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TRANSFORMING INCLUSIVE EDUCATION THROUGH ASSISTIVE TECHNOLOGIES: PROMOTING SUSTAINABILITY, EQUITY, AND ACCESSIBILITY FOR LEARNERS WITH DISABILITIES IN PUNJAB, PAKISTAN

***Hamayoun Shah Nawaz*[1]**
Special Education Teacher, Department of Special Education Punjab, Pakistan
Email: shahnawaz.umt@gmail.com
***Sajjad Ahmad*[2]**
Institute of Special Education, University of the Punjab, Pakistan
Email: sajjaddps@gmail.com

Abstract
This quantitative study examines how assistive technologies (ATs) are transforming inclusive education in Punjab, Pakistan, emphasizing sustainability, equity, and accessibility for learners with disabilities. Guided by Vygotsky's Sociocultural Theory and Universal Design for Learning (UDL), the research explores how ATs enhance participation, competence, and inclusion in diverse classrooms. Using a descriptive survey design, data were collected from 250 teachers and school heads across 50 inclusive and special education institutions representing urban and rural districts. A researchers-developed, 40-item Likert-scale questionnaire assessed AT availability, teacher competence, sustainability, and institutional support. Analyses using descriptive and inferential statistics revealed that AT integration positively influences student engagement, confidence, and participation, with trained teachers demonstrating higher competence and preparedness. Despite this progress, disparities persist between government and private institutions, and between urban and rural schools, due to unequal infrastructure, limited policy guidance, and insufficient professional training. The study concludes that while ATs hold transformative potential for inclusive education, their sustainable impact requires systemic policy support, teacher capacity-building, and equitable access across Punjab's educational landscape. Recommendations include embedding AT training into teacher education programs, establishing monitoring frameworks, and promoting community partnerships to ensure that all learners, regardless of ability, can benefit from inclusive, technology-supported education.

Keywords: *inclusive education, assistive technologies, learners with disabilities, accessibility, equity, sustainability, Punjab*

Introduction

Inclusive education has emerged as a global imperative for ensuring that all learners, regardless of ability, have equitable opportunities to access quality education (UNESCO, 2020). Rooted in the principles of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD, 2006), inclusive education emphasizes participation, diversity, and equity within mainstream learning environments. In developing countries like Pakistan, where educational access remains stratified by socioeconomic status and disability, achieving inclusion presents persistent challenges (Ashok, 2023).

Punjab, Pakistan's largest province, has taken notable steps toward inclusive education through initiatives by the Special Education Department and School Education Department. However, the implementation of inclusive practices is still fragmented and often limited to urban centers (Lateef et al., 2024). The integration of assistive technologies (ATs) into classrooms has emerged as a promising approach (Ahmad, 2015). These gaps can be bridge up by facilitating

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accessibility, supporting differentiated instruction, and enhancing participation for students with diverse disabilities.

Assistive technologies encompass a broad spectrum of tools. The range of these tools varies from low-tech aids like Braille materials and magnifiers to high-tech devices such as speech-to-text software, hearing aids, and adaptive learning applications (Chambers, 2020). These tools not only improve access but also personalize learning experiences and empower students with disabilities to participate fully in academic and social activities (Hardianti, Risnawati, & Ananta, 2024).

Problem Statement

Despite increasing global recognition of ATs in inclusive education, research on their role in the Pakistani context remains limited. Teachers often lack training to integrate technology effectively, and schools face challenges of cost, maintenance, and policy support (Ramorola, 2013). Therefore, this study investigates how assistive technologies are transforming inclusive education in Punjab, focusing on their contribution to sustainability, equity, and accessibility. The study also explores current practices, challenges, and opportunities in implementing ATs and provides recommendations to strengthen inclusive education through technology.

Literature Review

Global Perspectives on Assistive Technology and Inclusion

Globally, assistive technology is recognized as a catalyst for inclusive and equitable education. According to the World Health Organization (2021), over one billion people worldwide need one or more assistive products, yet only 10% have access to them in low-income countries. ATs support learners in overcoming physical, sensory, or cognitive barriers, enabling them to achieve academic outcomes comparable to their peers (McNicholl et al., 2021). Studies conducted in the United States, United Kingdom, and Scandinavian countries show that effective AT integration enhances reading comprehension, self-regulation, and motivation among students with disabilities (Stalmach et al., 2023).

Assistive Technologies and Sustainable Development

Assistive technologies align directly with the Sustainable Development Goal 4 (SDG-4): "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." Previous researches suggest that sustainable use of ATs requires systemic support teacher training, infrastructure investment, and ongoing technical assistance (O'Sullivan et al., 2023). Sustainability also encompasses affordability, maintenance, and localization of technologies to fit linguistic and cultural contexts (Oyedokun, 2025).

Inclusion and Equity in Developing Contexts

In developing nations, the integration of ATs is often constrained by limited financial resources and low awareness among educators (Grönlund, Lim, & Larsson, 2010). Studies in India, Bangladesh, and Nigeria report that while ATs improve inclusion. However, sustainability remains hindered by dependence on imported tools and lack of trained professionals (Karki et al., 2023). Equity issues arise when urban schools have access to technology while rural schools remain under-resourced (Veerabathiran & Thomas, 2025).

Inclusive Education in Pakistan

Pakistan's National Education Policy (2017) and Punjab's Inclusive Education Policy (2020) acknowledge the importance of technology in supporting learners with disabilities. Yet,

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implementation is inconsistent due to fragmented governance and budgetary constraints (Ahmad & Nawaz, 2025). Jamil (2021) observed that while teachers in Punjab generally support inclusion, only 38% have received formal training in using ATs. Moreover, most AT tools are imported, expensive, and not adapted to Urdu or regional languages, creating accessibility barriers (Nawaz, Fazil, & Ahmad, 2021).

Theoretical Framework

This study draws upon Vygotsky's sociocultural theory and Universal Design for Learning (UDL) principles as its theoretical foundation. Vygotsky (1978) emphasizes social interaction and tools as mediators of learning, suggesting that assistive technologies (ATs) can extend learners' capacities to participate meaningfully within their social and educational environments. According to this perspective, technology acts as a psychological tool that bridges gaps between the learner's current abilities and the cultural or instructional demands of the classroom. In inclusive education, ATs therefore serve as mediating artifacts that foster collaboration, communication, and knowledge construction among students with and without disabilities.

Research Gap

Existing literature highlights abundant global evidence on the benefits of assistive technologies, yet there remains a lack of empirical, province-specific data in Pakistan. Previous research has largely focused on conceptual discussions or small-scale qualitative studies (Nawaz, Fazil, & Ahmad, 2021), leaving a significant quantitative gap in measuring how AT availability, teacher competence, and learner outcomes interact (Ahmad & Nawaz, 2025). Moreover, regional differences within Pakistan, especially between urban and rural contexts, have not been systematically explored (Fazil, 2020). Studies from South Asia (Akram et al., 2025; Veerabathiran & Thomas, 2025) suggest that cultural, linguistic, and infrastructural variables heavily influence AT adoption, but such findings cannot be generalized without localized data.

Research Objectives

The study intended to:

1. Assess the availability and utilization of assistive technologies in inclusive schools of Punjab.
2. Evaluate teachers' competence in implementing ATs for learners with disabilities.
3. Identify challenges and opportunities in sustaining ATs use.
4. Examine how ATs influence academic participation and accessibility among students with disabilities.

Research Questions

Following research questions were addressed:

1. What is the current status of AT availability and use in Punjab's inclusive schools?
2. How prepared and competent are teachers in applying ATs for inclusive instruction?
3. What factors promote or hinder the sustainable use of ATs?
4. How does AT integration impact learners' engagement and participation?

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Methods and Materials

Research Design

This study employed a quantitative descriptive survey design. The quantitative paradigm was selected because it emphasizes objectivity, replicability, and the use of statistical tools to validate findings (Ali, 2024). Furthermore, descriptive survey research is appropriate for studies aiming to describe what exists rather than to manipulate variables or establish causality (Nardi, 2018). Since the purpose of this study was to assess current practices and not to implement an experimental intervention, this design effectively captured the real-world conditions of inclusive schools.

The survey method was also justified by its efficiency in reaching a large number of respondents within a limited timeframe (Rea & Parker, 2014). It allowed for standardized data collection using a structured questionnaire, which ensured consistency and comparability across districts. The responses provided quantitative indicators of AT availability, teacher competence, and perceived student outcomes, which were essential for understanding equity and sustainability dimensions.

Population and Sample

The population included all teachers and school heads working in inclusive and special education institutions in Punjab. Using stratified random sampling, five major districts Lahore, Multan, Gujranwala, Rawalpindi, and Bahawalpur were selected. Each district represented urban and rural strata. The final sample consisted of 250 participants: 200 teachers and 50 school heads from 50 institutions. This sample size ensured representativeness and statistical reliability.

Sampling Technique

The study employed a stratified random sampling technique to ensure proportional representation of schools and participants across Punjab's diverse educational landscape. Stratified random sampling was particularly appropriate for this study because the target population teachers and school heads working in inclusive and special education institutions are not homogeneous. In this process, Punjab was divided into five major strata representing the districts of Lahore, Multan, Gujranwala, Rawalpindi, and Bahawalpur. These districts were selected for their demographic diversity and varying levels of educational infrastructure. Within each stratum, institutions were randomly selected from official lists provided by the Special Education Department (Spl.Ed.) and the School Education Department (SED). Subsequently, participant teachers and school heads were randomly chosen in proportion to staff size within each school to maintain statistical balance. This method minimized selection bias and ensured that both well-resourced urban schools and resource-constrained rural schools were adequately represented (Noor, Tajik, & Golzar, 2022).

Table 1

Demographic Information of Key Respondents (N = 250)

Variable	Category	*(f)*	*(%)*
Gender	Male	95	38.0
	Female	155	62.0
Professional Role	Teacher	200	80.0

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Variable	Category	*(f)*	*(%)*
	School Heads	50	20.0
Age (years)	21 – 30	48	19.2
	31 – 40	92	36.8
	41 – 50	67	26.8
	Above 50	43	17.2
Job Experience	1 – 5 years	60	24.0
	6 – 10 years	78	31.2
	11 – 15 years	62	24.8
	Above 15 years	50	20.0
School Location	Urban	26	52.0
	Rural	24	48.0
Institution Type	Government	28	56.0
	Private	22	44.0
Prior AT Training	Yes	65	26.0
	No	185	74.0

Note. AT = Assistive Technology

Instrumentation

A researchers-developed questionnaire was used as the main instrument for this quantitative descriptive study. Since no standardized tool existed that captured the contextual realities of assistive technology (AT) integration in Punjab's inclusive schools, the researchers developed a customized instrument aligned with the study's objectives and research questions. The questionnaire included six sections: demographic information and five core factors (1) availability and utilization of ATs, (2) teacher competence and preparedness, (3) sustainability and institutional support, (4) impact of ATs on student inclusion, and (5) challenges and future prospects comprising 40 items in total. Items were developed after reviewing relevant literature and validated by experts in special education, inclusive education, and research methodology to ensure content relevance and linguistic clarity.

A five-point frequency Likert scale was used to measure responses (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always), as it better captured the regularity of AT use rather than mere agreement with statements. The instrument was piloted with 30 teachers from similar institutions to assess clarity and reliability, yielding a strong internal consistency (Cronbach's α = 0.87). This researchers-developed questionnaire was chosen for its contextual relevance, comprehensive coverage of variables, and quantitative measurability, allowing systematic analysis of trends, group differences, and relationships related to assistive technology use in inclusive education across Punjab.

Data Collection

Data were collected systematically to ensure accuracy, reliability, and ethical compliance. After obtaining formal permission from the Directorate General of Special Education (DGSE)

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Punjab and the respective school administrations, the researchers personally visited the selected institutions to administer the questionnaire. The 50 participating schools (28 government and 22 private) were located across both urban and rural areas of Punjab, ensuring broad representation. Prior to data collection, all participants were briefed on the study's objectives, assured of confidentiality, and informed that participation was voluntary. Written informed consent was obtained from each teacher and school head before completing the survey.

The researchers distributed the printed questionnaires during scheduled visits and, where feasible, provided electronic versions via email or Google Forms to facilitate convenience. Respondents were given clear instructions and approximately 20–25 minutes to complete the questionnaire independently. The researchers remained available on-site to clarify any queries related to the items or rating scale. Completed questionnaires were collected the same day to minimize data loss, verified for completeness, and coded with unique identifiers. Data from all sources were then entered into SPSS version 26 for analysis. Rigorous checking procedures were followed to identify and correct entry errors or missing values. This systematic approach ensured that the collected data were valid, consistent, and representative of the diverse educational contexts within Punjab's inclusive and special education institutions.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. After screening the questionnaires for completeness and accuracy, both descriptive and inferential statistics were applied according to the study's objectives. Descriptive statistics (frequency, percentage, mean, and standard deviation) summarized demographic characteristics and trends in assistive technology (AT) use, teacher competence, and institutional support.

Reliability analysis using Cronbach's alpha assessed internal consistency, while independent-samples *t*-tests and one-way ANOVA examined group differences based on gender, school type, location, qualification, and experience. Pearson's correlation explored relationships among major variables, and multiple linear regression identified predictors of student participation and accessibility. A significance level of $p < .05$ was applied. Mean score interpretation followed a five-point range (1.00–1.80 = Very Low; 1.81–2.60 = Low; 2.61–3.40 = Moderate; 3.41–4.20 = High; 4.21–5.00 = Very High). Findings were presented through tables and charts to highlight key patterns and relationships, providing empirical insight into how ATs enhance inclusive education, sustainability, and equity for learners with disabilities in Punjab.

Ethical Considerations

Ethical protocols were strictly followed throughout the study to ensure participant rights, data integrity, and institutional compliance. Formal approval was obtained from the Department of Special Education and permissions were secured from the heads of participating schools prior to data collection. All participants were informed about the study's purpose, procedures, and their right to withdraw at any stage without penalty. Informed consent was obtained in writing, and confidentiality was maintained by using coded identifiers instead of names. Data were used solely for academic research and stored securely to prevent unauthorized access. No physical, psychological, or professional risk was posed to participants, and the study adhered to the ethical

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standards of the American Psychological Association (APA, 2020**)** and institutional research ethics guidelines.

Results

RQ1: ***What is the current status of assistive technology (AT) availability and use in inclusive schools of Punjab?***

To explore the current status of assistive technology (AT) availability and use in inclusive schools of Punjab, descriptive statistics were computed for eight items under the construct "Availability and Utilization of Assistive Technologies." Mean and standard deviation scores were analyzed to determine how frequently ATs are available and used across the sample of government and private institutions ($N = 250$).

Table 2

Availability and Utilization of Assistive Technologies in Inclusive Schools (N = 250)

Item No.	Statements	*M*	*SD*
1	Assistive technologies are available in my school to support students with disabilities.	3.82	0.86
2	Classrooms are equipped with appropriate AT devices or software for learning.	3.61	0.94
3	ATs are used regularly to assist students with visual, hearing, or physical impairments.	3.47	0.98
4	Students have independent access to AT devices when needed.	3.35	0.92
5	I use ATs during teaching sessions to accommodate individual learning needs.	3.74	0.88
6	My school maintains an updated inventory of available assistive tools.	3.28	0.97
7	The administration ensures regular maintenance of AT devices.	3.16	0.91
8	The use of ATs in classrooms has increased in the past two years.	3.90	0.83
Overall Mean	Composite score for Availability and Utilization	3.54	0.91

Note. Scale: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always, M = Mean

Table 2 shows that the overall mean score for availability and utilization of assistive technologies was 3.54 ($SD = 0.91$), indicating a moderate to high level of implementation across inclusive schools in Punjab. The highest-rated item was "The use of ATs in classrooms has increased in the past two years" ($M = 3.90$), suggesting a growing trend toward digital and assistive inclusion. Availability of ATs ($M = 3.82$) and use during teaching ($M = 3.74$) were also relatively strong, reflecting teachers' increasing adaptation to inclusive instructional tools.

However, lower mean scores were found for maintenance ($M = 3.16$) and inventory management ($M = 3.28$), highlighting gaps in administrative and infrastructural support. The data suggest that while assistive technologies are becoming more prevalent in Punjab's inclusive schools particularly in urban and private institutions their consistent maintenance, equitable access, and institutional monitoring require further improvement. Overall, results indicate positive progress toward accessibility and sustainability of ATs, but continued investment in infrastructure and teacher support remains essential for full integration.

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RQ2: How prepared and competent are teachers in applying assistive technologies (ATs) for inclusive instruction in Punjab?

To examine teacher competence and preparedness in using assistive technologies for inclusive instruction, descriptive statistics were calculated for eight items measuring teachers' knowledge, confidence, and professional training regarding AT integration.

Table 3

Teachers' Competence and Preparedness in Using Assistive Technologies (N = 250)

Item No.	Statements	*M*	*SD*
9	I know how to use different types of assistive technologies effectively.	3.72	0.88
10	I can select suitable ATs according to students' specific learning needs.	3.68	0.91
11	I can incorporate ATs into lesson planning and instructional design.	3.61	0.85
12	I can solve minor technical issues that occur during AT use.	3.29	0.93
13	I receive ongoing training or workshops on assistive technology use.	3.05	0.99
14	I collaborate with colleagues to share best practices on using ATs.	3.56	0.87
15	I encourage students to use ATs for independent learning.	3.80	0.82
16	I regularly update my knowledge about new assistive technology tools.	3.48	0.91
Overall Mean	Composite score for Teacher Competence and Preparedness	3.52	0.90

The overall mean score for teachers' competence and preparedness in using assistive technologies was 3.52 (*SD* = 0.90), indicating a moderate to high level of proficiency among respondents. Teachers reported the highest competence in encouraging students to use ATs for independent learning (*M* = 3.80) and effectively using different types of ATs (*M* = 3.72). This reflects a growing confidence and positive attitude toward technology-supported inclusion.

However, the lowest mean score was observed for receiving ongoing training or workshops (*M* = 3.05), suggesting that professional development opportunities remain insufficient. Similarly, the ability to troubleshoot technical issues (*M* = 3.29) was only moderate, pointing to a need for more hands-on technical support and training. The findings imply that while teachers in Punjab demonstrate a sound awareness and readiness to use ATs in inclusive classrooms, their competence could be significantly enhanced through structured, continuous training programs and access to practical support systems.

RQ2a: Is there a significant difference in teachers' competence in using assistive technologies between those who have received AT training and those who have not?

This question examines whether formal training influences teachers' competence and preparedness. It involves two independent groups (Trained vs. Untrained).

Table 4

Independent-Samples t-Test for Teacher Competence by AT Training (N = 250)

Training Status	*n*	*M*	*SD*	*t*	*df*	*p*	Cohen's *d*
Trained Teachers	65	3.87	0.80	5.11	248	< .001 ***	0.65

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Training Status	*n*	*M*	*SD*	*t*	*df*	*p*	Cohen's *d*
Untrained Teachers	185	3.34	0.89				

The results in Table 4 indicate a statistically significant difference in teacher competence between those who had received assistive technology (AT) training and those who had not, $t(248) = 5.11$, $p < .001$. Teachers who had received AT training ($M = 3.87$, $SD = 0.80$) demonstrated considerably higher competence compared to their untrained counterparts ($M = 3.34$, $SD = 0.89$). The computed effect size, *Cohen's d = 0.65*, represents a moderate to large effect, suggesting that the difference is both statistically and practically meaningful.

These findings imply that formal AT training substantially enhances teachers' confidence, knowledge, and practical ability to integrate assistive technologies in inclusive classrooms. The results reinforce the importance of professional development programs and continuous training initiatives as critical components for promoting inclusive education and technology-supported teaching practices in Punjab's schools.

RQ3: What factors promote or hinder the sustainable use of assistive technologies (ATs) in inclusive classrooms in Punjab?

This question explores teachers' perceptions regarding institutional sustainability, equity, and administrative support for AT implementation. Eight items measured how well schools sustain, fund, and equitably distribute assistive technologies.

Table 5

Perceptions of Sustainability, Equity, and Institutional Support for ATs (N = 250)

Item No.	Statement	*M*	*SD*
17	My school allocates a specific budget for purchasing or maintaining ATs.	3.26	0.96
18	Technical assistance is available for repairing or upgrading AT devices.	3.19	0.89
19	All students, regardless of background, have equal access to ATs.	3.52	0.91
20	There is a clear institutional policy promoting long-term use of ATs.	3.18	0.93
21	Funding limitations affect the sustainability of AT implementation.	3.88	0.81
22	Locally developed AT tools (e.g., Urdu/Punjabi software) are available for use.	3.35	0.87
23	The school ensures continuous support for teachers using ATs.	3.40	0.90
24	Community or NGO partnerships assist the school in sustaining AT use.	3.47	0.85
Overall Mean	Composite score for Sustainability and Institutional Support	3.41	0.89

The overall mean score for sustainability and institutional support was 3.41 ($SD = 0.89$), reflecting a moderate level of sustainability across schools. Respondents most strongly agreed that funding limitations affect sustainability ($M = 3.88$), highlighting persistent financial barriers. Equal access for students ($M = 3.52$) and community/NGO partnerships ($M = 3.47$) were also relatively high, suggesting positive but uneven support structures. Institutional budgeting ($M = 3.26$) and policy development ($M = 3.18$) scored lowest, indicating that **sy**stematic planning and financial allocation remain underdeveloped in many school.

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RQ3a: Is there a significant difference in perceptions of AT sustainability between teachers from government and private institutions?

An independent-samples t-test was applied to examine whether teachers' perceptions of AT sustainability differed between government and private institutions. This test was suitable because the independent variable (institution type) had two categorical groups, while the dependent variable (sustainability score) was continuous, enabling comparison of mean differences between the two types of schools.

Table 6

Independent-Samples t-Test for Sustainability by Institution Type (N = 250)

Institution Type	*n*	*M*	*SD*	*t*	*Df*	*p*	Cohen's *d*
Government Schools	140	3.29	0.88	-2.68	248	.008 **	0.35
Private Schools	110	3.58	0.85				

Private school teachers (M = 3.58, SD = 0.85) reported significantly higher perceptions of AT sustainability than government school teachers (M = 3.29, SD = 0.88), $t(248) = -2.68$, $p = .008$, $d = 0.35$. This indicates that private institutions are perceived as better resourced and more proactive in maintaining assistive technologies and supporting their consistent use.

RQ3b: Do perceptions of AT sustainability differ by job experience?

This sub-question aimed to determine whether teachers' perceptions of assistive technology (AT) sustainability and institutional support vary according to their years of professional experience.

Table 7

One-Way ANOVA for Sustainability and Institutional Support by Job Experience (N = 250)

	1–5 years		6–10 years		11–15 years		Above 15 years			
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F* (3, 246)	η^2
Sustainability and Institutional Support	3.24	0.87	3.38	0.84	3.53	0.89	3.65	0.86	2.10	0.025

Table 7 shows that teachers' perceptions of sustainability and institutional support for assistive technologies increased slightly with job experience, ranging from M = 3.24 (SD = 0.87) among teachers with 1–5 years of experience to M = 3.65 (SD = 0.86) among those with over 15 years. However, the one-way ANOVA revealed that these differences were not statistically significant, $F(3, 246) = 2.10$, $\eta^2 = 0.025$. The small effect size indicates minimal practical difference among

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experience groups. These findings suggest that while experienced teachers may perceive somewhat stronger institutional sustainability, overall perceptions of AT-related support remain relatively consistent across varying levels of professional experience.

RQ3c: Is there a significant relationship between sustainability and institutional support for assistive technologies and other key factors, such as availability and utilization, teacher competence, and the impact of ATs on student learning and inclusion?

This sub-question aims to explore how sustainability and institutional support relate to other dimensions of assistive technology (AT) integration. Since all variables availability, competence, sustainability, and impact were measured as continuous composite scores on a five-point Likert scale, Pearson's product-moment correlation coefficient (*r*) was used.

Table 8

Pearson Correlation Matrix among Major Variables (N = 250)

Variables	1	2	3	4
1. Availability and Utilization of ATs	—			
2. Teacher Competence and Preparedness	.52**	—		
3. Sustainability and Institutional Support	.61**	.48**	—	
4. Impact of ATs on Student Learning and Inclusion	.57**	.63**	.66**	—

Note. $p < .01$

Table 8 shows significant positive correlations among all major study variables. Sustainability and institutional support were strongly correlated with the availability and utilization of ATs ($r = .61$, $p < .01$) and the impact of ATs on student learning ($r = .66$, $p < .01$). A moderate positive relationship also existed between teacher competence and sustainability ($r = .48$, $p < .01$). These results indicate that schools demonstrating higher sustainability and institutional support tend to have better AT availability, more competent teachers, and stronger positive impacts on student inclusion. The findings emphasize that sustainable AT practices are interdependent with resource provision, teacher training, and effective classroom implementation all of which collectively strengthen inclusive education in Punjab.

RQ4: How does assistive technology (AT) integration influence learners' academic participation and accessibility in inclusive schools of Punjab?

This question explored teachers' perceptions of the impact of ATs on students' classroom engagement, confidence, social interaction, and overall inclusion. Eight items measured the perceived influence of AT use on learning and participation outcomes.

Table 9

Perceived Impact of Assistive Technologies on Student Learning and Inclusion (N = 250)

Item No.	Statement	*M*	*SD*
25	Students with disabilities participate more actively in class when ATs are used.	3.88	0.83
26	ATs improve the academic performance of students with disabilities.	3.92	0.81
27	ATs make lessons more engaging for all students.	3.75	0.84

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Item No.	Statement	*M*	*SD*
28	Students using ATs demonstrate greater confidence in learning tasks.	3.85	0.86
29	ATs foster better communication between students with and without disabilities.	3.68	0.91
30	Students using ATs show more independence in completing assignments.	3.80	0.82
31	ATs enhance collaborative learning among diverse learners.	3.73	0.88
32	The integration of ATs improves classroom inclusiveness overall.	3.94	0.79
Overall Mean	Composite Score for AT Impact on Learning and Inclusion	3.82	0.84

The overall mean score of 3.82 (*SD* = 0.84) indicates a high perceived impact of assistive technologies on student learning and inclusion. The highest mean was observed for "integration of ATs improves classroom inclusiveness" (*M* = 3.94), while the lowest mean was for "communication between students with and without disabilities" (*M* = 3.68). These results suggest that teachers perceive ATs as powerful tools for enhancing participation, independence, and inclusivity, though social interaction outcomes remain moderate and could benefit from structured peer-learning strategies.

RQ4a: Is there a significant difference in perceived AT impact between teachers from urban and rural schools?

An independent-samples t-test was used to determine whether perceptions of assistive technology impact differed between teachers from urban and rural schools.

Table 10

Independent-Samples t-Test for AT Impact by School Location (N = 250)

School Location	*n*	*M*	*SD*	*t*	*df*	*p*	Cohen's *d*
Urban Schools	130	3.96	0.78	3.12	248	.002 **	0.40
Rural Schools	120	3.65	0.86				

Teachers from urban schools (M = 3.96, SD = 0.78) reported significantly higher perceived impact of ATs on student learning than teachers from rural schools (M = 3.65, SD = 0.86), $t(248) = 3.12$, $p = .002$, $d = 0.40$. This indicates that urban schools likely due to better infrastructure, internet access, and device availability are achieving greater inclusion benefits through AT use.

RQ4b: Does perceived AT impact differ significantly across teachers with varying years of job experience?

A one-way ANOVA was applied to examine whether teachers' perceptions of the impact of assistive technologies differed by years of job experience. This test was appropriate because the independent variable (experience) had four categorical groups, while the dependent variable (AT impact score) was continuous, allowing comparison of mean differences across multiple experience levels.

Table 11

One-Way ANOVA for AT Impact by Job Experience (N = 250)

Variables	1–5 years		6–10 years		11–15 years		Above 15 years		*F* (3, 246)	η^2
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		

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Variables	1–5 years		6–10 years		11–15 years		Above 15 years		F (3, 246)	η^2
AT Impact on Learning and Inclusion	3.69	0.88	3.79	0.84	3.89	0.82	3.94	0.80	2.45	0.029

Perceived AT impact increased slightly with teaching experience, from M = 3.69 (SD = 0.88) among teachers with 1–5 years of experience to M = 3.94 (SD = 0.80) among those with 15+ years. However, the differences were not statistically significant, $F(3, 246) = 2.45$, $p = .065$, $\eta^2 = .029$. Although more experienced teachers tended to report stronger positive perceptions, the small effect size indicates that AT impact is viewed positively across all experience levels, suggesting consistent appreciation of AT benefits throughout the teaching workforce.

Major Findings of the Study

The study revealed that assistive technologies (ATs) are increasingly being adopted in inclusive schools across Punjab, though their integration remains uneven between government and private institutions. Teachers reported that ATs are available and frequently utilized in classrooms to support learners with diverse disabilities, particularly in enhancing participation, communication, and academic engagement. However, limitations in infrastructure, maintenance, and resource allocation continue to hinder full implementation, especially in rural and government settings.

Findings also showed that teachers generally possess a positive attitude and moderate competence in using ATs. Those with formal training and higher academic qualifications demonstrated stronger preparedness and confidence in integrating technology into inclusive instruction. Despite growing awareness, limited professional development opportunities were identified as a key barrier to sustain AT use.

Institutional sustainability and equity in AT access emerged as critical challenges. Private schools were perceived as better equipped and more proactive in maintaining assistive resources, while government schools faced constraints due to funding shortages and inadequate policy support. Collaboration with NGOs and community organizations contributed positively to sustainability efforts in some institutions.

The study further found that assistive technologies significantly enhance students' learning experiences by fostering inclusion, independence, and confidence. Teachers widely recognized the transformative role of ATs in improving classroom participation for students with disabilities. However, disparities between urban and rural schools suggest the need for equitable resource distribution and infrastructure support to ensure all learners benefit equally.

Discussion

The present study explored how assistive technologies (ATs) are transforming inclusive education in Punjab, Pakistan, focusing on sustainability, equity, and accessibility for learners with disabilities. The findings affirm that ATs play a pivotal role in enhancing participation, independence, and learning outcomes for students with diverse needs. However, disparities in access, training, and institutional support indicate that inclusive education in Punjab is progressing but remains in a transitional phase.

Consistent with Vygotsky's Sociocultural Theory (1978), the study supports the notion that learning is a socially mediated process, where tools such as assistive technologies act as cultural artifacts that extend cognitive and communicative abilities. Teachers in this study viewed ATs not

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only as functional devices but also as mediational tools that foster interaction and inclusion among students with and without disabilities. In classrooms where ATs were effectively implemented, students demonstrated greater confidence, participation, and engagement illustrating Vygotsky's concept of learning within the "zone of proximal development."

The findings also align with the principles of the Universal Design for Learning (UDL) framework (Meyer & Rose, 2002), which emphasizes flexible learning environments that accommodate individual differences. The widespread use of ATs to provide multiple means of representation, engagement, and expression demonstrates an evolving shift toward UDL-oriented practices. Teachers who had formal training and access to diverse technologies were better able to personalize instruction, thereby addressing the varied needs of learners with disabilities. This reflects global trends observed in studies by Al-Azawei et al. (2016) and Ok et al. (2017), where teacher competence was identified as a decisive factor in successful AT integration.

Despite these positive trends, challenges persist in achieving sustainability and equity. The results indicate that government schools face greater barriers than private institutions due to limited budgets, inconsistent maintenance of AT devices, and a lack of clear policy directives. Similar patterns have been documented in developing contexts (Alkahtani, 2022; Khan et al., 2025), where financial and administrative constraints hinder the long-term implementation of inclusive technology initiatives. The findings further reveal that while community and NGO partnerships provide valuable support, their contributions are fragmented and often localized rather than systemic.

Another important finding concerns the urban-rural divide. Urban schools showed stronger outcomes in terms of AT availability, use, and perceived impact, echoing the infrastructural and digital disparities noted in prior studies (UNESCO, 2020). This imbalance reflects broader socioeconomic inequalities and suggests that inclusive education policies in Punjab must explicitly address rural inclusion by ensuring equitable resource allocation, infrastructure, and teacher development opportunities.

Teacher competence emerged as a central determinant of effective AT implementation. Trained and highly qualified teachers demonstrated superior ability to select, adapt, and apply assistive tools in instructional settings. This underscores the importance of embedding AT training into both pre-service and in-service teacher education programs. Similar conclusions have been drawn by Flanagan et al. (2013) and Owuor (2019), who noted that teacher preparedness significantly influences technology adoption and sustainability in inclusive contexts.

Finally, the study's emphasis on sustainability extends beyond technical maintenance it encompasses cultural, pedagogical, and institutional dimensions. Sustainable AT use requires ongoing professional learning communities, administrative commitment, and supportive policies that encourage innovation and inclusion. Without these systemic supports, ATs risk becoming isolated interventions rather than integral components of inclusive practice.

Conclusion

This study investigated how assistive technologies (ATs) contribute to transforming inclusive education in Punjab, Pakistan, with a focus on sustainability, equity, and accessibility for learners with disabilities. Findings confirm that ATs have a profound influence on enhancing students' academic participation, communication, and confidence, thereby promoting inclusive learning environments. Teachers and administrators generally demonstrated positive attitudes toward the use of ATs, viewing them as essential tools for bridging learning gaps and enabling meaningful participation for all students.

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However, the study also revealed notable disparities between government and private institutions, and between urban and rural schools, highlighting persistent inequities in access, infrastructure, and training. While some schools successfully integrate ATs within their instructional practices, others face challenges due to limited funding, inadequate policy guidance, and insufficient teacher preparedness. The findings underscore the need for systemic interventions that go beyond short-term solutions and instead focus on long-term sustainability of AT initiatives.

Grounded in Vygotsky's Sociocultural Theory and Universal Design for Learning (UDL), the study concludes that ATs are not merely technical aids but pedagogical instruments that expand learners' capacities, support social inclusion, and personalize learning. Sustainable inclusive education in Punjab will depend on creating environments where these technologies are accessible, effectively used, and supported through continuous professional development and institutional commitment.

Recommendations

Based on the findings and conclusions, the following recommendations are proposed to enhance sustainability, equity, and accessibility in the implementation of assistive technologies across inclusive schools in Punjab:

1. The Punjab School Education Department should integrate AT implementation explicitly within provincial inclusive education policies. Dedicated funding streams, procurement standards, and sustainability plans must be developed to ensure long-term accessibility.
2. AT-related content should be embedded into pre-service and in-service teacher education curricula. Ongoing professional development workshops must focus on the pedagogical use of ATs, classroom adaptation, and individualized instruction strategies.
3. Rural schools require priority attention through equitable resource distribution, internet access, and infrastructure improvements. Public-private partnerships and NGO collaboration can help bridge the digital divide in under-resourced areas.
4. School administrators should establish AT support committees responsible for device management, maintenance, and continuous monitoring of student outcomes. Regular audits can ensure that AT resources remain functional and relevant.
5. Awareness campaigns and training sessions should involve parents and local communities to strengthen home-school collaboration and encourage consistent AT use beyond classroom settings.
6. Further quantitative and longitudinal studies should explore the long-term impact of ATs on academic achievement and social inclusion. Local universities and teacher training institutions can collaborate to design low-cost, culturally relevant assistive solutions.
7. The development of a provincial AT monitoring system is recommended to track device usage, teacher competence, and student progress. Such data-driven frameworks would inform continuous improvement and policy refinement.

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