Proceedings of the 17th International Scientific and Practical Conference «International Forum: Problems and Scientific Solutions»

(September 26-28, 2026). Melbourne, Australia

No 311

INTERCONF
Scientific Publishing Center

PEDAGOGY AND EDUCATION

Modern Approaches to the Use of Digital Resources in Teaching Children with Visual Impairments

Mirzakhmedova Ulzhan[1],
Abayeva Galiya[2], **Kemeshova Akkumis**[3]

[1]2nd-year Doctoral Student, Educational Program 8D01901 - Special Pedagogy;
Abai Kazakh National Pedagogical University; Almaty, Kazakhstan

[2]PhD, Professor, Director of the Institute of Pedagogy and Psychology;
Abai Kazakh National Pedagogical University; Almaty, Kazakhstan

[3]Department of Special Pedagogy;
Abai Kazakh National Pedagogical University; Almaty, Kazakhstan

Abstract. This article provides a critical analytical synthesis of contemporary approaches to the use of digital resources in the education of children who are blind or have low vision. The analysis moves beyond a technology-centred understanding of digitalization and treats accessibility as a pedagogical design principle that must be embedded in curriculum, instructional interaction and assessment. Drawing on recent systematic and scoping reviews, accessibility standards and Universal Design for Learning (UDL), the paper systematizes digital resources into six interrelated groups: accessible textual resources, screen-reader and refreshable-Braille environments, audio and audio-described content, tactile-digital and multimodal resources, mobile and cloud-based learning tools, and emerging AI-supported interfaces. Particular attention is given to the distinction between formal technical accessibility and meaningful educational accessibility. A resource may comply with technical requirements yet remain pedagogically inaccessible when navigation is cognitively overloaded, visual information lacks an equivalent representation, tasks depend on drag-and-drop interaction, or teachers do not explicitly teach the assistive-technology skills required for independent use. The article proposes a pedagogical model based on four principles: multimodal equivalence, learner-controlled adaptability, compatibility with assistive technologies, and purposeful integration with corrective-developmental objectives. It is argued that effective digital inclusion requires coordinated work by classroom teachers, teachers of students with visual impairments, families, developers and support specialists. The paper concludes with practical criteria for selecting and designing digital resources and identifies research priorities related to learner autonomy, long-term outcomes, AI accessibility, multilingual resources and evidence from school-age populations.

Keywords: *visual impairment, blindness, low vision, digital resources, assistive technology, accessibility, inclusive education, Universal Design for Learning, screen reader, digital pedagogy.*

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

Introduction

Digital transformation has changed the architecture of schooling: textbooks are increasingly complemented by learning-management systems, interactive platforms, mobile applications, digital libraries, simulations, multimedia and AI-supported services. For children with visual impairments, however, the educational value of this transformation is not determined by the mere presence of technology. It depends on whether digital content can be perceived, navigated, interpreted and used independently through vision, hearing, touch or a combination of these modalities. A recent scoping review of digital accessibility for people with visual impairment and blindness, based on 49 included studies, showed that many applications and websites continue to communicate essential information visually without equivalent alternatives for users of assistive technologies [1]. Thus, digitalization can reduce barriers, but it can also reproduce or intensify them.

The educational problem is especially important because access is not identical to participation. A learner may technically open an electronic textbook and still be unable to locate headings efficiently with a screen reader, understand an unlabeled diagram, complete a visually structured matching task, or submit an answer through an inaccessible interface. In this sense, the central methodological question is not "Which technology should be used?" but "How should digital resources be pedagogically designed and integrated so that a learner with visual impairment can construct knowledge, act independently and demonstrate achievement on equitable terms?"

The relevance of this question is reinforced by evidence from rehabilitation and educational research. A systematic review of interventions for visually impaired and blind adolescents found that most identified studies focused on making curriculum content more accessible through audio, tactile or electronic means, while the overall evidence base remained limited and heterogeneous [2]. The finding is methodologically significant: educational practice is developing faster than the body of rigorous evidence that can guide decisions. Therefore, a contemporary framework should combine available empirical findings with established accessibility standards, principles of special pedagogy and learner-centred instructional design.

The purpose of this article is to systematize contemporary approaches to the use of digital resources in teaching

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

children with visual impairments and to formulate pedagogical conditions under which digital technologies support not only access to information but also comprehension, autonomy, participation and educational achievement. The objectives are: (1) to clarify the conceptual distinction between digital availability, technical accessibility and pedagogical accessibility; (2) to classify the principal types of digital resources used with blind and low-vision learners; (3) to identify methodological principles for their selection and adaptation; (4) to examine current barriers and risks; and (5) to propose a practice-oriented model for integrating digital resources into inclusive and special education.

Methodological Framework

The article is a conceptual and analytical review rather than an empirical intervention study. Its methodological basis combines comparative analysis, synthesis and pedagogical interpretation of recent peer-reviewed reviews and studies, together with internationally recognized accessibility and instructional-design guidance. Priority was given to sources published from 2023 onward that directly address visual impairment, assistive technology, digital accessibility or inclusive digital learning, while foundational normative frameworks were used to define design principles.

Two complementary frameworks structure the analysis. First, the Web Content Accessibility Guidelines (WCAG) 2.2 organize digital accessibility around four principles: content should be perceivable, operable, understandable and robust [3]. These principles are technically oriented but pedagogically consequential. Second, CAST's Universal Design for Learning Guidelines 3.0 emphasize reducing barriers through multiple means of representation, action and expression, and engagement; the 2024 revision explicitly strengthens attention to exclusionary systems and learner agency [4]. For children with visual impairments, these frameworks converge around a key requirement: information and learning activity must not depend on a single sensory channel or a single mode of interaction.

The analysis also adopts a typhlopedagogical perspective. Visual impairment changes the conditions under which information is acquired, not the learner's entitlement to conceptual complexity. Consequently, adaptation should preserve the cognitive goal while modifying the perceptual route, the interaction mechanism or the response format. This distinction is crucial. Replacing a complex map with a

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

simplified verbal summary may make a task easier, but it can also remove spatial reasoning from the learning objective. High-quality adaptation therefore seeks functional equivalence rather than curricular reduction.

From Technical Accessibility to Pedagogical Accessibility

Digital accessibility is frequently treated as a compliance issue: alternative text is added to images, keyboard navigation is enabled, contrast is increased and form controls are labeled. These measures are indispensable, but they represent only the first layer of access. WCAG 2.2 defines testable success criteria under the four principles of perceivability, operability, understandability and robustness [3]. Yet educational accessibility additionally requires that the resource support the learner's actual cognitive task. A technically accessible interface may still impose excessive navigation, fragment information into poorly ordered elements, or provide alternative text that names an image without explaining its educationally relevant relationships.

Pedagogical accessibility can therefore be understood as the degree to which a digital resource enables a learner to reach the intended learning outcome with reasonable effort, appropriate independence and no unnecessary sensory barrier. This definition shifts attention from the file or application alone to the interaction among learner, task, assistive technology, teacher support and curriculum. CAST similarly stresses that providing a tool is not sufficient; learners may need explicit support to use accessible and assistive technologies effectively, while instructional technologies should not create barriers to those tools [5].

This distinction has direct implications for teacher practice. Before assigning a digital resource, the teacher should test not only whether it opens with a screen reader or can be magnified, but whether the sequence of headings is logical, interactive controls are announced correctly, visual relationships are represented meaningfully, time limits are adjustable, and the learner can complete the task without continuous sighted mediation. Independence should be treated as an instructional outcome, not merely a convenience.

A Contemporary Typology of Digital Resources

Current digital resources for learners with visual impairments can be grouped according to the dominant mode of access and the pedagogical function they perform. The categories overlap in practice, and the most effective learning environments typically combine several of them.

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

PEDAGOGY AND EDUCATION

Table 1

Functional classification of digital resources for teaching learners with visual impairments.

Resource group	Examples	Pedagogical function	Key accessibility conditions
Accessible text and e-books	Structured HTML/EPUB, accessible PDF/DOCX, digital libraries	Reading, searching, note-taking, independent study	Semantic headings; correct reading order; reflow; text alternatives; keyboard access
Screen-reader and Braille environments	Screen readers, refreshable Braille displays, Braille notetakers	Literacy, navigation, writing, information retrieval	Meaningful labels; keyboard operability; predictable focus; compatible math/symbol notation
Audio and audio-described resources	Audiobooks, podcasts, narrated lessons, audio description	Concept introduction, review, access to visual events	Concise educational description; navigation by section; transcript; learner-controlled playback
Tactile-digital and multimodal resources	Tactile graphics with audio labels, haptic interfaces, 3D models, tangible-audio systems	Spatial concepts, STEM, diagrams, maps, object relations	Tactile clarity; audio-tactile correspondence; guided exploration; manageable information density
Mobile and cloud learning	Accessible apps, LMS, collaborative documents, cloud storage	Communication, homework, formative assessment, collaboration	Large targets; clear navigation; scalable text; contrast; feedback; screen-reader compatibility
AI-supported resources	OCR, image description, conversational interfaces, text simplification, speech technologies	Rapid access, explanation, drafting, navigation support	Human verification; privacy; bias awareness; age-appropriate use; accessible interface

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

Accessible Text, Screen Readers and Refreshable Braille

For blind learners, accessible text remains the foundation of digital academic participation. Screen readers transform interface elements and text into synthesized speech, while refreshable Braille displays provide tactile access to the same digital information. These technologies are most effective when documents have semantic structure rather than merely visual formatting. Headings, lists, tables, links and form fields should be encoded so that assistive technology can identify their roles. A visually attractive worksheet that consists of text boxes positioned on a page may be substantially less accessible than a simpler document with a clear heading hierarchy and linear reading order.

Refreshable Braille has a distinctive pedagogical value because it preserves orthographic, punctuation and spatial information that may be less salient in continuous speech output. For beginning readers and for tasks requiring precise spelling, terminology or symbolic notation, audio and Braille should be viewed as complementary rather than competing channels. The methodological decision should be driven by the learning goal: rapid information retrieval may favor speech, whereas detailed linguistic analysis may require tactile reading.

Teachers should also teach digital navigation explicitly. Efficient use of headings, landmarks, search commands, links, tables and keyboard shortcuts is part of contemporary functional literacy. Without these skills, an accessible resource may remain slow and cognitively demanding. The pedagogical task is therefore twofold: make the content accessible and develop the learner's competence to exploit that accessibility independently.

Audio, Audio Description and Multimodal Representation

Audio resources are among the most established means of compensating for inaccessible visual information, but effective educational audio is more than reading text aloud. Audio description should identify the features and relationships that are relevant to the learning objective. For example, when a diagram shows the water cycle, a useful description must communicate sequence, direction and causal relationships, not merely list the visible labels. Similarly, an educational video should provide access to demonstrations, gestures, changes on a graph and other visually conveyed information that carries meaning.

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

UDL 3.0 explicitly recommends offering information through different modalities and allowing users to adjust presentation; it also emphasizes multiple representations as a means of supporting perception and meaning-making [4, 6]. For learners with low vision, this may involve synchronized text, magnification, high contrast and audio. For blind learners, it may involve structured text, speech, Braille and tactile graphics. The principle is not maximal sensory stimulation but purposeful redundancy: the same essential concept should remain available through more than one viable route.

Tactile-Digital and Haptic Approaches

Digital learning is often mistakenly associated with screen-based interaction. For learners with visual impairments, some of the most promising approaches integrate tangible, tactile and auditory information. Research in STEM has explored tactile graphics, haptic applications, talking tactile devices and 3D-printed models. A systematic review of educational rehabilitation initiatives noted a concentration of studies on making STEM content accessible through tactile, haptic and electronic devices, although the evidence base remains small [2]. More recent qualitative research with visually impaired learners found that combining tangible objects with audio in playful STEM activities supported interest and conceptual understanding [7].

The methodological advantage of tactile-digital resources lies in their capacity to externalize spatial relationships. A tactile map can represent position and distance; a 3D model can make shape and structure explorable; an audio-tactile interface can connect a touched region with verbal information. Yet tactile graphics are not self-explanatory. Learners need systematic instruction in scanning strategies, reference points, legends, orientation and the relationship between a model and the represented object. Digital enhancement should therefore be embedded in a sequence of guided exploration, verbalization, comparison and independent application.

Mobile Learning and Learner Agency

Smartphones and tablets have become multifunctional accessibility platforms because they combine magnification, text-to-speech, OCR, voice input, camera-based recognition, note-taking and communication. Their educational significance is enhanced by portability: the same device can support reading in class, navigation during an excursion,

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

photographing enlarged material, accessing cloud documents and communicating with teachers. However, touchscreen interfaces can also create barriers when controls are unlabeled, gestures are complex, or information is organized primarily by visual position.

Evidence on mobile learning suggests that accessibility alone does not determine sustained use. A 2025 study of visually impaired university students found that competence and relatedness were important in technology acceptance, highlighting the role of skills mastery and social support [8]. Although the participants were adults, the implication for school education is relevant: teachers should not assume that children automatically acquire effective assistive-technology strategies simply because they use smartphones. Structured instruction, peer support and repeated successful use are necessary to transform a device from a compensatory aid into a learning tool.

User-centred design is equally important. Research on a mobile e-learning application for visually impaired children reported improved task completion and satisfaction after interface modifications and emphasized clear navigation, contrast, immediate feedback, appropriate button and text size [9]. These features illustrate a broader principle: accessibility should be designed from the beginning and validated with users, not added after the pedagogical product has been completed.

Artificial Intelligence as an Emerging Accessibility Layer

Artificial intelligence is rapidly becoming an additional layer of digital accessibility. OCR can convert printed material into editable text; image-description systems can provide preliminary verbal access to photographs and diagrams; conversational interfaces can explain unfamiliar terms; speech recognition can reduce the motor and visual demands of text entry; and generative systems can reformat content into more accessible representations. A 2026 systematic review of NLP-powered assistive technologies for visually impaired students reported substantial progress in speech recognition, text-to-speech, conversational interfaces and multilingual processing, while also identifying limited evidence on long-term educational integration, learner autonomy and institutional sustainability [10].

These tools should be treated as assistive mediators rather than authoritative sources. Automated descriptions may omit educationally important detail or introduce errors; OCR

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

quality depends on image and document quality; generative systems may produce plausible but inaccurate explanations. For children, additional issues include privacy, data protection, age-appropriate interaction and overreliance on automated assistance. The teacher's role therefore expands from selecting resources to teaching verification strategies: comparing AI output with source material, checking key facts, identifying uncertainty and deciding when human assistance is necessary.

A Pedagogical Model for Integrating Digital Resources

On the basis of the reviewed evidence and accessibility frameworks, four interdependent principles can guide the integration of digital resources in teaching children with visual impairments.

First, multimodal equivalence requires that essential information be available through functionally equivalent perceptual routes. The aim is not to duplicate every visual feature verbally, but to preserve the concept, relationship or action required by the learning objective. Second, learner-controlled adaptability means that the learner should be able to enlarge text, adjust contrast and spacing, change playback speed, choose speech or Braille where appropriate, and navigate content nonlinearly. Third, assistive-technology compatibility requires resources to work predictably with screen readers, keyboards, magnification and Braille devices. Fourth, corrective-developmental integration means that digital tools should simultaneously support curriculum learning and relevant functional skills such as tactile discrimination, visual efficiency, spatial orientation, independent information search and communication.

These principles can be operationalized through a five-stage instructional cycle: diagnostic analysis of the learner and task; selection or creation of an accessible resource; pre-teaching of navigation and concepts; supported then increasingly independent use; and evaluation of both academic outcome and accessibility experience. This cycle prevents a common methodological error—evaluating only whether the child answered correctly while ignoring whether the child could access and complete the task independently.

Criteria for Selecting a Digital Resource

A practical selection procedure should begin with the learning objective and then examine accessibility. Teachers and support specialists may use the following questions: Does the resource preserve the intended cognitive demand? Can all

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

essential information be perceived without relying exclusively on vision? Can the learner navigate and operate it using their established assistive technology? Is the structure predictable? Are images, diagrams and multimedia supplied with meaningful equivalents? Can text size, contrast, audio speed or display settings be adjusted? Is sufficient time available for nonvisual navigation? Can the learner produce and submit a response accessibly? Does the resource protect privacy and avoid unnecessary collection of personal data? Finally, can the learner use it with decreasing adult mediation?

The last criterion is particularly important. A resource that consistently requires a sighted adult to identify buttons, interpret images or correct focus order may create a hidden dependency. Digital inclusion should increase agency. CAST's current UDL framework identifies learner agency as a central goal and recommends optimizing access to accessible and assistive technologies while maintaining the intellectual challenge of the learning goal [4, 5].

Barriers, Risks and Conditions for Effective Implementation

The principal barriers are not exclusively technological. They include inaccessible procurement practices, limited teacher competence, fragmented responsibility between classroom teachers and specialists, insufficient time for accessible material preparation, lack of multilingual resources, inconsistent internet access and weak mechanisms for learner feedback. The 2024 scoping review of digital accessibility emphasized that inaccessible design remains widespread and that formal guidelines alone do not capture every difficulty reported by users with visual impairment [1]. This suggests that compliance testing should be supplemented by authentic user testing.

A second risk is technological substitution: replacing direct experience, tactile exploration, social interaction or mobility with screen-based content merely because it is convenient. Digital resources should extend access, not narrow the sensory and social basis of learning. In subjects involving the natural and social world, a digital model is most powerful when connected to real objects, field observation, movement, discussion and practical action.

A third risk concerns unequal competence among adults. If only the specialist teacher understands screen-reader navigation or accessible document creation, the learner's participation becomes vulnerable whenever that specialist is

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

absent. Sustainable practice requires distributed competence: classroom teachers should master basic accessible-design principles; teachers of students with visual impairments should provide specialized assessment and instruction; families should understand the learner's key tools without becoming permanent intermediaries; and technical staff should ensure platform compatibility.

Discussion

The contemporary development of digital education for children with visual impairments can be characterized by a transition from isolated assistive devices toward integrated accessibility ecosystems. Earlier models often positioned assistive technology as an individual adaptation added to a mainstream learning environment. Current approaches increasingly emphasize accessible-by-design platforms, interoperability, multimodal representation and learner agency. This shift corresponds with UDL 3.0 and with the broader understanding of accessibility as a property of the educational environment rather than a deficit located in the learner [4].

At the same time, the evidence cautions against technological optimism. The systematic review of educational rehabilitation for visually impaired adolescents identified only ten eligible studies from 3,210 screened records and judged the evidence insufficient for firm decision-making [2]. The digital-accessibility scoping review documented persistent barriers across applications and websites [1]. These findings indicate a paradox: the number and sophistication of technologies are increasing, but high-quality evidence on their long-term educational impact, transfer to independent learning and implementation at scale remains comparatively limited.

For pedagogy, the implication is clear. The quality of digital inclusion should be evaluated through a multidimensional lens: technical accessibility, cognitive accessibility, curricular alignment, independence, efficiency, participation and learner experience. A child who can technically access a platform but requires disproportionate time, constant assistance or repeated workarounds is not experiencing equivalent access. Conversely, a well-designed digital environment can provide advantages that are difficult to achieve in print: instant enlargement, rapid search, synchronized speech and Braille, personalized display, reusable tactile-audio links and immediate formative feedback.

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

Future research should prioritize school-age populations, longitudinal designs and ecologically valid classroom outcomes. Particular attention is needed to AI-supported image description, accessible mathematics and science notation, multilingual screen-reader resources, tactile-digital learning, accessible assessment and the transition from supported access to autonomous learning. Studies should report not only task accuracy but also time, cognitive load, independence, user preference, retention and transfer. Co-design with blind and low-vision learners is essential if research is to move from technologies that are theoretically accessible to resources that are educationally meaningful.

Conclusion

Digital resources can substantially expand educational opportunities for children with visual impairments, but their effectiveness depends on pedagogical design rather than technological novelty. Contemporary practice should integrate accessible text, speech, Braille, magnification, tactile-digital representations, mobile tools and emerging AI systems within a coherent instructional strategy. The decisive criterion is functional equivalence: the learner must be able to perceive essential information, operate the resource, construct meaning, act with growing independence and demonstrate the intended learning outcome without unnecessary sensory barriers.

Accordingly, the modern teacher's task is not simply to "use digital technologies" but to design an accessible learning pathway. This requires collaboration among classroom teachers, teachers of students with visual impairments, families, developers and support specialists; explicit instruction in assistive-technology competence; and continuous evaluation of the learner's experience. When accessibility is embedded at the stage of planning rather than added after difficulties arise, digital resources become not compensatory accessories but instruments of participation, agency and equitable learning.

References:

[1] Kerdar, S. H., Bächler, L., & Kirchhoff, B. M. (2024). The accessibility of digital technologies for people with visual impairment and blindness: A scoping review. Discover Computing, 27, Article 24. https://doi.org/10.1007/s10791-024-09460-7
[2] Milde, N., Schmidt, D. C., Larsen, A., & Kessel, L. (2024). Which rehabilitation initiatives can effectively improve participation in an educational setting for visually impaired and blind adolescents?

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).

A systematic review. BMC Ophthalmology, 24, 10. https://doi.org/10.1186/s12886-023-03267-8

[3] World Wide Web Consortium (W3C). (2023). Web Content Accessibility Guidelines (WCAG) 2.2. W3C Recommendation. https://www.w3.org/TR/WCAG22/

[4] CAST. (2024). Universal Design for Learning Guidelines version 3.0. CAST. https://udlguidelines.cast.org/

[5] CAST. (2024). Optimize access to accessible materials and assistive and accessible technologies and tools. In Universal Design for Learning Guidelines 3.0. https://udlguidelines.cast.org/action-expression/interaction/assistive-technologies/

[6] CAST. (2024). Perception: Design options for perception. In Universal Design for Learning Guidelines 3.0. https://udlguidelines.cast.org/representation/perception/

[7] Cardenas Castaneda, J. A., Lin, P.-C., Hung, P. C. K., et al. (2025). Designing inclusive tech playful educative solutions for visually impaired learners in STEM education. Smart Learning Environments, 12, Article 4. https://doi.org/10.1186/s40561-024-00358-x

[8] Şahin, F. (2025). Psychological drivers shaping mobile learning utilization among visually impaired university students. Education and Information Technologies, 30, 16163-16187. https://doi.org/10.1007/s10639-025-13430-x

[9] A mobile e-learning application for enhancement of basic mathematical skills in visually impaired children. (2023). Universal Access in the Information Society. https://doi.org/10.1007/s10209-023-00990-3

[10] Kulkarni, M., Dange, P., & Bedarkar, M. (2026). A PRISMA systematic review of NLP-powered assistive technologies supporting visually impaired students. Discover Sustainability. https://doi.org/10.1007/s43621-026-04440-x

[11] Shoaib, M., Fitzpatrick, D., & Pitt, I. (2023). Assistive technology-based solutions in learning mathematics for visually-impaired people: Exploring issues, challenges and opportunities. Multimedia Tools and Applications, 82, 46153-46184. https://doi.org/10.1007/s11042-023-17409-z

This work is distributed under the terms of the Creative Commons Attribution-ShareAlike 4.0 International License (https://creativecommons.org/licenses/by-sa/4.0/).