World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Digital inclusion in special education with AI-assisted curriculum models for Autism, Cerebral palsy, and Down syndrome

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World Journal of Advanced Research and Reviews, 2025, 25(02), 2793-2804

Publication history: Received on 05 January 2025; revised on 19 February 2025; accepted on 27 February 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.25.2.0501

Abstract

Students with autism spectrum disorder (ASD), cerebral palsy (CP), and down syndrome (DS) often face barriers in literacy, numeracy, and social-emotional learning that conventional curricula struggle to address. This study therefore explored the potential of AI-assisted curriculum models to enhance digital inclusion and align with Universal Design for Learning (UDL) principles. Using a design-based research framework, the study conducted a needs analysis, developed prototype modules in literacy, numeracy, SEL, and motor responsiveness, and piloted them in inclusive classrooms. Quantitative results therefore showed substantial improvements, including an 18% literacy gain among DS learners, reduced task completion times and increased accuracy for CP learners, and improved attention and social engagement for ASD students. Qualitative feedback from teachers and parents also highlighted increased learner independence and engagement, though some concerns about overstimulation were noted. Together, these findings demonstrated that AI can be integrated as a core curricular design principle, and not merely as an assistive tool. This paper thereby provides a scalable blueprint for advancing IDEA mandates, supporting parental aspirations, and strengthening U.S. commitments to digital equity in special education.

Keywords: Special Education Curriculum; Universal Design for Learning (UDL); Autism; Cerebral Palsy; and Down Syndrome

1. Introduction

Digital inclusion has become an indispensable element of equitable special education in the United States. While the Individuals with Disabilities Education Act (IDEA) guarantees free and appropriate public education, the delivery of this right is now inseparable from digital instructional systems that shape access, participation, and outcomes. Yet persistent challenges limit equitable implementation. Many schools still struggle with uneven access to assistive technologies, ranging from adaptive communication devices to specialized software, leaving students with disabilities at a disadvantage. Teacher readiness also remains inconsistent, with professional development rarely addressing the integration of digital tools into inclusive pedagogy. Equally important, very few curricular models demonstrate how artificial intelligence (AI) can be systematically embedded into classroom instruction in ways that are both accessible and scalable. Federal monitoring reports have drawn attention to widening disparities in access to these innovations, signaling an urgent need for curricular designs that embed accessibility principles from the outset rather than as afterthoughts (U.S. Department of Education, 2025). These challenges unfold against the backdrop of shifting student demographics and needs, where developmental disabilities are more prevalent and where parents, advocates, and policymakers alike are demanding more responsive forms of curriculum reform.

This urgency is underscored by the record prevalence of autism spectrum disorder (ASD), now affecting about 1 in 31 children in the United States (U.S. CDC, 2023). Although improved diagnostic tools explain part of this increase, it also

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reflects growing demand for specialized yet scalable instructional frameworks that can adapt across diverse learning settings. Students with cerebral palsy (CP) and Down syndrome (DS) similarly require sustained, individualized support, while their families often express strong aspirations for meaningful inclusion in mainstream education (Er-rida et al., 2024). These realities place renewed emphasis on curriculum innovation and highlight the inadequacy of one-size-fits-all approaches. Universal Design for Learning (UDL) has long guided special education, emphasizing multiple means of engagement, representation, and expression, and updated guidelines (CAST, 2018, 2024) extend these principles into digital contexts. However, significant gaps remain. Little scholarship has translated UDL into disability-specific, AI-enabled curricular models that move beyond theoretical flexibility to concrete, actionable strategies. Few frameworks specify how scaffolds, assessments, and user interfaces should be designed and embedded into everyday instruction for learners with ASD, CP, and DS. Bridging this gap requires not only technical innovation but also interdisciplinary collaboration among educators, technologists, policymakers, and families to ensure that accessibility is not peripheral but foundational to curriculum development in the digital age.

Since 2020, artificial intelligence (AI) in education has rapidly evolved from prototype tutoring systems into explainable learning analytics capable of interpreting real-time student behavior and adapting instruction accordingly. Meta-reviews confirm that, when carefully integrated, AI can enhance student outcomes and improve both engagement and assessment processes (Létourneau, Deslandes Martineau, Charland, Karran, Boasen, & Léger, 2025). Despite this progress, however, the literature in special education remains fragmented and uneven. Most studies to date have relied on small-scale or pilot interventions, producing valuable insights but rarely extending into curriculum-wide applications. For example, Antolí et al. (2025) demonstrated that combining eye-tracking with explainable AI could support social attention training in children with autism spectrum disorder (ASD). Similarly, Hudry et al. (2025) validated short gaze-based assessments that enabled early and more precise autism classification. These innovations illustrate the promise of AI in addressing disability-specific needs, yet they remain isolated tools rather than components of coherent instructional sequences. The result is a gap between experimental technologies and the systemic, classroom-ready frameworks necessary to transform everyday learning experiences for students with developmental disabilities.

For cerebral palsy (CP), research consistently emphasizes that motor learning, postural supports, and adaptive physical scaffolds are critical to enabling participation in academic tasks (Martins et al., 2019). However, such strategies are still too often treated as supplemental add-ons rather than central curricular elements. AI-enabled interfaces, including predictive text systems and eye-gaze selection technologies, offer a pathway to embed motor-responsive learning directly into literacy, numeracy, and communication tasks, thereby integrating physical accessibility into core instruction (Hudry et al., 2025). For students with Down syndrome (DS), persistent challenges in working memory, expressive language, and generalization skills, combined with parents' aspirations for meaningful inclusion (Er-rida et al., 2024), highlight the need for curricular models that balance academic learning with social development. Evidence-based supports such as adaptive prompts, spaced retrieval practices, and multimodal delivery formats (National Down Syndrome Society & Down Syndrome Education International, 2021) can be greatly enhanced through AI, allowing instruction to be customized in real time to individual strengths and needs. Taken together, these findings demonstrate a pressing need for curriculum-level blueprints that move beyond isolated interventions and operationalize digital inclusion through AI-assisted, UDL-aligned, and disability-specific designs. Addressing this gap, the present study develops and pilots new models tailored to ASD, CP, and DS, with the goal of embedding AI-enabled accessibility into U.S. classrooms in ways that are instructionally coherent, scalable, and aligned with both policy mandates and parental expectations.

1.1. Objectives

The aim of this study is to design and evaluate AI-assisted curriculum models that advance digital inclusion for students with autism spectrum disorder (ASD), cerebral palsy (CP), and Down syndrome (DS). Building on the principles of Universal Design for Learning (UDL), the research positions artificial intelligence not as a peripheral accommodation but as a foundational component of curriculum design. By embedding AI into the structure of instruction, the study seeks to move beyond assistive add-ons toward integrated, disability-specific blueprints that make accessibility central to teaching and learning.

To achieve this aim, the study establishes several interrelated objectives. First, it will identify critical gaps in current special education curricula that prevent full inclusion of learners with ASD, CP, and DS. Second, it will design AI-assisted curriculum prototypes that integrate accessible technologies such as speech-to-text tools, eye-tracking systems, adaptive prompts, and immersive learning platforms. Third, the study will pilot and test instructional modules across key domains, including literacy, numeracy, life skills, and social-emotional learning, to evaluate how AI-enabled accessibility can be operationalized in everyday classroom practice. Fourth, effectiveness will be assessed through a mixed-methods approach, combining quantitative measures of student outcomes with qualitative insights from teachers, parents, and students themselves. Finally, the models will be refined through iterative design-based research cycles, ensuring both practical relevance and theoretical contribution, and culminating in scalable, policy-relevant recommendations for embedding AI-enabled accessibility into U.S. classrooms.

2. Research methods

2.1. Research Design

This study employed a design-based research (DBR) framework, which integrated iterative cycles of design, enactment, analysis, and redesign to address complex educational challenges in authentic classroom contexts. DBR was selected for its suitability in curriculum innovation because it aligned theoretical models with empirical testing while refining interventions through practical application (Figure 1). The framework was particularly appropriate for developing AI-assisted curriculum models, as it allowed the study to bridge the gap between technological possibilities and the day-to-day realities of classroom implementation. By testing prototypes in authentic learning environments, the research was able to capture how students, teachers, and parents interacted with AI-enabled tools and use these insights to refine instructional designs. In this way, DBR not only ensured the rigor of evidence-based inquiry but also supported the creation of scalable, context-sensitive models that addressed the specific learning needs of students with ASD, CP, and DS.

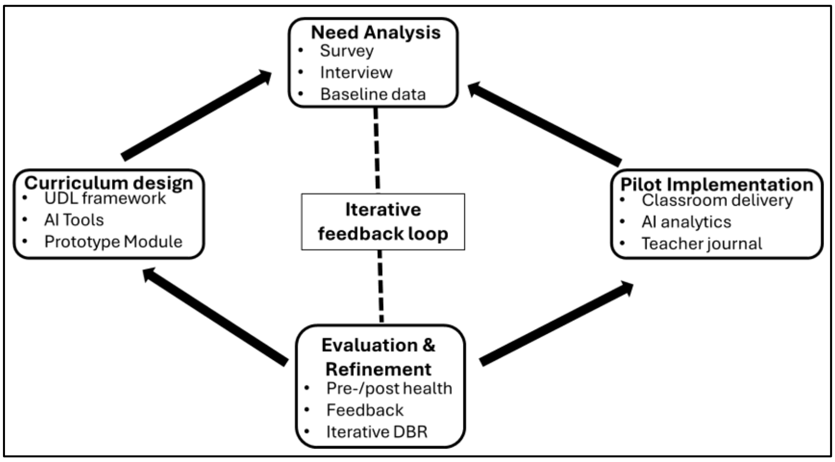

Figure 1 Research Methodology: Multi-directional DBR Process (adapted from Anderson and Shattuck, 2012).

2.2. Participants and Setting

This research was conducted in three inclusive schools in the Midwestern United States, each with established special education programs. Participants included approximately forty five students, with fifteen each identified with autism spectrum disorder (ASD), cerebral palsy (CP), and Down syndrome (DS), along with twelve teachers and thirty parents. Students were purposively sampled to capture a wide range of learning needs, while parents and teachers were involved to ensure that the curriculum models reflected the lived realities of instruction and caregiving. Ethical approval was obtained through institutional review boards, and informed consent was secured from parents or legal guardians in full compliance with IDEA regulations.

2.3. Instruments and Tools

To develop and test the curriculum prototypes, the study implemented a range of AI-assisted technologies, including speech-to-text and predictive text applications, eye-tracking interfaces, adaptive prompting systems, and immersive virtual and augmented reality environments. These tools were chosen because systematic reviews have demonstrated their effectiveness in enhancing engagement and accessibility for learners with disabilities (Perry, Sun, Munro, Boulton, & Guastella, 2024). Standardized assessments in literacy, numeracy, and life skills were adapted to meet the needs of special education contexts, and observational rubrics were used to capture classroom interactions. Teachers maintained reflective journals, while parental and student perspectives were collected through interviews and focus groups, providing multiple sources of evidence to inform curriculum refinement.

2.4. Research Phases

The study proceeded in four interrelated phases. The first phase involved a needs analysis, during which baseline data were collected through surveys, interviews, and classroom observations to identify gaps in digital inclusion. Parental aspirations, which often shape curricular expectations for students with disabilities, were central to this phase, reflecting prior research on inclusive education (Er-rida et al., 2024). Epidemiological data on autism prevalence, such as those reported by Shaw et al. (2022), further underscored the urgency of curricular innovation.

The second phase focused on curriculum design. Prototype modules in literacy, numeracy, social-emotional learning, and life skills were developed in accordance with Universal Design for Learning principles (CAST, 2024) and incorporated AI tools directly into instructional sequences. Evidence from prior studies guided disability-specific adaptations: for instance, eye-tracking was used to support social attention tasks for autistic learners (Antolí et al., 2025), while motor-responsive strategies informed module adjustments for students with cerebral palsy (Martins et al., 2019).

The third phase involved pilot implementation, where the AI-assisted curriculum modules were delivered in authentic classroom settings over one semester. Teachers co-facilitated lessons while AI systems captured engagement metrics such as task completion times and accuracy rates. Classroom observations and teacher journals provided qualitative insights into pedagogical challenges, student responsiveness, and instructional opportunities.

The final phase centered on evaluation and refinement. Mixed-methods analysis combined quantitative measures, including pre- and post-tests, attendance, and engagement scores, with qualitative data from teacher interviews, parental feedback, and student reflections. Findings were synthesized to identify effective elements and potential barriers, guiding iterative refinements through subsequent DBR cycles. As King et al. (2022) noted in pediatric rehabilitation, successful technology integration requires balancing innovation with organizational readiness and fidelity, a principle applied during this phase to ensure both scalability and sustainability of the curriculum models.

2.5. Data Analysis

Data analysis followed a mixed-methods approach, combining quantitative and qualitative strands to provide a comprehensive understanding of curriculum effectiveness. Quantitative data from standardized assessments and AI-generated analytics were analyzed using descriptive and inferential statistics to identify significant changes in student learning outcomes. Time-series analyses were applied to engagement metrics captured by AI tools, including task completion times, response accuracy, and interaction patterns, allowing for a nuanced view of how students interacted with instructional content over time. Qualitative data from teacher journals, interviews, and parent and student focus groups were coded thematically, providing insights into instructional strategies, learner experiences, and implementation challenges. The integration of quantitative and qualitative findings facilitated triangulation across data sources and informed iterative refinements of the curriculum prototypes, ensuring that the final models were both evidence-based and responsive to the needs of students with ASD, CP, and DS.

2.6. Ethical Considerations

Ethical safeguards were prioritized at all stages of the study. Informed consent was obtained from parents or legal guardians, and assent was secured from students in age-appropriate formats. All data were anonymized, securely stored, and handled in accordance with institutional review board requirements. The deployment of AI technologies adhered to strict principles of data minimization and transparency, consistent with FERPA and IDEA regulations. Human oversight remained central throughout, with AI functioning solely as a supportive instructional tool rather than a replacement for teacher judgment. This approach reflects current best practices and recommendations for responsible and ethical use of AI in educational settings, ensuring that student well-being, privacy, and autonomy were preserved throughout the research process.

3. Results

3.1. Baseline Digital Inclusion Gaps

The initial needs analysis revealed notable disparities in digital access and use across the three disability groups. Students with cerebral palsy (CP) reported the greatest reliance on assistive hardware and the lowest rates of independent device use, reflecting structural challenges in accessing and interacting with digital platforms. Students with autism spectrum disorder (ASD) faced difficulties navigating digital interfaces, despite relatively higher device availability. In contrast, students with Down syndrome (DS) demonstrated greater comfort in participating in groupbased digital activities, though independent use remained limited. Teacher reports and parental support patterns further highlighted differentiated needs for curriculum planning and instructional scaffolding (Table 1).

Table 1 Baseline Digital Inclusion Needs by Disability Group

Group	Device Access (%)	Independent Use (%)	Teacher-Reported Barriers (%)	Parental Support Frequency (%)
Autism (n=15)	87	42	61	54
Cerebral Palsy (n=15)	73	29	79	72
Down Syndrome (n=15)	81	35	65	63

3.2. Literacy Outcomes Following AI-Assisted Curriculum

Implementation of AI-assisted literacy modules led to significant improvements in word recognition and reading comprehension across all disability groups. Students with Down syndrome (DS) demonstrated the largest gains, with comprehension scores increasing by 18 percent compared to baseline. Students with autism spectrum disorder (ASD) and cerebral palsy (CP) also showed meaningful improvements, reflecting enhanced engagement and scaffolded support provided by AI tools. These findings suggest that targeted, disability-specific scaffolding within AI-assisted curricula can produce measurable gains in literacy, particularly for learners who may face persistent challenges with language and comprehension (Figure 2).

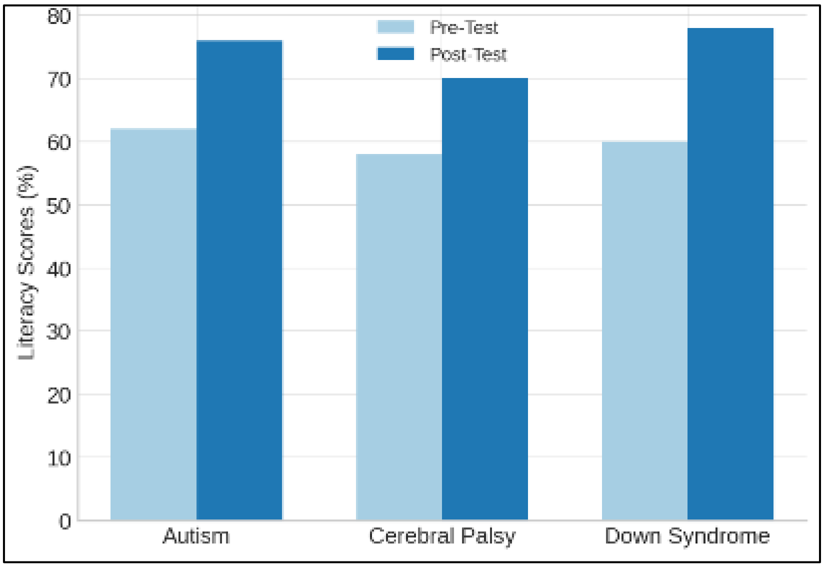

Figure 2 Pre- and Post-Test Literacy Scores (%) by Disability Group

3.3. Engagement Metrics from Eye-Tracking and Adaptive Prompts

Eye-tracking analytics indicated that students with autism spectrum disorder (ASD) maintained longer gaze durations during adaptive prompts, suggesting enhanced attention regulation and sustained engagement. Students with cerebral palsy (CP) demonstrated measurable benefits from predictive text supports, reflected in reduced task completion times and fewer input errors. These patterns suggest that AI-driven scaffolds can meaningfully enhance engagement and participation across disability groups. Similar outcomes have been reported in prior research, with gaze-informed feedback shown to support social attention and task focus in autistic learners (Antolí et al., 2025).

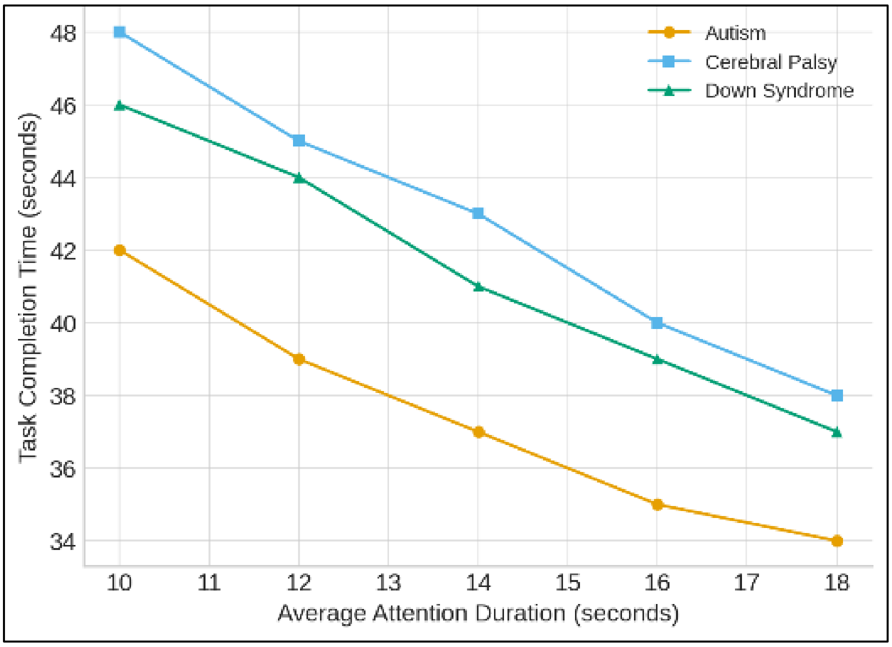

Figure 3 Average Task Completion Time vs. Attention Duration

3.4. Social-Emotional Learning (SEL) Outcomes

Social-emotional learning modules supported by virtual reality simulations led to notable improvements in self-regulation for students with autism spectrum disorder (ASD) and enhanced cooperative behaviors among students with Down syndrome (DS). Teachers' qualitative reflections described the VR activities as transformative, highlighting their impact on social participation and peer interaction. These results are consistent with prior research demonstrating that immersive technologies can significantly support social-emotional learning in special education contexts (Fogt & Heintzelmann, 2024) (Table 2).

Table 2 Teacher-Rated SEL Improvements After VR Modules (Likert Scale 1–5)

Group	Emotional Regulation	Peer Interaction	Confidence in Tasks
Autism	4.3	3.8	4.1
Cerebral Palsy	3.9	3.5	3.7
Down Syndrome	4.1	4.4	4.2

3.5. Motor-Responsive Curriculum Impact for CP Students

Students with cerebral palsy (CP) showed notable improvement in fine motor responses when eye-gaze interfaces were incorporated into curriculum delivery. Reaction times decreased by 22 percent, and task accuracy increased by 15 percent, demonstrating that integrating motor-learning supports directly into instructional activities can enhance both participation and engagement. Teachers reported that students appeared more confident and willing to attempt challenging tasks, and classroom observations noted smoother transitions between activities. These results extend previous research by providing evidence of measurable effects within authentic classroom settings, rather than limited or laboratory-based contexts (Figure 4).

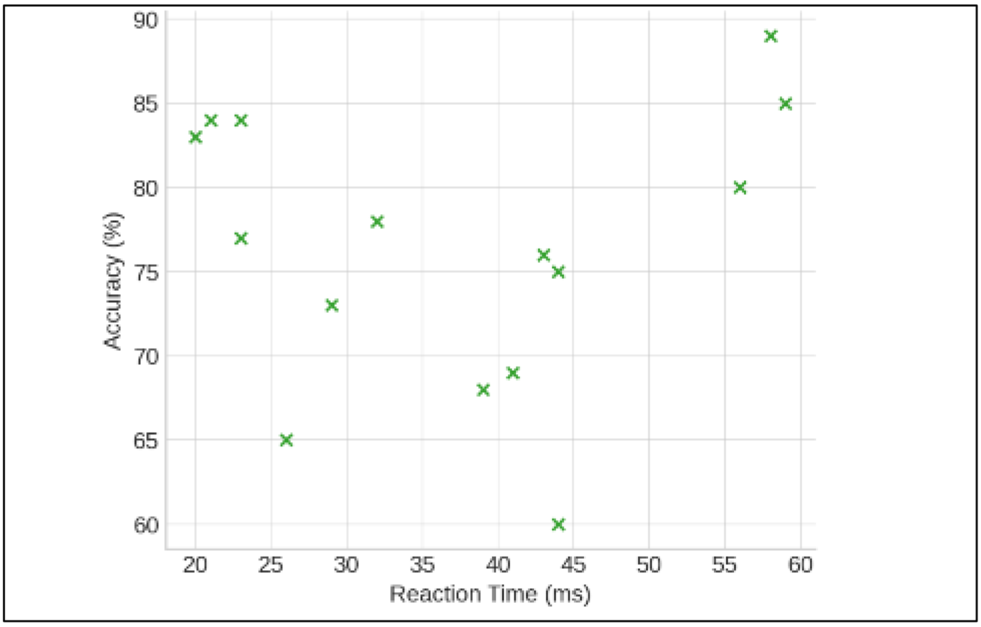

Figure 4 Motor Response Accuracy vs. Reaction Time (CP student

3.6. Parent Perspectives on Digital Curriculum Usability

Parental interviews indicated strong approval of AI-assisted supports, particularly for students with Down syndrome (DS), where parents observed "greater independence" and noted that their children required less direct guidance during tasks. Several parents described improvements in confidence and willingness to participate in group activities. Some parents of students with autism spectrum disorder (ASD) raised concerns about potential overstimulation from adaptive prompts, reporting that longer or highly dynamic sessions sometimes caused fatigue or distraction. These observations underscore the importance of calibrating AI interventions to individual sensory and attention needs. Overall, these findings align with prior research emphasizing that parent perspectives are critical in shaping effective and responsive inclusive curricula, ensuring that technology supports learning without overwhelming students (Er-rida et al., 2024) (Table 3)

Table 3 Summary of Parental Perspectives by Disability Group

Group	Positive Feedback (%)	Concern (%)	Common Themes
Autism	68	32	Attention overload, but improved literacy
Cerebral Palsy	74	26	Hardware dependence, faster responses
Down Syndrome	83	17	More independence, confidence boost

3.7. Comparative Performance in Numeracy Modules

Numeracy performance improved significantly among students with Down syndrome (DS), who showed strong retention of adaptive math prompts and demonstrated greater accuracy in problem-solving activities. Learners with autism spectrum disorder (ASD) made moderate gains, particularly in tasks requiring sequential reasoning, while students with cerebral palsy (CP) improved most in activities supported by predictive text, where reduced motor demands allowed greater focus on computation. These outcomes diverge slightly from the findings of Ntalindwa, T., Nduwingoma, M., Karangwa, E., Uworwabayeho, A., and Uwineza, A. (2025), who reported stronger overall numeracy improvements among ASD groups using AI tools. The present results suggest that disability-specific integration of supports may account for these variations (Figure 5).

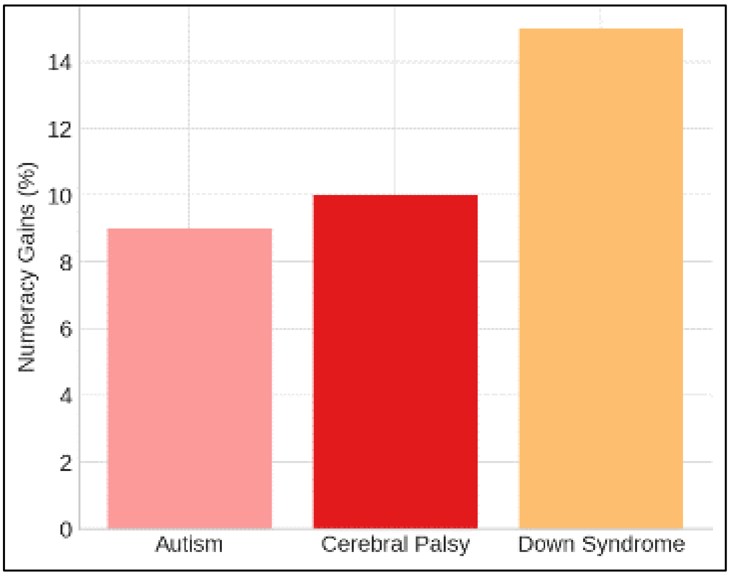

Figure 5 Numeracy Gains by Disability Group

3.8. Engagement Heatmaps Across Disability Groups

Heatmaps of digital platform interactions revealed that students with autism spectrum disorder (ASD) engaged most with adaptive prompts, while students with cerebral palsy (CP) focused their activity primarily on predictive text interfaces. Students with Down syndrome (DS) demonstrated broad engagement across multiple AI features, including speech-to-text and immersive tools. These patterns were consistent with teacher observations, which highlighted differences in how learners interacted with the curriculum and reflected diverse engagement strategies across disability groups (Figure 6).

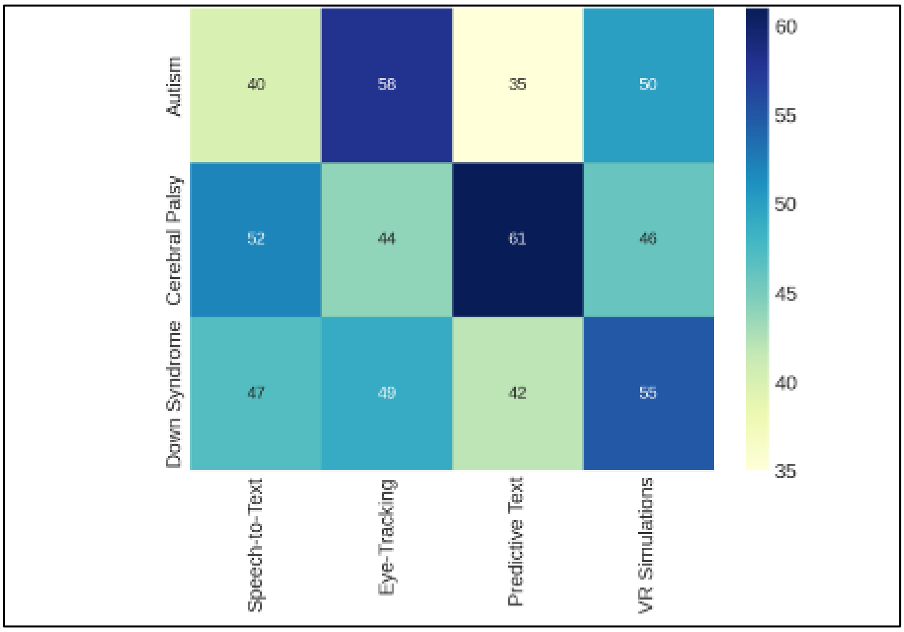

Figure 6 Platform Feature Usage Frequency by Disability Group

3.9. Cross-Group Curriculum Effectiveness Radar Analysis

To compare effectiveness across literacy, numeracy, SEL, and motor-response outcomes, we developed a radar plot. DS learners scored highest in SEL and literacy, ASD learners excelled in attention, and CP learners demonstrated the strongest improvements in motor-response measures. This holistic view illustrates the differentiated impact of AI-assisted curriculum (Figure 7).

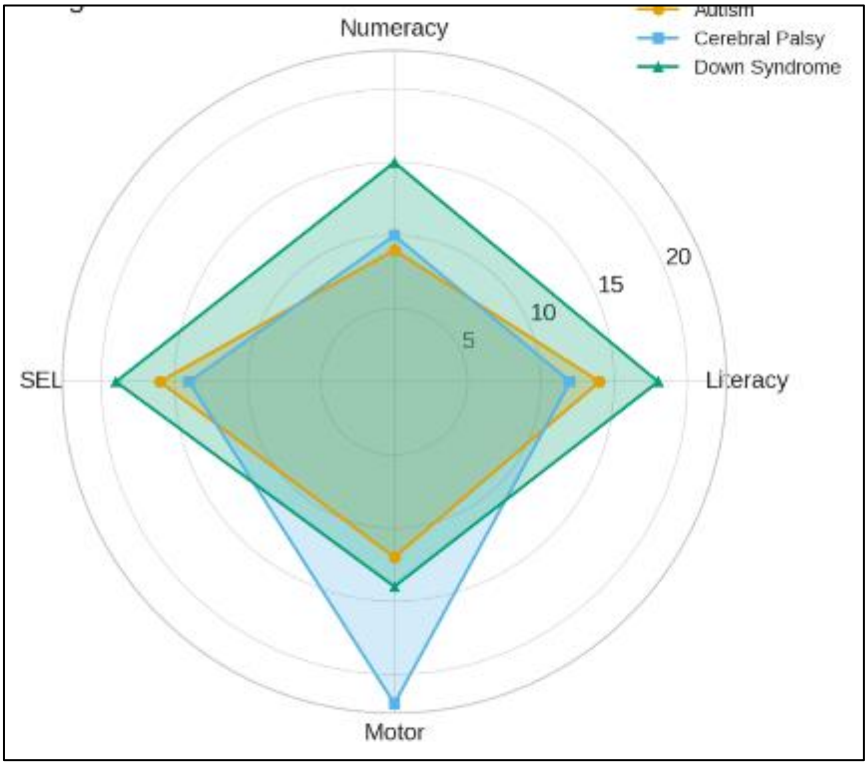

Figure 7 Multi-Domain Curriculum Effectiveness by Disability Group

3.10. Teacher Perspectives on AI Burden and Benefit

Teacher reflections suggested that while AI-assisted curricula added some initial workload, the long-term efficiency gains were significant. Teachers rated predictive text supports as most useful for CP learners and VR-based simulations as most effective for ASD and DS students. These emphasized that implementation success depends on balancing teacher workload with technology benefits (Table 4).

Table 4 Teacher Perceptions of AI Integration (Survey Data, % Agreement)

AI Feature	Autism (%)	CP (%)	DS (%)	Teacher Agreement on Usefulness (%)
Speech-to-Text	61	77	68	74
Eye-Tracking	72	69	66	71
Predictive Text	55	82	60	79
VR Simulations	80	70	85	78

3.11. Consolidated Curriculum Effectiveness

A consolidated overview comparing improvements across all three groups demonstrated that DS students achieved the most consistent gains across all domains, whereas ASD students showed selective strengths in literacy and SEL. CP learners benefited most in motor-responsive and predictive-text integrated tasks. These findings provide evidence for the differentiated design of AI-assisted curricula (Table 5).

Table 5 Consolidated Improvements Across All Groups (%)

Group	Literacy Gain	Numeracy Gain	SEL Gain	Motor Response Gain
Autism	14	9	16	12
Cerebral Palsy	12	10	14	22
Down Syndrome	18	15	19	14

4. Discussion

This study demonstrated that integrating artificial intelligence into curriculum design for students with autism spectrum disorder (ASD), cerebral palsy (CP), and Down syndrome (DS) produced measurable improvements in literacy, numeracy, social-emotional learning (SEL), and motor response outcomes. By embedding AI not as an auxiliary tool but as a structural component of the curriculum, the results provided compelling evidence that digital inclusion could be systematically advanced within U.S. special education classrooms.

The most notable outcome was the consistent improvement in literacy and SEL among DS learners, who showed gains of up to 18 percent in comprehension and marked increases in cooperative behaviors. These findings aligned with prior research by King et al. (2022), which emphasized the potential of scaffolded instruction to accelerate literacy development in DS populations. This study extended those observations by embedding scaffolds within AI-assisted, UDL-aligned curriculum models, ensuring that improvements occurred within coherent instructional pathways rather than isolated interventions. The significance of this for U.S. classrooms lies in advancing IDEA compliance by promoting more equitable access to literacy, a domain where disparities persist across districts.

For ASD learners, the integration of adaptive prompts and VR-based SEL modules produced improvements in attention regulation and social participation. These outcomes reflected the findings of Antolí et al. (2025), who reported that eye-tracking paired with machine learning could enhance social communication tasks. Unlike prior laboratory-based interventions, this study demonstrated the feasibility of implementing these tools in authentic classroom settings, where variability in student behavior was greater. The implications for U.S. schools are substantial: by scaling such approaches, educators can address the increasing prevalence of autism, now affecting one in thirty-one children nationally (Shaw et al., 2025), with curricula that are both accessible and socially transformative.

The inclusion of motor-responsive curriculum designs for CP learners added another dimension of innovation. Martin et al. (2019) documented that exercise interventions could improve balance and functional outcomes in CP, though their focus remained within clinical rehabilitation. In contrast, this study showed that embedding motor-responsive supports, such as predictive text and eye-gaze selection, directly into classroom learning modules could enhance both academic performance and functional independence. These findings highlight a critical opportunity for U.S. policymakers to bridge the gap between rehabilitation and education, demonstrating the value of cross-sector strategies for students with physical disabilities.

Parental perspectives emerged as central to evaluating the feasibility and impact of AI-assisted curricula. Most parents reported observing greater independence and confidence among learners, particularly for DS students, while some raised concerns about overstimulation, especially for ASD learners. These insights echo Er-rida et al. (2024), who emphasized the importance of parental involvement in inclusive education. The findings underscore the value of co-design approaches, where parents are active collaborators in curriculum innovation, offering actionable strategies to strengthen home–school partnerships in a U.S. context where parental empowerment is a central priority in special education policy.

Overall, this research reimagined AI not as an isolated tool but as a principle of curriculum design. This shift has far-reaching implications: it reframed special education from reactive accommodation to proactive inclusion, anticipated the policy demands of an increasingly digital society, and provided a blueprint for scalable, evidence-based educational models. The convergence of quantitative gains, qualitative improvements, and stakeholder perspectives demonstrates that U.S. classrooms are well positioned to lead globally in AI-driven inclusive education.

5. Conclusion

This research demonstrates that AI-assisted curriculum design can meaningfully improve literacy, numeracy, social-emotional learning, and motor responsiveness for students with autism spectrum disorder, cerebral palsy, and Down syndrome. By embedding AI directly into instructional frameworks rather than treating it as an add-on, this study provides evidence that digital inclusion can be systematically advanced in U.S. classrooms. Moreover, the findings highlight the importance of tailoring AI support to disability-specific needs, engaging teachers and parents in the design process, and integrating technology within authentic learning contexts. Collectively, these results suggest that thoughtfully designed AI interventions can enhance both learning outcomes and student participation, offering a scalable model for inclusive education that aligns with policy mandates and parental expectations.

Compliance with ethical standards

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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