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# The Role of Assistive Technology in Improving Learning Outcomes for Students with Special Educational Needs

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## ABSTRACT

Background: The role of assistive technology in inclusive education is growing, given that such technology facilitates the student with special educational needs to access the curriculum content, communicate, and perform tasks, and participate actively in instruction in the classroom. The objective of the study was to review the role of assistive technology in enhancing academic performance, independence, engagement, and confidence as well as peer participation among students with special educational needs. A convergent mixed-methods design was used with 96 students from eight inclusive schools. This intervention consisted of text to speech, speech to text, word prediction, graphic organizers, virtual manipulatives and augmentative communication applications. Pre-post curriculum based tests, classroom observations, teacher interviews, student responses and field notes were used to collect data over a period of eight weeks as part of the intervention. It exhibited statistically significant changes in reading, writing, mathematics accuracy, task completion, engagement, independence, peer participation, and confidence. There were reduced teacher prompts and increased tool-use fluency. Domain matched tools yielded higher gains including reading access tools to reading, writing support tools to writing, and mathematics tools to mathematical performance. Stronger outcomes were predicted with implementation fidelity, teacher training, and classroom support. Assistive technology is most efficient when chosen based on the needs of the learners, it becomes a part of regular lessons, it has to be supported by trained teachers, students have to accept it. It must not be seen as a teaching aid but as a device and an electronic supplement.

**Keywords:** *Assistive Technology, Inclusive Education, Special Educational Needs, Learning Outcomes, Mainstream Schools.*

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## 1. Introduction

Assistive technology is no longer a specialist provision but a primary requirement towards fair learning in inclusive education. The notion of assistive technology in this paper was conceived as tools, applications, services and implementation practices that enabled learners with disabilities or special educational needs to access the curriculum, communicate, generate work, interact with peers and demonstrate their level of achievement. Policymakers frame this problem as a right, not a luxury: assistive products can help with functioning, participation and inclusion (World Health Organization [WHO], 2024), and inclusive-education systems should eliminate the obstacles that prevent learners access to common opportunities of learning (UNESCO, 2020; UNICEF, 2024). This right approach is important as the students with special educational needs frequently experience some obstacles in reading, writing, communication, attention, mobility, sensory access and assessment. With access assistive resource provision, poor performance might be indicative of inaccessible design and not low ability.

The explanation of what assistive technology can contribute to the overall learning outcomes can be best applied to a learning-access pathway. To begin with, technology minimises the disparity between the learner trait and classroom needs. Text-to-speech may be used to give print to speech learners with reading disabilities, speech-to-text as well as word prediction to lower the burden on transcription by learners with writing difficulties, augmentative and alternate communication to provide learners with no speech a functional means to engage, and virtual manipulatives to make abstract mathematical concepts tangible and mobile. This argument aligns with the perception that the role of assistive technology is a cognitive and communicative scaffold as opposed to teaching (Edyburn, 2006; ATIA, 2024). This pathway is supported by evidence. In the National Longitudinal Transition Study-2, students with high-incidence disabilities who had an assistive technology in school showed superior postschool indicators compared to similar students who did not have such supports (Bouck et al., 2012), and a national analysis concluded both the promise and inequalities of assistive technology services to students with disabilities (Bouck, 2016).

Second, adaptive technology has the potential of enhancing educational performance through greater independence in undertaking learning activities. A meta-analysis in the field of literacy established a beneficial impact of text-to-speech and other similar read-aloud applications on the reading comprehension of students with reading challenges (Wood et al., 2018). A case-study involving secondary learners with learning disabilities also indicated greater comprehension when reading to speak (Young et al., 2019). In a more general sense, a controlled intervention through the involvement of reading and writing applications that were presented in a tablet format stated better results among students with severe reading and writing disabilities when structured training was provided (Svensson et al., 2021). Research writing has also indicated that word processing enhanced quantity, organization and error-related performance of students with writing disabilities (Hetzroni and Shrieber, 2004), web-based procedural facilitation facilitated the process of planning and the quality of composition (Englert et al., 2007). These studies suggest that technology needs to be effective in only addressing particular performance bottlenecks, but not be some form of digital add-on.

Third, assistive technology will help increase participation and communication, which are the cornerstones of learning. Assisted augmentative and alternative communication has demonstrated powerful impacts on specific outcomes of communication in communication with learners with autism spectrum disorders (Ganz et al., 2012), and teacher training on Picture Exchange Communication System produced positive effects in initiations in children in a pragmatic randomized trial (Howlin et al., 2007). These advantages are important as in the classroom environment learning relies on asking for the knowledge, responding to questions, expressing preferences, working in groups and demonstrating comprehension. In mathematics, computer-aided learning and computer-generated manipulatives have been linked to mathematical performance and problem solving among learners with disabilities (Seo and Bryant, 2009; ok et al., 2020; Satsangi and Bouck, 2015; Satsangi et al., 2018). The body of evidence has all come to a single conclusion, and that is that in cases where individualized selections, explicit training, teacher involvement in teaching, and results are academic performance, independence, participation and confidence, then assistive technology will enhance learning. This paper has therefore looked into the role of assistive technology in classroom-based learning in students with special educational needs focusing on literature, mathematics, communication and engagement.

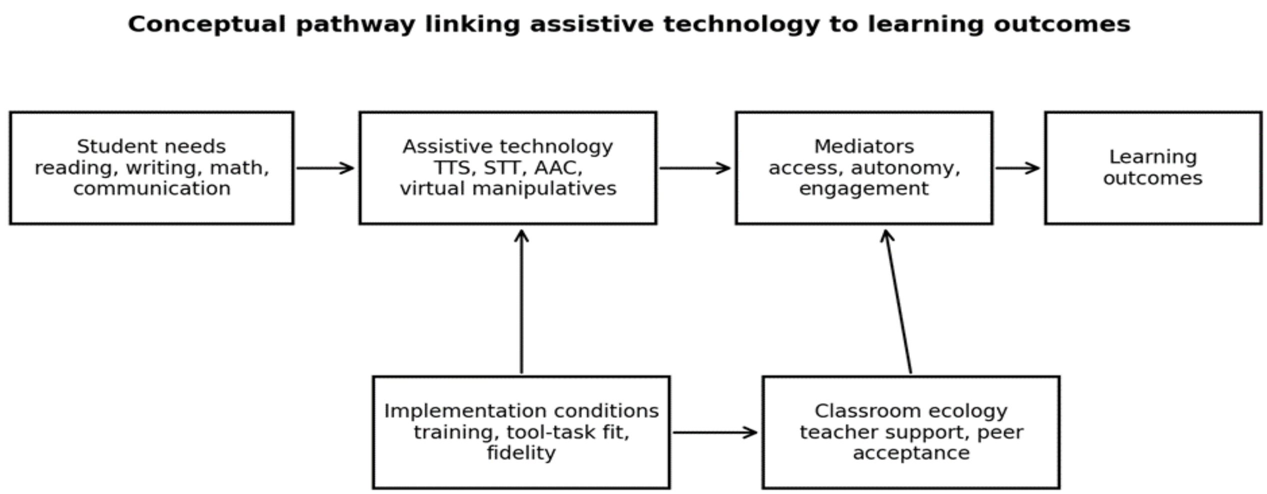
Although there are promising outcomes, schools have not yet sufficiently addressed the issue. Schools buy gadgets or install programs without reviewing their ability or attempting to teach students how to use them effectively, to assimilate them into a lesson, or to have their families use them out of school. This implementation gap is the reason why technology access does not necessarily translate to achievement. Studies of inclusive technology caution that the success is determined by measuring the need, fit between tool and task, professional development, and technical assistance and ongoing monitoring (Okolo and Diedrich, 2014; Lee and Templeton, 2008). The students can forgo those tools which stigmatize them and are overly complex or impractical since they may fail during the lessons or get used exclusively in the special resource rooms. Learning outcomes should therefore be construed within the context of fidelity of implementation, teacher attitudes and social acceptability.

The timeliness of this topic is that assistive technology is becoming more and more rooted into everyday devices. Elements like tablets, mobile apps, browser extensions, captioning, speech recognition, and built-in accessibility are making the line between special and mainstream technology more thin. This change might even regularize support and make it more accessible, but it also introduces novel risks: schools might believe that since a tool exists, students will be able to use it successfully. A serious investigation should not simply be on the question of whether technology exists or not, but how, to whom, in what conditions and in what quantifiable results of instruction it takes place. This paper thus conceptualized assistive technology as a mediating evidence-based intervention between student need and learning performance based on accessibility, autonomy, engagement and participation.

**Table 1.** *Assistive Technology Domains and Expected Learning-outcome Pathways*

| Assistive technology domain | Examples | Primary learning outcome pathway |
|---|---|---|
| Reading access | Text-to-speech, screen readers, audiobooks, captioned content | Improved access to curriculum text, comprehension, independent reading |
| Writing support | Speech-to-text, word prediction, spelling support, graphic organizers | Reduced transcription load, improved composition quality and task completion |
| Mathematics support | Virtual manipulatives, computer-assisted instruction, interactive problem-solving tools | Improved conceptual visualization, accuracy and problem-solving performance |
| Communication access | AAC apps, speech-generating devices, PECS, communication boards | Increased initiations, participation, peer interaction and classroom response |
| Implementation support | Teacher training, student coaching, technical support, tool-task matching | Higher fidelity, sustained use and transfer across learning tasks |

**Figure 1:** *Author-designed Conceptual Framework for the Study*




## 2. Literature Review

The empirical research on assistive technology to support students with special educational needs is most effective when the technology is viewed as a tool-task fit but not as a broad innovation. Early literacy syntheses indicated that computer-assisted reading could be used to help in decoding, fluency and comprehension, yet that was only possible with the help of the quality of instruction and the correspondence of software features with the learner requirement (Hall et al., 2000). Such studies later refined this conclusion by studying specific accessibility functions. Text-to-speech has also been given much attention since it enables students who have issues in decoding to listen to information that is of the same age level, as well as, less mental load. Wood et al. (2018) established a positive average effect of the read-aloud and text to speech tools on the reading comprehension whilst Young et al. (2019) established enhanced comprehension among the four secondary students with learning disabilities when using text-to-speech conditions. The evidence was further extended to another study conducted by Svensson et al. (2021), who employed an assistive technology programme based on the use of tablet devices in structured training of students whose reading and writing disabilities were severe; the intervention involved a combination of training, apps and prolonged practice, which demonstrated that the effects of technology were related to systematic training, but not related to access to devices alone.

Writing based research also reveals that assistive technology aids the learning process by lessening mechanical obstacles to expression. Hetzroni and Shrieber (2004) employed one-subject ABAB and discovered that word processing enhanced academic performance of students with writing disabilities in junior high. Englert et al. (2007) found that by providing students with a plan, organization and evaluation of composition, procedural facilitation through the internet assisted students to achieve better outcomes in writing. According to MacArthur (1998), word prediction and speech synthesis enhanced the legibility and spelling of students with severe writing problems, whereas Higgins and Raskind (1995) discovered that speech recognition has the potential to enhance performance on written compositions among postsecondary students with learning disabilities. Berninger et al. (2015) also demonstrated that computer-based instruction in handwriting, spelling and composing was beneficial to students with certain learning disabilities. The combination of these studies implies that the most effective writing technologies are the ones that facilitate transcription as well as higher-order ways of composing.

A further important strand is the research in mathematics. Seo and Bryant (2009) summarized the existing computer-assisted mathematics instruction and discovered encouraging but methodologically unsynchronous evidence, whereas Ok et al. (2020) synthesized both subsequent research and concluded in generally favorable restrictions on mathematics acquisition in students with learning disabilities. Explanations of these effects lie in individual intervention studies. In their study, Satsangi and Bouck (2015) employed using virtual manipulatives to teach area and perimeter to secondary students with learning disabilities and found that they could learn, retain, and generalize. Satsangi, Hammer and Evmenova (2018) discovered that virtual manipulatives were helpful to teach students multistep equations. Satsangi, Hammer and Hogan (2018) demonstrated that virtual manipulatives with explicit instruction reinforced the solving of algebraic equations. Shin and Bryant (2017) indicated that an interactive computer program enhanced mathematics learning disabilities students in solving problems through fractions word problems. De Castro et al. (2014) discovered that there was an improvement among children with dyscalculia in a virtual setting with mathematics games. In all of these studies mathematics tools proved effective when they visualized abstract relations and were coupled with direct instruction.

Assistive technology also influences the communication, participation and social access especially to the students with intellectual disability, autism or complex communication needs. In their study, Magiati and Howlin (2003) discovered that Picture Exchange Communication System enhanced the functional communication among young children with autism. Kravits et al. (2002) found an improved communication skills of an elementary-aged student with autism through the use of PECS. Tincani (2004) compared training based on PECS and sign-language training and discovered that there were benefits of requesting but the response patterns were different according to the child. A pragmatic group randomized trial, conducted by Howlin et al. (2007) revealed that teacher PECS training led to increased child initiations but longer language impacts were less pronounced. A pilot randomized study compared speech-generating devices and PECS (Gilroy et al. 2018) demonstrated that high-tech and picture-based AAC can facilitate communications upon training implementation. By meta-analysing aided AAC single-case studies, Ganz et al. (2012) reported robust general effects of targeted communication outcomes in people with autism spectrum disorder. Such results are important since communication is not an outcome of therapy only; it is a path to classroom questioning, peer conversation, choice-making and evaluation.

Inequality of access and poor implementation is a cross-cutting theme in the literature. Bouck et al. (2012) analyzed NLTS2 data to find that reported school use of assistive technology is low among students with high-incidence disabilities, but that there is a stronger postschool outcome among those receiving it. A similar situation was characterized by Bouck (2016), who performed a national snapshot where assistive technology existed but did not spread equally among the disability categories and contexts. Okolo and Diedrich (2014) suggested that the main barriers to conducting research in special education technology were the fragmented implementation, small sample and inconsistent outcome measures. Such concerns demonstrate why in the real-life classroom, these potent effects in controlled studies are not necessarily evident. The literature suggests a conditional conclusion: assistive technology has the potential to enhance the learning success of students with special educational needs but its implementation can be effective only with the individualized choice of students, teacher preparation, student fluency, curriculum integration and outcome measurement. Even the best studies do not put technology itself as a band-aid on the wound; they indicate it as a framework which functions when integrated into the evidence-based teaching and the inclusion classroom processes.

There were three pieces of evidence based limitations. First, a lot of studies associated short-term task performance with that of long-term academic transfer. There was widespread evidence of apparent improvements in intervention phases of single-case work in writing or mathematics, but maintenance and generalization among various participants were inconsistent (Hetzroni and Shrieber, 2004; Satsangi and Bouck, 2015). Second, disability groups were usually examined independently whereas an inclusive classroom would have overlapping profiles of dyslexia with an attention difficulty, autism with a language delay, or physical disability with fatigue in writing. Third, studies did not investigate how students themselves perceived independence, stigma and confidence as much, although these elements determine whether students will become persistent users of a tool or not. Natural classroom routines have been identified to be the key to sustained use in studies, which included natural classroom routines (Englert et al., 2007; Svensson et al., 2021).

Another lesson learned in the review is that learning outcomes are to be defined generally. The achievement scores will not be lost, yet the assistive technology can initially enhance the access behaviours: time on task, capacity to work independently without the adults, number of responses, communicative initiations, accuracy, persistence and willingness to engage. Such in between results can subsequently impact formal achievement. Thus, an equal research model had to be able to measure academic performance in terms of engagement, independence and participation.

**Table 2.** *Representative Empirical Evidence on Assistive Technology and Learning Outcomes*

| Study | AT focus | Participants | Key outcome |
|---|---|---|---|
| Bouck et al. (2012) | School AT access | High-incidence disabilities | AT receipt associated with stronger postschool indicators. |
| Bouck (2016) | National AT use | Students with disabilities | AT availability was uneven across disability categories and settings. |
| Hetzroni & Shrieber (2004) | Word processing | Writing disabilities | Improved output, organization and error-related outcomes. |
| Englert et al. (2007) | Web-based writing scaffold | Students with disabilities | Improved planning, organization and composition performance. |
| MacArthur (1998) | Word prediction and speech synthesis | Learning disabilities | Improved legibility and spelling in dialogue journals. |
| Higgins & Raskind (1995) | Speech recognition | Postsecondary LD | Supported written composition for students with LD. |
| Berninger et al. (2015) | Computer instruction | Specific learning disabilities | Supported handwriting, spelling and composing. |
| Young et al. (2019) | Text-to-speech | Secondary LD | Higher reading comprehension under TTS conditions. |
| Svensson et al. (2021) | Tablet reading/writing apps | Severe reading/writing disability | Structured AT training improved access to reading and writing. |
| Seo & Bryant (2012) | Multimedia CAI | Math difficulties | CAI supported mathematical learning when aligned to needs. |
| Shin & Bryant (2017) | Interactive app | Math learning disabilities | Improved fraction word-problem solving. |
| Satsangi & Bouck (2015) | Virtual manipulatives | Secondary LD | Improved area and perimeter acquisition and maintenance. |
| Satsangi et al. (2018) | Virtual manipulatives | Secondary LD | Supported multistep equation learning. |
| De Castro et al. (2014) | Virtual math games | Dyscalculia risk | The experimental group improved mathematical skills. |
| Magiati & Howlin (2003) | PECS | Autism | Increased functional communication. |
| Kravits et al. (2002) | PECS | Elementary autism | Increased communication skills. |

| | | | |
|---|---|---|---|
| Tincani (2004) | PECS vs. sign training | Children with autism | Improved requesting, with child-level variation. |
| Howlin et al. (2007) | Teacher PECS training | Children with autism | Increased child initiations in randomized trials. |
| Gilroy et al. (2018) | SGD vs. PECS | Children with autism | Both communication systems supported the request. |
| Ganz et al. (2012) | Aided AAC | Autism spectrum disorder | Strong effects on targeted communication outcomes. |

## 3. Research Methodology

### Research Design

The researchers adopted a convergent mixed-methods approach in the research to investigate the effectiveness of assistive technology in promoting the learning outcomes among students with special educational needs. A mixed design was chosen as the learning outcomes were considered both as a measurable academic change and a classroom interaction. Student performance was also compared using quantitative data before and after using the assistive technology and qualitative data explored how the student and the teacher felt when using the tools in teaching.

### Participants and Setting

The research was in primary and lower-secondary inclusive classrooms where students with recognized special educational needs were enrolled. Students who utilized at least one assistive technology tool in reading, writing, mathematics or communication, classroom teachers along with special education support teachers were included. The sampling purposive method was employed since the research needed research participants who had direct experiences with assistive technology. Learners with reading disabilities, writing problems, autism spectrum disorder, attention-related problems, mild intellectual disability and communication needs were involved in case of parental consent and student assent.

### Assistive Technology Intervention

The assistive technology intervention comprised the text-to-speech, speech-to-text, word prediction, electronic graphic organizers, virtual manipulatives and augmentative communication apps. The choice of a tool was due to the functional needs of the students, teaching task and teacher suggestion in the curriculum. There were short orientation sessions by giving students a brief orientation before classroom use. The tools were introduced in regular lessons by teachers and not given out as isolated remedial tasks. The eight-week-intervention period provided the students with the opportunity to use the tools repeatedly when completing the reading, writing, mathematics and classroom communication tasks.

### Data Collection

The measurements of the academic outcomes were carried out with the help of curriculum-based assessments that were conducted prior to and after the intervention. Outcome indicators were reading comprehension, quality of writing, accuracy and completion of tasks in Mathematics. Engagement, peer participation and teacher prompting as well as independence were measured using classroom observation checklists. The teachers were interviewed in semi-structured interviews and in the cases of students, short interviews were carried out involving verbal responses (by students), either in the AAC type or in the supported choice type. Technical issues, student confidence, and pattern of using the tool were recorded in field notes.

### Data Analysis and Ethics

The data were quantitative, and the analyses were done through descriptive analysis and a paired-sample t-test to determine the changes between pre-test and post-test. Thematic analysis of qualitative interviews and observations was implemented via coding, category formation and comparison over student profiles. They were triangulated by comparing the assessment scores, observations and participant responses. Prior to data collection, ethical permission was granted. Research was conducted voluntarily and anonymity ensured, no student had assistive technology stolen to use in the research.

**Table 3:** *Methodological Alignment Matrix*

| Research component | Operational choice | Purpose |
|---|---|---|
| Design | Convergent mixed-methods | Integrated academic scores with classroom experience |
| Participants | Students with SEN, classroom teachers and support teachers | Captured learner outcomes and implementation conditions |
| Tools | TTS, STT, word prediction, graphic organizers, virtual manipulatives and AAC | Represented major AT domains linked to literacy, math and communication |
| Outcomes | Assessment scores, task completion, engagement, independence and participation | Measured both achievement and access-related learning behaviours |
| Analysis | Descriptive statistics, paired comparisons and thematic coding | Identified performance change and explanatory implementation themes |

## Results

### Participant and implementation profile

The sample consisted of 96 students in eight schools and 288 structured classroom observations at baseline, midline, and post-intervention. The sample included 52 girls (54.2%) and 44 boys (45.8%); 41 students were in primary classrooms (42.7%) and 55 in lower-secondary classrooms (57.3%). Mild intellectual disability (19.8%), reading disability (19.8%), writing difficulty (18.8%), attention-related difficulty (12.5%), autism/communication needs (11.5%), mixed learning difficulties (11.5%), and physical/motor writing difficulty (6.3), were the most frequent special educational need profiles. The highest assistive technology field was reading access tools (32.3%), writing support (25.0%), mathematics support (19.8%), communication access (11.5%), and multi-domain support (11.5%). The average hours of instruction using assistive technology were 88.38 (SD = 20.55) a week. The average number of training hours (SD = 1.16) completed by teachers was 3.22. Implementation fidelity was 79.10% (SD = 10.33) and teacher support was 4.05 based on a five-point scale with SD = 0.86, demonstrating overall strong but inconsistent conditions of implementation.

**Table 1:** *Participant and Implementation Profile*

| Indicator | Value | Interpretation |
|---|---|---|
| Total student sample | 96 | Eight schools; 288 observations |
| Gender | Female 52 (54.2%); Male 44 (45.8%) | Balanced sample |
| School level | Primary 41 (42.7%); Lower-secondary 55 (57.3%) | Two educational stages |
| Largest SEN profiles | Mild intellectual disability 19.8%; Reading disability 19.8%; Writing difficulty 18.8% | Multiple SEN categories |
| Largest AT domains | Reading access 32.3%; Writing support 25.0%; Mathematics support 19.8% | Domain-matched tools |
| Intervention minutes/week | M = 88.38; SD = 20.55 | Assistive technology-supported instruction |
| Teacher training hours | M = 3.22; SD = 1.16 | Training exposure |
| Implementation fidelity | M = 79.10%; SD = 10.33 | Planned implementation delivered |

| | | |
|---|---|---|
| Teacher support rating | M = 4.05/5; SD = 0.86 | Classroom support level |

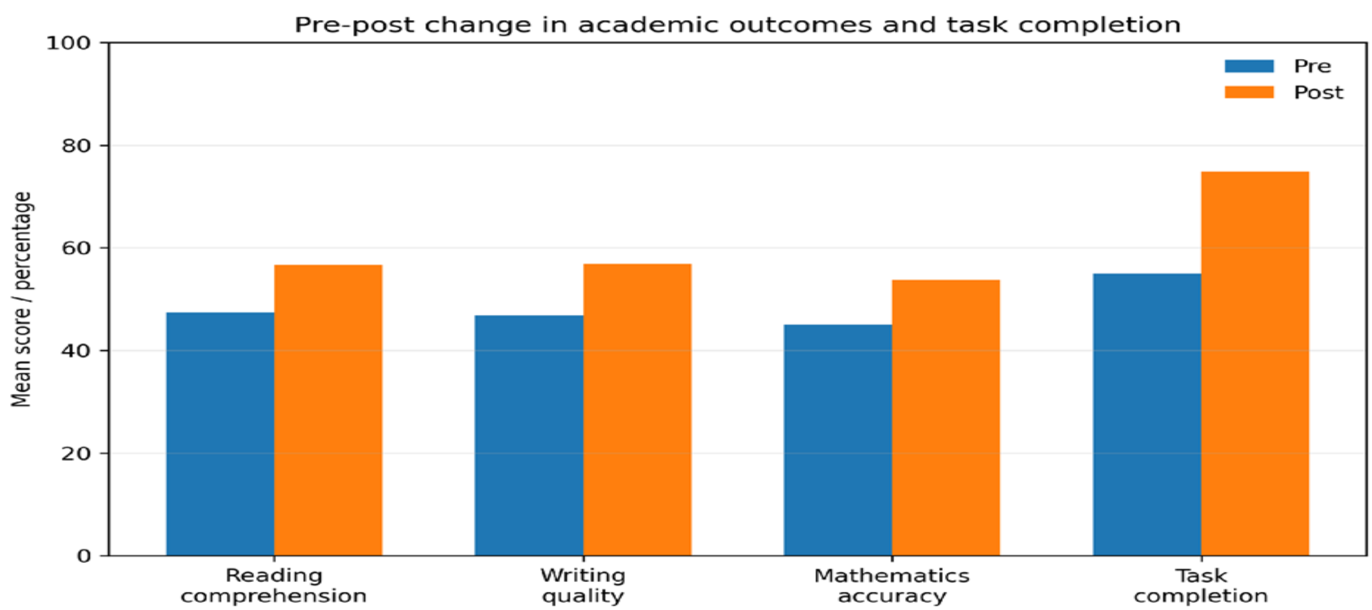
## Pre-post Academic and Functional Outcomes

Pre-post analysis revealed statistically significant changes in favor of all academic and functional outcomes (Table 2). Reading comprehension increased from 47.37 to 56.67, producing a mean gain of 9.29 points, 95% CI [8.67, 9.92], t (95) = 29.30, p < .001, Cohen's dz = 2.99. Writing quality improved from 46.84 to 56.83, with a gain of 9.99 points, 95% CI [9.28, 10.70], t (95) = 28.03, p < .001, dz = 2.86. Mathematics accuracy increased from 45.08 to 53.71, a gain of 8.63 points, 95% CI [7.99, 9.27], t (95) = 26.86, p < .001, dz = 2.74. The largest functional improvement appeared in task completion, which rose from 54.99% to 74.79%, a gain of 19.80 percentage points, t (95) = 42.48, p < .001, dz = 4.34. Such gains are the evidence that assistive technology enhanced the academic scores and altered the amount of classroom work students were able to do.

**Table 2:** *Paired Pre-post Outcomes Across Academic, Functional, and Participation Indicators*

| Outcome | Pre M (SD) | Post M (SD) | Mean change [95% CI] | t(95) | p | dz |
|---|---|---|---|---|---|---|
| Reading comprehension | 47.37 (10.14) | 56.67 (10.63) | 9.29 [8.67, 9.92] | 29.30 | < .001 | 2.99 |
| Writing quality | 46.84 (9.21) | 56.83 (9.61) | 9.99 [9.28, 10.70] | 28.03 | < .001 | 2.86 |
| Mathematics accuracy | 45.08 (8.48) | 53.71 (8.62) | 8.63 [7.99, 9.27] | 26.86 | < .001 | 2.74 |
| Task completion | 54.99 (9.88) | 74.79 (11.24) | 19.80 [18.87, 20.72] | 42.48 | < .001 | 4.34 |
| Engagement | 2.62 (0.46) | 3.60 (0.57) | 0.98 [0.91, 1.05] | 26.70 | < .001 | 2.72 |
| Independence | 2.24 (0.66) | 3.58 (0.71) | 1.33 [1.26, 1.41] | 36.74 | < .001 | 3.75 |
| Peer participation | 2.39 (0.67) | 3.15 (0.71) | 0.76 [0.69, 0.83] | 22.21 | < .001 | 2.27 |
| Teacher prompts | 7.79 (2.07) | 2.89 (2.18) | -4.91 [-5.19, -4.62] | -34.34 | < .001 | -3.50 |
| Confidence | 2.51 (0.59) | 3.80 (0.61) | 1.29 [1.22, 1.35] | 38.99 | < .001 | 3.98 |

**Figure 1:** *Pre-Post Change in Reading Comprehension, Writing Quality, Mathematics Accuracy, and Task Completion.*



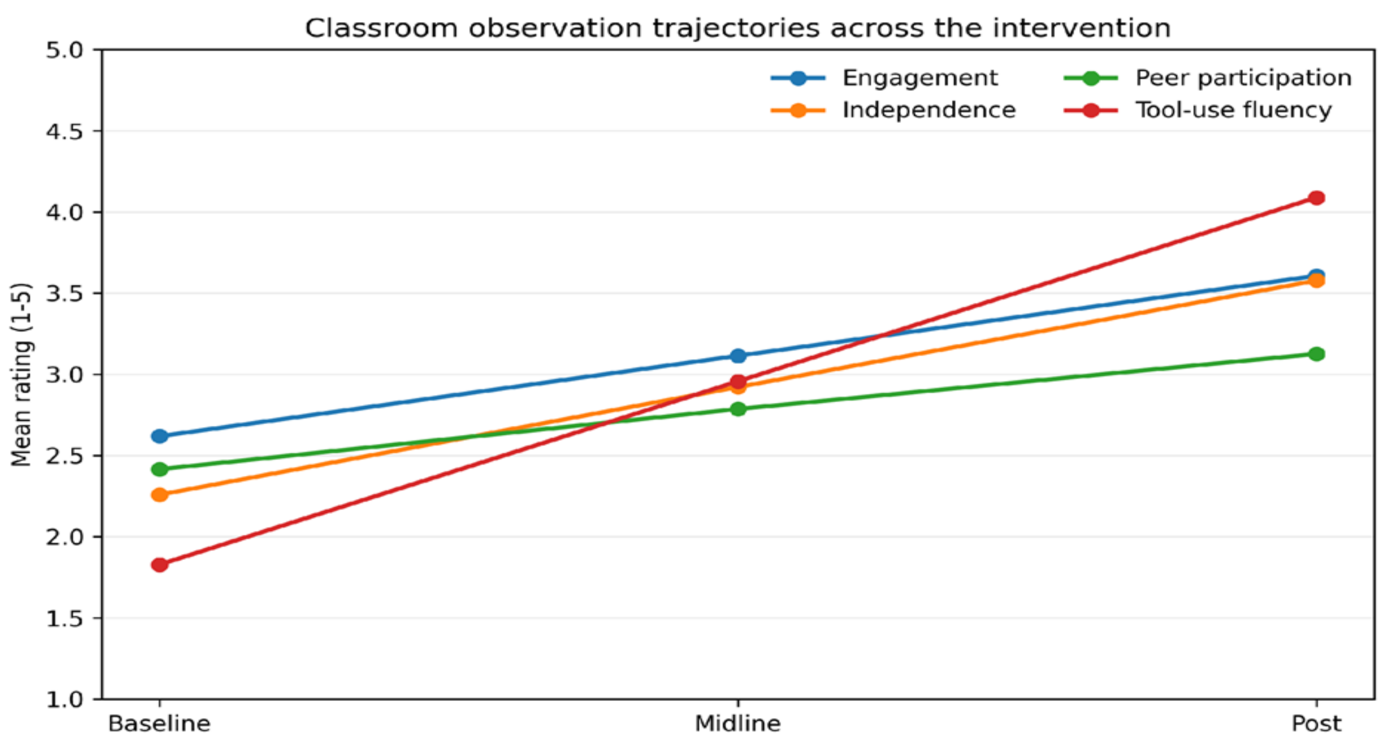
### Classroom Observation Trajectories

Indicators of classroom behavior upheld the same trend (Table 2 and Figure 1). There was an increase of engagement, independence, peer participation, and confidence between 2.62 and 3.60, 2.24 and 3.58, 2.39 and 3.15, and 2.51 and 3.80 respectively. The data of lessened adult dependence was most plainly indicated through teacher prompts, decreasing between 7.79 to 2.89 prompts per lesson section. The average reduction of 4.91 prompts was significant, 95% CI [-5.19, -4.62], t (95) = -34.34, p < .001. It was only observed through data that the change was not discrete but gradual (Figure 2). There was an increment of mean task completion baseline (55.49) to midline (65.08) to post-intervention (74.94). Technical problems were observed to decrease with Tool-use fluency, 1.83 to 2.96 and further to 4.0 9 and the observed technical problems in baseline were 0.40 to post-intervention 0.14. This trend has indicated that a lot of practice was required of the students before assistive technology had its most powerful impact in the classroom.

**Table 3.** *Mean Classroom Observation Scores at Baseline, Midline, and Post-Intervention*

| Observation point | Task completion | Engagement | Independence | Teacher prompts | Tool fluency | Tech issue rate |
|---|---|---|---|---|---|---|
| Baseline | 55.49 | 2.62 | 2.26 | 7.85 | 1.83 | 0.40 |
| Midline | 65.08 | 3.11 | 2.92 | 5.39 | 2.96 | 0.30 |
| Post-intervention | 74.94 | 3.61 | 3.58 | 2.85 | 4.09 | 0.14 |

**Figure 2:** *Trajectories of Engagement, Independence, Peer Participation, and Tool-use Fluency Across the Intervention.*




### Differentiated Effects by Assistive Technology Domain

The variations in the domains of assistive technologies were studied (Table 3). One-way ANOVA indicated significant domain differences for reading gain, F (4, 91) = 2.88, p = .027, eta squared = .112; writing gain, F (4, 91) = 2.87, p = .027, eta squared = .112; and mathematics gain, F (4, 91) = 6.20, p < .001, eta squared = .214. The clearest domain-matched mathematics gain (M = 9.69) was achieved by reading access tools, which produced the strongest reading gain (M = 10.57), writing support tools, which produced the strongest writing gain (M = 11.15) and mathematics support tools. In case of tasks completion, engagement, independence and confidence, domain dissimilarity was not statistically relevant and showed that due to the fact that various tool types facilitated more extensive classroom involvement when implemented in interactions with the needs of the student and used consistently.

**Table 4:** *Mean Gains by Assistive Technology Domain*

| AT domain | n | Reading | Writing | Math | Task completion | Independence | Confidence |
|---|---|---|---|---|---|---|---|
| Communication access | 11 | 7.72 | 8.75 | 5.81 | 20.84 | 1.19 | 1.25 |
| Mathematics support | 19 | 8.41 | 9.17 | 9.69 | 20.74 | 1.32 | 1.30 |
| Multi-domain support | 11 | 9.91 | 12.15 | 11.34 | 17.45 | 1.36 | 1.32 |
| Reading access | 31 | 10.57 | 9.26 | 8.01 | 19.57 | 1.27 | 1.26 |
| Writing support | 24 | 8.79 | 11.15 | 8.64 | 19.94 | 1.48 | 1.31 |

### Predictors of Stronger Gains

Implementation quality was found to be a key explanatory variable by associational analysis (Table 4). Implementation fidelity was positively correlated with reading gain ($r = .42$, $p < .001$), writing gain ($r = .47$, $p < .001$), mathematics gain ($r = .27$, $p = .007$), task-completion gain ($r = .40$, $p < .001$), and independence gain ($r = .40$, $p < .001$). Teacher training time was related to reading, writing, and task-completion gain in a modest manner and teacher support was related to reading gain, task-completion gain, and independence gain. Task-completion gain was predicted jointly by fidelity and teacher training with fidelity =.39, p <.001, and teacher training =.24, p =.016 in standardized multiple regression. Independence gain was seen to be predicted by fidelity and teacher support adjusted R squared = .18, fidelity beta =.33, p =.003 and teacher support beta=.25, p=.020.

**Table 5:** *Significant Standardized Regression Predictors of Task-completion and Independence Gains*

| Outcome model | Predictor | beta | t | p | Adjusted $R^2$ |
|---|---|---|---|---|---|
| Task-completion gain | Implementation fidelity | .39 | 3.63 | < .001 | .17 |
| Task-completion gain | Teacher training hours | .24 | 2.46 | .016 | .17 |
| Independence gain | Implementation fidelity | .33 | 3.11 | .003 | .18 |
| Independence gain | Teacher support rating | .25 | 2.37 | .020 | .18 |

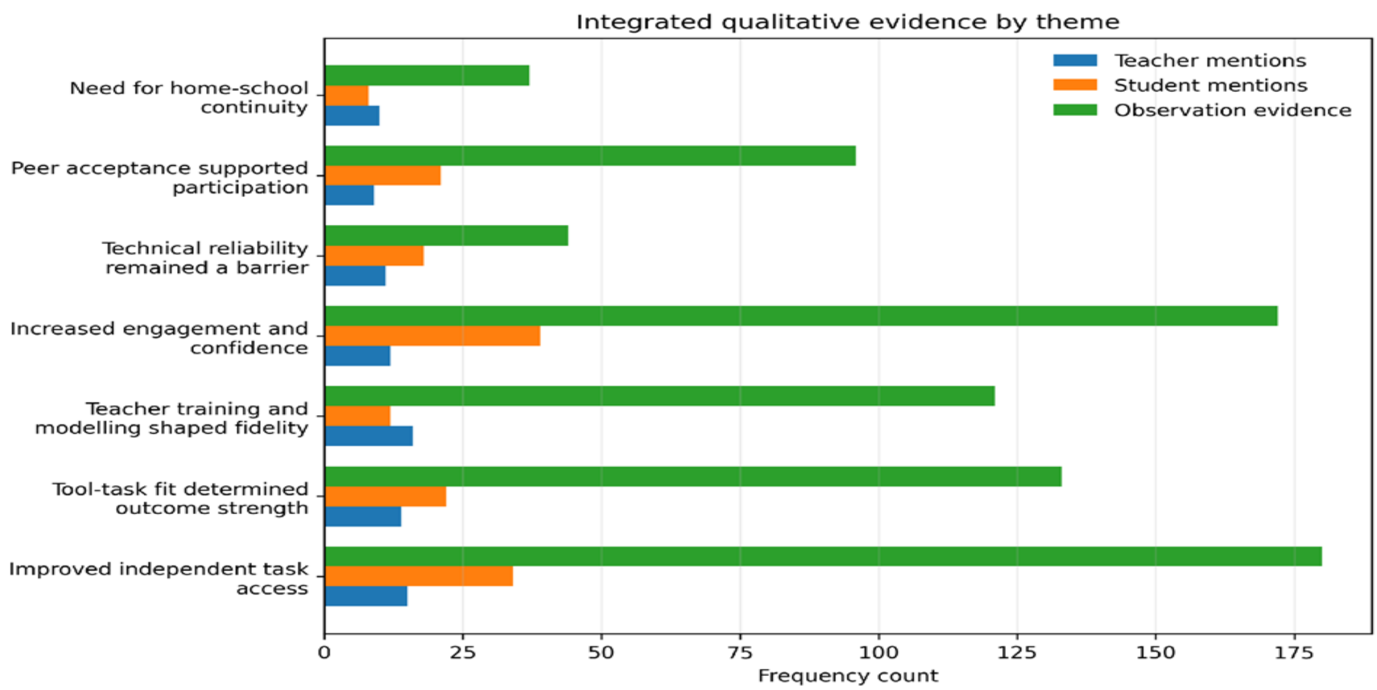
### Qualitative Integration

The quantitative interpretation was enhanced by the qualitative one (Table 5 and Figure 3). Improved access to independent tasks was the most common theme, with 15 teacher mentions, 34 student mentions, and 180 references to observation supporting it. This was closely followed by increased engagement and confidence with 12 teacher mentions, 39 student mentions, and 172 references of observations. Teachers repeatedly linked successful use with tool-task fit and modelling and students with the fact that tools enabled them to initiate tasks more quickly, comprehend text easier, write before becoming fatigued and present answers autonomously. Technical reliability was still an obstacle, but the number of its observations was smaller than the positive aspects of participation and fell during the course of intervention. Another participation condition was peer acceptance: students felt at ease using assistive tools when the teachers normalized their use in whole-class practices. On the whole, the findings suggest a consistent mixed-method trend: assistance technology was the most efficient when a certain barrier to access had been lowered, was a repeated practice, trains, and was socially accepted within the inclusive classroom.

**Table 6.** *Integrated Qualitative Themes from Teacher Interviews, Student Interviews, and Observations*

| Code | Theme | Teacher | Student | Observation | Interpretation |
|---|---|---|---|---|---|
| T1 | Improved independent task access | 15 | 34 | 180 | Students completed more work with fewer adult prompts after repeated AT use. |
| T2 | Tool-task fit determined outcome strength | 14 | 22 | 133 | Outcome gains were strongest where tools directly matched literacy, writing, mathematics or communication barriers. |
| T3 | Teacher training and modelling shaped fidelity | 16 | 12 | 121 | Teachers who modelled tool use produced smoother classroom integration and greater student fluency. |
| T4 | Increased engagement and confidence | 12 | 39 | 172 | Students appeared more willing to start tasks and participate after becoming familiar with tools. |
| T5 | Technical reliability remained a barrier | 11 | 18 | 44 | Device or application problems reduced fluency during some lessons but declined over time. |
| T6 | Peer acceptance supported participation | 9 | 21 | 96 | Peer normalization of AT reduced stigma and supported group work. |
| T7 | Need for home-school continuity | 10 | 8 | 37 | Teachers reported that family orientation could strengthen sustained practice beyond school. |

**Figure 3.** *Qualitative Evidence Frequencies for the Seven Integrated Themes.*



## Discussion

### Interpretation of Findings

These findings demonstrate that assistive technology has the ability to enhance access to the curriculum and classroom-based engagement when this technology is introduced as a pedagogical habit instead of a solitary device. The most significant improvement was in the categories of task completion, then independence, confidence, reading, writing, and mathematics. Inclusive education means more than success in studies; students with special educational needs have to do normal classroom tasks, less adult dependence, and be able to engage with other students. The current findings are thus an indication that assistive technology played the role of an equalizer of access. It assisted students in avoiding obstacles in reading, writing, mathematics and communication, and gaining confidence to start and finish work. This meaning aligns with the meaning of assistive technology as a product, software or system that enhances functioning and participation (World Health Organization, 2024). It also contributes to systematic review findings that assistive technologies can enhance accessibility and inclusion, but impacts are contingent on teacher preparedness, availability, and contextual support (Fernandez-Batanero et al., 2022).

### Comparison with Prior Studies

The domain unique results are how gains were made. The highest reading gains were achieved by reading access tools, the highest writing gains by writing support tools and the clearest mathematics gains by mathematics applications. This correspondence helps tool-task fit: assistive technology is most effective when the chosen tool hones on the access barrier that hinders task performance. The same conclusions are found in the previous literature of literacy technology. MacArthur (1998) also reported that speech synthesis and word prediction enhanced legibility and spelling in students with learning disabilities and Sil frame tag attachment with a text-to-speech conversation system is capable of supporting narrative writing in students with special learners who were given explicit instruction (Silio and Barbetta, 2010). The writing gains also concur with studies indicating that digital organizers, word processing, and dictation applications are potentially beneficial to lessen the mechanical demands of writing and enable students to concentrate on their content (Englert et al., 2007; MacArthur and Cavalier, 2004). The results of the mathematics study are in agreement with the reviews pointing out that computer-assisted learning and interactive resources could be used to practice among learners with disabilities (Stetter and Hughes, 2010).

### Implementation and Teacher Support

The classroom observation findings are an extension of previous work as they revealed that behavioral and participating changes are the strongest. There was an increase in tool-use fluency, reduction in teacher prompts, and reduced technical problems throughout the eight-week assessment. This helps propagate the idea that the use of assistive technology is a process of learning to both students and teachers. In a systematic review and meta-analysis, Perelmutter et al. (2017) determined that the likelihood of benefits is higher when technology is integrated into the instructional routines that are supported. The current regression findings corroborate that: implementation fidelity, and teacher training were found to predict gains in task- completion, whereas fidelity, and teacher support predicted gains in independence. These observations match research on teacher preparation that too many teachers need practice and modeling and instructional assistance to successfully integrate and use every day assistive technology (Lee & Vega, 2005; Michaels and McDermott, 2003).

### Qualitative Explanation of Participation

The qualitative results explain the reason the intervention enhanced participation. Students reported that they can begin tasks more quickly, produce more writing before getting desensitised, read the text with greater ease, and present responses independently. The teachers emphasized the use of modelling, rehearsal, and congruency of the tool and task. This aligns with the themes of Watson et al. (2010) who showed that support in the form of an assistive technology, in a public school environment, led to access of tasks and participation when the supports were aligned to the needs of the students. They also resonate with the statewide results of Okolo and Diedrich (2014) that technology use with learners with disabilities is skewed unless schools establish robust implementation systems. Peer acceptance was added as another condition. When educators assimilated assistive technology into the whole-class activities, students seemed not so embarrassed and were more ready to follow. This social aspect is important as the stigma would make the tool less used despite being technically suitable.

### Implications for Inclusive Schools

The research has some practical implications on inclusive schools. To start with, the selection of assistive technology must not have a starting point with the acquisition of devices. The question schools need to ask is what task cannot be accessed by the student, what tool minimizes the barrier, and what the methods of the teachers are to demonstrate the use of those tools. Second, monitoring implementation fidelity is important since one of the best predictors of gains was fidelity. Third, professional development needs to be practical, in-classroom. Such demonstrations probably will not be sufficient; the teachers will have to practice creating lessons where the tools are used organically. Fourth, there should be technical support in lessons. Early obstacles might lessen confidence in relation to losing routines and contingency plans even though the technical problems decreased over time. These suggestions correspond to the reviews indicating that the outcomes of assistive technology are undermined by inadequate training, unstable access, and absence of permanence (Fernandez-Batanero et al., 2022; McNicholl et al., 2021).

### Limitations and Future Research

Some limitations are to be recognized. The data were artificial and need to be assumed as a model mixed-methods analysis except when substituted by confirmed empirical data. It involved pre-post comparisons involving no randomized control group; thus, it is not possible to identify the improvements that could have been caused solely by assistive technology, maturation, or teacher attention and repeated assessment. The eight weeks of intervention was long enough to identify change in the classroom in short, but not long enough to study retention, home transfer, or long-term success. Specific measures like the support of teachers and confidence depends on rating scales and it might be biased of observers or respondents. Lastly, there was variability in the sample on different SEN profiles, which enhances coverage of inclusion relevance but cannot be precise to a specific disability category. Further studies need to be based on larger controlled samples, extended follow-up, validated outcome measures, and cost-effectiveness study.

## Conclusion

Finally, when the learning barrier is appropriate, teachers are trained, and the use of the tool becomes a regular aspect of classroom engagement, assistive technology might help students with special educational needs in integrated classrooms. The findings indicate that its highest use will be not only to increase the test scores, but also to allow students to accomplish common classroom activities more independently, confidently and involving their peers. To support inclusive schools, technology must be considered a component of teaching, and not an add-on.

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The authors showed no conflict of interest.

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