Integrating AI in VR for Real-Time Assessment and Pedagogical Recommendations

Lucas Yeykelis, Neon Cao, Marie P.P.M. Holm, Nasir Grant, Christopher Eagar, Bryson Rudolph, Anna Queiroz

University of Miami, Coral Gables, FL

Abstract

Virtual reality (VR) is transforming education, yet **leveraging AI for real-time assessment within these environments remains an underexplored opportunity**. We present a framework for integrating generative AI into VR to enable continuous learner assessment and adaptive pedagogical recommendations.

The framework leverages **GPT-4** for real-time performance analysis and personalized activity generation, with a **Teacher Dashboard** featuring conversational AI that analyzes error patterns and generates evidence-based teaching strategies.

We validate this approach through **LexiLearn**, a literacy VR application where learners interact with 3D letter objects while receiving synchronized visual, auditory, and haptic feedback. The AI continuously monitors accuracy, identifies weak points, and adapts difficulty to maintain optimal challenge.

AI Assessment · Virtual Reality · Adaptive Learning · Pedagogical AI · Real-Time Analytics · Generative AI

Introduction

Supporting students in early literacy acquisition remains an urgent challenge in global education. Literacy is a fundamental prerequisite for equitable participation in society—ensuring access to effective literacy education is essential for enabling transformative life opportunities.

The Gap

Currently, most educational environments and digital interventions rely heavily on visual and auditory modalities. However, research indicates that **multisensory and embodied learning** can enhance cognitive processing, memory, and engagement.

While VR offers immersive, embodied learning environments, the potential of artificial intelligence integration for real-time assessment within these experiences remains largely unexplored. We investigate how generative AI can be embedded in VR to provide continuous assessment and adaptive pedagogical recommendations.

Adaptive AI Scaffolding

The AI system functions as both an **activity generator** and an **adaptive scaffold**, dynamically calibrating task difficulty to mirror a teacher's responsive guidance.

- **GPT-4 API Pipeline:** Each round, the AI receives user age, current difficulty (1-10), accuracy from previous round, correct answers, user's actual attempts, and identified error patterns.
- **Two-Phase Priority:** Initial 5 words use age-based calibration; subsequent words shift to accuracy-based priority with a 90% mastery threshold.
- **Error-Driven Generation:** If a learner consistently misspells certain characters, GPT-4 generates targeted practice words containing those patterns.

This creates a personalized learning gradient that maintains optimal challenge within each learner's zone of proximal development.

Real-Time Data Capture

Every learner interaction is logged to **Firebase Firestore** in real-time, creating a comprehensive assessment record. Each round document captures: **userId** (anonymized), **sessionId**, **roundNum**, **category**, **difficulty** (1-10), **roundTime** (seconds), **userAnswers** (character sequence entered), **correctAnswers** (target sequence), **correctRate**, and server **timestamp**.

The **userAnswers** and **correctAnswers** fields enable character-level error analysis which compares what the learner typed against the target, revealing specific letter confusions (e.g., "b" for "d"). The dashboard aggregates this data per-student to compute accuracy trends, words practiced, mistake frequency, and category-specific performance over time.

This granular logging supports both **immediate adaptive responses** (difficulty adjustment after each round) and **longitudinal analysis** (identifying persistent patterns across sessions for teacher review).

Progression Safety Net: To prevent learners from getting stuck, the system tracks attempts at each difficulty level. If a student fails to reach 90% accuracy after 3 attempts, the system advances them with a smaller difficulty increment (+0.25 instead of +0.5), ensuring continued progress while maintaining appropriate challenge.

Classroom Integration: Currently in development is the ability for teachers to generate a unique classroom code through the dashboard. Students enter this code in the VR environment to join their teacher's class, automatically linking their session data to the teacher's dashboard for real-time progress monitoring across the entire classroom.

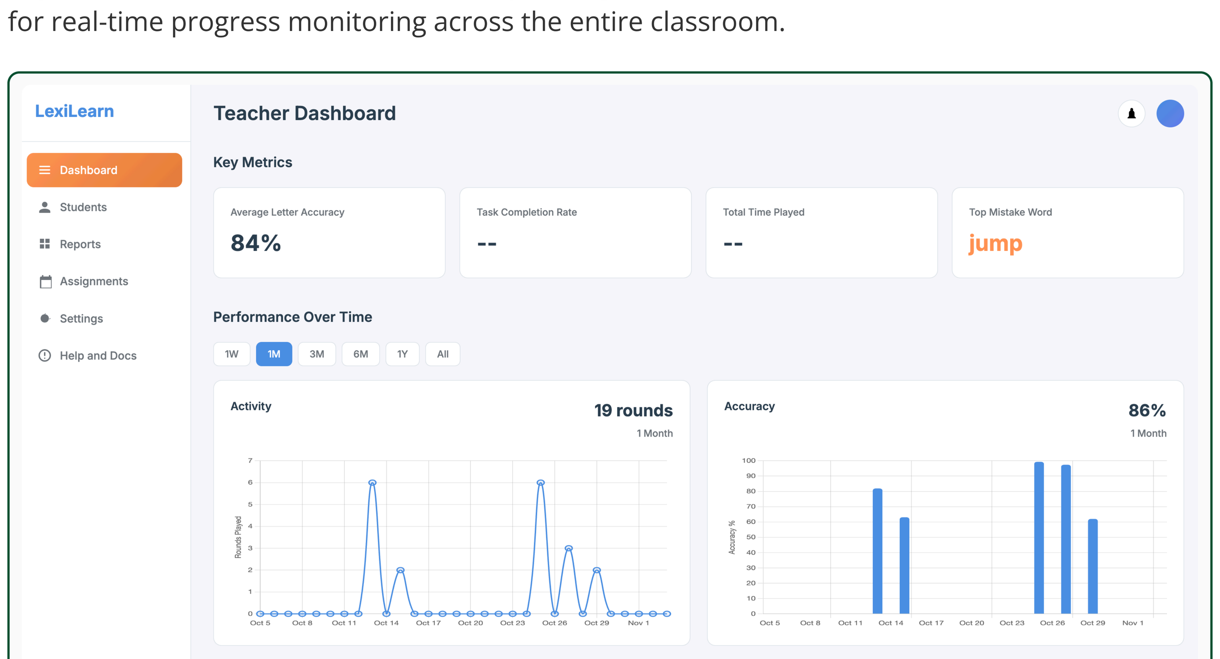


Fig. 2: Teacher Dashboard displaying student performance analytics

AI Assessment Capabilities

Session Metrics: Tracks accuracy rate, response time per word, difficulty progression, and rounds completed. Aggregates data across sessions to show improvement trends and identify persistent weak areas.

Skill Gap Analysis: GPT-4 analyzes error logs to identify specific literacy gaps—letter reversals, phonetic confusion, or silent letter struggles—and generates summary reports for teachers with recommended interventions.

Phoneme-Grapheme Alignment: CMUdict + GPT-4o-mini performs structured JSON alignment mapping letters to sounds, enabling per-character phonetic feedback synchronized with TTS output.

System Architecture

The framework orchestrates multiple generative AI platforms within a continuous assessment loop. The VR application (Unity + XR Toolkit) captures learner interactions and streams performance data to Firebase in real-time. The Teacher Dashboard queries this anonymized data for conversational analytics via a language model.

Content Pipeline: GPT-4 generates age-appropriate words → DALL-E 3 creates visual associations → CMUdict + GPT-4o-mini align graphemes to phonemes → OpenAI TTS synthesizes per-phoneme audio

Data Pipeline: Every interaction logged to Firestore (accuracy, timing, error sequences) → Dashboard aggregates per-student → GPT-4 analyzes patterns → Generates recommendations

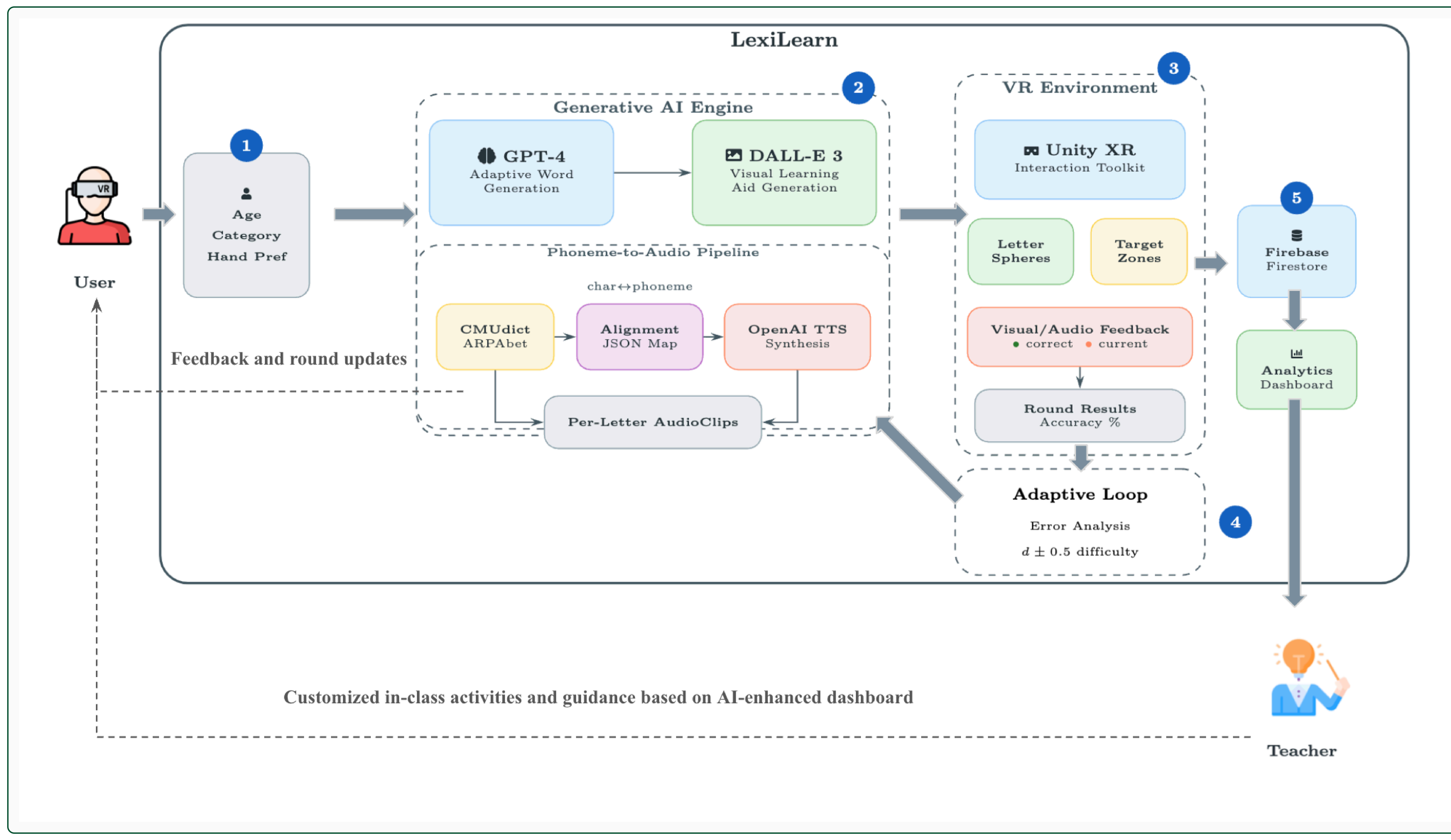
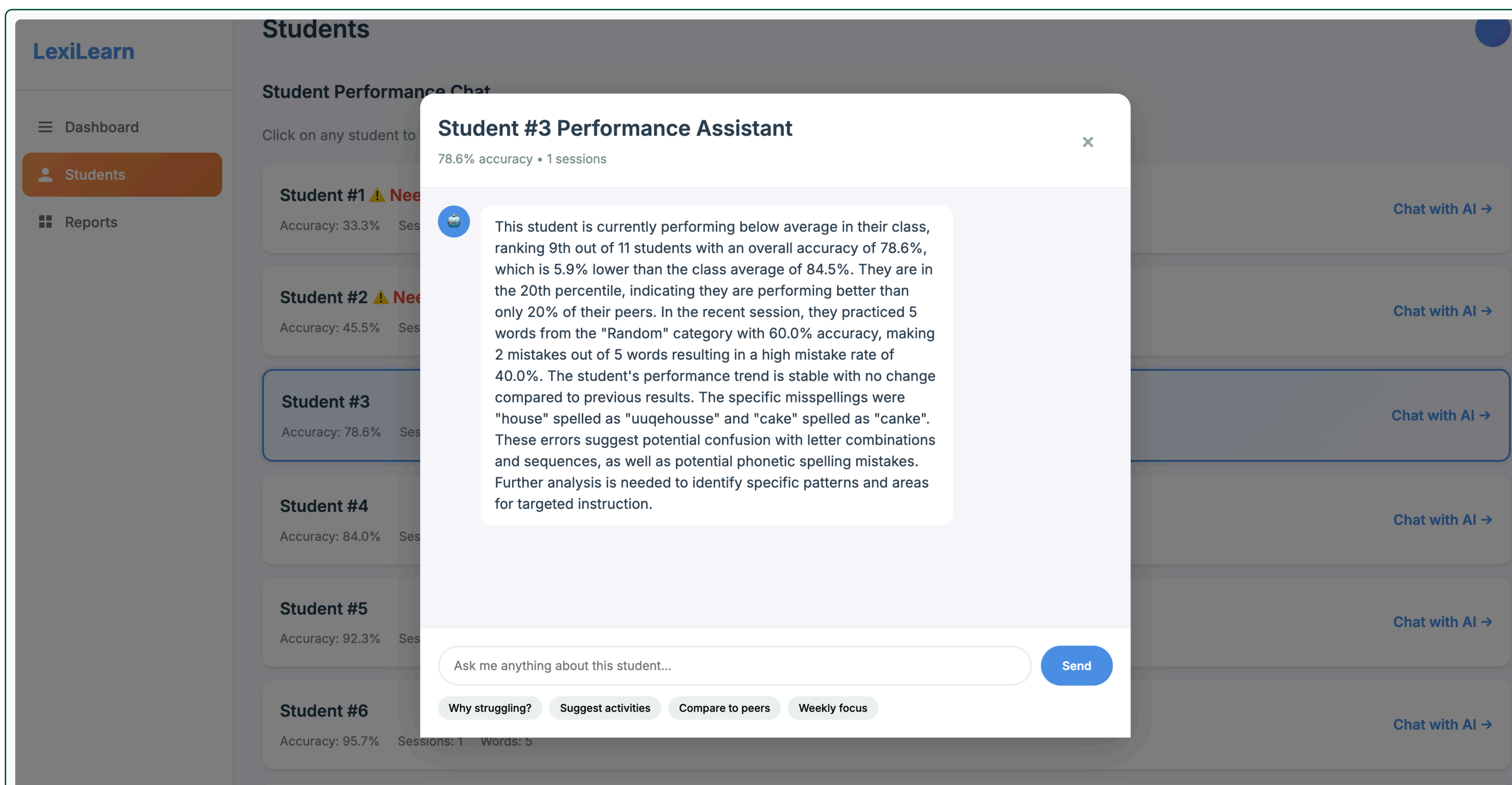


Fig. 1: Real-time data flow between VR application, generative AI services (GPT-4, DALL-E 3, TTS), Firebase, and Teacher Dashboard

AI-Powered Teacher Dashboard



Conversational AI Assistant

Teachers query student data via natural language. GPT-4 receives full performance context and generates evidence-based pedagogical recommendations.

Key Features:

- **Pattern Recognition:** Analyzes misspellings for letter substitutions (b/d, ie/ei), phonetic errors, and silent letter omissions
- **Activity Generation:** Produces 5 classroom activities (3 reinforcement, 2 remediation) with materials and instructions
- **Secure Architecture:** Express.js proxy server holds API keys; browser never exposes credentials

Multisensory Feedback Integration

Research shows that temporal synchronization of haptic, auditory, and visual input creates robust perceptual-motor associations. Our system integrates three synchronized feedback channels:

- **Visual (DALL-E 3):** AI-generated images pair each word with a visual representation, creating multi-path memory traces through dual coding.
- **Auditory (TTS Pipeline):** CMUdict provides phoneme lookup; GPT-4o-mini performs grapheme-phoneme alignment; OpenAI TTS generates per-phoneme audio.
- **Haptic (LRA Gloves):** Linear Resonant Actuators deliver vibrotactile stimulation. Each phoneme maps to a specific vibration pattern.

This multimodal integration supports embodied cognition since body movement establishes action-based memory traces that enhance lexical encoding.

Future Directions

School District Pilots

- Partner with elementary school districts for classroom implementation
- Measure impact on student literacy outcomes
- Study teacher interaction with dashboard and AI recommendations

AI Architecture: Develop custom literacy models grounded in learning science research using fine-tuning or retrieval-augmented generation (RAG); deploy smaller distilled models directly on VR headsets for lower latency and offline capability

Technical Extensions: Multimodal analytics (gaze tracking, gesture recognition); expansion to other domains (math, L2 vocabulary); multiplayer collaborative learning

References & Acknowledgements

[1] Vygotsky (1978). Mind in Society. [2] Paivio (1990). Dual Coding. [3] Ernst & Banks (2002). Multimodal integration. [4] Glenberg & Kaschak (2002). Grounding language in action. [5] Damsgaard et al. (2022). PLAYMORE Project. [6] OpenAI (2024). GPT-4 Technical Report.

Scan for demo video. Supported by University of Miami Frost Institute for Data Science & Computing, The Virtual Experiences and Simulations Lab (VESL) and Future Reality Lab (FRL).