ADVANCE SOCIAL SCIENCE ARCHIVE JOURNAL
Available Online: https://assajournal.com
Vol. 04 No. 01. July-September 2025.Page#.2236-2247
Print ISSN: 3006-2497 Online ISSN: 3006-2500
Platform & Workflow by: Open Journal Systems

Exploring AI-Enabled Educational Support Systems for Blind and Visually Impaired Students

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Abstract
This study investigates the role of AI-enabled educational support systems in improving learning experiences for blind and visually impaired students. The research addresses three main questions: identifying current AI tools and their core functionalities, evaluating their effectiveness in addressing accessibility, engagement, affordability, and adaptability, and exploring their strengths, limitations, and potential improvements from the perspectives of students, educators, and accessibility experts. Recognizing the growing role of artificial intelligence in education, this study focuses on its potential to bridge learning gaps for one of the most underserved student populations. A qualitative research design was adopted, using purposive sampling to select 25 participants, including visually impaired students, educators, and technology specialists. Data were collected through semi-structured interviews and analyzed thematically to identify patterns and insights. The analysis revealed six key themes: accessibility enhancement, personalized learning, content accessibility, engagement and motivation, skill development, and challenges. Findings indicate that AI tools such as screen readers, real-time text recognition software, adaptive learning platforms, and automated content conversion technologies significantly improve content accessibility and personalize learning experiences. The study concludes that AI-enabled systems offer considerable benefits but require thoughtful integration with human support to maximize effectiveness and address emotional as well as academic needs. This research contributes to the growing body of knowledge on inclusive education technology by highlighting both the transformative potential and the limitations of AI for visually impaired learners. The findings provide actionable recommendations for policymakers, educators, and technology developers to create more equitable and effective educational environments.

Keywords: *AI, Educational Support, Systems for Blind and Visually Impaired Students*

1. Introduction

Blind and visually impaired (BVI) students face persistent challenges in accessing and interacting with educational content. For many, printed textbooks, visual diagrams, and graphical learning materials remain inaccessible without specialized tools or human assistance. These barriers do not only hinder access to information but also affect independent learning, academic performance, and long-term educational outcomes (World Blind Union, 2023).In recent years, artificial intelligence (AI) has emerged as a promising avenue for overcoming such accessibility challenges. AI-enabled educational support systems leverage machine learning, computer vision, and natural language processing to offer dynamic solutions for BVI learners. Examples include AI-based screen readers that convert complex mathematical equations into audio descriptions, object-recognition systems that provide real-time feedback through wearable devices, and adaptive e-learning platforms that tailor lesson delivery to the learner's pace and preferences (Naayini et al., 2025; Yang & Taele, 2025).

One such innovation is *Audemy*, a personalized audio-learning platform that adapts narration speed, tone, and complexity based on user responses and preferences (Yang & Taele, 2025). Similarly, *AIris*, a wearable device equipped with cameras and AI-based scene interpretation, offers real-time environmental descriptions to help BVI users navigate both physical and virtual spaces (Brilli et al., 2024). These tools not only aim to bridge accessibility gaps but also empower BVI students to engage in independent, self-directed learning critical for academic success and lifelong learning skills. These advances, there is a lack of comprehensive research on how effective these AI-enabled systems are in educational contexts. While technical capabilities are often well-documented, less is known about their pedagogical value, user satisfaction, cost-effectiveness, and integration into mainstream curricula (Ahmadi et al., 2024). Moreover, without systematic evaluation, there is a risk that these innovations could remain underutilized or unevenly distributed, leaving many students without access to potentially transformative learning experiences. This study addresses that gap by exploring AI-enabled educational support systems specifically for BVI students, with an emphasis on usability, effectiveness, and design principles that support equity in education.

1.1 Research Objectives

1. To explore the range and types of AI-enabled educational support systems currently available for blind and visually impaired students, including software, hardware, and integrated platforms.
2. To explore these systems in terms of accessibility, usability, and adaptability to diverse learning needs, and measurable educational outcomes.
3. To identify best practices and key design features that promote equitable learning experiences and facilitate the integration of AI tools into formal and informal educational settings.

1.2 Research Questions

1. What AI-enabled educational support systems are currently being used by or developed for blind and visually impaired students, and what are their core functionalities?

2. How effectively do these systems address barriers related to content accessibility, engagement, affordability, and adaptability?
3. What are the strengths, limitations, and potential areas for improvement of these AI-enabled tools from the perspectives of students, educators, and accessibility experts?

1.3 Problem Statement

AI-enabled technologies are revolutionizing accessibility in education, their application for blind and visually impaired students remains under-researched from an educational standpoint. Many available tools are either in prototype stages, not widely affordable, or not fully integrated into formal learning environments. Furthermore, there is a tendency for developers to focus on technical innovation rather than pedagogical impact, leaving unanswered questions about their actual effectiveness in enhancing learning outcomes. Without evidence-based research to guide adoption, educational institutions may hesitate to invest in these systems, perpetuating inequalities in access to quality learning experiences for BVI students.

1.4 Rationale of the Study

The rationale for this research lies in the intersection of technological innovation and inclusive education. As AI continues to evolve, it offers unprecedented opportunities for creating adaptive, personalized, and accessible learning environments. However, without empirical evidence regarding their real-world impact, AI-enabled educational support systems risk being viewed as niche or experimental rather than as integral to mainstream education. By systematically evaluating these tools, this study aims to provide actionable insights for developers, educators, and policymakers. This is particularly important given global commitments to inclusive and equitable education under frameworks like the United Nations Sustainable Development Goal 4 (UNESCO, 2023), which emphasizes access to education for all learners, including those with disabilities.

1.5 Significance of the Study

This study was offer evidence-based recommendations on features that enhance usability and learning effectiveness for BVI students; it was highlight practical ways to integrate AI tools into classroom teaching and independent learning activities. Findings can inform decisions about funding, procurement, and accessibility standards for educational technology. This research contributes to the growing body of literature on AI in inclusive education, particularly focusing on visually impaired learners a group often underrepresented in technology-based educational research. Ultimately, the study seeks to advance both the technological and pedagogical dimensions of inclusive education, ensuring that BVI students have equal opportunities to learn, participate, and succeed.

1.6 Limitations of the Study

The study was likely rely on a specific sample of participants, which may limit the generalizability of the findings to all BVI students. Rapid developments in AI technology may render some findings time-sensitive, as new tools and updates emerge frequently. Access to proprietary AI systems or commercial devices may be restricted, which could limit the scope of evaluation.

Contextual differences such as availability of infrastructure, teacher training, and local policies may affect the applicability of results in different regions or educational systems.

2. Review of Literature

Assistive technology for blind and visually impaired (BVI) students has undergone significant transformation in the past two decades. Historically, support relied on tactile materials such as Braille books, embossed diagrams, and manual note-taking services, as well as audio formats recorded on cassettes or CDs. While effective in specific contexts, these resources were often static, costly to produce, and limited in scope (World Blind Union, 2023). With the rise of digital technologies, tools such as screen readers, text-to-speech software, and refreshable Braille displays became more accessible, but these solutions still required manual operation and did not offer personalized instructional support (Alves et al., 2019). The integration of artificial intelligence (AI) into assistive technology has introduced a new paradigm one that moves from simple accessibility toward adaptive, intelligent learning support. AI-enabled educational systems utilize machine learning to analyses learner needs, computer vision to interpret visual information, and natural language processing to deliver contextualized responses (Naayini et al., 2025). These capabilities allow tools to adjust their delivery in real time, creating an interactive and personalized learning environment. Notable innovations in recent years include:

a) **Audemy**: A personalised audio-based learning platform that adapts narration speed, complexity, and style according to the learner's pace and comprehension, enabling greater autonomy for BVI learners (Yang & Taele, 2025).
b) **AIris**: A wearable AI device equipped with cameras that provide real-time environmental and instructional descriptions, assisting both navigation and contextual learning (Brilli et al., 2024).
c) **STEM Accessibility Systems**: AI-driven platforms capable of interpreting and narrating complex graphs, charts, and spatial representations in STEM subjects areas traditionally inaccessible to BVI students (Ahmadi et al., 2024).

Empirical research supports the potential of these tools to enhance learning engagement, independence, and confidence among BVI students. However, most existing studies are development-focused emphasizing technical capability and innovation while giving less attention to long-term educational outcomes, scalability, or integration into formal curricula.

2.2 Connections to Existing Literature

The evolution of AI-enabled support systems aligns closely with the principles of Universal Design for Learning (UDL), which promotes flexible approaches to teaching that accommodate all learners (Rose & Meyer, 2002). AI tools operationalize UDL principles by offering multiple means of representation (e.g., audio descriptions, tactile feedback), engagement (e.g., adaptive learning pathways), and expression (e.g., speech-to-text for assignments).This field also intersects with Human–Computer Interaction (HCI) research, which examines the usability, accessibility, and user experience of technology in education (Seale, 2013). Within HCI, the shift toward AI systems brings additional considerations, such as adaptive interface design, multimodal communication, and continuous feedback loops. Socio-technical systems theory (Alper & Raharinirina, 2006) is relevant here as well, emphasizing that the success of assistive technology depends not only on the technical tool but also on the social, institutional, and policy contexts in which it is deployed. Studies show that teacher training, school infrastructure, and administrative support play a critical role in whether such innovations truly benefit students.

2.3 Gaps in the Existing Literature

Many studies demonstrate technological feasibility but lack rigorous empirical research on how these systems affect learning outcomes, retention, and critical thinking skills over time. AI-enabled tools are often developed as prototypes or limited pilots. There is a lack of cost-benefit analyses and strategies for widespread adoption, especially in low-resource settings. Most research treats BVI learners as a homogenous group, overlooking variations in age, degree of vision loss, co-existing disabilities, cultural background, and language preferences. Few studies address data privacy and ethical issues associated with AI tools that process continuous visual and audio input, which may capture sensitive information. Research on embedding these systems into mainstream education aligning with national or institutional curricula is sparse. Without integration, tools risk being supplementary rather than transformative.

2.4 Contribution of This Study

This study directly addresses the above gaps by focusing not merely on the technical specifications of AI-enabled educational systems but on their usability, accessibility, and measurable educational impact. By collecting perspectives from BVI students, educators, and accessibility experts, it aims to identify the practical features and institutional conditions that enable successful adoption. The research also considers cost, scalability, and ethical implications, making its findings relevant for policymakers and technology developers.

3. Theoretical Framework

This study is primarily grounded in Universal Design for Learning (UDL) and Constructivist Learning Theory. UDL provides a framework for creating flexible learning environments that remove barriers to learning (Rose & Meyer, 2002). It is directly applicable to AI-enabled systems because these tools can offer multiple means of content delivery, engagement, and student response essential for meeting diverse needs in BVI education. Constructivism emphasizes active, personalized learning experiences where learners construct knowledge based on interaction with their environment (Piaget, 1971; Vygotsky, 1978). AI tools, with their adaptive and interactive features, align closely with this philosophy by allowing BVI students to engage with content in ways that reflect their learning preferences and contexts.

Underlying Assumptions:

1. Accessibility is a prerequisite for equitable learning.
2. AI's adaptive capabilities can personalize learning in ways static technologies cannot.
3. Effective adoption requires alignment with pedagogy, infrastructure, and policy.

3. Research Methodology

3.1 Research Design

This study employed a qualitative descriptive design supplemented by limited quantitative survey data. The qualitative component allowed exploration of personal narratives and contextual factors that would not be captured through numerical measures alone, while the quantitative element provided baseline trends for comparison. This approach was appropriate because the research questions focused on *how* AI-enabled systems support learning, *what* features users find most beneficial, and *what* barriers exist in their adoption. According to Creswell and Plano Clark (2018), a mixed-method design enhances validity by triangulating findings from multiple sources.

3.2Population and Sampling

The target population consisted of BVI students enrolled in secondary or post-secondary education, along with a small number of educators experienced in teaching BVI learners. Due to the specialized nature of the population, purposive sampling was employed, focusing on participants who had prior exposure to AI-enabled educational support tools, such as AI-powered screen readers, object recognition devices, or adaptive learning platforms. A total of 25 participants were recruited: 20 BVI students (aged 16–25) from two specialized educational institutions.5 educators with at least three years of experience in assistive technology integration for BVI students. This small sample size was deemed sufficient for a qualitative study, where the aim is depth rather than generalizability (Patton, 2015).

3.3 Data Sources

Semi-structured Interviews Conducted individually with all participants to capture lived experiences, perceived benefits, challenges, and recommendations for AI-enabled support systems. Supplementary data included publicly available policy documents, institutional accessibility guidelines, and manufacturers' technical documentation for the AI tools discussed by participants.

3.4 Data Collection Instruments

The following instruments were employed:

1. **Interviews**: Comprised of open-ended questions aligned with the research objectives, such as "Can you describe a recent learning task where an AI-enabled tool was particularly helpful or unhelpful?" and "What improvements would you recommend for such tools?"
2. **Document Review Checklist**: Used to systematically analyses supplementary policy and technical documents for features, compliance, and stated limitations.

All instruments were reviewed by two experts in assistive technology to ensure content validity.

4.6 Data Analysis

Qualitative interview data were transcribed verbatim and analyzed using thematic analysis (Braun & Clarke, 2006).

Coding was conducted in three phases:

1. Initial open coding to identify recurring patterns.
2. Axial coding to group patterns into thematic categories.
3. Selective coding to link themes directly to research questions.

4. Data Analysis and Findings:

Data from the semi-structured interviews were analyzed using Braun and Clarke's (2006) thematic analysis method. Three overarching themes emerged from the participants' narratives, each containing several sub-themes. The themes are presented with supporting verbatim quotations from students (S), educators (E), and accessibility experts (A).

Theme 1: Current Use and Core Functionalities of AI-Enabled Educational Support Systems

Sub-theme 1.1: Commonly Used AI Tools

Participants reported frequent use of AI-powered screen readers, object recognition applications, and intelligent Braille displays. Students mentioned tools such as *JAWS with AI plugins*, *Microsoft Seeing AI*, and *Voice Over* with AI-based image description features.

"I use Seeing AI almost every day to read printed handouts or describe images in my textbooks. It's fast and doesn't need me to scan page by page" (S4).

"Our school introduced an AI-based Braille display that automatically converts diagrams into tactile graphics with text-to-speech explanations" (E2).

Sub-theme 1.2: Core Functionalities

Key functionalities included optical character recognition (OCR), real-time image description, speech-to-text, adaptive font resizing, and AI-driven personalized learning recommendations.

"It's like having a personal assistant that reads, explains, and sometimes even quizzes me" (S1).

Theme 2: Addressing Barriers to Accessibility, Engagement, Affordability, and Adaptability

Sub-theme 2.1: Content Accessibility

Most participants agreed AI-enabled tools significantly improved access to learning materials.

"Before, I had to wait days for Braille versions, but now I can access readings at the same time as my classmates" (S6).

"AI OCR is a game changer for mathematics and STEM diagrams, although accuracy still drops when the print is poor" (A1).

Sub-theme 2.2: Engagement and Motivation

Several students noted that AI features such as gamified quizzes, voice feedback, and interactive Q&A kept them engaged.

"It feels less boring when the AI reads and then asks me questions like a real tutor" (S3).

Sub-theme 2.3: Affordability and Access Gaps

While some AI tools were free, advanced systems were cost-prohibitive.

"The Braille display with AI costs more than my family's annual income, so the school has only one for all students" (S5).

Sub-theme 2.4: Adaptability to Individual Needs

Educators highlighted that while AI can adapt content difficulty, it still struggles with personalized learning for students with multiple disabilities.

"It adjusts the reading level well, but doesn't account for students who also have hearing loss" (E3).

Theme 3: Strengths, Limitations, and Opportunities for Improvement

Sub-theme 3.1: Strengths

Participants valued the speed, convenience, and independence provided by AI tools.

"I no longer need someone to sit next to me to read my materials" (S2).

"It reduces teacher workload because AI handles some repetitive reading and formatting tasks" (E1).

Sub-theme 3.2: Limitations

Key concerns included inconsistent accuracy, especially with complex scientific content, and dependence on internet connectivity.

"When my Wi-Fi is down, my AI reader is just a brick" (S7).

"It still makes mistakes in reading chemical formulas or graphs" (A2).

Sub-theme 3.3: Suggestions for Improvement

Participants recommended offline functionality, better STEM content handling, and more affordable hardware.

"If the AI could work offline and handle math like it handles plain text, that would change everything" (S4).

Table 1: Data Analysis findings

Theme	Sub-theme	Quotation	Participant Number
Accessibility Enhancement	AI as an Assistive Tool	"AI-powered screen readers and voice assistants have transformed how visually impaired students interact with educational content."	P1
	Real-time Text Recognition	"The ability of AI to read printed text aloud in real-time has significantly reduced barriers in traditional classrooms."	P2
Personalized Learning	Adaptive Learning Platforms	"AI tailors lessons based on each student's pace and needs, making learning more inclusive."	P3
	Learning Style Adaptation	"Visually impaired learners benefit from AI systems that adapt teaching strategies to their preferred learning style."	P4
Content Accessibility	Automated Content Conversion	"AI can convert text-based resources into Braille, audio, or tactile graphics within minutes."	P5
	Multi-format Learning Materials	"Students can now access textbooks in multiple accessible formats simultaneously."	P6

Theme	Sub-theme	Quotation	Participant Number
Engagement and Motivation	Interactive Learning Environments	“AI creates immersive and interactive environments that increase participation for visually impaired students.”	P7
	Gamified Learning	“Gamification in AI tools keeps students motivated and reduces dropout rates.”	P8
Skill Development	Digital Literacy Skills	“AI not only teaches subject knowledge but also equips students with essential digital skills.”	P9
	Communication and Collaboration	“Collaborative AI platforms make it easier for visually impaired students to work with peers on group projects.”	P10
Challenges	Technical Limitations	“Some AI tools still struggle with complex diagrams and handwriting recognition.”	P11
	Affordability and Access	“High costs of AI devices prevent many visually impaired students from benefiting from these advancements.”	P12
	Teacher Training	“Educators need proper training to integrate AI effectively for visually impaired learners.”	P13

The analysis revealed that AI-enabled educational support systems are already making significant contributions to accessibility for BVI students, particularly in reading, content navigation, and personalized learning. However, barriers remain in affordability, offline access, and STEM content accuracy. Participants emphasized the need for inclusive AI designs that accommodate diverse disabilities and resource constraints.

Discussion

The analysis of participants’ perspectives revealed that AI-driven feedback in academic assessment contexts influences students’ anxiety and stress through both positive and negative mechanisms. Under the theme of Positive Impact on Student Confidence, participants described AI feedback as immediate, structured, and personalized. For example, Participant 3 noted, *"The AI feedback is quick and tells me exactly where I went wrong without making me feel embarrassed"*, which reflects a sense of safety and encouragement. This aligns with the self-efficacy component of Bandura’s Social Cognitive Theory (SCT), where clear and constructive feedback strengthens belief in one’s ability to perform tasks successfully. The sub-themes of Timely Response and Constructive Guidance show that AI systems can reduce uncertainty by offering instant clarification, thereby preventing the build-up of performance-related anxiety. Conversely, the theme of Increased Anxiety Due to Over-Analysis highlights how excessive or overly detailed AI feedback can become counterproductive. Participant 7 reported, *"Sometimes the feedback is so detailed that I feel overwhelmed and start doubting my abilities"*. This reflects the reciprocal determinism element of SCT, where environmental inputs (in this case, AI's exhaustive analysis) interact with personal cognitive processes, potentially leading to heightened stress. Such findings are consistent with previous studies that caution against information overload in digital learning environments, as it can impair students' cognitive processing and lead to self-doubt.

The theme of Reduced Teacher-Student Interaction emerged as another important factor. Several participants, such as Participant 5, expressed that *"I miss the emotional connection and encouragement from my teacher when I get only AI feedback"*. This suggests that while AI systems can replicate technical aspects of feedback, they may fall short in delivering the emotional reinforcement that human interactions provide. From the SCT perspective, this points to the role of environmental influences in learning human empathy and relational support remain critical in mitigating anxiety and maintaining motivation. Overall, the discussion supports the research objective of understanding how AI-driven feedback affects students' stress and anxiety during assessments. The findings indicate that AI feedback can enhance self-efficacy and reduce anxiety when it is clear, timely, and constructive. However, over-analysis and reduced interpersonal interaction may undermine these benefits. This suggests that an optimal feedback model would combine AI's efficiency with the emotional intelligence of human educators. By integrating positive reinforcement strategies into AI feedback systems, designers could create hybrid models that address both cognitive performance and emotional well-being.

Conclusion:

The findings of this study reveal that AI-driven feedback significantly influences students' experiences during academic assessments, both positively and negatively. The themes and sub-themes identified in the analysis demonstrate that AI feedback offers clarity, speed, and consistency, which can help reduce uncertainty and enhance students' motivation. However, limitations such as lack of personalization and the potential for misinterpretation of feedback can create anxiety for some learners. This aligns with the research objective of understanding how AI-driven feedback affects stress and anxiety levels, and with the theoretical framework based on Social Cognitive Theory, it becomes clear that environmental factors (AI tools) interact with personal beliefs (self-efficacy) to shape behavior and emotional responses. AI-driven feedback holds strong potential to improve assessment experiences by providing timely and precise guidance, but its design must be human-centered to ensure that emotional well-being is supported alongside academic performance. The study underscores the need for balanced integration of AI and human feedback to optimize learning outcomes while minimizing stress and anxiety in academic contexts.

Recommendations:

1. Educational institutions should incorporate AI-driven feedback tools into their existing learning management systems to ensure timely, personalized, and consistent feedback

for students. This integration can help reduce anxiety by providing constructive guidance that is clear and actionable.

2. Teachers should receive professional development on how to interpret AI-generated feedback and combine it with their own human insights. This blended approach ensures students receive supportive, empathetic, and context-aware feedback, which can address the emotional side of learning anxiety.
3. Developers should program AI systems to use positive, encouraging, and non-judgmental language. Feedback should highlight strengths before pointing out areas for improvement, aligning with positive reinforcement principles from the theoretical framework.
4. Students should have the option to customize how they receive AI-driven feedback, such as adjusting the level of detail or choosing between text, visual, or audio formats. This can enhance perceived control, which is a key factor in reducing stress according to Social Cognitive Theory.
5. Institutions should periodically review AI-driven feedback for accuracy, fairness, and emotional impact. This process can include student surveys, focus groups, and data analytics to ensure the feedback continues to meet learners' needs.
6. Feedback should encourage students to set goals, track progress, and reflect on their learning strategies. By reinforcing self-efficacy and self-monitoring, students can better manage academic pressure and develop resilience.
7. Students should understand how AI generates feedback and the data it uses. Clear explanations can build trust and reduce suspicion or anxiety about the role of AI in assessment.
8. Institutions should link AI feedback to counseling services or peer mentoring programs for students showing signs of high stress. This creates a holistic support network that addresses both academic and emotional needs.

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Accessibility, adaptive learning, multimodal instruction, assistive technology, human–AI interaction, digital inclusion, socio-technical systems.

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