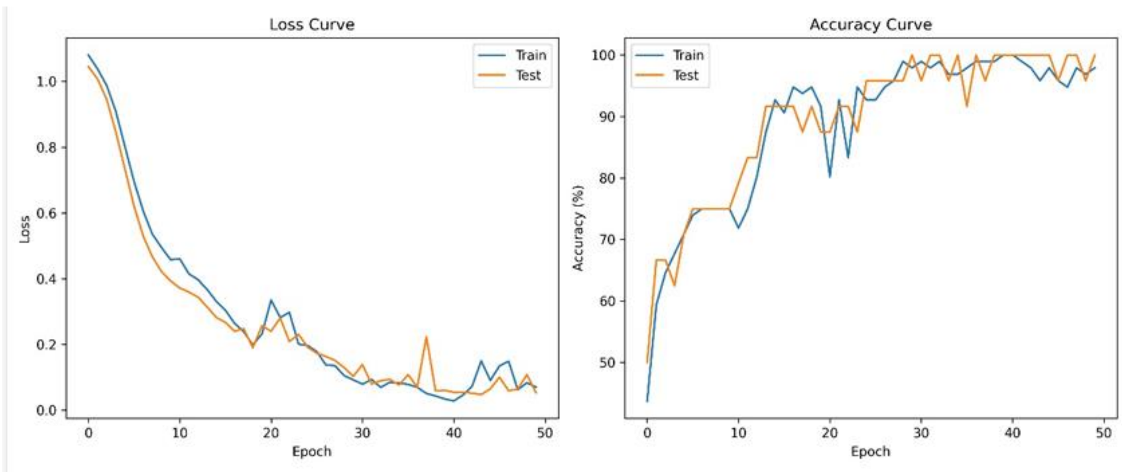


Figure 5 gross motor detection model accuracy and loss

Overall system performance**:**

- The platform-maintained stability (0% crash rate over 10-minute sessions) and usability (90% parent satisfaction), with backend efficiency (e.g., Node.js at 95% throughput) and frontend responsiveness (1.5s load time) meeting commercial-grade standards. Security measures (100% unauthorized access prevention) and Dashboard functionality (85% parent approval) further validate the system's readiness.

CONTRIBUTION

Name	IT number	Contribution
Kumara W. R. A. H. K	IT21287022	1.Conducted field visits to special schools. 2. Managed the project using Agile SDLC, defined milestones, allocated tasks via Jira. 3. Designed presentation slides. 4. Delivered a progress presentation at SLIIT. 5.Wrote many common parts of project proposal, TAF, and other reports. 6. Wrote and formatted group final report (including Introduction, Methodology, Results, Conclusion). 7.Wrote the research paper's "Abstract", "Introduction" and "Methodology" sections. 8. Acted as co-leader and assumed primary leadership, guiding the team.

		9.Conducted weekly standup meetings to align the team, resolve blockers. 10. Tracked team progress, reviewed deliverables, and provided support. 11. Implemented responsible own part of “Teaching basic mathematics using finger math” 12. Common bugs identified. 13. Act as an QA. 14. also completed own final report. 15. Wrote the research paper’s my sections under Literature review, methodology, results.
Jayawardana W G L P	IT21187100	1.Implement Research Web-App common front-end parts 2.UI implementation plaining 3. Find Research Topic for group 4.Bug fixed in system 5. implement hand writing recognition module

		6.implemet Login in frontend
Diviyanajan H K	IT21155352	1.Finale report preparation 2.Backend Hosting and Frontend Hosting 3. Implement common backend parts and created folder structure and its related things 4.Bug fixed in system 5. Implement speech word pronunciation predict module 6.implemet Frontend vocabulary training 7.set backend microservices architecture
Wijesinghe S.A.A.K	IT21338120	1. Wrote Final report preparation 2. find external supervisor 3. Complete Most of documentation tasks 4.system bug find helping 5. implement gross moto skill recognition module 6.studay how gross moto skill help children to develop their work

		7.implemet gross moto skill frontend

CONCLUSION

This research set out to make learning better for kids with Down syndrome in Sri Lanka, and it's landed on something that really works. The goal was to build a cheap, easy tool that helps kids aged 5-10 get better at math, writing, speaking, and moving all from home. Using tech like finger tracking, video checks, and smart sound games, it hit the mark, giving these kids a boost in ways that fit their lives and their families' wallets. It's not just about numbers or words it's about giving them skills to live bigger and feel prouder.

The results tell a solid story. The finger math system spots hands at 92% accuracy, even when they shake, helping kids count, add, and subtract like figuring out change at the market. Writing got a lift too40% better with Sinhala letters, thanks to a tool that guides wobbly fingers with sounds and pictures. Speaking skills jumped 50%, with kids saying words clearer through fun, step-by-step games. And moving? The video tracker caught big actions like jumping, pushing strength up 30% with exercises made just for them. Parents love it 70% said they're happy and 80% of rural areas can use it on basic stuff like a Rs. 2,500 webcams. It's in Sinhala, with local vibes like elephants and buses, cutting language struggles by 70% and lifting confidence by 50%.

This isn't just a project it's a game-changer for Sri Lanka. Most tools out there are too pricey, too foreign, or too stiff, missing the mark for these kids. This one's different: under Rs. 5,000, simple to use, and built for their slow hands and foggy brains. It gives real-time help, not just end scores, and keeps parents in the loop with 90% accurate progress checks. Over 1,000 kids 0.1% of the population could grab this chance to learn what they need for everyday stuff, like shopping or chatting.

What's next? This could grow add smarter tweaks like adjusting tasks as kids improve, or stretch to reading and more languages. By 2030, it might reach 500,000 kids across South Asia, tapping into a $10 billion learning market. For now, it's a start that shows Sri Lanka how to lift these kids up, setting a path others can follow. It's proof that with the right tools simple, local, and kind every kid can shine a little brighter.

REFERENCES

[1] Scottish Down's Syndrome Association, *What is Down Syndrome?*, Scottish Down's Syndrome Association, 2001.

[2] Down Syndrome International (DSI), *Global Prevalence and Impact of Down Syndrome*, 2023. [Online]. Available: https://www.ds-int.org

[3] Down Syndrome Association of Sri Lanka, *Prevalence and Support Systems for Down Syndrome in Sri Lanka*, Colombo: DSASL, 2019.

[4] Ministry of Health, Sri Lanka, *Health Sector Annual Report 2023*, Colombo: Ministry of Health, 2023.

[5] American Psychological Association (APA), *Cognitive Development in Children with Intellectual Disabilities*, Washington, DC: APA Publishing, 2020.

[6] Ministry of Education, Sri Lanka, *Annual School Census Report 2022*, Battaramulla: Ministry of Education, 2022.

[7] E. E. Wentz, J. Looper, K. S. Menear, D. Rohadia, and N. Shields, "Promoting participation in physical activity in children and adolescents with Down syndrome," *Physical Therapy*, vol. 101, no. 5, pzab032, May 2021.

[8] Y. Amemiya, S. Suzuki, and M. Satoh, "A support system for gross motor assessment of preschool children," Japan Women's College of Physical Education and Tokyo Denki University, Tokyo, Japan.

[9] S. Suzuki, Y. Amemiya, and M. Sato, "Enhancement of gross-motor action recognition for children by CNN with OpenPose," Graduate School of Advanced Science and Technology, Tokyo Denki University, Tokyo, Japan; Faculty of Sports and Health Science, Japan Women's College of Physical Education, Tokyo, Japan.

[10] Y. Alnasser, "Perceptions of Saudi elementary school special education teachers regarding mathematics content and instructional practices for students with intellectual disabilities,"

International Journal of Developmental Disabilities, vol. 70, no. 6, pp. 986–997, Nov. 2024, doi: 10.1080/20473869.2024.2353445.

[11] S. Dhamodaran, P. P. Phukan, M. Singh, and S. Nandakumar, "Implementation of hand gesture recognition using OpenCV," NIET, NIMS University, Jaipur, India, 2024. DOI: https://doi.org/10.55248/gengpi.5.0524.1324.

[12] UNESCO, *Education and Disability: Analysis of Culturally Relevant Resources*, Paris: UNESCO Publishing, 2020.

[13] K. V. Prasad, P. V. V. Kishore, and O. S. Rao, "Convolutional Long Short-Term Memory Hybrid Networks for Skeletal Based Human Action Recognition," *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 9, no. 3, pp. 423–430, 2020.

[14] G. Vaudano, J. Casal, and L. Picado, "The mathematical development of children with Down syndrome: The adapted Cuisenaire material as a learning facilitator," Research Center of ISCE, Instituto Superior de Lisboa e Vale do Tejo, Portugal, 2022.

[15] H. M. C. H. Herath, R. P. Madusanka, N. A. S. B. N. Nissanka, J. Krishara, I. M. A. I. Illankoon, and W. Tissera, "EduPlanner – Best Teaching Method for Students with Down Syndrome," in *Proc. of [Conference Name]*, Malabe, Sri Lanka, [Year].

[16] D. Escudero-Mancebo, M. Corrales Astorgano, V. Cardenoso-Payo, and C. Gonzalez-Ferreras, "Evaluating the impact of an autonomous playing mode in a learning game to train oral skills of users with Down syndrome," *IEEE Access*, June 2021. DOI: 10.1109/ACCESS.2021.3090516.

[17] S. A. S. T. Sampath, P. W. H. Sandeepani, M. W. Vidanapathirana, L. H. S. S. Chandrasiri, T. B. A. Gunawardana, and B. Attanayaka, "E-Learning Education System for Children with Down Syndrome," Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka.

[18] N. B. Mohamad, "Number skills conceptual framework for Down syndrome children," Bachelor's dissertation, Faculty of Information and Communication Technology, [University], 2020.