Assistive Technology and Cognitive Development of Children with Special Needs: Implication on Science Learning in Early Childhood Education

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Abstract

Assistive Technology (AT) plays a transformative role in enhancing the cognitive development of children with special needs, such as those with intellectual impairments, dyslexia, Attention Deficit Hyperactivity Disorder (ADHD) or Autism Spectrum Disorder (ASD). Assistive technological tools such as Speech-Generating Devices (SGDs), Artificial Intelligence (AI)-powered Adaptive Learning Platforms (ALP) and Brain-Computer Interfaces (BCIs) help improve memory, executive function, problem-solving, language acquisition and early childhood science learning skills. This study explores the theoretical foundations, cognitive benefits, implementation challenges and future directions of assistive technology in science teaching and learning in early childhood education. The study employed a correlational study and utilized purposive sampling technique. The population of the study comprised children with special needs in selected privately owned early childhood/special education schools. The sample consists of 30 children with various impairments guided by their caregivers, found in various privately owned early childhood/special education centres surveyed, in Ikeja Local Government Area of Lagos State. The study was guided by three (3) objectives and three (3) hypotheses. Instrument for data collection is researcher developed questionnaire titled Assistive Technology Special Needs Children Questionnaire (ATSNCQ). The instrument was validated by experts in the department of special needs education and early childhood/primary education. The instrument's reliability was assessed using the split-half method and subsequently subjected to analysis using Cronbach's Alpha (α) method, which yielded a correlation coefficient of 0.72 (α= 0.72) indicate that the instrument is reliable for the study. Correlational statistical method was used to analyze the data collected.

Keywords: Assistive Technology; Children with Special Needs; Cognitive Development; Early Childhood Education; Science Learning.

Introduction

Assistive technology (AT) is any device, software or tool designed to support children with disabilities in performing daily tasks, improving accessibility and enhancing their independence. According to the World Health Organization (WHO), assistive technology includes a broad range of products, from low-tech aids like magnifiers and crutches to high-tech solutions such as speech-generating devices and powered wheelchairs (WHO, 2018). Assistive technology in early childhood education refers to tools and devices that support children with disabilities in accessing, engaging with and benefiting from learning experiences. Assistive technology helps bridge the gap for children with sensory, cognitive or learning disabilities, promoting inclusion and equal opportunities in the classroom (Edyburn, 2020). The Individuals with Disabilities Education Act (IDEA) mandates that special education/preschools provide assistive technology to children who need it to access their education effectively (U.S. Department of Education, 2021).

Assistive technology has become an essential tool for enhancing cognitive development and promoting inclusive early childhood education, assistive technology. Itranges from simple visual aids to advanced artificial intelligence (AI)-driven applications that personalize learning experiences (Edyburn, 2021). Cognitive development refers to processes such as memory, problem-solving, language acquisition and executive functioning (Piaget, 1952). Science in early childhood education refers to the science concepts and exploration activities conducted for children in their early years. The introduction of assistive technology in early childhood science education has revolutionized how children with special needs learn science in early childhood by providing customized interventions that support their unique science learning needs (Scherer et al., 2019).

Research indicates that assistive technology significantly improves early childhood science learning outcomes for children with special needs, by providing structured, interactive and adaptive support (Scherer et al., 2019). Special needs children including those with intellectual disabilities, learning disorder, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD) and impairments in functioning memory, executive function and problem-solving, often experience cognitive challenges that hinder learning and academic progress (Diamond & Ling, 2019). These cognitive challenges can manifest as difficulties in memory

retention, problem-solving, language development and executive functioning, affecting language acquisition, reasoning, self-regulation, problem-solving and attention control, which are fundamental for academic success especially in early childhood science learning (Butterworth et al., 2021; Diamond & Ling, 2019).

Various types of assistive technology which exists include mobility aids, which help children with physical disabilities move independently, examples include, wheelchairs, manual and powered models for children with mobility impairments. Prosthetic limbs, these are artificial limbs that restore functionality for amputees (Resnik et al., 2019). Walkers and Canes, these are devices that provide balance and support for walking. Children with mobility impairments require technology that assists with writing, communication and movement. Adaptive Keyboards and Mice, assistive technological tools like the IntelliKeys keyboard allow children with motor impairments to type more easily (Hersh, 2020). Eye-Gaze Technology, these are devices such as Tobii Dynavox which enable children to control computers using eye movements. Switch-Activated Devices, these are buttons or switches that allow children with limited motor control to interact with technology.

Assistive technology for communication enable children who have difficulty speaking or understanding spoken language to express themselves clearly, examples is speech synthesizer for kids who have trouble reading or speaking, this is a text-to-speech technology that can transform written words into spoken ones (Beukelman & Light, 2020). Augmentative and Alternative Communication (AAC) devices, which are speech generators for kids with disorders like aphasia or cerebral palsy (Beukelman & Light, 2020).

Hearing aids are assistive technological tools made for children with hearing impairments that aid in amplifying sound to provide access to spoken information in classrooms. Cochlear Implants, these are surgically implanted electronic devices that provide a sense of sound to those with severe hearing loss (Zeng, 2020). FM Systems, these are wireless microphones that transmit the spoken words of a caregiver to the hearing of the children, this enable the children to hear more clearly even in noisy environments. Communication Access Real-Time Translation (CART) provides live captions of spoken content. Visual Alert Systems (VAS), these are assistive technological tools that use lights or vibrations to indicate important auditory cues in the classroom.

Visual Aids, these assistive technological tools support children with visual impairments. Children with low vision or blindness require tools to access learning materials such as Screen Reader, this is a software that convert text into speech or braille and reads digital text aloud, such as Job Access with Speech (JAWS) and NonVisual Desktop Access (NVDA) (Wolfram, 2021). Braille Displays and embossers are devices that convert digital text into braille for visually impaired children, enabling them to read materials tactilely. Magnifiers, these are optical and electronic tools that enlarge printed text for individuals with low vision. Magnification Software ZoomText enlarges text and images on computer screens for children with low vision.

Cognitive aids assist individuals with memory retention, attention or learning difficulties and include Reminder Apps, applications like GoogleKeep and Microsoft To-Do, help users remember tasks. Voice Assistants, Artificial Intelligence-powered assistants, for instance, Siri, Alexa, help children with reminders and information retrieval (Hersh, 2020). Learning aids are made for children with learning disabilities, they are supplementary tools designed to help young children who have difficulty with learning. For example, there is speech-to-text software that can help dyslexic young child by translating spoken words into written text (MacArthur, 2019). There are reading and writing software known as text-to-speech software. Programmes like Kurzweil 3000 and Read&Write assist children with learning disabilities by providing text-to-speech, word prediction and writing assistance and reading digital or printed text aloud (MacArthur, 2019).

Assistive technology for children with Autism Spectrum Disorder (ASD) or cognitive disabilities. Children with autism spectrum disorder or cognitive disabilities benefit from technology that supports communication and behavioural skills, such as some devices that generate speech like Proloquo2Go that help non-verbal children communicate, these devices are called Augmentative and Alternative Communication (AAC) Devices (Beukelman & Light, 2020). Visual Schedules and Social Stories, these are apps like Choiceworks which assist children with organization and understanding social interactions. Noise-Canceling Headphones, these help reduce sensory overload in classroom environments.

Assistive technology is categorized based on its complexity and applications such as: Low-tech, mid-tech and high-tech (Edyburn, 2021). Low-tech assistive technology include visual schedules and cue cards, these devices help children with autism spectrum disorder organize daily activities,

reducing anxiety and improving task completion by providing structured routines (Hodgson et al., 2020). Graphic organizers these devices assist children with learning disorder in structuring written work, improving coherence and readability and organizing thoughts for better reading comprehension (Graham et al., 2018). Tools like Inspiration and MindMeister assist with structuring ideas for writing and studying (Hall et al., 2021). Adapted books these devices provide multisensory engagement for children with visual or cognitive impairments. It enable children with visual impairments to access text through tactile and auditory features (Lindstrom et al., 2018). Social Stories these enhance social cognition in children with autism spectrum disorder.

Mid-tech assistive technology include, text-to-speech software which helps children with reading disabilities (dyslexia) by converting text into spoken words (speech) therefore, improving comprehension (Lindstrom et al., 2018). Speech-to-text software which supports children with dysgraphia by allowing them to dictate rather than write (Scherer et al., 2019). Gamified learning apps, improve problem-solving (Goh et al., 2020). Talking calculators enhance mathematical comprehension for children with dyscalculia by vocalizing operations (Butterworth et al., 2021).

High-tech assistive technology, Augmentative and Alternative Communication (AAC), facilitates language development and improve communication in non-verbal children by providing alternative means of communication (Light & McNaughton, 2019). Brain-Computer Interfaces (BCIs), these are emerging technologies that allow children with severe disabilities to interact using brain signals (Butterworth et al., 2021). Eye-tracking systems, these devices enable children with severe mobility impairments to control digital interfaces (computers) and engage in learning (Parsons et al., 2019). Virtual Reality (VR) and gamified learning, foster engagement and cognitive skill development through immersive environments (Goh et al., 2020).

Benefits of assistive technology to children with special needs, assistive technology enhances independence, accessibility and quality of life for young children with special needs. According to the United Nations (UN, 2021), assistive technologies promote inclusion by enabling children to participate in education and social activities. In early childhood education, assistive technology allows children with disabilities to access learning materials. Assistive technology-based interventions improve memory recall by 35% in children with learning disabilities (Diamond & Ling, 2019). Digital reminders and task-management applications enhance attention span in

children with Attention Deficit Hyperactive Disorder (ADHD). Interactive learning software encourages children to develop analytical skills. Research suggests that adaptive learning software like adaptive math apps increase problem-solving abilities in children with phobia in calculation, by 40% (Butterworth et al., 2021).

Augmentative and Alternative Communication (AAC) devices lead to a 30% increase in expressive language acquisition in children with speech impairments (Smith, Johnson & Taylor, 2022; Light & McNaughton, 2019). Assistive technology tools like digital organizers improve cognitive flexibility and time management in children with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactive Disorder (ADHD) (Diamond & Ling, 2019). Assistive technology allows teachers and caregivers to tailor learning experiences to individual child needs (Edyburn, 2020) and improves reading, writing and comprehension skills among children with learning disabilities (Hall et al., 2021).

Implementation of Assistive Technology (AT) in Early Childhood Education (ECE) for innovative teaching and creative learning of young children with special needs, requires reasonable groundwork such as planning and training of caregivers for effective integration of assistive technologies into their teaching activities. There is need also, for better teamwork among caregivers, researchers and software designers for assurance of assistive technological software appropriately designed for teaching young children (Aiyegunle, Adikuru & Awotola, 2020; Oshin, Okoronkwo & Okezue, 2018).

Consequently, skillful training of caregivers using novel high-tech teaching and learning assistive technology will upgrade caregivers and make them confident in using assistive technology for teaching young children with special needs and become a significant feature of the effective use of assistive technology in formal early childhood educational learning environment. Efficient teaching and effective learning in young children lies with confident caregivers, made capable by good training with novel educational assistive technology, who understands curricular progressions and innovative technology use in early childhood education (Aiyegunle, Adikuru & Awotola, 2020; Oshin, Okoronkwo & Okezue, 2018). The main implementation strategies include, conducting needs assessments and individualized planning, before introducing assistive technology, early childhood and special education schools should conduct thorough needs

assessments to identify the specific requirements of children with special needs and caregivers. This process include, collaboration with special education teams, caregivers, therapists and information technology specialists should work together to determine appropriate assistive technological tools for young children having impairments (Zabala, 2021).

Statement of the Problem

The inclusion of children with special needs in early childhood education has drawn increasing attention in recent years, particularly in the context of science learning, which demands active observation, manipulation and exploration. Despite global advocacy for inclusive education, many children with disabilities continue to experience barriers that limit their participation and cognitive development in science activities. One major challenge is the inadequate integration of assistive technology devices and digital tools designed to enhance learning, communication and cognitive engagement within early childhood classrooms. More so, teachers often lack training and resources to effectively employ assistive technology to support the cognitive development of children with special needs in early childhood science learning. Consequently, these children may fail to develop essential cognitive skills such as observation, classification, prediction and problem-solving skills which are foundational to scientific inquiry and lifelong learning. Therefore, this study seeks to investigate the relationship between the use of assistive technology and the cognitive development of children with special needs in early childhood science learning. The study aims to determine the extent to which assistive technology enhances cognitive processes, identify challenges in its classroom application and provide recommendations for improving science learning experiences among children with special needs.

Theoretical Frameworks of Assistive Technology

Vygotsky's sociocultural theory, Vygotsky (1978) emphasized the role of social interaction and cultural tools in cognitive development. He argued that cognitive development is socially mediated, that is to say, cognitive growth occurs when children interact with more knowledgeable individuals and tools that scaffold their learning. Assistive technology serves as a cognitive scaffold, allowing children with disabilities or special needs to engage in learning early childhood science tasks beyond their independent capabilities (Daniels, 2016). Assistive technology also serves as a mediational tool, extending children's Zone of Proximal Development (ZPD) by

enabling them to complete tasks they cannot perform independently. For example, speech-generating devices (SGDs) facilitate language acquisition in non-verbal children with Autism Spectrum Disorder (ASD) by providing structured linguistic input (Light & McNaughton, 2019).

Assistive technology enables children with autism spectrum disorder to express thoughts, thereby improving cognitive and social engagement (Light & McNaughton, 2019). Similarly, artificial intelligence-powered adaptive learning systems provide real-time feedback, functioning as a digital scaffold that personalizes early childhood science learning. Interactive learning applications help children with dyslexia improve reading comprehension through structured support (Lindstrom et al., 2018). Vygotsky's concept of the Zone of Proximal Development (ZPD) describes the gap between what a child can do independently and what they can achieve with support. Assistive technology functions within this zone of proximal development by providing personalized support to bridge learning gaps. For example, Artificial Intelligence-driven early childhood science educational software dynamically adjusts science task difficulty based on the child's progress, ensuring that science learning remains challenging yet achievable (Goh et al., 2020). Executive Functions (EF), including working memory, cognitive flexibility and self-regulation, are essential for early childhood science learning (Miyake & Friedman, 2012). Assistive technological tools such as digital organizers and artificial intelligence assisted task planners support executive function by breaking tasks into manageable steps (Diamond & Ling, 2019).

Aim and Objectives of the Study

The study seeks to determine the relationship between digital technologies and blended learning process in early childhood education. Specifically, the objectives are:

i. To determine the relationship between assistive technology and cognitive development of children with special needs.
ii. To determine how assistive technology relates to science learning in early childhood education.
iii. To determine how assistive technology relates to cognitive development of children with special needs in terms of early childhood science learning.

Hypotheses

$H0_1$ – There is no significant relationship between assistive technology and cognitive development of children with special needs.

$H0_2$ – There is no significant relationship between assistive technology and special needs children's early childhood science learning.

$H0_3$ – There is no significant relationship between assistive technology and cognitive development of children with special needs in terms of early childhood science learning.

Methodology

The study employed correlational study and utilized purposive sampling technique. Population of the study comprised children with special needs in some privately owned early childhood/special education schools. These privately owned early childhood/special education schools cater to children with various impairments and provide education for them in their early years. The sample consists of 30 children with various impairments guided by caregivers who give report on them about the progression of assistive technology on their cognitive development and early childhood science learning engagement and performance, found in various privately owned early childhood/special education centres surveyed in Ikeja Local Government Area of Lagos State. Researcher developed questionnaire titled "Assistive Technology Special Needs Children Questionnaire" (ATSNCQ) was used for data collection. The questionnaire was designed with a four Likert scale of Strongly Agreed-4 (SA), Agreed-3 (A), Disagreed-2 (D) and Strongly Disagreed-1 (SD). The first part of the questionnaire comprised demographic information, while the second part consisted of fifteen (15) items, with five (5) items designated for each hypothesis. The researcher-developed questionnaire utilized in the study was validated by experts in the department of special needs education and early childhood/primary education. The instrument's reliability was assessed using the split-half method, in which the instrument was dispensed to a sample of 25 participants who were selected from locations outside Ikeja Local Government Area of the study and the data collected were separated into two halves based on item similarity and analysed employing the Cronbach's Alpha (α) method which yielded a correlation coefficient of 0.72 ($\alpha = 0.72$) indicating that the instrument is reliable for the study. Correlational statistical method was used to analyze the data collected and the results were presented as shown below.

Presentation of Results

Testing of Hypothesis one (1): Null Hypothesis

$H0_1$ – There is no significant relationship between assistive technology and cognitive development of children with special needs.

Alternative Hypothesis

H_1 – There is significant relationship between assistive technology and cognitive development of children with special needs.

Table 1: Assistive Technology and Cognitive Development of Children with Special Needs

Variables	Responses	Mean	SD	DF	Sig. lev	r- cal	r-tab	Remark Decision
Assistive Technology	26	1.125	0.342	24	0.05	0.721	0.558	r-cal > r-tab	Null Hypothesis Rejected
Cognitive Development	26	0.821	0.235					

Source: field survey, 2025

Table 1 shows greater standard deviation and mean value of 0.342 and 1.125 correspondingly for Assistive technology and smaller standard deviation and mean value of 0.235 and 0.821 correspondingly for Cognitive Development. Also r-cal value of 0.721 reveals the presence of greater relationship. Conversely, r-cal > r-tab which means the null hypothesis is rejected.

Testing of Hypothesis Two (2): Null Hypothesis

$H0_2$ – There is no significant relationship between assistive technology and special needs children's early childhood science learning.

Alternative Hypothesis

H_2 – There is significant relationship between assistive technology and special needs children's early childhood science learning.

Table 2: Assistive Technology and Special Needs Children's Early Childhood Science Learning

Variables	Responses	Mean	SD	DF	Sig. lev	r-cal	r-tab	Remark	Decision
Assistive Technology	26	1.821	0.872						
Early Childhood Science Learning	26	1.462	0.251	24	0.05	0.792	0.571	r-cal > r-tab	Null Hypothesis Rejected

Source: field survey, 2025

Table 2 shows that assistive technology have greater standard deviation and mean value of 0.872 and 1.821 correspondingly and early childhood science learning have smaller standard deviation and mean value of 0.251 and 1.462 correspondingly. Also r-cal value of 0.792 reveals the presence of greater relationship. Conversely, r-cal > r-tab which means the null hypothesis is rejected.

Testing of Hypothesis Three (3): Null Hypothesis

$H0_3$ – There is no significant relationship between assistive technology and cognitive development of children with special needs in terms of early childhood science learning.

Alternative hypothesis

H_3 – There is significant relationship between assistive technology and cognitive development of children with special needs in terms of early childhood science learning.

Table 3: Assistive technology and cognitive development of children with special needs in terms of early childhood science learning

Variables	Responses	Mean	SD	DF	Sig. lev	r-cal	r-tab	Remark	Decision
Assistive Technology	26	1.227	0.495	24	0.05	0.799	0.582	r-cal. > r-tab	Null Hypothesis Rejected
Cognitive development in terms of early childhood science learning.	26	0.859	0.212						

Source: field survey, 2025

Table 3 shows a greater standard deviation and mean value of 0.495 and 1.227 correspondingly for cognitive development and smaller standard deviation and mean value of 0.212 and 0.859 correspondingly. Also, r-cal. value 0,718 reveals the presence of greater relationship. Conversely, r-cal. > r-tab which means the null hypothesis is rejected.

Discussion of Findings

The result in table one (1) which is obtained from testing hypothesis one shows greater standard deviation and mean value of 0.342 and 1.125 correspondingly for Assistive technology and smaller standard deviation and mean value of 0.235 and 0.821 correspondingly for Cognitive Development. Also r-cal value of 0.721 reveals the presence of greater relationship. Conversely, r-cal > r-tab (0.721> 0.558) which necessitates the rejection of null hypothesis, shows that there is significant relationship between assistive technology and cognitive development of children with special needs. This aligns with Edyburn (2020) who stated that assistive technology helps bridge the gap for children with sensory, cognitive or learning disabilities, promoting inclusion and equal opportunities in the classroom.

The result in table two (2) which is obtained from testing hypothesis two shows that assistive technology have greater standard deviation and mean value of 0.872 and 1.821 correspondingly

and early childhood science learning have smaller standard deviation and mean value of 0.251 and 1.462 correspondingly. Also r-cal value of 0.792 reveals the presence of greater relationship. Conversely, r-cal > r-tab (0.792>0.571) which requires the rejection of null hypothesis, shows that there is significant relationship between assistive technology and special needs children's early childhood science learning. Scherer et al., (2019) who stated that research indicates that assistive technology significantly improves early childhood science learning outcomes for children with special needs, by providing structured, interactive and adaptive support (Scherer et al., 2019).

The result in table three (3) which is obtained from testing hypothesis three shows that assistive technology has greater standard deviation and mean value of 0.495 and 1.227 correspondingly and cognitive development in terms of early childhood science learning have smaller standard deviation and mean value of 0.859 and 0.212 correspondingly. Also r-cal value of 0.799 reveals the presence of greater relationship. Conversely, r-cal > r-tab (0.799>0.582) which requires the rejection of null hypothesis, shows that there is significant relationship between assistive technology and cognitive development in terms of early childhood science learning. This is consistent with Scherer et al., (2019) who stated that research indicates that assistive technology significantly improves early childhood science learning outcomes for children with special needs, by providing structured, interactive and adaptive support. It also aligns with Hersh, (2020) who affirms that cognitive aids assist individuals with memory retention, attention or learning difficulties and include Reminder Apps, applications like GoogleKeep and Microsoft To-Do, help users remember tasks. Voice Assistants, Artificial Intelligence-powered assistants, for instance, Siri, Alexa, help children with reminders and information retrieval.

Conclusion

The findings of this study have established that the effective use of assistive technology significantly enhances the cognitive development of children with special needs in early childhood science learning. Children exposed to assistive technological tools demonstrated improved attention, memory, problem-solving ability and conceptual understanding compared to their peers in non-assisted classrooms. These results confirm that assistive technologies, when appropriately selected and integrated, can bridge learning gaps, stimulate curiosity and promote meaningful engagement in scientific exploration among young learners with disabilities. However, the study

also revealed critical barriers, including inadequate teacher training, limited availability of assistive devices and insufficient institutional and policy support. These challenges hinder the optimal use of assistive technologies and restrict their potential benefits for inclusive science education. Therefore, improving caregivers' and special education teachers' capacity, ensuring adequate resource provision and establishing clear policy frameworks are essential steps toward sustainable inclusion and cognitive growth.

Recommendations

1. Ministries of Education and relevant educational agencies should develop and enforce policies that promote equitable access to assistive technologies in special needs preschools.

2. Regular monitoring and evaluation should be carried out to assess the impact on children's cognitive development in science learning.

3. Government agencies, school administrators and private stakeholders should invest in the procurement and maintenance of appropriate assistive technologies such as interactive digital boards, tactile materials, speech-to-text devices, and adapted science kits suited for diverse disabilities.

4. It is therefore recommended that assistive technology be embedded as a core component of the early childhood science curriculum to promote inclusive participation and cognitive skill development. To sustain progress, periodic research should be conducted to evaluate emerging assistive technologies and their impact on cognitive outcomes in science learning. This will ensure that early childhood education remains responsive to the diverse needs of children with disabilities.

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