

Project ID:

R26-IM-005

1. Topic (12 words max)

AR Educational Suite for Primary Students' Geometry and Literacy.

2. Research group the project belongs to

MR - Mixed Reality

3. Specialization of the project belongs to

Interactive Media (IM)

4. If a continuation of a previous project:

Project ID	
Year	

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

Primary school students often struggle to understand 3D geometric concepts like volume and nets because they are taught using static 2D images that do not clearly demonstrate how shapes exist and behave in real space. [1] [3] At the same time, they face difficulties in mastering correct English letter stroke sequences due to the lack of real-time individual supervision in classrooms, and they find it challenging to connect visual objects with corresponding English vocabulary in engaging ways. [7] [8] Current educational systems do not support real-time conversion of student-drawn sketches into validated 3D models, [4] [6] cannot verify whether a hand-drawn geometric net forms a correct 3D structure, lack affordable AI-based gesture recognition optimized for common mobile devices, [10] [11] and fail to integrate geometry learning, handwriting practice, and vocabulary development into a single interactive AR-based learning environment.

The Core Research Problem:

How can a mobile-based AI and Augmented Reality (AR) system be designed to accurately convert student-drawn 2D sketches into validated 3D geometric models, verify geometric net correctness, and simultaneously support English letter stroke guidance and vocabulary learning in a single low-cost, real-time interactive educational environment optimized for primary school learners? (ages 6-12).

Impact of the Problem:

- **Social/Educational:** Persistent difficulties in early-stage geometry lead to long-term disinterest in STEM subjects. Improper writing habits cause "Engagement Issues" and academic frustration. [1] [3]
- **Economic:** Physical educational kits and high-end haptic systems are cost-prohibitive for many local schools.
- **Technical:** There is a significant "Recognition Logic" gap in existing apps, which fail to validate if a student's hand-drawn "Net" is mathematically foldable or if their air-writing follows the correct path. [7] [8]

Research Alignment:

This project is situated within the Mixed Reality (MR) research cluster, utilizing Augmented Reality, Computer Vision, and 3D Object Representation. It falls under the Education industry vertical.

Attainment of Sustainable Development Goals (SDGs):

The problem directly aligns with SDG 4: Quality Education. By providing a low-cost, AR-based solution for mobile devices, it ensures inclusive and equitable quality education and promotes lifelong learning opportunities for students regardless of their geographical location or economic status. [1]

References

- [1] A. D. S. D. V. a. C. D. K. M. B. Ibáñez, "Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness," in *IEEE Global Engineering Education Conference (EDUCON)*, 2014.
- [2] I. Radu, "Augmented reality in education: A meta-review and cross-media analysis," in *IEEE Int. Symposium on Mixed and Augmented Reality (ISMAR)*, 2012.
- [3] H. K. a. D. Schmalstieg, "Mathematics and geometry education with collaborative augmented reality," in *CM SIGGRAPH Int. Conf. on Virtual Reality Continuum and Its Applications*, 2003.
- [4] X. T. a. L. Z. C. Y. Wang, "Sketch2Model: Sketch-based 3D modeling for novice users," in *IEEE Virtual Reality Conference (VR)*, 2011.
- [5] Q. H. W. X. a. X. Z. P. Xu, "Deep learning for sketch-based 3D shape retrieval," in *IEEE Conf. on Computer Vision and Pattern Recognition Workshops (CVPRW)*, 2015.
- [6] Z. L. H. H. E. K. a. Y. Y. X. Han, "eepSketch2Face: A deep learning based sketching system for 3D face modeling," in *Eurographics Symposium on Geometry Processing*, 2018.
- [7] M. G. a. T. S. C. Amma, "Airwriting: Hands-free mobile text input by spotting and continuous recognition of 3D-space handwriting with inertial sensors," in *ACM Int. Conf. on Multimodal Interaction (ICMI)*, 2012.
- [8] Y. X. F. Y. a. C. L. X. Chen, "Online handwritten text recognition using recurrent neural networks," in *Conf. on Document Analysis and Recognition (ICDAR)*, 2015.
- [9] P. X. a. Y. W. S. Yang, "Vision-based air-writing recognition using deep convolutional neural networks," in *IEEE Int. Conf. on Image Processing (ICIP)*, 2017.
- [10] S. G. K. K. a. J. K. S. Molchanov, "Hand gesture recognition with 3D convolutional neural networks," in *IEEE Conf. on Computer Vision and Pattern Recognition Workshops (CVPRW)*, 2015.
- [11] T. S. S.-E. W. a. Y. S. Z. Cao, "Realtime multi-person 2D pose estimation using part affinity fields," in *IEEE Conf. on Computer Vision and Pattern Recognition (CVPR)*, 2017.

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

Current educational systems primarily utilize static 2D visuals in textbooks or standard mobile applications that offer simple click-and-drag interactions. [1] [3] Some advanced AR platforms like Hand- ControlAR allow students to view 3D geometric shapes in a real-world environment using mobile cameras. [1] [2] [3] For literacy, applications like Writey or LetterSchool provide tracing exercises on touchscreens, using simple 2D overlays to guide the user's stylus or finger.

Recent research has shifted toward markerless AR and AI-driven recognition to enhance spatial learning. Studies like Sketch2Model explore transforming 2D free-hand sketches into 3D models using view-aware deep learning. [4] [6] In the domain of literacy, the Rtawr and Trajectory-Based research papers demonstrate the use of Convolutional Neural Networks (CNNs) to recognize "Air-Writing" by tracking fingertip coordinates in a 3D coordinate system (x, y, z). [7] [8] [9] These studies prove that trajectory-based tracking is superior to simple image classification for identifying the movement flow of a writer. [7] [8]

Gaps/Limitations Identified:

- **Lack of Mathematical Validation:** While existing systems can visualize a 3D shape, they lack the Recognition Logic to verify if a student's hand-drawn "Net" is geometrically valid. [4] [6]
- **Passive Feedback:** Most tools provide binary "Correct/Incorrect" feedback rather than Visual Scaffolding, which uses "Ghost Images" to show the exact spatial difference between a student's error and the correct model. [1] [2]
- **Sequential Blindness:** Current literacy apps often focus on the final shape of a letter but fail to monitor the Stroke Order and Direction in real-time, which is critical for long-term handwriting development. [7] [8]
- **Hardware Constraints:** Many air-writing research models require high-performance sensors, leaving a gap for lightweight, Mobile-Optimized finger tracking on standard Android hardware. [7] [10]

Feature / Criteria	AR Geometry Learning Systems [1] [3]	Sketch2Model [4]	DeepSketch2Face [6]	Air-Writing (ICMI) [7]	Online Handwriting (ICDAR) [8]	Gesture CNN (CVPRW) [10]	Proposed System
AR-Based Visualization	Yes	No	No	No	No	No	Yes
2D-to-3D Sketch Conversion	No	Yes	Yes	No	No	No	Yes
Mathematical Net Foldability Validation	No	No	No	No	No	No	Yes
Real-Time Stroke Order Monitoring	No	No	No	Yes	Partial	No	Yes
Trajectory-Based Recognition	No	No	No	Yes	Yes	Partial	Yes
Visual Scaffolding (Ghost Feedback)	No	No	No	No	No	No	Yes
Mobile Optimization for Classroom Use	Partial	No	No	Partial	Partial	Partial	Yes
Integrated Geometry and Literacy Learning	No	No	No	No	No	No	Yes

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

The proposed solution is an integrated, multisensory AR mobile application designed to bridge cognitive gaps in spatial geometry and foundational English literacy. By utilizing markerless AR and AI-driven computer vision, the system transforms passive learning into an interactive, self-correcting experience.

Unlike existing systems that provide binary feedback, this solution introduces Recognition Logic to mathematically validate if a student's 2D hand-drawn sketch can be successfully folded into a 3D volume. It addresses "Sequential Blindness" in literacy by employing a CNN-based Trajectory Recognition system that monitors the specific "Start Point" and "Stroke Direction" of letters in real-time. Furthermore, the system implements Visual Scaffolding through "Ghost Images," which visually demonstrate the difference between a student's error (e.g., an invalid cube net) and the correct geometric structure.

System Perspective (Input, Process, Output):

The system operates as a real-time feedback loop, allowing students to learn through active experimentation and visualization:

Input:

- **Visual Data:** Real-time video feed of a student's hand-drawn 2D net on paper or their finger movements in 3D space (Air-Writing).
- **Audio Data:** Voice input for English pronunciation tasks to trigger interactive 3D rewards.

Process:

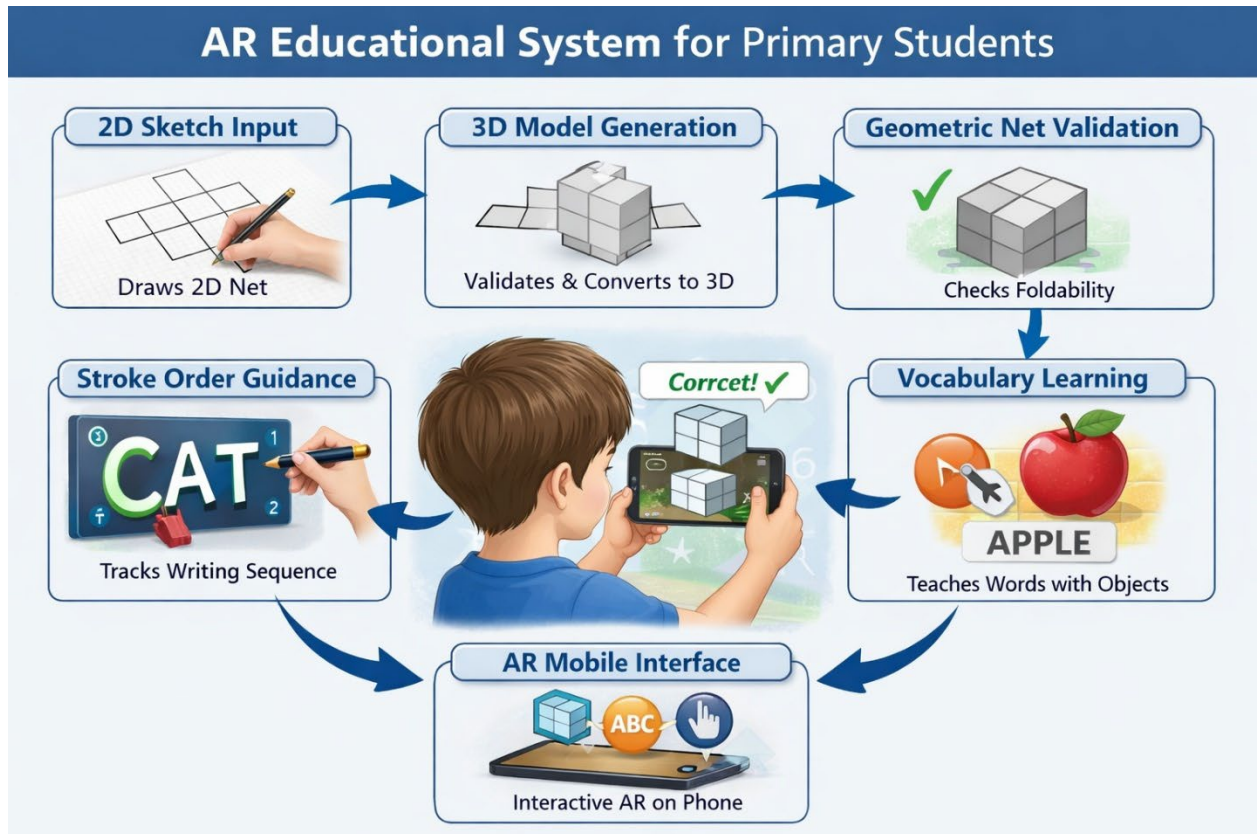
- **Mathematical Validation:** AI algorithms analyze the 2D "Net" to determine if it meets the geometric criteria to form a closed 3D volume.
- **Trajectory Analysis:** A CNN model processes fingertip coordinates to verify the stroke path against a database of standard English character paths.
- **Error Visualization:** When a mistake is detected, the system calculates the overlap difference between the student's input and the correct "Ghost Image".

Output:

AR Overlay: A 3D model appears on the screen, either folding from the 2D sketch or appearing as a reward for correct writing.

Corrective Scaffolding: Transparent "Ghost Images" guide the student's next attempt.

Audio-Visual Feedback: Pronunciation sounds and 3D animations (e.g., a "Cat" meowing after the word is written) to reinforce engagement.



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

The success of this project relies on a multidisciplinary blend of pedagogy, computer vision, and interactive media design. The team has identified clear pathways to bridge knowledge gaps and secure the necessary data for development and validation.

Members will gain specialized expertise in Primary Education Pedagogy and 3D Spatial Cognition by reviewing existing literature on how children perceive geometric volumes and develop motor skills. Consultations with primary grade teachers and educational psychologists will provide insights into the common "weak points" students face with 2D-to-3D transitions and English stroke order. Furthermore, the group will study the SLIIT Faculty of Computing Research guidelines to align the project with institutional standards for Mixed Reality.

Technical Knowledge and Skill Acquisition:

Technical proficiency in Augmented Reality (AR) and Artificial Intelligence (AI) will be acquired through structured learning paths:

- **AR Development:** Utilizing official documentation and community resources for Unity 3D and Vuforia/ARCore to master markerless tracking and 3D object representation.
- **Computer Vision & AI:** Engaging with research papers like Sketch2Model and Rtawr to understand CNN-based trajectory recognition and view-aware 3D modeling.
- **Creative Tools:** Leveraging the team's existing interest in Blender and Maya for UV unwrapping, texturing, and creating the "Ghost Image" scaffolding assets.

Data Collection Strategy:

The project utilizes a two-phase data collection approach:

- **Primary Data (Technical):** Collecting hand-drawn 2D nets and air-writing trajectories from group members and volunteers to train and test the Recognition Logic and CNN models.
- **Primary Data (User-Centric):** Conducting User Acceptance Testing (UAT) and Comparative Learning Analysis (pre-test/post-test) with a target group of students (Age 6-12) to measure system usability and learning retention.
- **Secondary Data:** Analyzing grade-specific science and language curricula to ensure the "Live Sketch-to-Word" game aligns with local educational standards.

Ethical Clearance:

Yes, this project requires Ethical Clearance. Since the research involves interaction with a vulnerable group (minors aged 6-12), the team must obtain formal approval from the SLIIT Ethics Review Committee. This process includes securing informed consent from parents/guardians and ensuring data privacy (anonymization) of all student participants.

9. Objectives and Novelty
Main Objective:

The main objective of this research is to design and develop an integrated, mobile-based Augmented Reality (AR) and Artificial Intelligence (AI) framework that transforms static 2D learning into interactive 3D experiences to overcome spatial visualization barriers in geometry and foundational literacy gaps among primary school students. By utilizing markerless AR and CNN-based trajectory recognition, the system aims to provide a low-cost, accessible educational tool that mathematically validates hand-drawn geometric nets and corrects English air-writing stroke order through real-time, corrective visual scaffolding.

Member Name with Registration No	Sub Objective	Tasks	Novelty
IT22274298 Himsara M.K.D.L.	2D-to-3D Geometry Validation: To develop a recognition logic that mathematically validates hand- drawn 2D nets and converts them into interactive 3D volumes.	- Develop a vision-based algorithm to detect and extract 2D geometric nets from paper sketches. - Create a mathematical validation engine to check if the detected net can physically form a closed cube. - Implement a real-time 3D folding animation based on the validated sketch.	Real-time Mathematical Validation: Unlike current apps that simply display pre-made models, this logic verifies if a student's custom hand-drawn net is geometrically viable before conversion.

IT22179876 De Costa M.M.P.	Adaptive Scaffolding & Virtual Slicing: To implement interactive visual feedback that explains spatial errors through 3D overlapping and volumetric slicing.	- Design "Ghost Image" overlays to guide correct 3D spatial alignment during the folding process. - Build a virtual slicing tool to demonstrate volume fractions (1/2, 1/3) in an AR environment. - Develop an error-comparison module using 3D overlapping visuals to show discrepancies.	Visual Scaffolding (Ghosting): This component replaces standard binary "Correct/Incorrect" feedback with transparent 3D guides that visually explain why a spatial perception failed.
IT22081698 Abhilash K.A.T.W.	AI Air-Writing Trajectory Tracking: To design a CNN-based system that monitors and corrects the specific path and stroke order of English letters in 3D space.	- Integrate finger-tracking using computer vision to capture 3D coordinates (x,y,z) in a mobile environment. - Train a CNN model to recognize trajectory flow and stroke direction. - Implement real-time corrective visual alerts for stroke order errors.	Stroke-Direction Awareness: While traditional apps check the final character shape, this tracks the dynamic movement path to ensure foundational writing habits are established correctly.

IT22214102 Wickramasingha N.N.	Multisensory Phonics Integration: To develop an end-to-end pipeline linking live sketches to animated 3D models via air-writing and pronunciation.	• Create a Sketch-to-Object recognition pipeline using a database of common items (e.g., Cat, Tree). • Develop an audio-visual feedback system for English pronunciation training. • Animate 3D models as "gamified rewards" for correct literacy and pronunciation sequences.	Integrated Cross-Domain Loop: This introduces a unique synergy where a 2D sketch, 3D air-writing, and audio pronunciation must all align to "unlock" an interactive 3D animation.
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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:

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	Title	First Name	Last Name	Signature
Supervisor		Ishara	Gamage	
Co-Supervisor		Nushkan	Nisme	
External Supervisor				
Summary of external supervisor's (if any) experience and expertise				