International Journal on Applications in Engineering and Technology
Volume 11: Issue 2 : May 2025, pp 1 –4 www.aetsjournal.com ISSN (Online) : 2455 - 0523

Platform for Visually and Hearing - Impaired People

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Abstract— This project aims to develop an accessible web-based educational platform designed to empower visually and hearing-impaired students. The platform integrates advanced assistive technologies, including screen reader compatibility, Braille-friendly content, and sign language video support, to create an inclusive learning experience. Interactive web-based modules featuring multimodal content (text, audio, video, and tactile graphics) ensure engagement and comprehension for diverse learners. The platform is built following WCAG guidelines and supports adaptive features like high-contrast themes, adjustable fonts, and keyboard navigation. By addressing existing accessibility gaps, this initiative seeks to bridge the educational divide, foster independence, and provide equal learning opportunities for students with disabilities, ultimately contributing to a more inclusive society.

Keywords— Braille-friendly, high-contrast themes, adjustable fonts, and keyboard navigation etc.

I. Introduction

In the evolving landscape of education, digital platforms have transformed how knowledge is accessed and shared. However, the benefits of these platforms are not equitably distributed, particularly for individuals with sensory impairments. Visually and hearing-impaired students often face significant barriers in accessing mainstream digital content due to the absence of integrated assistive technologies, leading to systemic exclusion from equitable educational opportunities [1], [2].

Inclusive education—defined by UNESCO as the process of addressing and responding to the diverse needs of all learners—remains a global priority. Yet, accessibility gaps persist, especially in digital learning environments [3]. Most existing educational platforms offer isolated support features (e.g., captions, screen readers) but rarely combine them into a unified, adaptive solution. This fragmented approach fails to address the real-world needs of students with multiple or complex impairments.

Recent innovations in artificial intelligence, web technologies, and human-computer interaction have paved the way for more sophisticated assistive solutions. For example, text-to-speech (TTS) systems allow visually impaired users to consume textual content audibly, while automatic speech recognition (ASR) enables real-time captioning for the hearing-impaired [4]. Simultaneously, avatar-based sign language interpreters and AI-driven visual alert systems are emerging as viable tools to bridge communication gaps [5], [6]. Wearable and tactile technologies, such as AI-powered haptic devices, further enhance mobility and understanding of visual data for blind individuals [7].

This paper introduces a novel web-based educational platform specifically designed to serve the dual needs of visually and hearing-impaired learners. Unlike conventional tools, this platform integrates multimodal content—text, audio, video, tactile graphics—and supports advanced features such as:

- Real-time text-to-speech and voice command controls for navigation.
- AI-generated visual cues and haptic feedback to enhance non-verbal interaction.
- Avatar-based sign language translation and gamified learning modules for sign therapy.
- Compliance with WCAG 2.1 AA standards to ensure cross-platform accessibility.

The development follows a user-centered design approach, leveraging insights from real users and inclusive design frameworks. By consolidating diverse accessibility features into a unified, adaptive system, this platform aims to overcome the fragmented landscape of current assistive technologies.

The remainder of this paper is structured as follows: Section II reviews relevant literature and prior systems; Section III describes the system design and methodology; Section IV outlines evaluation metrics and user testing results; Section V discusses implications, limitations, and future work; and Section VI concludes the study.

II. Related Work

The field of assistive technology has witnessed significant advances in recent years, particularly in addressing the educational needs of individuals with visual and hearing impairments. However, despite the technological progress, many solutions remain fragmented, addressing only isolated challenges. This section surveys the most recent and relevant developments—spanning avatar-based communication, AI integration, wearable solutions, gamified learning, and inclusive web design—that inform and inspire the integrated platform proposed in this study.

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A. Assistive Technologies for Hearing Impairment

Sign language avatars are emerging as powerful tools for enhancing accessibility in digital platforms. Aziz and Othman [8] presented a comprehensive review of sign language avatar systems, tracing their evolution over four decades and identifying recent improvements in AI-driven animation and facial expression modeling. These avatars are becoming increasingly effective at bridging communication gaps for deaf users when integrated into multimedia systems.

Further development in avatar-based systems was demonstrated by Chen et al. [9], who introduced a mixed-reality design for customizable sign language generation, allowing avatars to adapt to the linguistic and emotional nuances of user interaction. This approach aligns with modern principles of Deaf-Centric design, providing flexibility across diverse communication needs.

Gamification has also been shown to be a useful pedagogical strategy. Alam et al. [10] developed ASL Champ!, a virtual reality-based game incorporating deep learning for American Sign Language recognition. The system encourages active engagement and skill reinforcement through interactive play, which is especially beneficial for children and young learners with hearing impairments.

AI-driven captioning has also made great strides. Tools like Google's Live Caption or Microsoft's accessibility suite provide real-time transcription. Verbit's technology [11], for instance, focuses on enhancing educational experiences with automated captions and transcription tailored for academic environments.

B. Assistive Technologies for Visual Impairment

In parallel, innovations aimed at supporting the visually impaired are equally transformative. Brilli et al. [12] introduced AIris, an AI-powered wearable that uses a camera and real-time feedback to help blind users navigate unfamiliar environments. The integration of AI with haptics ensures non-verbal communication of environmental cues, enhancing independence.

Khan et al. [13] proposed TactileNet, a system capable of converting visual data into tactile graphics, bridging the gap between digital imagery and tactile learning. These systems are particularly useful in STEM education, where understanding complex visual representations is crucial.

Voice-controlled navigation and TTS (text-to-speech) technologies continue to evolve. According to Gotalk.ai [14], TTS systems are not only becoming more natural in tone and inflection but are also being embedded into browser-level extensions to support seamless accessibility. Similarly, Verbatik [15] emphasizes how AI-based TTS enhances comprehension in assessment contexts.

C. Integrated and Inclusive Platforms

Despite these advances, most technologies are deployed as independent solutions. Efforts toward unified platforms are beginning to surface. Microsoft's Accessibility Tools (2024) [16] and Apple's Global Accessibility updates (2023) [17] have introduced frameworks that integrate multiple assistive features—voice, captions, sign language—but often lack deep customization or user-driven adaptability.

ResearchGate studies [18] have highlighted the necessity of personalized interaction models in e-learning tools for blind and deaf students. Adaptive features like font control, color contrast, and gesture-based UI enhancements have proven to be critical for effective engagement.

A critical meta-analysis by Al-Azawei et al. [19] also underscores the importance of Universal Design for Learning (UDL), urging systems to accommodate sensory diversity from inception rather than as an add-on.

D. Socio-Technical and Real-World Impact

Media outlets have begun to spotlight the role of inclusive AI in mainstream society. TIME [20] and AP News [21][22] showcased how AI and smart devices are transforming special education and even enabling blind individuals to experience events like solar eclipses through sound and vibration.

Likewise, community-driven resources such as Battle for Blindness [23] and Scholarly [24] curate top-tier technologies, showing practical implementations of inclusive tools in classrooms. These efforts have proven that low-cost, scalable innovations can create a profound impact when designed with end-users in mind.

Governmental and international support also plays a vital role. The National Center on Deafblindness [25] and AccessiblyApp [26] provide frameworks, toolkits, and datasets to guide ethical and effective assistive tech development.

Despite promising innovations, higher education still struggles to offer consistent accessibility. Reports by The Guardian [27] and TIME [28] stress the ongoing gaps post-pandemic and how funding cuts continue to jeopardize inclusive efforts.

III. PROPOSED SYSTEM

The proposed platform is a comprehensive web-based application designed to support visually and hearing-impaired learners through a single, unified digital environment. The system is built on four foundational pillars:

1. Multimodal Content Delivery
2. AI-Enhanced Assistive Features
3. User-Centric Design
4. Standards-Based Accessibility

The architecture of the platform is modular, allowing scalable integration of features that can be independently updated or enhanced based on user feedback and technological evolution.

A. System Overview

The system consists of three main layers:

1. Presentation Layer (Frontend):

Responsible for user interaction and interface rendering, this layer implements WCAG-compliant components using React.js. All interactions are designed with accessibility-first principles, including ARIA labels, semantic HTML, and responsive layouts.

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2. Application Logic Layer (Middleware/API):

Built using Node.js, this layer handles business logic such as user authentication, profile management, content streaming, and adaptive feature toggling based on user preferences (e.g., visual contrast, sign language, TTS).

3. Data and AI Processing Layer (Backend):

This includes:

• A MongoDB database for storing user settings, educational content, and session data.

• TensorFlow.js models for real-time AI functions including gesture detection, speech-to-text conversion, and visual cue generation.

B. Key Features and Their Architecture

1. Text-to-Speech (TTS) Engine

The TTS module is integrated with browser-native APIs and supports multiple languages. It offers natural-sounding speech output for reading educational material, labels, menus, and system feedback. It includes voice customization and reading speed adjustment.

2. Voice Navigation and Command Interface

This feature allows users with limited motor or visual capabilities to operate the entire platform through vocal commands. It includes command parsing, contextual action execution, and error feedback.

3. Automatic Captions and Sign Language Avatars

Using pre-trained ASR models, the platform can transcribe live audio streams into real-time captions. These captions are simultaneously fed to an avatar rendering engine (based on WebGL and 3D assets) that converts them into animated sign language representations using dynamic gestures.

4. Gamified Sign Language Therapy

The platform includes interactive sign language learning modules that use webcam input to recognize user gestures. It provides feedback and progression scores, motivating continuous learning through gameplay.

5. AI Visual Cue Generator

Alerts and system messages are converted into visual signals (color-coded popups, icon flashes, etc.), replacing audio alerts for deaf users. These cues are dynamically triggered based on user interaction and system state.

6. Tactile Feedback Integration

For users with compatible haptic devices, the system delivers vibration-based feedback confirming actions such as form submissions, navigation changes, or incorrect input.

7. Adaptive UI Settings

Includes features like:

- Font size scaling
- High-contrast themes
- Color-blind-safe palettes
- Keyboard-only navigation
- Focus highlighting

C. Standards Compliance

The platform is developed to conform to WCAG 2.1 Level AA guidelines, ensuring compatibility with screen readers (NVDA, JAWS), braille displays, and voice control tools. Additionally, the architecture is aligned with Universal Design for Learning (UDL) principles to ensure content accessibility across varying cognitive and sensory needs.

IV. Proposed Methodology

This project aims to develop a feature-rich, inclusive Learning Management System (LMS) tailored specifically for individuals with hearing and visual impairments, offering a unified platform that addresses their diverse accessibility needs. Our methodology focuses on delivering a state-of-the-art, web-based application that integrates accessibility tools rarely found together in a single system.

A. User-Centric Accessibility Design

We adopt a universal design approach to ensure inclusivity from the ground up. The platform supports:High-contrast mode, customizable text size, and dark mode to assist users with complete or partial blindness, low vision, and color blindness.

Text-to-speech functionality, audio navigation, and support for keyboard-only interactions, enabling full access for blind users.

B. Sign Language Generator and Interpreter

For users who are deaf or non-verbal, the platform features a real-time sign language generator. This AI-powered tool converts spoken or written content into sign language animations, bridging the communication gap in learning environments. Additionally, support for video captioning and text-based learning materials will be integrated.

C. Feature Integration and Innovation

The novelty of this project lies in consolidating a wide range of accessibility features into a single, user-friendly web application. While existing platforms may address individual disabilities, our methodology ensures that all accessibility tools are available in one coherent system, designed to serve the educational needs of all differently-abled learners.

D. Iterative Development with Real-World Testing

We will engage with target users (students and teachers from special schools) throughout development, conducting usability testing and incorporating their feedback. This ensures our features remain practical, intuitive, and genuinely impactful.

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