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Assistive Technologies and Interventions for Dyslexia: The role of AI, Robotics and Adaptive Systems

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Systematic Review

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RESEARCH ARTICLE

Assistive Technologies and Interventions for Dyslexia: The role of AI, Robotics and Adaptive Systems

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Abstract

Dyslexia is a hereditary, neurodevelopmental learning disorder found to appear in around 10% of the population, characterized by difficulty in reading. Cutting-edge advancements in technology, particularly breakthroughs in artificial intelligence and robotics, have paved the way for innovative approaches to support individuals with learning disabilities such as Dyslexia. This study critically reviews the role of assistive technologies specifically Artificial Intelligence (AI), Machine Learning (ML), and Robotics in addressing the educational challenges faced by children with dyslexia. This paper explores the use of AI, Machine Learning, and Robotics as assistive technologies for children with dyslexia. A systematic PRISMA-based review of 30 selected studies highlights how early detection, multimodal feedback, and personalized interventions improve learning outcomes. Robotics offers multisensory, emotionally engaging support, AI enables real-time, adaptive feedback and ML aids in early diagnosis. Despite clear benefits, challenges remain in real-world classroom integration, personalization, and connecting detection to intervention. The study concludes that AI-powered robotics provides the most effective and child-centered solution, calling for ethical, inclusive, and scalable implementation across educational systems.

Keywords Dyslexia· Artificial intelligence · Assistive technology · Personalized Learning · Adaptive tools · Robotics · Machine Learning.

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1 Introduction

Assistive technologies and innovative pedagogical strategies are being explored to address the challenges faced by students with dyslexia, with a focus on creating inclusive educational environments that cater to diverse learning needs. Creative teaching methodologies that incorporate Information and Communication Technology tools can facilitate student participation and cooperative learning, offering alternative and compensatory strategies to help students with dyslexia achieve their academic goals (M.Tan et al., 2025) [1].

2 Literature Survey

Early Detection and Visualization for Learning Disabilities: Early detection and visualization of learning disabilities such as dyslexia are critical for dyslexia at an early stage preferably in preschool or early primary years allows educators and parents to understand a child's specific challenges before they escalate into more complex academic and emotional struggles.

KY Fung et al., (2025) [8].suggests Visualization techniques, such as brain imaging and eye-tracking data, offer clear, evidence-based insights into the unique cognitive and neurological profiles of dyslexic learners. These insights not only validate the presence of learning difficulties but also inform the personalized structuring of assistive learning systems. By tailoring tools such as adaptive reading software, robotic tutors, or gamified platforms based on a child's precise cognitive needs.

Early detection ensures that interventions are not generic but strategically aligned to support reading fluency, comprehension, and engagement. As concluded by Z. Nurseitova et al., (2021) [25].Early detection serves as the foundational blueprint for designing effective, responsive, and child-centered assistive learning.

3 Search Strategy

A comprehensive keyword strategy encompassing critical terms related to dyslexia detection, extraction and selection. Keywords included “dyslexia,” “machine learning,” “deep learning,” “behavioural assessments,” “learning Disorders,” “artificial intelligence,” “multi modal,” and “robotics.” To ensure thorough coverage of the literature, synonyms, alternative spellings, and related concepts were also considered during the search process.

To identify relevant peer-reviewed 417 papers, the authors accessed major academic databases spanning multiple disciplines, including dyslexia research, computational neuroscience, psychology, computer science, and linguistics. Specifically, databases such as PubMed, Web of Science, Scopus, IEEE Xplore, and ResearchGate were queried. Boolean operators (AND, OR, NOT) were employed to logically combine keywords. Removing 216 duplicate and irrelevant articles. Then, constructed tailored search strings for each platform. These strings were further refined and screened 177 papers based on the specific search syntax requirements of each database. To optimize the retrieval of relevant publications and included most recent 43 papers and further reviewed the most relevant 30 articles.

enabling timely and targeted interventions that significantly improve educational outcomes. DMJ Masalesa et al., (2019) [9] analyzes that identifying

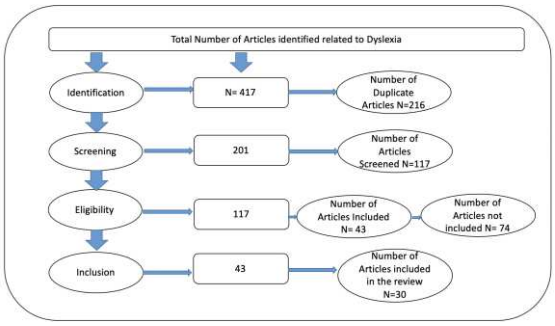


Figure 1. Shows the number of identified Articles related to Dyslexia.

3.1 Review Methodology

R. Sarkis-Onofre et al., (2021) [19].Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to present a structured framework highlighting the significance of technologies in detecting dyslexia using multiple modalities.

Fig.2 presents PRISMA Analysis on the inclusion and exclusion criteria along with the corresponding search strategies.

PRISMA Analysis	
Inclusion	**Exclusion**
Published articles in peer reviewed journals retrieved via Scorpus, Researchgate, Pubmed, web of Science, Google Scholar and IEEExplore	Publications which focus purely on detection of Dyslexia
Studies published 2018 onwards	Non-English language studies
Original studies related to Assistive systems and multimodal tutoring	Study reports related to Eye Tracking and Eye movement
Articles related to kids with Dyslexia	Studies related to other neurological disorders such as Dysgraphia, ADHD etc
Studies involving educational support systems for people with dyslexia using technologies such as ML, AI, Robotic tools.	Animal studies, case reports and non-research articles.
Search String = ("Dyslexia" OR "Reading disability" OR "Developmental dyslexia" OR "Learning disorder") AND ("Detection" OR "Diagnosis" OR "Identification" OR "screening") AND ("Multi Modal" OR "Machine learning" OR "Deep learning" OR "Artificial intelligence") AND ("Dyslexia") AND ("Kids" OR "Children") AND ("Multi Modal" OR "Multi-Modal") AND ("Robotics") - "Eye Tracking"	

This review includes original research articles published from 2018 onwards that are focused on assistive systems and multimodal tutoring technologies designed to support children with dyslexia. These studies contribute valuable insights into the development and implementation of

intelligent support systems that can adapt to the unique needs of learners with dyslexia.

Conversely, the exclusion criteria ensured that the review remained focused by omitting studies that dealt solely with detection of dyslexia, or those that used eye-tracking or eye-movement analysis as the core methodology. In addition, non-English language publications, animal studies, case reports, and non-research articles were excluded to maintain the academic rigor and relevance of the findings. Research focusing on other neurological conditions such as dysgraphia or ADHD, which might have overlapping symptoms but require different support systems, was also excluded to preserve the specificity of the review.

4 Research Questions

A. How Assistive learning can help kids with Dyslexia?

B. How do robotics and other tools enhance learning outcomes for children with dyslexia?

C. What are advantages of using specific tools over other tools used for assisting Dyslexia learners?

4.1 Related Work

A. How Assistive learning can help kids with Dyslexia?

According to N. Farhah et al. (2025) [2] proposes Assistive technology devices and software have shown promise in supporting students with learning disabilities, particularly in areas such as reading and writing. These tools can enhance a child's functional abilities, but training is essential to ensure students can effectively use these devices (KY Fung et al,. 2025) [8].

R. Nakamoto (2025) [7] analyzes that students with learning difficulties often struggle to adapt to conventional learning environments, facing challenges in following instructions, understanding course content, and engaging with textbooks.

M. Berryhill (2024) [5] suggests application of technology in special education has been an active area of research for several decades, with significant advancements in the last 10 years, despite the increasing number of publications on the use of technology to promote inclusive education.

Mitra et al. (2024) [6] suggests that assistive technology supports students with learning disabilities in terms of access and success in general education and special education settings. With the rapid proliferation of digital technologies, the educational landscape has undergone significant transformation particularly in the domain of special education. Learners with cognitive, emotional, or physical impairments often face unique barriers in conventional learning environments. Emerging technologies especially AI, robotics, data visualization systems, and immersive tools offer innovative ways to address these barriers by personalizing content, detecting learning difficulties early and enhancing engagement.

Additionally, Noll et al. (2018) [12] integrates pictorial symbols into textual content that can support reading comprehension for students with limited literacy or cognitive challenges.

B. How do robotics and other tools enhance learning outcomes for children with dyslexia?

Machine Learning (ML), Artificial Intelligence (AI), and Robotics each contribute uniquely to assistive interventions for dyslexia yet they differ significantly in functionality, personalization, engagement, and practical application (Harshani Perera et al.(2016) [23].

Ahmad MI (2019) [25] analyses the implementation of ML, AI and Robotics involves moderate complexity due to hardware and curriculum integration requirements. The direct tangible impact on learner motivation, emotional development, and inclusive participation makes robotics a preferred intervention pathway. The level of engagement afforded by robotics surpasses that of both ML and AI alone.

According to Fung, K. Y et al. (2025) [8] Children often respond to robots with higher motivation and emotional connection, fostering an environment conducive to sustained and enjoyable learning from an ethical standpoint, robotics tends to be less invasive, with concerns primarily centered on physical safety and appropriate use policies rather than data exploitation. In inclusive educational settings especially for students with dyslexia robotics holds the strongest potential to bridge the gap between technological intelligence and human-centered pedagogy.

B.1 Robotics

KY Fung et al. (2025) [29]Investigate that Robotics offers a unique advantage by providing interactive and multisensory learning experiences for students with dyslexia. Robots can serve as embodied agents capable of engaging students through visual, auditory, and tactile stimuli, which is particularly beneficial for maintaining attention and reinforcing learning.

N Farhah et al. (2025) [2] concludes that robots can facilitate interactive storytelling and phonics-based games, creating an engaging and supportive learning environment. When integrated with AI, offers a

compelling and multifaceted advantage for learners with dyslexia. Beyond mere automation, educational robots serve as embodied agents capable of engaging in interactive and multisensory learning combining visual, auditory, and tactile stimuli.

E. Chaidi et al.,(2024) [[31].explains its particularly beneficial for students with learning disabilities, who often require support to sustain attention and reinforce learning. Robotic tools can facilitate a variety of use cases including interactive storytelling, phonics-based games, reading assistance, and even social learning. While default personalization in robotics may be limited, it becomes significantly enhanced when AI is embedded, allowing robots to adapt in real-time to individual learners' needs.

B.2 Artificial Intelligence

Mitra et al.((2024) [6] and CC Lin et al.(2023) [23] suggests AI provides a dynamic and responsive layer of intervention through real-time decision-making and multimodal processing. AI systems deliver adaptive content and immediate feedback, allowing for highly personalized learning experiences that adjust to individual behavioural cues.

Entzminger et al.((2024) [4]. suggests AI-powered systems can support diverse learning styles, including auditory and visual modalities, and can be integrated with tools like Augmentative and Alternative Communication (AAC) to enhance verbal communication.

M Wang et al.(2022) [14] integration of AI provides a more dynamic and responsive layer of intervention. These systems excel at real-time decision-making and multimodal processing, which makes them suitable for delivering adaptive content, providing immediate feedback, and even recognizing user emotions.

M Buzzi et al[10] reviews tells that domain such as STEM education that includes multi-disciplinary research shows that multi-modal educational boost motivation and cognitive engagement, particularly for students with dyslexia.

Ates et al(2024) [30] analyses highly personalized learning experiences that adjust to individual behavioural cues that support diverse learning styles including auditory and visual modalities.

B.3 Machine Learning

M. Berryhill (2024) [30] analysed that Machine learning is primarily used for pattern recognition across large datasets, enabling the identification of reading and handwriting patterns associated with dyslexia. It also plays a crucial role in early detection and diagnostic support (Y. Alkhurayyif et al. 2024)[17]

KY Fung et al.(2025)[[3] investigates that systems like DysVis use data visualization to pre-screen for dyslexia, improving detection accuracy.

SS Abdul Hamid et al. 2018 [13] suggests ML models can also predict student engagement to tailor learning materials. However, ML tools typically operate with limited real-time interactivity and offer relatively low learner engagement, which restricts their standalone effectiveness in instructional settings.

Thomais Asvestopoulou et al.(2019) [21] supports the use of ML techniques using the DysLexML a screening tool for Dyslexia detection.

B.4 Gamification

JM Alcalde-Llergo et al.(2022) [15] strongly suggest Gamification enhances user motivation and participation by incorporating game design elements such as rewards and challenges within non-game contexts. It provides an engaging platform where children can interact with reading, phonological, and memory-based tasks

DMJ Masalesa et al. (2019) [9] suggest that However, these systems often track micro-level behaviors, which AI or ML algorithms can analyze to identify early signs of dyslexia.

A VR serious game, for instance, can increase empathy towards students with phonological dyslexia by simulating their reading difficulties (JM Alcalde-Llergo et al.2022) [15].

B.5 AI-Driven Adaptive Learning and Feedback

SS Abdul Hamid et al. (2018) [13] created an AI-driven adaptive learning system that offer personalized support by adjusting instruction and feedback to meet individual learning needs.

N Hany et al. (2024) [13] introduces Nexia Tutor as an AI-powered language learning system designed to personalize learning experiences for children with dyslexia. This system leverage AI to assess a student's knowledge, skills, and learning style, tailoring content and delivery accordingly.

However, W Rasheed-Karim et al. (2021) [16] and D Gomes et al(2025) [20] conclude that Intelligent Tutoring Systems (ITS) can also be used to provide customized support and improve learning outcomes when integrated with AI.

B.6 Visual and Symbol-Supported Learning Tools

Additionally, A Noll et al., (2018) [12] suggests that Visual and symbol-supported learning tools aid reading comprehension by using pictorial symbols to represent learning tasks. This approach is beneficial for children with and without special needs, as it enhances understanding and engagement.

B.7 Multi-modal Robotics for Inclusive Engagement

KY Fung (2025) [29] strongly suggest Robot-assisted education using multi-modal robots or robotic tools when integrated with AI has shown promise in boosting engagement, especially for students with learning differences.

These robots integrate animations, gestures, and touch responses to manage cognitive load and foster emotional connection which is the key factors in sustaining motivation.

B.8 General strategies and teaching approaches

D.M. Ancheta-Hernandez (2025) [11] teacher readiness and training remain inconsistent, with many educators lacking the skills or confidence to effectively implement these tools in inclusive classrooms.

N. M. I. P. Dewi (2022) [31] Addresses teaching strategies tailored for students facing learning challenges such as dyslexia in the classroom and social settings and also provide inclusive educational support. Effective teaching strategies used to help dyslexic students with their learning difficulties. This can be achieved by being creative using various strategies that can stimulate students' interest.

DMJ Masalesa et al.(2019) [9] suggests the use of games, pictures, and realia in teaching learning process by creating small group and use multisensory teaching and providing step by step instructions this will encourage the kids to perform better.

B.9 Implications for Practice

N Hany et al.(2024) [18] implicates that educators and instructional designers should consider integrating AI-driven personalization and robotic engagement into special education settings. AI can assist with individualized feedback and adaptive content delivery, while robotics can enhance motivation through embodied interaction. Multisensory learning environments supported by these technologies have the potential to bridge accessibility gaps and create more inclusive classrooms. Training programs for teachers should also be revised to include competencies in using AI and robotics effectively and ethically.

5 Methodological Approaches

The studies reviewed in this paper employed a mix of qualitative and quantitative methodologies, including case studies, experimental designs, semi-structured interviews, and systematic reviews. For example, case studies was used to evaluate usability and engagement in robot-assisted learning environments. While, surveys and user studies provided insights into teacher's and student's experiences, allowing for an all rounded understanding of both the efficacy and limitations of each technology. Review of existing studies has concluded that eye-tracking based detection of Dyslexia is a well understood and researched area.

Table 1. Papers selected according to the technologies most used for assistive learning.

NO	Title of the Paper	Author	Classifier	Goals	Limitations
1	Vocabulary Instruction, Reading Comprehension, and Writing-Examining the effectiveness of an online intervention literacy programme for secondary students with dyslexia.	M Tan et al.(2025)	ALT	Assistive learning technology.	assistive online literacy tool without AI or ML.
2	AI-Driven Innovation Using Multimodal And Personalized Adaptive Education For Students with Special Needs.	N Farhah et al. (2025)	AI	personalized adaptive education system with AI-driven multimodal tool.	complexity and scalability of AI models.
3	DysVis: A User-Centred Data Visualization System for Dyslexia Pre-screening.	KY Fung et al.(2025)	ALT	assistive technology that utilizes data visualization.	lack of integration with AI or ML.
4	The Impact of Language Intervention on At-Risk Kindergarten and First-Grade Students' Receptive and Expressive Vocabulary: A Quantitative, Quasi-Experimental Study	Entzminger et al.((2024).	ALT	language-based assistive intervention.	does not incorporate AI or ML, limiting personalization.

5	A LOOK INSIDE: A MULTIPLE-CASE STUDY OF SCHOOLS THAT SPECIALIZE IN DYSLEXIA	M. Berryhill (2024).	ALT	qualitative, assistive education-focused methods	context-specific its multiple-case design.
6	AI-Powered Adaptive Education for Disabled Learners.	Mitra et al.((2024).	AI	AI-powered adaptive education technology	dependence on diverse datasets for effective AI personalization.
7	Development of a Mathematics Learning Support System through the Analysis of Handwritten Responses and Self-Explanations	R. Nakamoto (2025).	ML+ ALT	machine learning-based assistive system.	accuracy and variability in handwriting recognition.
8	Exploring the impact of robot interaction on learning engagement: a comparative study of two multi-modal robots.	KY Fung (2025)	Robotics + ALT	assistive, multi-modal robotic technology.	does not integrate AI or adaptive learning algorithms.
9	Challenges faced by educators in the inclusion of beginners with dyslexia in mainstream primary schools	DMJ Masalesa et al. (2019)	-	focusing on instructional, institutional, and resource-related learning.	does not incorporate AI, ML, or assistive technology,
10	How Artificial Intelligence Is Impacting on the STEM Education of Students with Disabilities: A Five Years Review	M Buzzi et al.	AI	AI technologies have influenced STEM education.	inconsistent implementation of AI
11	The Learning Center (LC): A Platform for Instructional and Learning Environment for Mild/Moderate Students with Learning Disabilities' Self-Directed Learning Gains	D.M. Ancheta-Hernandez (2025).	ALT	An assistive learning platform.	does not incorporate AI or ML for adaptive learning.
12	Fostering Reading Comprehension of Learning Tasks with Pictorial Symbols: A Qualitative Study of the Subjective Views and Reading Paths of Children with and without Special Needs	A Noll et al.(2018)	ALT	assistive pictorial symbol support.	does not utilize AI or ML technologies.
13	Dyslexia adaptive learning model: student engagement prediction using machine learning approach	SS Abdul Hamid et al.(2018)	ML+ ALT	machine learning-based adaptive learning model	making it difficult for educators to understand or trust the ML decisions.
14	Smart assistance to dyslexia students using artificial intelligence based augmentative alternative communication.	M Wang et al.(2022)	AI	AI-based augmentative and alternative communication (AAC)	interface does not support AI accuracy.
15	A vr serious game to increase empathy towards students with phonological dyslexia.	JM Alcalde-Llergo et al.(2022)	ALT	VR-based serious game assistive tool.	does not incorporate AI or ML for adaptive feedback or personalization.
16	Intelligent tutoring systems, learning and cognitive styles of dyslexic students.	W Rasheed-Karim et al.(2021)	AI	AI-powered Intelligent Tutoring Systems (ITS)	ITS struggles to fully adapt to the complex, individualized needs.
17	A Review of Artificial Intelligence-Based Dyslexia Detection Techniques	Y. Alkhurayyif(2024)	AI	AI-based evaluation.	does not incorporate ML or adaptive feedback.
18	Nexia Tutor: An AI-Powered Language Personalized Learning System for Kids with Dyslexia and Reading challenges	N Hany et al.(2024)	AI	AI-powered personalized learning system	dependence on continuous user data and system training.
20	A Comprehensive Study of Advancements in Intelligent Tutoring Systems Through Artificial Intelligent Education Platforms.	D Gomes et al(2025)	AI	Intelligent Tutoring Systems (ITS) developed through AI-powered educational platforms	Lacks comparative assessment and scalability.
21	"DysLexML: Screening Tool for Dyslexia Using Machine Learning"	Thomais Asvestopoulou et al.(2019)	ML	machine learning-based screening tool	limited by dataset bias
22	"Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review"	CC Lin et al.(2023)	AI	artificial intelligence is integrated into Intelligent Tutoring Systems (ITS)	lack of unified evaluation frameworks.
23	"Computational Approaches to Detecting and Addressing Dyslexia: A Review. Review of the Role of Modern	Harshani Perera et al.(2016)	AI + ML	Includes AI and ML techniques	lack of standardized diagnostic protocols and datasets.

	Computational Technologies in the Detection of Dyslexia"				
24	Teaching Strategies Used to Deal with Dyslexic Students' Learning Difficulties	Jurnal Pendidikan Bahasa Inggris undiksha et al. (2022)	_	teaching strategies and classroom practices	does not utilize AI, ML, or assistive technology
25	DYSLEXIA IN PRIMARY SCHOOL CHILDREN	Z.Nurseitova et al(2021)	_	does not incorporate AI, ML, or assistive technology	does not incorporate AI, ML, or assistive technology
26	Dyslexia and Inclusive Education	Vasanthi, A. et al.(2023).	_	inclusive education practices	does not involve AI, ML, or assistive technologies
27	Dyslexia as Learning Disability: Knowledge, Belief and Approach in Language Teaching. European Proceedings of Educational Sciences.	NA Norwahi et al(2022)		employ AI, ML, assistive technology	Dependence on teachers knowledge and instructional approaches.
28	Robot's adaptive emotional feedback sustains children's social engagement and promotes their vocabulary learning: a long-term child–robot interaction study.	Ahmad MI et al.(2019)	AI	AI-based social interaction	dependency on controlled environments.
29	Motivating Students With Different Needs to Learn Chinese in a Mixed-Background Classroom by Robot-Assisted Learning.	Fung, K. Y et al(2025)	Robotic tool+ ALT	robot-assisted learning as an assistive tool	does not integrate AI or ML for adaptive instruction
30	A brief reference to AI-driven audible reality (AuRa) in open world.	Ates et al(2024)	AI	artificial intelligence to personalize and enhance auditory experiences.	Depends only on high-quality audio data.

Terms Used: ALT = Assistive Learning Tool, AI = Artificial Intelligence, ML = Machine Learning, Robotics.

C. What are advantages of using specific tools over other tools used for assisting Dyslexia learners?

C.1 DISCUSSION

This review affirms that AI, ML, and robotics offer complementary solutions for supporting children with dyslexia and broader special education needs. Robotics excels in delivering multisensory, emotionally engaging experiences that increase motivation and attention. AI systems shine in their ability to provide dynamic, personalized content, while ML facilitates data-driven insights into learning behaviours and early diagnosis.

However, realizing the full potential of these technologies demands a multi-stakeholder approach. Collaboration among researchers, educators, policy-makers, technologists, and families is crucial to co-design systems that are ethically sound, culturally relevant, and scalable. Furthermore, educational ecosystems must evolve, not only in terms of infrastructure and training but also in pedagogy embracing flexibility, adaptability, and student centered methodologies.

Addressing the outlined challenges will involve only through sustained, collaborative effort from educational technologies that can become truly transformative for learners with special needs.

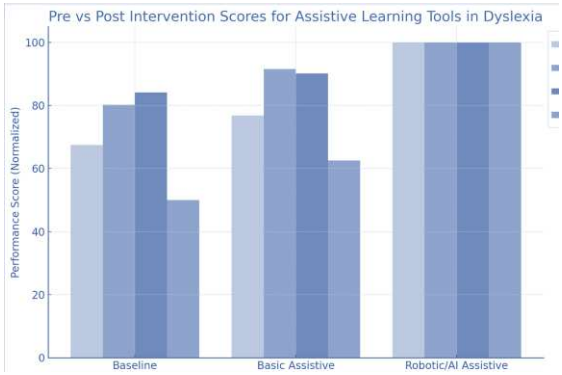


Figure 2: Pre Vs post intervention scores of Assistive learning tools on Dyslexia.

C.2 CONCLUSION FROM COMPARISON

While machine learning (ML) and artificial intelligence (AI) provide strong foundational capabilities for dyslexia intervention. such as data-driven analysis and dynamic content adaptation, robotics offers a distinct advantage through its immersive, interactive, and emotionally engaging experiences. By supporting multisensory learning and fostering intrinsic motivation, robotics proves especially effective in sustaining attention and enhancing the overall learning experience for children with dyslexia. When integrated with AI-driven personalization, robotics becomes an even more powerful tool for inclusive, real-time classroom support, emerging as the most child

centered and impactful approach in educational technology.

For classroom inclusion and real-time support, robotics especially when paired with AI emerges as the most effective and child-friendly approach.

CONCLUSION

Based on rigorous review findings and the above discussion in AI, ML, and assistive technologies for dyslexia, key research gaps remain particularly in personalization, emotional responsiveness, and cross-context application. Addressing these gaps requires interdisciplinary collaboration, real-world classroom validation, and ethical frameworks that ensure inclusive, adaptive, and equitable educational technologies for all learners with dyslexia.

One of the major limitation is Limited Personalization in Non-AI Tools.

Many assistive technologies still lack adaptive capabilities; integrating AI/ML can enable dynamic personalization based on real-time learner behaviour and progress. The implementation of AI comes with notable complexities, including integration challenges, data privacy concerns, and the need for ethical safeguards especially in live educational environments.

Another concern involves Gaps Between Detection and Intervention as many studies focus on detection of dyslexia using ML, but do not connect these systems to tailored intervention platforms—missing the opportunity for early, guided support and Underutilization of Multimodal Feedback

Few systems fully leverage multisensory learning modalities (visual, auditory, tactile) in combination to support dyslexic learners, which is critical for diverse cognitive engagement. This limits the ability to draw broad conclusions applicable across diverse educational systems and student populations.

Furthermore, ethical considerations including data privacy, algorithmic bias, and over-reliance on automated decision-making pose ongoing risks, particularly for vulnerable groups such as children with cognitive impairments.

There are also technical limitations, such as insufficient natural language processing for non-English users and the limited adaptability of some AI systems to individual learner variability.

Insufficient Real-World Classroom Integration for example many tools are developed and tested in controlled settings; research is needed on their scalability, usability, and effectiveness in real classroom environments.

Lastly, the high cost of development, deployment, and maintenance of robotics solutions can hinder large-scale implementation.

DECLARATIONS:

COMPETING INTERESTS

The authors hereby declare that there are no competing interests, either financial or nonfinancial, directly or indirectly related to the work submitted for publication.

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AVAILABILITY OF DATA AND MATERIALS

Data will be made available on request.

CONSENT FOR PARTICIPATION AND PUBLICATION

This study did not involve human participants or personal data. All data used in this research were obtained from publicly available datasets and system-generated experimental results, ensuring compliance with standard research ethics guidelines.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: Conceptualization, Data collection, Formal Analysis, Writing – original draft: Saniya Sehar; Supervision, Writing – review & editing: Dr. Ambili P S and Dr. Vishwanath Hullippaled; All authors reviewed the results and approved the final version of the manuscript.

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