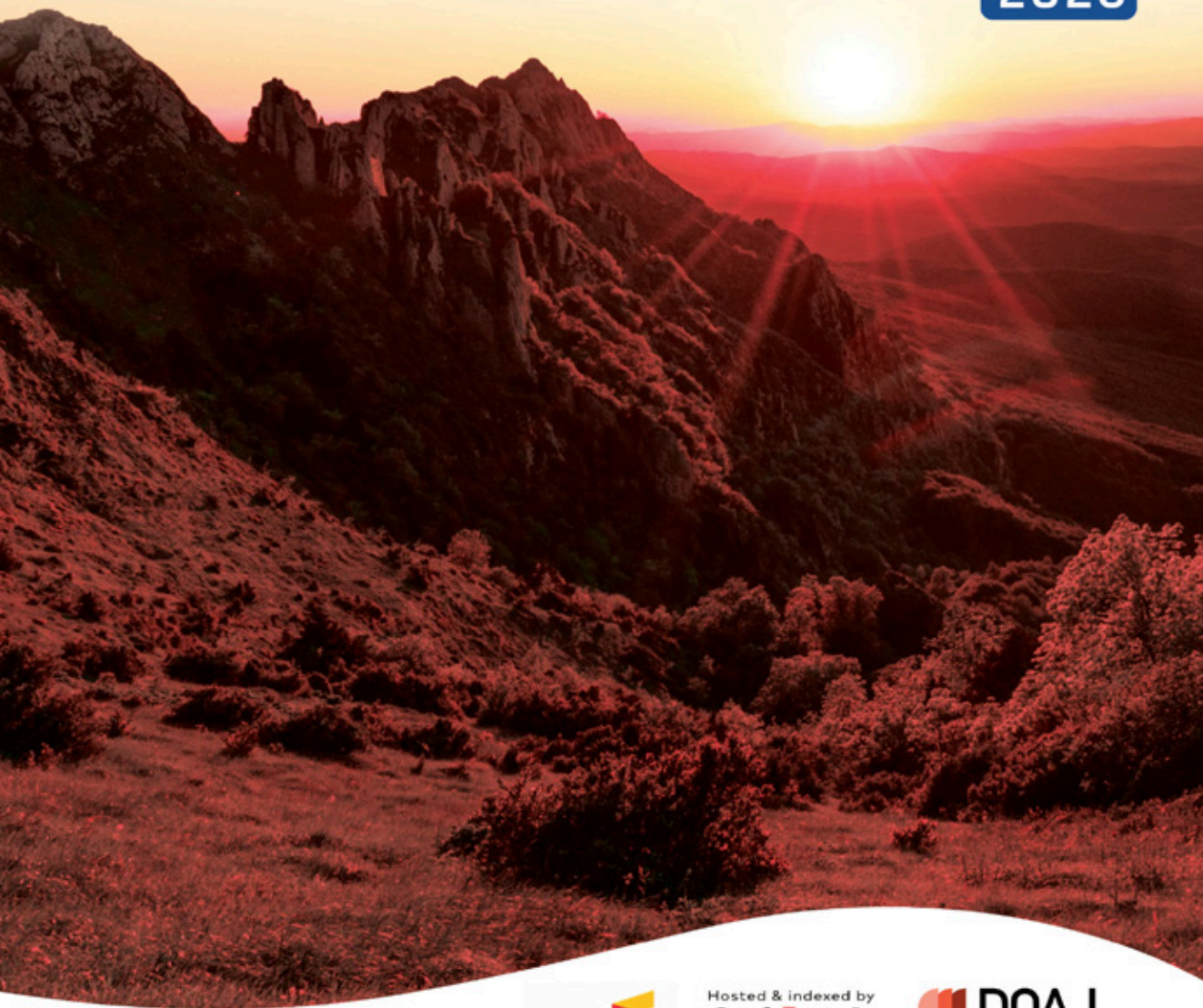


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The impact of AI-enhanced assistive technologies on the learning experiences of children with disabilities in Zimbabwe

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Abstract

Educational inclusion for children with disabilities remains constrained by structural inequalities, limited specialist resources and persistent disparities in access to quality learning opportunities. Although specialised learning environments have traditionally relied on dedicated infrastructure and human support, such arrangements frequently reinforce educational segregation and restrict equitable participation in mainstream schooling, particularly in low-resource contexts. Artificial intelligence-enhanced assistive technologies (AI-AT) present a transformative opportunity to reconfigure these constraints by personalising learning, improving accessibility and extending instructional support beyond conventional pedagogical boundaries. Yet, evidence on their effectiveness within resource-constrained education systems remains limited. This study examines the influence of AI-AT on the learning experiences of children with disabilities in Zimbabwean primary schools, where infrastructural, financial and institutional limitations continue to shape inclusive education outcomes. Rather than assuming technological determinism, the study interrogates how contextual conditions mediate the educational value of AI-AT and the extent to which these technologies advance or reproduce existing inequalities. Guided by the Technology Acceptance Model and sociocultural theory, the study adopts a mixed-methods research design involving ten purposively selected primary schools in Zimbabwe. The findings demonstrate that AI-AT substantially enhances learner engagement, instructional accessibility, communication, personalised learning and participation, thereby expanding opportunities for meaningful educational inclusion. However, these gains are contingent upon institutional readiness, teacher digital competence, affordability and supportive policy environments. The analysis further reveals that algorithmic bias, data governance, cultural relevance and digital inequities represent systemic rather than merely technical challenges, with significant implications for equitable implementation. The study argues that the educational potential of AI-AT in developing countries depends less on technological sophistication than on its contextual adaptation within local pedagogical, socio-economic and cultural realities. It therefore contributes empirical evidence to debates on inclusive artificial intelligence by demonstrating that sustainable educational transformation requires the co-evolution of technology, institutional capacity and inclusive policy frameworks.

Keywords: Artificial Intelligence, Assistive Technologies, Children with Disabilities, Inclusive Education, Social Inclusion

Introduction

The rapid diffusion of artificial intelligence (AI) is reshaping educational systems by redefining how knowledge is accessed, personalised and delivered. While these technological advances promise to democratise learning, their transformative potential remains unevenly distributed, particularly among children with disabilities in low-resource settings. Despite international commitments under the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD, 2006) and the Sustainable Development Goals (SDGs) to ensure equitable and inclusive education, millions of children with disabilities continue to experience systemic exclusion from meaningful learning opportunities.

In Zimbabwe, this exclusion extends beyond physical access to schooling and reflects deeper structural inequities embedded within educational infrastructure, teacher preparedness, assistive resource provision and digital capability. Disability and educational disadvantage become mutually reinforcing phenomena, limiting learners' agency, participation and long-term human development. The emergence of AI-enhanced assistive technologies (AI-AT) introduces the possibility of disrupting these entrenched inequalities through intelligent, adaptive and personalised learning environments. However, whether AI-AT functions as an instrument of educational inclusion or merely reproduces existing digital inequalities depends fundamentally on the institutional, technological and socio-cultural contexts within which it is deployed.

Although growing international scholarship highlights the pedagogical benefits of AI-enhanced assistive technologies, including adaptive instruction, intelligent communication support, automated accessibility and personalised feedback, existing evidence is dominated by studies conducted in technologically mature educational systems. Prevailing assumptions regarding the effectiveness of AI-AT remain insufficiently tested within resource-constrained environments where unreliable electricity, limited connectivity, inadequate funding, low digital literacy and weak institutional capacity fundamentally reshape technology adoption and educational outcomes. Rather than treating AI-AT as a universally transferable innovation, there is a need to interrogate how contextual realities mediate its educational value and determine whether technological innovation translates into substantive educational inclusion.

Zimbabwe provides an important setting for addressing this gap because its inclusive education agenda continues to evolve amid persistent resource limitations and widening digital inequalities. This study, therefore, explores the impact of AI-enhanced assistive technologies on the learning experiences of children with disabilities in Zimbabwean primary schools, while critically examining the institutional, socio-cultural and ethical conditions that enable or constrain their transformative potential. By integrating quantitative and qualitative evidence, the study contributes to emerging debates on inclusive artificial intelligence by demonstrating that educational transformation depends not solely on technological capability but on the interaction between technology, institutional readiness, human capacity and contextual appropriateness.

Background

The educational marginalisation of learners with disabilities in Zimbabwe reflects a persistent disjunction between rights-based commitments and the material conditions required to realise inclusive schooling. Although the United Nations Convention on the Rights of the Child and the Convention on the Rights of Persons with Disabilities establish education as an enforceable entitlement, access remains mediated by poverty, inaccessible infrastructure, limited specialist provision, stigma and weak implementation capacity (United Nations, 1989, 2006; UNICEF Zimbabwe, 2021, 2025). Recent evidence indicates that children with disabilities in sub-Saharan Africa continue to experience markedly poorer educational opportunities, while Zimbabwean learners remain especially vulnerable to exclusion from enrolment, participation and progression (UNESCO-IICBA, 2023; UNICEF Zimbabwe, 2025). These inequalities are intensified where mainstream pedagogy assumes uniform sensory, cognitive and communicative capacities, thereby converting learner difference into institutional disadvantage rather than accommodating it through flexible instructional design (Mugumbate & Cherenje, 2018; UNESCO, 2023). The scarcity of assistive technologies, limited awareness of available tools and insufficient teacher preparation consequently operate not as isolated constraints, but as mutually reinforcing mechanisms that reproduce disparities in achievement, autonomy and social participation (Chikozho & Muziringa, 2021; WHO & UNICEF, 2022; UNESCO, 2025).

Assistive technology encompasses products, systems and services designed to maintain or improve functioning, independence and participation among persons with disabilities (Cook et al., 2020; WHO, 2024). Its convergence with

artificial intelligence extends this function from static compensation towards adaptive mediation. Through machine learning, natural language processing, computer vision, speech recognition and augmented reality, AI-enhanced assistive technologies (AI-AT) can personalise content, translate information across sensory modes, support communication and recalibrate learning tasks to individual capabilities (Luckin et al., 2016; Zdravkova et al., 2022; Hopcan et al., 2023; Harkins-Brown et al., 2025). Such affordances can improve accessibility, engagement and learner agency; however, technological capability alone does not guarantee educational inclusion. Evidence increasingly shows that affordability, connectivity, electricity, technical support, teacher competence, data governance and culturally responsive design determine whether AI-AT reduces exclusion or merely relocates it within a new digital architecture (UNESCO, 2023, 2025; WHO, 2024; Kooli, 2025).

This tension is particularly consequential in Zimbabwe, where AI-AT is introduced into an education system already marked by resource asymmetries and uneven institutional readiness. Yet, empirical evidence on how these technologies shape the learning experiences and social inclusion of primary-school learners with disabilities remains limited. The resulting knowledge deficit constrains policy design, investment prioritisation and context-sensitive implementation. Accordingly, this study evaluates the influence of AI-AT on learning and social inclusion, identifies the barriers and enabling conditions shaping implementation, and examines educators' and caregivers' interpretations of its educational value.

Literature Review

Scholarship on artificial intelligence-enhanced assistive technologies (AI-AT) has expanded rapidly, yet its empirical architecture remains geographically and conceptually uneven. Research from technologically advanced systems predominantly evaluates technical functionality, usability and short-term learning gains, whereas considerably less is known about how AI-AT operates within resource-constrained African schools where infrastructure, institutional capacity, language and disability intersect (Zdravkova et al., 2022; UNESCO, 2023, 2025; Zhang & Holden, 2025). This imbalance matters because technological affordances do not travel unchanged across contexts. Their educational effects are mediated by electricity, connectivity, affordability, teacher competence, curricular compatibility, family support and the social meanings attached to disability. Thus, evidence that an application performs effectively under stable

technological conditions cannot be treated as evidence that it will produce equivalent outcomes in Zimbabwean primary schools. The literature must, therefore, move beyond asking whether AI-AT works to examining for whom, under what conditions, through which mechanisms and with what distributive consequences it works.

AI-AT marks a shift from conventional assistive devices that compensate for a specific functional limitation towards systems capable of interpreting user behaviour, modifying content and responding dynamically to individual learning needs. Machine learning, natural language processing, computer vision, speech recognition and augmented reality enable educational content to be translated across visual, auditory and textual modes, potentially reducing the dependence of learners with disabilities on standardised pedagogical delivery (Luckin et al., 2016; Zheng et al., 2020; Zdravkova et al., 2022; ZainEldin et al., 2024). Speech-to-text applications, for example, convert spoken instructions into readable content for learners with hearing impairments, while screen readers, intelligent navigation systems and adaptive platforms can improve access for learners with visual impairments. Yeratziotis et al. (2023) similarly demonstrate how AI-mediated accessibility can extend participation beyond the classroom by making digital and social communication environments more usable for deaf users.

The significance of these technologies, however, lies less in the novelty of their interfaces than in their capacity to redistribute educational agency. By allowing learners to control pace, format, repetition and modes of response, AI-AT may reduce the extent to which participation depends on conformity to a single instructional norm. Seo et al. (2021) associate AI-supported learning with altered learner–instructor interaction, while Zdravkova et al. (2022) show that intelligent communication and learning technologies can widen opportunities for participation among children with disabilities. UNESCO (2025) likewise identifies adaptive learning tools, communication aids and sensory technologies as potentially important mechanisms for personalisation and social integration. Collectively, these studies suggest that AI-AT can convert accessibility from a peripheral accommodation into an embedded feature of pedagogy. Its contribution is therefore not merely to help learners perform existing tasks, but potentially to reshape which learners can participate, how competence is demonstrated and whose needs structure classroom practice.

Yet, the literature frequently slides from technological possibility to educational effect without adequately specifying the intervening processes. Personalisation may improve access but does not automatically deepen understanding; engagement may increase because a tool is novel rather than pedagogically effective; and task completion may signal technological dependence rather than durable learning. Anastasiou et al. (2025), in their critique of universal design assumptions, caution against treating apparently inclusive frameworks as theoretically neutral or universally responsive. Similar caution is required in AI-AT research. A system may simplify a task while simultaneously narrowing opportunities for reasoning, dialogue and independent problem-solving. Greene-Harper (2023) and Yin (2024) raise concerns that excessive dependence on AI may displace rather than strengthen critical cognitive work. The appropriate analytical question is not whether AI support should be maximised, but where assistance should be positioned so that it removes disability-related barriers without substituting for intellectual engagement. This places the teacher at the centre of AI-mediated inclusion: not as a passive technology user, but as the professional who calibrates support, interrogates outputs and preserves learner autonomy.

From Technological Access to Educational Conversion

The literature demonstrates that possession of a device is an inadequate measure of meaningful access. WHO and UNICEF (2022) distinguish between the availability of assistive products and the wider ecosystem required to select, adapt, maintain and use them effectively. Globally, need substantially exceeds provision, with access in some low-income settings reaching only a small fraction of those requiring assistive products (WHO, 2024). This disparity reveals that AI-AT is embedded within broader political economies of technology: procurement costs, imported hardware, subscription models, proprietary software, connectivity charges and maintenance requirements collectively determine who can use it and for how long. Accordingly, the digital divide is not simply a binary separation between users and non-users; it includes disparities in device quality, frequency of access, technical support, digital competence and the capacity to convert occasional access into sustained educational benefit (WHO & UNICEF, 2022; UNESCO, 2023, 2025).

Infrastructure is constitutive of AI-AT effectiveness rather than an external implementation detail. Intelligent applications that depend on cloud processing, regular updates or continuous connectivity may be poorly matched to schools experiencing unreliable electricity and internet access. Even where devices are

procured, limited maintenance capacity can reduce them to dormant assets. The recurring policy tendency to foreground acquisition while underfunding training, repair, content localisation and user support consequently produces what may be termed symbolic digital inclusion: technology is visibly present, but pedagogically underutilised. UNESCO (2025) locates infrastructure development, teacher competence, collaboration and continuing capacity-building within the same implementation architecture. This systems perspective challenges intervention models that treat hardware distribution as the principal indicator of progress.

Human capability is equally decisive. Miller et al. (2022) and Vashishth et al. (2025) argue that AI-enhanced education alters teachers' professional roles, requiring them to act as pedagogical designers, mediators, evaluators and curators of technologically generated content. For learners with disabilities, these roles become more demanding because technology must be aligned with individual impairments, developmental levels, curricular objectives and communication preferences. Training confined to basic device operation is therefore insufficient. Teachers require the capacity to evaluate algorithmic recommendations, identify inaccessible features, combine digital and non-digital support, and judge when AI assistance enables or constrains learner agency. Caregivers similarly shape whether skills developed at school are reinforced at home. Adoption consequently depends on a distributed support system linking learners, teachers, specialists, school leaders, families and technical personnel rather than on the individual competence of a single user.

Ethical, Cultural and Distributional Risks

AI-AT does not enter education as a neutral instrument. Its algorithms embody assumptions drawn from training data, design environments and commercial priorities that may not represent African learners, minority languages or heterogeneous disability experiences. Farahani and Ghasemi (2024) locate AI within wider structures of inequality, showing that systems may reproduce social disparities even while promising greater access. For learners with disabilities, algorithmic error may have disproportionate consequences: speech-recognition tools may misinterpret non-standard speech or local accents; vision systems may fail under unfamiliar environmental conditions; and adaptive platforms may construct narrow performance profiles from incomplete behavioural data. Bias in this context is not merely a technical defect. It can determine who receives support, whose responses are recognised and which learners are misclassified as incapable.

Data governance creates an additional tension. AI-AT may process highly sensitive information concerning disability, speech, behaviour, academic performance and patterns of interaction. Djeki et al. (2024) observe that digital learning environments frequently lack sufficient clarity regarding data collection, storage, access and secondary use. These concerns intensify when the users are children who may neither comprehend nor meaningfully consent to complex data practices. Privacy cannot, therefore, be reduced to obtaining parental permission. It requires data minimisation, secure storage, transparent processing, age-appropriate explanation, institutional accountability and clear limits on commercial or research reuse. Ethical implementation must also recognise that surveillance may be normalised under the language of personalisation: the more precisely a system adapts to the learner, the more extensively it may monitor the learner.

Cultural fit is equally underdeveloped in the literature. Ripat and Woodgate (2011) established that assistive technology use is shaped by cultural meanings, family relations and conceptions of disability; this remains salient for AI-enabled tools designed outside their intended contexts. Technologies built around dominant languages, individualised interaction and Western pedagogical assumptions may conflict with local linguistic repertoires, collective learning practices and caregiver expectations. Contextualisation must therefore extend beyond translating interfaces. It requires co-design with learners with disabilities, teachers, families and disability organisations so that systems reflect local communication practices, curricula and definitions of meaningful participation. Duncan et al. (2021) similarly position user-centred development as critical to technology acceptance, while recent co-design scholarship argues that involving persons with disabilities can expose embedded ableist assumptions before they become institutionalised in technological systems.

Zimbabwe has progressively strengthened the normative basis for disability inclusion through the amended Education Act, the National Disability Policy and programmes promoting the integration of children with disabilities into mainstream schooling. However, policy recognition has not eliminated the institutional conditions producing exclusion. Recent evidence indicates that many learners remain outside formal education, enter school late or depend on a limited network of specialised schools and resource units. UNICEF Zimbabwe (2024), drawing on Education Management Information System data, reports that 141,177 learners with disabilities are in education, estimated

to represent only a small proportion of children with disabilities nationally. The same evidence illustrates both the value of assistive devices and the continuing dependence of access on specialist teachers, externally funded equipment and customised support. The policy–practice gap is, therefore, not caused by the absence of inclusive aspirations, but by weak conversion of those aspirations into sufficiently financed, accessible and pedagogically supported provision.

Research on inclusive education in Zimbabwe similarly reports teacher support for inclusion alongside limited preparation, resource shortages and the continued placement of many learners with disabilities in segregated settings. These findings complicate optimistic accounts of AI-AT. Introducing intelligent technologies into an under-resourced system may improve access for some learners while widening inequalities between schools, provinces and households able to sustain them. Imported systems may also produce linguistic and cultural mismatches, while urban schools may capture benefits unavailable to rural institutions. AI-AT must consequently be examined as a potentially stratifying intervention whose effects depend on how resources, expertise and decision-making power are distributed.

The principal gap is thus not a lack of claims about what AI-AT might achieve, but a lack of grounded evidence explaining how its benefits are produced or obstructed in African primary-school settings. Existing studies privilege prototypes, higher-income contexts or single stakeholder groups and rarely integrate learners' experiences with educators' and caregivers' interpretations. They also insufficiently connect technological experience to the accessibility and support conditions through which learning effects are realised. This study addresses that gap by examining whether and how AI-AT influences learning experiences and social inclusion among Zimbabwean primary-school learners with disabilities; identifying the infrastructural, institutional and sociocultural conditions that enable or constrain implementation; and analysing how teachers and caregivers interpret its usefulness, risks and sustainability. In doing so, it shifts the debate from technological potential to contextualised educational conversion.

Conceptual Framework

This study is anchored in the Technology Acceptance Model (TAM), which explains technology adoption through two principal determinants: perceived usefulness (PU) and perceived ease of use (PEOU) (Davis, 1989). Within the context of AI-enhanced assistive technologies (AI-AT), PU reflects the extent to

which learners, educators and caregivers perceive AI-AT as improving learning, accessibility and participation, while PEOU encompasses not only the usability of the technologies but also the availability of training, technical support and institutional assistance required for their effective utilisation. However, because technology adoption in resource-constrained educational settings is shaped by infrastructural limitations, cultural beliefs and institutional capacity, TAM alone provides only a partial explanation of AI-AT adoption.

To address these contextual limitations, TAM is integrated with sociocultural perspectives and the Capability Approach. Sociocultural perspectives emphasise that technology use is socially mediated through cultural values, institutional practices and interpersonal support rather than individual perceptions alone (Lewis & Moje, 2003). Complementing this, the Capability Approach (Sen, 1999) shifts attention from technology ownership to the real opportunities that AI-AT creates for learners with disabilities to participate meaningfully in education. The integrated framework therefore conceptualises AI-AT adoption as a product of technological perceptions, contextual support and learners' capabilities, providing a more comprehensive explanation of how accessibility, AI experience and support mechanisms interact to influence learning outcomes and social inclusion in Zimbabwean primary schools.

Methodology

This study adopted a mixed-methods research design to examine the impact of AI-enhanced assistive technologies (AI-AT) on the learning experiences of learners with disabilities in Zimbabwean primary schools. The quantitative component employed structured questionnaires to measure three latent constructs: Accessibility and Support (AI support, training, mentorship and assistive technology accessibility), Experience with AI (current usage, natural language processing, computer vision and user experience), and Impact on Learning (improved access, understanding and overcoming learning barriers).

The qualitative component comprised semi-structured interviews with educators and caregivers, complemented by structured classroom observations, to explore perceptions, implementation experiences and contextual factors influencing AI-AT adoption. Ten purposively selected primary schools across Harare, Midlands, Manicaland and Bulawayo provinces participated in the study. Selection criteria included evidence of inclusive education, integration of learners with disabilities into mainstream classrooms, willingness to participate and utilisation of AI-AT. The study focused on learners with visual and hearing

impairments because these groups are the primary beneficiaries of AI-enabled assistive technologies.

Participants comprised 250 learners (Grades 4–7), 50 educators and 50 caregivers selected purposively (Patton, 2015). Before data collection, the instruments were pilot-tested to enhance clarity, validity and reliability. Ethical procedures included informed consent from participants and parents or guardians of learners, anonymisation of data and secure digital storage in accordance with WHO (2022) guidelines. Quantitative data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM), which was appropriate for prediction-oriented modelling involving latent constructs measured with Likert-scale data and relatively modest sample sizes. Qualitative data were analysed thematically, while findings from questionnaires, interviews and classroom observations were triangulated to provide a comprehensive understanding of the educational impact and implementation dynamics of AI-AT in resource-constrained learning environments.

Findings

This section presents the integrated quantitative and qualitative findings on the impact of AI-enhanced assistive technologies (AI-AT) on the learning experiences of learners with disabilities in Zimbabwean primary schools. The quantitative analysis, based on Partial Least Squares Structural Equation Modelling (PLS-SEM), examined the influence of Accessibility and Support and Experience with AI on Impact on Learning, while the qualitative findings from interviews and classroom observations were used to explain the mechanisms underlying the statistical relationships. Of the 250 learner questionnaires administered, 152 were complete and retained for analysis (60.8%), while 78 of the 100 questionnaires distributed to educators and caregivers were fully completed and included in the study (78.0%). As a preliminary analysis, the frequency of AI-enabled technologies used by educators and caregivers was examined to establish prevailing patterns of AI-AT utilisation across participating schools, with the results presented in Table 1.

Table 1: Patterns of AI-Enhanced Assistive Technology Usage, Implementation Challenges and Support Needs (n = 78 Educators and Caregivers)

Panel A: Frequency of AI-AT Use	%	Panel B: AI-AT Tools Used	%
Daily	34.62	Other AI-assisted tools	84.62
Weekly	26.92	Interactive educational tools	23.08
Rarely	15.38	Screen readers	19.23
Never	23.08	Text-to-speech software	15.38
Monthly	0.00	Smart navigation assistance	3.85

Panel C: Major Implementation Challenges	%	Panel D: Support and Resources Required	%
Limited resources	69.23	More resources	65.38
Lack of training and support	50.00	Collaboration with specialists	57.69
Technical issues	38.46	Access to technical support	53.85
Resistance from learners	15.38	More training on AI tools	50.00
Other challenges	7.69	Other support	3.85

The quantitative analysis begins by examining the prevalence of AI-enhanced assistive technology (AI-AT) use among educators and caregivers before assessing the measurement and structural models. Table 1 shows that AI-AT has achieved moderate penetration across participating schools, with 61.5% of respondents reporting daily or weekly use, suggesting that AI-supported teaching and learning is gradually becoming embedded within inclusive education practices. However, approximately 25% of respondents reported never using AI-AT, indicating uneven adoption across schools. The most frequently utilised technologies were interactive educational tools, screen readers and text-to-speech applications, reflecting a strong emphasis on improving curriculum accessibility for learners with visual and hearing impairments. At the same time, the high proportion of respondents indicating the use of other AI-assisted tools suggests an increasingly diverse technological ecosystem within participating schools.

Despite this growing adoption, respondents identified substantial implementation constraints. Limited resources emerged as the dominant barrier, followed by inadequate training and technical challenges, highlighting that technology availability alone is insufficient to realise meaningful educational benefits. These findings demonstrate that infrastructural readiness and human

capacity remain critical determinants of successful AI-AT implementation. Consistent with these challenges, respondents prioritised increased resource provision, collaboration with specialists, improved technical support and continuous professional development as the principal interventions required to strengthen AI-AT integration.

Measurement Model Assessment

Table 2 presents the obtained values for the tests performed on the measurement model. Based on the results obtained from these tests, all constructs exhibit Cronbach's alpha (α) and Composite Reliability (CR) values above the threshold of 0.7, which implies strong reliability and convergent validity, and Average Variance Extracted (AVE) values were all above the commonly known threshold of 0.5. The obtained values of less than 3 for VIF suggest that there are no serious issues with multicollinearity among the constructs.

Table 2: Reliability and Convergent Validity

Construct	Indicator	Loading	VIF	Cronbach's α	CR	AVE
Accessibility & Support	AT_Accessibility	0.852	1.89	0.821	0.882	0.652
	AI_Support	0.789	1.65			
	Support_Training	0.811	1.77			
	Support_Mentorship	0.754	1.54			
Experience with AI	Current_Usage	0.801	2.01	0.845	0.897	0.687
	AI_Tool_CV	0.865	2.23			
	AI_Tool_NLP	0.833	2.10			
	Level_of_Experience	0.798	1.95			
Impact on Learning	Improved_Access	0.880	2.45	0.903	0.929	0.724
	Better_Understanding	0.845	2.18			
	Noticeable_Changes	0.821	2.05			
	Challenge_Overcome	0.867	2.31			

In addition, the Heterotrait-Monotrait (HTMT) ratio was used to establish the discriminant validity. Table 3 presents the HTMT ratios for the constructs. A value of less than the conservative threshold of 0.85 shows that the construct is distinct, with all given constructs obtaining values far below this threshold.

Table 3: HTMT Ratio-Discriminant Validity

	Accessibility & Support	Experience with AI
Experience with AI	0.412	
Impact on Learning	0.683	0.559

Before estimating the structural relationships, the psychometric properties of the measurement model were evaluated through tests of reliability, convergent validity and discriminant validity. As shown in Table 2, all constructs demonstrated satisfactory internal consistency, with Cronbach's alpha and Composite Reliability values exceeding the recommended threshold of 0.70, while Average Variance Extracted (AVE) values surpassed the minimum acceptable level of 0.50, confirming adequate convergent validity. Furthermore, Variance Inflation Factor (VIF) values below 3.0 indicated the absence of problematic multicollinearity among the indicators. Discriminant validity was subsequently assessed using the Heterotrait-Monotrait (HTMT) ratio. All HTMT values fell well below the conservative threshold of 0.85, confirming that Accessibility and Support, Experience with AI and Impact on Learning measured conceptually distinct constructs (Tables 2 and 3).

Structural Model Assessment

Given the validity values in Tables 2 and 3, the structural model was then induced. Figure 1 is an illustration of the induced path model along with the estimated coefficients showing Accessibility & Support (AS), Experience with AI (EXP), and Impact on Learning (IMP).

The significance of the path coefficients was assessed by performing a bootstrapping procedure with 10,000 samples. Table 4 presents the results obtained by relying on the bias-corrected and accelerated bootstrap confidence intervals to enhance the interpretation, given that the data are non-normally distributed.

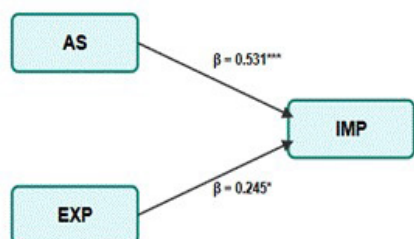


Figure 1: PLS-SEM Structural Model Results.

*** $p < 0.001$, * $p < 0.005$

Table 4: Structural Model Path Coefficients

Path	β	T-Stat	P-Value	95% CI [LL, UL]	f^2	Decision
Accessibility & Support -> Impact on Learning	0.531	5.892	0.000	[0.355, 0.702]	0.341	Supported
Experience with AI -> Impact on Learning	0.245	2.150	0.032	[0.021, 0.465]	0.058	Supported

Having established measurement validity, the structural model was estimated using bootstrapping with 10,000 resamples. The results revealed that Accessibility and Support exerted a strong positive influence on Impact on Learning ($\beta = 0.531$, $p < 0.001$; $f^2 = 0.341$), demonstrating that institutional support, training and access to AI-AT constitute the principal drivers of improved learning experiences among learners with disabilities.

Experience with AI also exhibited a statistically significant positive relationship with learning outcomes ($\beta = 0.245$, $p = 0.032$), although its smaller effect size ($f^2 = 0.058$) indicates that familiarity with AI contributes to learning only when accompanied by adequate institutional support. Overall, the model explained 51.8% of the variance in learning outcomes ($R^2 = 0.518$), representing moderate explanatory power, while the blindfolding procedure produced a Q^2 value of 0.362, confirming satisfactory predictive relevance (Figure 1 and Table 4).

Qualitative Analysis

To gather perceptions of teachers and caregivers, semi-structured interviews were conducted that focused on AI technology usage, perceived effectiveness, challenges, and ethical concerns. Thematic analysis revealed the following three core themes: Transformative learning enablement; Resource chasm; and crucial need for human support. Table 5 presents the codebook for the thematic analysis.

Table 5: Codebook for Thematic Analysis

Theme	Definition	Example Quote (Teacher/Caregiver)
Transformative Learning Enablement	The perception that AI-AT is transformative for learners living with disabilities in how they access the curriculum, participate in the learning process, and demonstrate their understanding.	<i>"My daughter was previously a passive learner who simply listened to the discussion; however, as of now, with the aid of text-to-speech software, she can actively participate in the discussion. It's like a lamp that has been lit in her life"</i> (Caregiver)
The Resource Chasm	The existing gap between what is currently on the ground and the potential of AI-AT is yet to be realised due to several challenges, such as a lack of resources and unreliable infrastructure.	<i>"Learners are being engaged in learning activities using gamification applications. The main challenge is that we only have a few of these gadgets, which makes it difficult for everyone to get a chance. It's a real struggle."</i> (Teacher)
The Crucial Need for Human Support	The realisation that the use of technology in learning requires a human in the loop to monitor and supervise the learning process; therefore, requires extensive capacity building for both teachers and caregivers.	<i>"Computers have been accumulating dust since the day they were brought into the lab. They just provided the machines but did not provide the much-needed training on how to use them in lessons. Manuals are not enough; we need workshops and training to fully embrace the technology."</i> (Teacher)

The qualitative findings reinforced and extended the quantitative evidence. Three interrelated themes emerged from interviews with educators and caregivers: Transformative Learning Enablement, The Resource Chasm, and The Crucial Need for Human Support. Participants consistently described AI-AT as transforming learner participation, communication and curriculum access by enabling learners with disabilities to engage more actively in classroom activities. However, these benefits were constrained by inadequate infrastructure, unreliable electricity, unstable internet connectivity and insufficient numbers of assistive devices, creating what participants characterised as a persistent resource gap between technological potential and educational reality.

Equally prominent was the recognition that AI-AT cannot function independently of human capability. Teachers and caregivers emphasised the need for sustained professional development, technical mentorship and collaborative support if

From the qualitative findings, the role of teachers in an AI-driven educational landscape is evolving. This sheds light on the debate about the new role of teachers, whether to be facilitators, curators, or other roles, which stresses the theme of “The Crucial Need for Human Support”. That is, teachers find their new role in providing personalised support to augment AI-AT, whereby they monitor, supervise, and guide the learning process, thereby enhancing learning. As such, AI is emerging as a tool to support and enhance learning, but not to replace teachers and caregivers in the learning ecosystems of learners with disabilities. For teachers and caregivers to play these new roles requires extensive professional development and training.

Classroom Observation

The findings from the classroom observations revealed convincing evidence of the impact of AI-AT in the learning experience of learners with disabilities, highlighting both benefits and challenges that this technology presents in a classroom setting.

Classroom observations corroborated findings by providing direct evidence of AI-AT use during instruction. Learners using screen readers, speech-to-text applications, adaptive learning platforms and smart navigation tools demonstrated higher levels of engagement, participation and independent task completion than previously observed under conventional instructional approaches. AI-AT enabled learners to access instructional content through multiple communication modes and supported personalised learning pathways that accommodated individual abilities and learning pace. Nevertheless, observations also revealed frequent interruptions arising from limited device availability, unreliable internet connectivity and technical failures, while teachers remained indispensable in scaffolding learning, encouraging critical thinking and ensuring that AI-assisted learning did not replace independent reasoning. These observations further confirmed that technology enhances rather than substitutes human pedagogy.

Mixed-Methods Integration

A detailed presentation of the findings is realised when the quantitative component is fused with the qualitative one. This integration promotes an in-depth analysis of the interplay between technology, support, and learning outcomes. Table 6 presents the joint results of the quantitative and qualitative components. To further strengthen the validity of the findings, these results were triangulated with classroom observations.

Table 6: Display of Quantitative and Qualitative Findings

Integrated Finding	Quantitative Evidence (PLS-SEM)	Qualitative Evidence (Themes & Quotes)
Strong Link Between Support and Impact	The obtained values ($\beta = 0.531$, $f^2 = 0.341$) for the path from <i>Accessibility & Support</i> -> <i>Impact on Learning</i> imply that access to technology, combined with the right support system, drives positive learning outcomes.	"The Resource Chasm" and "The Crucial Need for Human Support" support the findings provided by quantitative evidence. (Teacher): "AI-AT is so impactful, and I'm conversant in using it. It is awesome; just imagine a visually impaired learner instantly accessing a textbook. But unstable internet or power blackouts defeat the whole purpose. The support structure is everything."
Experience Matters, But Support is Key	A reduced model performance of ($\beta = 0.245$, $f^2 = 0.058$) for the path from <i>Experience with AI</i> -> <i>Impact on Learning</i> implies that the provision of resources and support is more influential compared to AI experience, though this experience is very helpful.	The theme "Transformative Learning Enablement" reflects the findings related to Experience with AI by supporting the idea that transformation becomes possible because of the availability and usability of the tools. (Caregiver): "My child is doing very well with technology, but there is only one compatible device at the school. Her experience only matters when she gets hold of that device. What matters most is the access that unlocks her potential"
The Unmeasured Barriers	The induced model provides a 51.8% explanation of the variance in Impact on Learning, whereas the remaining 48.2% is most likely due to factors that are not considered in PLS-SEM and are emerging qualitatively.	The theme "Ethical Concerns & Digital Equity" sheds light on why there are some unmeasured factors in PLS-SEM. The issues raised by teachers and caregivers about data privacy and lack of transparency in technology stand as barriers to the adoption of this technology. (Teacher): "Several parents raised concerns over their children spending too much time on screens and the criteria used by those systems to evaluate their children's performance. These issues are real concerns to the extent they impact the implementation of technology in everyday class learning"

Integration of the quantitative and qualitative evidence revealed substantial convergence across methods. The strong statistical effect of Accessibility

and Support on learning outcomes was reinforced by interview narratives describing institutional support as the essential condition for successful AI-AT implementation. Similarly, although AI experience positively influenced learning, qualitative evidence demonstrated that its educational value depended fundamentally on equitable access to functioning technologies and sustained support systems. Finally, while the structural model explained over half of the observed variance in learning outcomes, qualitative findings illuminated additional influences, including ethical concerns, digital equity, infrastructure limitations and stakeholder perceptions, that were not captured quantitatively. Together, the convergent evidence demonstrates that the effectiveness of AI-enhanced assistive technologies in Zimbabwean primary schools depends less on technological sophistication than on the broader institutional, infrastructural and human ecosystems within which the technologies are embedded.

Discussion

The findings demonstrate that the educational value of AI-enhanced assistive technologies (AI-AT) in Zimbabwe extends well beyond technological functionality and is fundamentally conditioned by the institutional, infrastructural and sociocultural environments within which these technologies operate. This finding directly addresses the central problem identified in the introduction, that the transformative potential of artificial intelligence remains unevenly distributed despite international commitments to inclusive education under the UNCRPD and SDGs. Rather than supporting technologically deterministic assumptions that AI automatically improves educational outcomes, the present study demonstrates that AI-AT generates meaningful educational gains only when embedded within supportive educational ecosystems characterised by adequate infrastructure, institutional commitment and sustained human capacity. The findings confirm the argument advanced in the background section that disability-related educational exclusion is produced less by impairment itself than by structural conditions that restrict learners' opportunities to participate meaningfully in education.

The strong influence of Accessibility and Support on learning outcomes represents the study's most important empirical contribution. Quantitatively, accessibility and support emerged as the strongest predictors of improved learning experiences, while qualitative evidence consistently revealed that teachers and caregivers viewed institutional support, technical assistance and resource availability as the principal determinants of successful implementation.

These findings substantially strengthen earlier observations by WHO and UNICEF (2022), UNESCO (2023; 2025) and Cook et al. (2020), who argued that assistive technologies cannot be evaluated solely according to device availability but must be understood as components of broader assistive ecosystems. The present study extends this literature by demonstrating that, within resource-constrained educational systems, accessibility should not be conceptualised merely as physical access to AI-enabled devices but rather as the interaction between infrastructure, technical support, teacher competence, mentorship and institutional readiness. Consequently, educational inclusion emerges not as a technological achievement but as an institutional accomplishment. This finding moves the debate from technology provision towards educational conversion, whereby AI capabilities are translated into genuine learning opportunities through enabling institutional conditions.

Findings similarly reinforce the Capability Approach underpinning the conceptual framework. Sen (1999) argued that development should be evaluated according to individuals' real freedoms rather than the resources they possess. The present findings support this proposition by demonstrating that ownership or availability of AI technologies alone does not expand learners' educational capabilities. Rather, learners realise educational benefits only when schools possess the capability to deploy technologies effectively through teacher expertise, technical support, accessible infrastructure and sustained pedagogical guidance. AI-AT, hence, expands educational capability only when institutional capability exists simultaneously. This distinction between technological availability and capability expansion represents an important theoretical contribution because it demonstrates that educational technologies acquire value through conversion processes rather than technological presence alone.

The relatively smaller, although statistically significant, influence of Experience with AI further illustrates this argument. Existing literature assumed that increased familiarity with AI naturally improves educational performance (Luckin et al., 2016; Zheng et al., 2020; Zdravkova et al., 2022). However, the present study demonstrated that prior experience contributes comparatively little unless accompanied by adequate accessibility and institutional support. The findings challenge implicit assumptions within portions of the AI education literature that digital competence independently drives successful technology integration. Instead, the Zimbabwean evidence suggests that experience is a necessary but insufficient condition for educational transformation.

The observation aligns more closely with UNESCO's (2025) systems perspective, which conceptualises AI implementation as the product of interacting technological, organisational and human factors. The finding therefore reinforces the study's integrated conceptual framework by demonstrating that perceptions of usefulness and ease of use, as proposed by the Technology Acceptance Model (Davis, 1989), are themselves mediated by broader sociocultural and institutional realities.

The qualitative findings equally challenge dominant narratives that position AI as an autonomous educational solution. Participants consistently described AI-AT as transformative because it enabled learners to participate actively, communicate more effectively and engage with learning materials through personalised instructional pathways. These findings strongly support previous studies reporting improved accessibility through intelligent communication systems, adaptive learning and speech technologies (Seo et al., 2021; Yeratziotis et al., 2023; ZainEldin et al., 2024). However, unlike much of the existing literature conducted within technologically mature educational environments, the present study demonstrated that the pedagogical gains remain fragile where electricity, internet connectivity and assistive devices are unreliable. The *Resource Chasm* theme, therefore, contributes a new conceptual understanding by illustrating that the principal divide in Zimbabwe is not between technologically advanced and technologically backward schools but between technological potential and implementation capacity. This finding advances the literature by identifying resource insufficiency as a structural mediator rather than merely an implementation challenge.

Similarly, the emergence of *The Crucial Need for Human Support* reinforces growing international debates concerning the changing role of teachers within AI-enabled educational environments. Rather than replacing teachers, AI-AT appears to redistribute professional responsibilities towards facilitation, mediation, personalisation and ethical oversight, consistent with arguments advanced by Miller et al. (2022) and Vashishth et al. (2025). Classroom observations further demonstrate that teachers remained indispensable in balancing AI-supported learning with independent reasoning and critical thinking. These findings directly address concerns raised by Greene-Harper (2023), Yin (2024) and Anastasiou et al. (2025), who warned that excessive reliance on AI may weaken learners' cognitive independence. Instead, the Zimbabwean evidence suggests that where teachers actively scaffold learning,

AI functions as a cognitive amplifier rather than a substitute for intellectual engagement. This paper, therefore, supports emerging perspectives that position AI as augmenting rather than replacing human pedagogy.

Findings further illuminate the ethical and governance dimensions introduced in the literature review. Although the structural model explained over half of the observed variance in learning outcomes, qualitative evidence revealed additional barriers associated with privacy, algorithmic bias, transparency and digital equity. These concerns closely mirror observations by Djeki et al. (2024) and Farahani and Ghasemi (2024), who argue that AI systems may inadvertently reproduce existing social inequalities through biased datasets and opaque decision-making processes. The paper demonstrated that these concerns are not abstract ethical questions but practical implementation issues influencing stakeholder confidence and technology acceptance. Teachers and caregivers expressed apprehension regarding algorithmic evaluation, learner privacy and prolonged screen exposure, suggesting that ethical governance forms part of the institutional infrastructure necessary for sustainable AI adoption. Equitable implementation requires governance frameworks that address fairness, transparency and accountability alongside technological deployment.

Perhaps the most significant contribution of this study lies in demonstrating that the relationship between AI-AT and educational inclusion is fundamentally contextual. Throughout the introduction and literature review, the paper argued that evidence generated within technologically advanced educational systems could not simply be transferred to resource-constrained African settings. The findings strongly validate this proposition. AI-AT undoubtedly improves accessibility, learner engagement and participation, yet these improvements remain conditional upon contextual factors largely absent from studies conducted in higher-income countries. Zimbabwe therefore emerges not merely as another implementation site but as an important empirical context demonstrating that educational technologies behave differently when embedded within unequal institutional environments. These findings advance scholarship by illustrating that contextual adaptation, rather than technological sophistication, constitutes the principal determinant of AI-enabled educational inclusion.

Taken together, the quantitative, qualitative and observational evidence provides strong support for the integrated conceptual framework developed for this study. The Technology Acceptance Model (TAM) explains why perceptions of usefulness and ease of use remain important; sociocultural

perspectives explain how institutional relationships, professional support and cultural contexts shape technology adoption; while the Capability Approach explains why educational transformation depends upon expanding learners' real opportunities to participate rather than merely increasing access to technological devices. The convergence of these theoretical perspectives suggests that AI-AT should be understood as a socio-technical educational intervention whose success depends upon the co-evolution of technology, institutional capacity, human capability and inclusive policy environments. In doing so, this study contributes one of the few empirically grounded African perspectives demonstrating that sustainable educational transformation is achieved not by introducing artificial intelligence into schools, but by embedding intelligent technologies within inclusive educational systems capable of converting technological innovation into meaningful educational participation.

Limitations and Future Work

This study should be interpreted within several limitations. First, although the study covered multiple provinces, the purposive sampling strategy and relatively modest sample size limit the statistical generalisability of the findings to all learners with disabilities in Zimbabwe. The findings, therefore, provide context-specific rather than nationally representative evidence. Second, the quantitative component relied primarily on self-reported perceptions from learners, educators and caregivers, which may be influenced by recall error, social desirability bias and differences in respondents' understanding of AI-enhanced assistive technologies. Furthermore, linguistic diversity across participating districts occasionally required contextual interpretation during data collection, introducing the possibility of subtle variations in meaning despite efforts to standardise the research instruments. Finally, the cross-sectional design captures AI-AT implementation at a single point in time and therefore cannot adequately assess how learning outcomes, technology acceptance and user competence evolve with prolonged exposure.

These limitations provide important directions for future research. Larger probability-based studies conducted across a wider range of educational contexts would strengthen the external validity and transferability of the findings. Longitudinal investigations are also required to examine the sustained effects of AI-AT on academic achievement, learner independence, social inclusion and well-being, while assessing potential unintended consequences such as technological dependency, diminished critical thinking and changes in traditional pedagogical practices.

Future studies should further investigate the ethical dimensions of AI-AT, including algorithmic fairness, data governance, learner privacy and culturally responsive AI design within African educational contexts. Comparative studies across countries in sub-Saharan Africa would also enhance understanding of how institutional capacity, digital infrastructure and educational policy shape the effectiveness of AI-enhanced assistive technologies. Such evidence would provide a stronger empirical foundation for developing contextually appropriate, equitable and sustainable AI-supported inclusive education systems in Zimbabwe and comparable resource-constrained settings.

Conclusion

This study examined the influence of AI-enhanced assistive technologies (AI-AT) on the learning experiences of learners with disabilities in Zimbabwean primary schools within a resource-constrained educational environment. The findings demonstrate that AI-AT substantially improves learner engagement, curriculum accessibility, communication, personalised learning and social participation, thereby supporting more inclusive educational practices. However, the study equally demonstrates that technological innovation alone is insufficient to transform educational outcomes. Rather, the effectiveness of AI-AT is fundamentally determined by the availability of institutional support, adequate infrastructure, technical expertise, teacher competence and supportive policy environments.

The study further establishes that Accessibility and Support exert a substantially greater influence on learning outcomes than learners' prior experience with AI technologies, highlighting that meaningful educational inclusion depends more on supportive implementation ecosystems than on technology exposure alone. Qualitative evidence reinforced this conclusion by revealing that inadequate infrastructure, limited resources, insufficient professional training and emerging ethical concerns relating to privacy, transparency and algorithmic bias continue to constrain the educational potential of AI-AT.

The study argues that AI-enhanced assistive technologies should be understood as socio-technical interventions whose success depends upon the co-evolution of technology, institutional capacity and inclusive educational policy rather than technological sophistication in isolation. In doing so, the study contributes important scholarly evidence from Zimbabwe to the growing international discourse on inclusive artificial intelligence by demonstrating that sustainable

educational transformation requires contextually adapted implementation strategies that address both technological and structural inequalities.

Recommendations

Based on the findings, the following recommendations are proposed to strengthen the implementation of AI-enhanced assistive technologies within Zimbabwe's inclusive education system.

Strategic Investment in AI-AT Infrastructure

Governments should establish dedicated national and provincial funding mechanisms to support the acquisition, maintenance and upgrading of AI-enhanced assistive technologies in schools. Investment should extend beyond devices to include reliable electricity, affordable broadband connectivity, technical maintenance and digital infrastructure. Partnerships with universities, local technology developers and disability organisations should be promoted to encourage locally developed AI-AT solutions that reflect, in this case, Zimbabwe's linguistic, cultural and educational contexts, thereby reducing dependence on imported technologies.

Capacity Building for Teachers and Caregivers

The successful implementation of AI-AT requires sustained investment in human capacity. Comprehensive training programmes should be developed to strengthen teachers' technical competencies alongside inclusive pedagogical practices. A train-the-trainer approach should be adopted to develop school-based AI-AT champions capable of providing ongoing technical and pedagogical support. Caregivers should similarly receive basic AI-AT orientation to reinforce learner support within home environments and strengthen school–family collaboration.

Establishment of a Teacher Support Ecosystem

Professional development should become a continuous rather than one-off activity. National teacher development programmes should integrate AI literacy, inclusive education principles, ethical AI use and adaptive pedagogical strategies into both pre-service and in-service teacher education. This support ecosystem should enable teachers to function as facilitators, mentors and evaluators who effectively combine AI-assisted learning with critical thinking and learner-centred instruction.

Evidence-Based Monitoring and Research

Educational authorities should establish continuous monitoring and evaluation systems to assess the educational, social and economic outcomes of AI-AT implementation. Future evaluations should extend beyond learner achievement to include learner independence, social inclusion, well-being, ethical governance and cost-effectiveness. Such evidence would support informed policy decisions regarding resource allocation and long-term sustainability of AI-supported inclusive education.

Strengthening Multi-Stakeholder Partnerships and Governance

Effective AI-AT implementation requires coordinated collaboration among government ministries, schools, universities, disability organisations, technology companies, development partners and international agencies. These partnerships should facilitate knowledge exchange, resource mobilisation, technical support and innovation. Simultaneously, national policy frameworks should incorporate explicit guidance on ethical AI use, learner data protection, algorithmic fairness and equitable access to ensure that AI technologies advance rather than reproduce educational inequalities.

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