

Project ID:

R26-IT-006

1. Topic (12 words max)

Multimodal Adaptive AAC-Based English Learning for Autistic Children

2. Research group the project belongs to

SST - Software Systems & Technologies

3. Specialization of the project belongs to

Information Technology (IT)

4. If a continuation of a previous project:

Project ID	N/A
Year	N/A

5. Brief description of the research problem including references (300 words max) – references not included in word count.

Nature and Gravity of the Problem

Autistic children often face significant challenges in acquiring the fundamental English Language competencies such as reading, writing, pronunciation and concept understanding. These challenges arise due to stress responses, sensory sensibilities, motor coordination difficulties and diversity in cognitive processing pace [1]. Existing AAC-based (**Augmentative and Alternative Communication**) [2] learning platforms and early literacy applications employ fixed instructional sequences, uniform feedback strategies and static difficulty levels. Such initiatives fail to accommodate individual differences in stress tolerance, motor ability and interaction behavior, which eventually leads to frustration, disinterest and reduced learning effectiveness. The primary users affected by this problem are **young autistic children** [3] in early learning stages and **special education teachers** who use the AAC tools to educate and support the learning process.

Impact of the Problem

The impact of this problem is primarily **social** and **technical** in nature. From a **social perspective**, the limited availability of adaptive learning resources restricts access to effective education for children with neurological and developmental disorders, contributing to educational exclusion and unequal learning opportunities. From a **technical perspective**, current AAC-based applications lack mechanisms to adapt learning content based on behavioral and interaction data collected from users. This limitation reduces personalization and diminishes the overall effectiveness of these systems in meeting diverse learner needs [4].

Research Cluster and Industry Vertical(s)

This proposed initiative is developed under the research cluster of **Software Systems and technologies** (SST), targeting to cater to the needs of **Education** and **Technology** industry verticals. The following research contributes towards the Sustainable Development Goals [5] of, **Quality Education** and **Reduced Inequalities**. As for the former development goal, we hope to ensure inclusive and equitable quality education through adaptive learning. As for the latter development goal, we wish to provide equal learning opportunities by addressing to the diverse needs of neurodivergent learners through personalized AI-driven innovations.

References

- [1] J. J. Stekelenburg, M. Keetels and J. Vroomen, "Multisensory integration of speech sounds with letters vs. visual speech: only visual speech induces the mismatch negativity," *European Journal of Neuroscience*, p. 1135–1145, 01 04 2018.
- [2] M. o. H. S. L. Family Health Bureau, *Management of Children with Special Needs*.
- [3] A. S. L. H. Association, "Augmentative and Alternative Communication (AAC)," *American Speech-Language-Hearing Association*, 2024. [Online]. Available: https://www.asha.org/practice-portal/professional-issues/augmentative-and-alternative-communication#collapse_1.
- [4] G. R and M. DM, "Teaching receptive vocabulary to two autistic children: A replicated, clinic-based, single case experimental design," *Autism & Developmental Language Impairments*, 27 05 2024.
- [5] U. N. D. P. (UNDP), "Quality education | Sustainable Development Goals," *UNDP Sustainable Development Goals*, [Online]. Available: <https://www.undp.org/sustainable-development-goals/quality-education>. [Accessed 11 01 2025].

6. Brief description of Existing Research and Systems (300 words max)

Summary of Existing Products/Systems

Current AAC applications and early English language learning platforms primarily rely on static curricula with fixed alphabetical instruction and correctness-based feedback mechanisms. Applications such as **ReadAlong** and **Writing Wizard**, although well-designed and accessible for early literacy development, follow predetermined learning paths. These systems offer uniform content progression, fixed feedback timing, and predefined difficulty levels, without adapting to individual learner engagement or learning pace. Feedback is delivered instantly and uniformly, assuming equal benefit across all learners.

Similarly, widely used AAC applications such as **Proloquo2Go**, **Avaz**, and **TouchChat** emphasize symbol selection accuracy and structured vocabulary acquisition rather than adaptive or personalized learning. Speech-based learning tools commonly depend on speech-to-text accuracy as a core performance metric. Writing-focused applications typically assume consistent fine motor abilities, providing fixed letter sequencing and stroke difficulty levels. Concept learning tools also rely on predefined difficulty tiers with minimal responsiveness to real-time learner behavior.

Summary of Existing Research

Existing research largely investigates isolated learning components such as pronunciation assessment, handwriting analysis, or affect recognition within educational environments. Studies have explored these dimensions independently to improve specific aspects of learning performance. However, research efforts rarely integrate these components into a unified, adaptive learning framework. Within AAC-based learning contexts, only limited research has examined personalized feedback mechanisms. There is minimal exploration of adaptive feedback timing or stress-aware feedback modulation tailored to the needs of autistic learners.

Limitations Identified

A key limitation across both existing products and research is the lack of **dynamic adaptivity**. Current systems do not adequately respond to individual learner engagement levels, hesitation, repeated errors, or disengagement. Speech-based systems perform poorly for children with autism due to atypical pronunciation, prosody, or speech motor planning differences. Additionally, writing applications fail to adapt to variations in fine motor performance or fatigue, while concept learning tools lack responsiveness to real-time behavioral cues. Most current applications overlook **behavioral timing data, motor interaction patterns, and stress-related indicators**, despite their relevance for autistic learners. The absence of an integrated, personalized, and stress-aware adaptive framework represents a significant gap in existing AAC-based learning solutions.

7. Brief description of the solution's nature, including a conceptual diagram (maximum 500 words).

The proposed Multimodal Adaptive AAC-Based English Learning platform addresses the gaps identified, through the systematic integration of machine learning, reinforcement learning–inspired adaptation, computer vision, and speech processing techniques within a unified educational framework. Unlike existing AAC applications that rely on static rule-based logic and correctness-only evaluation, this platform operationalizes **adaptive intelligence** by continuously learning from user interaction data and dynamically modifying **instructional strategies** in real time. The novelty of the approach lies not in using a single AI technique, but in **orchestrating multiple lightweight AI components** that collectively support personalization while remaining suitable for early ages.

From a system perspective, **the input layer** consists of **multimodal data streams** captured during natural learner interaction. **Behavioral interaction data** such as response latency, hesitation duration, retry frequency, and task abandonment are collected from touch-based AAC activities. **Motor interaction data** including stroke order, stroke duration, pause frequency, and tracing accuracy are gathered from guided writing interfaces. For pronunciation tasks, raw audio signals are captured and transformed into **acoustic feature representations** using speech signal processing techniques rather than direct speech-to-text conversion, thereby avoiding bias against atypical pronunciation. **Optional visual input** related to learner stress is obtained using the device camera and processed as low-level facial or movement cues under strict ethical constraints.

The **processing layer** uses AI-based adaptation to personalize learning based on learner interaction patterns. Behavioral and motor data are analyzed to estimate individual engagement, learning pace, and difficulty tolerance. A **reinforcement learning–inspired mechanism** adjusts task difficulty, sequencing, and repetition dynamically instead of following fixed instruction paths. **Stress-related interaction cues** guide feedback timing and modality, while pronunciation is evaluated using similarity-based speech analysis to provide gradual, improvement-focused feedback rather than binary correctness.

The **output layer** delivers **adaptive learning experiences** rather than static responses. Learners receive dynamically adjusted image-based concept recognition tasks, motor-informed alphabet sequencing, pronunciation feedback emphasizing progress, and stress-sensitive multimodal feedback. Educators receive **analytical dashboards** summarizing **learner interaction patterns**, **adaptation decisions**, and **longitudinal progress**. Through the combined use of **machine learning** for pattern discovery, reinforcement learning for adaptation, CNNs for stress-related visual processing, and **speech signal modeling** for pronunciation, the system directly resolves the technical and methodological gaps identified in existing AAC research while maintaining ethical, computational, and developmental appropriateness.

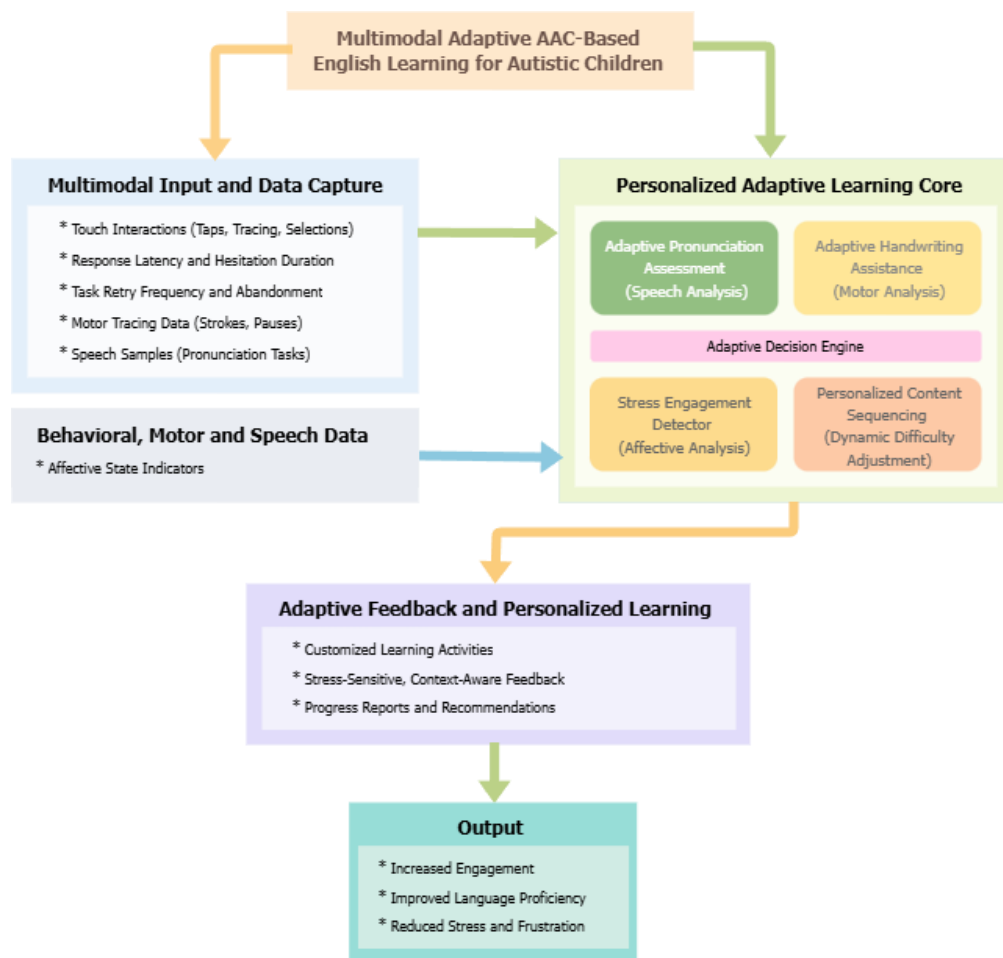


Figure 1 - Conceptual Diagram

8. Brief overview of the availability of necessary specialized domain expertise, knowledge, and data. (500 words max)

Essential domain expertise related to autism spectrum disorder, **augmentative and alternative communication systems**, and early childhood English language learning is gained through close collaboration with a **Special Education School**, where trained special educators provide continuous guidance. Through observations, structured discussions, and feedback sessions, the team gains practical understanding of autistic learners' behavioral patterns, sensory processing differences, attention variability, communication preferences, and effective instructional strategies commonly used **in special education settings**. This real-world exposure is further supported by an in-depth review of academic and **clinical literature on AAC based learning**, autism friendly interface design, adaptive learning methodologies, and inclusive educational technologies, enabling the team to ground system design decisions in established research and evidence-based practices.

The technical knowledge and skills required for the project are developed through a combination of undergraduate coursework, self-directed learning, and hands on implementation. Team members build **competency in mobile application development**, interaction event logging, and adaptive system design using widely adopted programming frameworks and development tools. Additional technical expertise is gained through the study and application of **pretrained machine learning models**, including **lightweight convolutional neural networks (CNN)** for detecting stress related visual cues and speech processing techniques such as MFCC based feature extraction for analyzing pronunciation patterns. **Reinforcement learning** inspired strategies and **rule-based adaptation mechanisms** are explored to support personalized feedback timing and difficulty adjustment, allowing the system to respond dynamically to individual learner interaction patterns while remaining computationally efficient and feasible within the project timeline.

The data required for the project is collected in a non-invasive and ethically responsible manner. Primary data consists of **interaction based behavioral metrics** automatically captured by the application during normal learning sessions, including response latency, hesitation duration, retry frequency, task completion time, task abandonment, and overall engagement duration. These metrics provide sufficient information to analyze learner interaction trends and evaluate the **effectiveness of adaptive mechanisms**. Where applicable, optional visual indicators related to learner stress are captured under supervised and consented conditions using the device camera and are strictly limited to identifying general stress related cues rather than emotional classification or **psychological assessment**. All data collection activities take place in familiar and supportive learning environments to minimize disruption and discomfort for learners, and the project generates its **own anonymized dataset** for analysis rather than relying on external clinical or sensitive data sources.

As the project involves interaction with autistic children, **ethical clearance** is **required** prior to data collection. All collected data will be anonymized, securely stored, and used **solely for academic research purposes**. The research is clearly positioned as an **assistive educational tool** and **does not attempt diagnosis** or clinical evaluation, ensuring that it remains ethically sound, respectful, and aligned with accepted research and educational standards.

9. Objectives and Novelty

Main Objective To design and evaluate a multimodal, adaptive AAC-based English learning system that personalizes feedback, instruction sequencing, and concept difficulty for autistic children using behavioral, motor, and stress-aware interaction data			
Member Name with Registration No	Sub Objective	Tasks	Novelty
H. H. Jayasundera IT22084590	Adaptive Interactive Word and Concept Recognition Module	• Design image-based activities for introducing basic English concepts such as colors using visual and audio stimuli • Implement guided identification tasks where learners select correct images based on simple prompts • Develop interactive game-based activities to reinforce concept recognition through different interactions • Implement a lightweight reinforcement learning mechanism to adapt task difficulty based on learner behavior	Introduces an interaction-driven adaptive learning approach for early English concept recognition. Unlike existing AAC applications with fixed difficulty levels, this component dynamically adjusts concept complexity using learner interaction data, enabling personalized scaffolding tailored to the unique learning patterns of autistic children

		Maintain a learner-specific concept understanding profile to guide future content adaptation	
M. C. Gunawardena IT22166838	Multimodal Stress & Engagement Observer with Adaptive Feedback Controller	- Integrate real-time facial landmark detection and gaze estimation during concept learning activities. - Implement advanced touch behavior analysis capturing pressure, duration, and tap frequency to detect stress patterns. - Implement a stress score calculation using child-specific baselines (normal speed, retry) to detect stress levels automatically - Design adaptive multimodal feedback delivery system that adjusts audio, visual or combination feedback based on detected stress levels - Create educator dashboard displaying real-time stress monitoring and session pattern analysis - Implement a stress profile generation tracking individual stress triggers and recovery patterns per learner - Develop concept progression recommendations based on stress-	Introduces a multi-sensor stress detection and adaptive feedback system for AAC concept learning in autistic children. Unlike existing AAC applications that provide uniform feedback regardless of emotional state, this observer component dynamically analyzes facial expressions, touch behaviors, and engagement patterns to deliver personalized stress-contingent feedback while providing educators with explainable stress analytics and optimal learning window recommendations.

		adjusted mastery assessment from learning outcomes	
R. S. Liluksha IT22216700	Motor-Informed Personalized Alphabet Sequencing	- Establish motor pattern classification logic (curves, straight lines, diagonals, and mixed strokes) and design a trace-based writing interface. - Build a motor performance data collection module (time, pauses, strokes, retries) and assign motor difficulty scores. - Create a personalized alphabet sequencing engine - Apply mastery-based progression and letter family unlocking. - Introduces stress-aware fallback support and perform usability testing and analysis	Current methods also do not involve the motor effort or present letters in order from the entire alphabet. This section describes the revolutionary method using the first letter family approach where the data from the actual motor performance is used to dynamically rank the letters on the criterion of the movements in the strokes. This is the personalized method used in the AAC system which is not used frequently in other systems.
N. G. Samaranayake IT22266378	Sensory-Aware Deep Learning–Based Pronunciation Assessment	- Review on automatic pronunciation assessment, speech similarity modeling, and speech comparison - Identify limitations on pronunciation evaluation approaches for autistic learners. - Prepare reference pronunciation audio samples of letters and simple words	Introduces a similarity scoring system instead of the traditional correct/incorrect format based on the score system provides autism-aware pronunciation feedback by identifying low-scoring sounds

		• Capture real pronunciation audio samples from students • Implement a speech representation model for pronunciation comparison by using a model to extract embeddings from both the reference and the student audio • Identify the lower and high-scoring sounds and generate simple, detailed feedback on the performance of each task given to the student.	
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**10. This part is to be filled by the
Supervisor and the Co-supervisor of the Project.**

- a) This research topic possesses a comprehensive scope suitable for a final-year project.

Yes	✓	No	
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- b) The proposed topic exhibits novelty.

Yes	✓	No	
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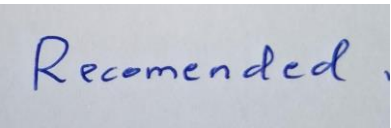
- c) The student group can successfully execute the proposed project.

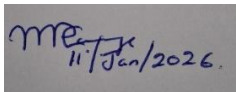
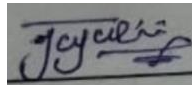
Yes	✓	No	
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- d) The proposed sub-objectives reflect the students' areas of specialization.

Yes	✓	No	
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- e) Any other comments:



	Title	First Name	Last Name	Signature
Supervisor	Senior Lecturer	Manori	Gamage	
Co-Supervisor	Senior Lecturer	Suriya	Kumari	
External Supervisor	Principal	Devika	Jayasiri	
Summary of external supervisor's (if any) experience and expertise She has been serving as the Principal of a Special Education School in Gampaha for the past few years and has extensive experience in supporting children with disabilities, including Down syndrome and Autism				