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Determining Effective Technology-Enhanced Learning Resources for Inclusive Classroom Education of Vision-Impaired Students in Ghana

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Abstract
Analyses of Educational Technology Enhanced Learning (ETEL) resources required by students with vision impairment for advancing their learning as determinants of effective inclusive education, used mixed methods approach. 1532 students, including 60% fully sighted, 31.6% partially sighted, and 8.4% with no sight, responded to interviews on differential available, accessible and preferred ETEL resources relevant to their academic engagement and performance. Average rating for adequacy of available learning resources 3.10, std 1.140, indicates moderately adequate. Accessible resources rated 3.11, std 1.098 implies moderately accessible. ETEL resources improve speed, accuracy, scalability, and flexibility towards consistency at Kendall Coefficient of concordance (W), 0.434 Sig. (2-tailed) 95% CI. Effective ETEL resources include Available High-Speed Internet, Accessible e-textbooks, Regular software updates, Interactive Multimedia Content & Dedicated Technical Supports, and Cloud-based storage. T-statistic of 0.47 and p-value, 0.64 suggests no statistically significant difference in perceptions on ETEL resource adequacy between fully sighted and vision impaired students, meaning students share similar perspectives regarding adequacy of classroom resources for effective technology use.

Keywords: Inclusive Classroom Education, Vision Impairment Problems, Students, Technology Enhancement Resources

1. Introduction

Background of the Study

Barriers to participation in inclusive education cannot be removed without paying adequate attention to vision impairment problems. By disregarding vision statuses of diverse categories of students involved in inclusive classroom education, the traditional pedagogical approaches often present significant barriers, hindering full participation and academic achievement of students with vision impairments in scientific disciplines. This research evaluates the transformative role of Educational Technology-Enhanced Learning (ETEL) resources in advancing science education for students with vision impairment. It focuses on identifying and examining the specific resources that can facilitate accurate, scalable, and accessible learning experiences to support consistency and reliability in science education outcomes, thereby promoting equitable, inclusive, and effective science education for vision-impaired students. The study analyses Educational Technology Enhancement Learning resources that sustain the performance of required TEL tools for inclusive education of vision impaired students.

Statement of the Problem

The integration of Educational Technology-Enhanced Learning (ETEL) has transformed educational landscapes globally, offering immense potential to enhance inclusivity and accessibility for students with vision impairment. Technologies such as screen readers, tactile learning systems, and interactive tools are known to significantly improve science learning outcomes for these students [1]. However, the implementation of TEL remains inconsistent and underdeveloped in many TEL resource-limited settings, such as Ghana. This is because, historically, educational systems have prioritized general learning enhancements without focusing on accessibility for students with disabilities [2], [3]. In science education, where visualization and interaction are critical, students with vision impairment face significant disadvantages due to limited access to tailored tools that need specific resources. For instance, [4] highlight the absence of inclusive design approaches in TEL environments, which prevents students with vision impairment from fully engaging with digital learning platforms, but in this context focusing on engagement in the inclusive classroom. The current state of TEL in Ghana reveals infrastructural gaps, inadequate teacher training, and limited resource allocation for inclusive education [5], [6]. These challenges perpetuate inequities in learning outcomes and hinder students with vision impairment from pursuing science-related disciplines, thereby restricting their participation in science and technology-driven industries. The real-world implications of this problem are significant when diverse students with different categories of vision impairment statuses [7] are excluded from science education due to technological barriers or carelessly bulked together for inclusive classroom education. [7] classify vision problems of students in inclusive classrooms to show that, seemingly sighted and fully non-sight students share similar vision problems because all students sought various vision assistances to overcome classroom participation barriers. This suggests that, carelessly bulking together students for inclusive classroom education without paying attention to their vision problems perpetuates systemic inequalities and limits the contributions of students with vision impairment to socio-economic development. Addressing this issue is crucial to fostering inclusivity and ensuring that students with vision impairment can access opportunities to thrive in academic and professional spheres [8], [9]. This study determines effective TEL resources that sustain the performance of required TEL tools for inclusive education of vision impaired students.

Relevant Literature on the Subject

The need for technology-enhanced resources to support vision-impaired students has gained considerable attention in the field of inclusive education. This empirical review critically examines contributions from prior research to identify essential resources, evaluate their effectiveness, and highlight gaps using evaluative expressions. In analysis of Sensor-Based Assistive Devices, [10] provide a comprehensive review of sensor-based assistive devices for vision-impaired individuals, emphasizing their potential to enhance accessibility and independence. Their research is commendable for its rigorous categorization of sensor technologies such as ultrasonic, GPS-based, and camera-integrated devices. However, the study lacks detailed exploration of the cost-effectiveness of these technologies, which is a critical factor for their adoption in resource-constrained educational settings. Moreover, the authors neglect to address the cultural and contextual suitability of these devices, which limits the practical applicability of their findings to diverse educational environments. Looking at Auditory Description and Interactive Displays, [11] explore auditory description systems for interactive displays, presenting a storytelling-to-sensemaking framework. Their study is notable for its systematic methodology in designing auditory systems tailored to vision-impaired users. Nevertheless, the study by [11] overlook the integration of this technology with existing learning management systems, an essential consideration for seamless inclusion in digital classrooms. Furthermore, while the findings of [11] highlight the importance of clear and engaging auditory content, the study did not adequately consider the diversity of user preferences and learning styles, potentially limiting its applicability across varied learner demographics. In following Digital Technologies in Education, [12] review the role of digital technologies in education, providing valuable insights into the transformative potential of these tools. The research by [12] is laudable for its broad scope, which includes technologies such as Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI). However, [12] fails to focus on the specific needs of vision-impaired students, treating this group as a peripheral audience rather than a central focus. Additionally, the review by [12] does not adequately address barriers to technology adoption, such as lack of infrastructure and digital literacy among educators, which are critical in ensuring equitable access to these resources. Taking a look at Digital Literacy Strategies, [13] examines digital literacy strategies for students with special educational needs, offering actionable recommendations for educators. The study by [13] is exceptionally relevant for identifying frameworks that could be adapted for vision-impaired students. However, [13] underestimated the role of assistive technology in bridging the digital literacy gap among students with vision impairment, focusing more on generalized strategies rather than tailored interventions. Moreover, while [13] emphasizes the importance of teacher training, [13] does not explore how these resources can be integrated with assistive technologies to create a holistic learning experience. Discussing Computer-Generated Descriptions for Blind Users, [14] investigate computer-generated image descriptions for blind users in social network contexts, demonstrating the potential of automatic alt-text systems. The study by [14] is innovative in applying machine learning algorithms to generate descriptive content, which can be adapted for educational purposes. However, [14] did not sufficiently consider the limitations of these technological resources in conveying complex visual information, which is crucial for STEM education. Additionally, [14] fails to evaluate the accessibility of these systems in low-resource settings, a key barrier to their adoption in inclusive classrooms. In conclusion, while the reviewed literature highlights significant advancements in technology-enhanced learning resources for vision-impaired students, it also reveals critical gaps that must be addressed to ensure effective and equitable deployment of those. Hence this study addresses accessibility and effectiveness of those technology-enhanced learning resources required in the learning environment of students with vision impairment. The reason is, accessibility and effectiveness of technological resources play a crucial role in enhancing learning experiences and outcomes, particularly in inclusive educational settings. Understanding how the diverse Educational Technology-Enhanced Learning (ETEL) resources support diverse categories of students with vision impairments, is essential for promoting equitable education. This review further analyses existing studies to evaluate availability, usability, and impact of technology resources on learning environments. For instance, studies on Teacher Competence and Inclusive Learning Design by [15] investigate the role of teacher competencies in designing inclusive learning experiences, emphasized importance of training educators to use technology effectively. The study by [15] is commendable for recognizing the critical role of teacher preparedness in fostering inclusive education. However, the research neglects to address how digital competencies of teachers influence accessibility of technology for students, particularly in under-resourced schools. Further, the findings by [15 are limited by a narrow focus on theoretical frameworks, with insufficient empirical evidence to demonstrate effectiveness of proposed interventions. Additional studies on Digital Technologies in Education by [12] provide a broad review of digital technologies in education, highlighting tools like artificial intelligence, virtual reality, and e-learning platforms. While the study by [12] is laudable for its comprehensive coverage of emerging technologies, it overlooks the unique challenges faced by vision-impaired students in accessing these resources. Additionally, [12] fails to explore how digital tools can be adapted to meet the needs of diverse vision-impaired students in inclusive classrooms, which limits its practical application in real-world contexts. [12] underestimate infrastructural barriers and digital divides prevalent in rural and low-income regions, where access to these technologies remains a significant issue. Looking at Evidence-Based Strategies in Inclusive Education, [16] explore evidence-based strategies for special and inclusive education, offering practical teaching methods to support diverse learners. The work by [16] is highly relevant for highlighting strategies that enhance learning outcomes in inclusive settings. However, the study by [16] does not adequately examine the role of assistive technologies in enabling accessibility, focusing more on general pedagogical approaches. Moreover, [16] neglect to consider the scalability of these strategies in resource-constrained environments, an essential factor for widespread implementation. Focusing on Pedagogical Approaches to Inclusive Education, [17] provides detailed analysis of pedagogical approaches that promote inclusivity, emphasizing student-cantered practices. The study by [17] is exceptional in its exploration of theoretical frameworks for inclusive pedagogy, but it lacks sufficient empirical evidence to validate effectiveness of these approaches when paired with technology-enhanced resources. Additionally, [17] overlooks cultural and contextual factors that affect implementation of inclusive pedagogies in diverse educational environments, a significant gap in its applicability. Examining Challenges in Rural Online Learning, [18] examines rural online learning during the COVID-19 pandemic in South Africa, highlighting the role of technology in supporting inclusive education. The study by [18] is notable for addressing challenges of accessibility in rural contexts, particularly during periods of crisis. However, the research by [18] fails to investigate how these challenges intersect with specific disabilities, such as vision impairments, thereby limiting its focus on inclusivity. Moreover, while [18] provides valuable insights into infrastructural barriers, [18] does not offer actionable solutions to enhance accessibility of online learning platforms as required educational technology resource. Studies by [19] on Learning Management Systems and Accessibility analyses the use of Learning Management Systems (LMS) in online instruction, emphasizing their potential to improve accessibility and engagement. The study by [19] is commendable for its focus on the practical application of LMS in education, but [19] underestimates technical challenges that vision-impaired students face when navigating these systems. Furthermore, [19] lacks critical evaluation of user interface designs of LMS platforms, which is essential for ensuring accessibility for all students. Concluding, the reviewed literature underscores the potential of technology-enhanced resources to improve accessibility and learning outcomes in inclusive classrooms. However, addressing theoretical, empirical, practical, and contextual gaps is essential to fully realize this potential. Future research should focus on integrating pedagogical theories with technology design, validating interventions through robust empirical studies, and ensuring affordability and scalability to promote equity in education. Further, analysis of the specific technology-enhanced learning resources that address unique needs of students with vision impairment in science education focused on student learning needs that necessitate tailored technology-enhanced resources to ensure accessibility and engagement. Hence, specific resources designed to address these needs and their effectiveness are discussed [20]. [20] explores the role of assistive technology in inclusive education, emphasizing its ability to accommodate diverse learning needs. The study by [20] is noteworthy for providing a comprehensive overview of assistive tools, including tactile graphics and screen readers, which are particularly relevant for science education. However, [20] fails to focus on the integration of these tools within the specific context of science curricula, limiting its applicability to STEM subjects. Additionally, the findings by [20] are primarily descriptive, with little empirical evidence to support the effectiveness of the proposed solutions in practice. Digital Technologies for Vision-Impaired Students in Higher Education were studied by [21]. The study by [21] is commendable for addressing the transition from traditional assistive devices to digital tools, such as mobile applications and e-learning platforms, which hold significant potential for science education. However, [21] neglects the unique demands of scientific content, such as the visualization of complex data and laboratory experiments, which limits its relevance to this specific field. Furthermore, [21] does not adequately address challenges faced by educators in adapting these technologies for classroom use, a critical oversight in ensuring successful implementation. Further, the work by [21] is highly relevant for identifying innovative solutions that could enhance the accessibility of science education for students with vision impairment. However, the research by [21] lacks specificity in addressing unique needs of vision-impaired students, focusing instead on general educational innovations. Additionally, the study overlooks the practical challenges of integrating these technologies into existing curricula, particularly in resource-constrained settings. Analysing New Tools for Teaching and Learning, [22] discuss the potential of emerging technologies to transform teaching and learning, focusing on tools such as virtual simulations and interactive platforms. A review of Assistive Technologies for Special Educational Needs by [23] highlights tools such as Braille displays, screen magnifiers, and auditory learning aids. The study by [23] is valuable for its focus on accessibility features tailored to students with vision impairments, offering actionable insights into technology design. However, [23] fails to provide a detailed evaluation of how these tools perform in hands-on science activities, such as experiments and data analysis. Moreover, [23] does not sufficiently consider cultural and contextual factors that influence adoption of assistive technologies in diverse educational environments. [24] investigate the potential of mobile learning as an alternative to traditional assistive technology devices for students with special needs. The study by [24] is notable for exploring the flexibility and affordability of mobile solutions, which can be particularly beneficial in science education. However, [24] does not adequately address limitations of mobile learning for students with vision impairment, such as screen size and compatibility with tactile learning needs. Additionally, the findings by [24] are limited by lack of empirical data, relying heavily on theoretical discussions rather than practical evaluations. In sum, the reviewed literature highlights the potential of assistive and digital technologies to support students with vision impairment in science education. However, significant gaps remain, particularly in addressing the unique requirements of STEM learning, integrating pedagogical theories, and providing empirical evaluations of proposed solutions. Future research should prioritize development and testing of tailored resources that are adaptable, context-sensitive, and empirically validated to ensure their effectiveness and accessibility in diverse educational environments.

The Proposed Approach or Solution

The study brings attention to the significant barriers vision-impaired students in inclusive classrooms encounter, including insufficient resources and inadequate support systems within the educational environment. These challenges are further compounded in resource-limited settings where infrastructure, policy implementation, and teacher training remain insufficient to meet the unique needs of diverse students with different categories of vision impairment. By identifying these challenges and reviewing existing research, this study establishes a strong foundation for addressing the gaps in technology integration for science learning. While technology has shown promising potential to bridge learning disparities, there remains a need for practical, evidence-based solutions tailored to the diversity of students with vision impairment in inclusive classrooms. This research, therefore, informs educators, policymakers, and stakeholders on how technology can be effectively leveraged to create an inclusive, equitable, and empowering learning environment. In doing so, this study aspires to not only improve science education for students with vision impairment but also to open pathways for their active participation in scientific and technological fields, fostering greater inclusion and opportunities for all.

The New Value of Research which is Innovation

Existing studies by [25] and [4] focus on conceptual frameworks but lack empirically validated theoretical models to explain influence of TEL on science education for students with vision impairment. The lack of theoretical models explaining interaction between TEL tools and resources and learning outcomes for students with vision impairment, especially in science education presents theoretical research gap. Employing robust mixed-method and longitudinal approaches is critical to evaluate the long-term impact of TEL tools and associated required resources. These approaches are needed to provide comprehensive insights into effectiveness of TEL, sustainability, and challenges over time, addressing the gaps in short-term studies and ensuring lasting solutions for students with vision impairment. Also, limited resources for effective implementation of TEL tools, including teacher training, resource allocation, and infrastructure improvements present practical research gaps. [3] and [6] emphasize implementation barriers without offering practical, scalable solutions for resource-limited settings. Insufficient research efforts on TEL for students with vision impairment in developing contexts like Ghana, particularly in science education by [5] and [26] pose contextual research gap. There is also insufficient empirical evidence on effectiveness of TEL resources for sustaining TEL tools in enhancing science education outcomes for students with vision impairment. Studies by [2] and [8] provide valuable insights but lack empirical investigations specific to science education. Further, there is limited objective data to assess challenges and benefits of TEL, with reliance on qualitative or self-reported information. [27] and [28] rely heavily on qualitative approaches, which may lack measurable, generalizable findings, resenting an empirical research gap. There is lack of interdisciplinary frameworks that combine educational theories with assistive technologies to address unique challenges faced by students with vision impairment. Studies such as [8] and [9] emphasize tools but overlook the integration of educational pedagogy with technological resources that advance science education for students with vision impairment which require interdisciplinary research. There is need to avert methodological research gap of lack of robust mixed-method approaches to evaluate the long-term impact of TEL on students with vision impairment in resource-constrained environments. For instance, while studies like [5] and [29] adopt mixed-methods, they fail to incorporate longitudinal evaluations that assess sustained TEL outcomes. For Context-Specific Solutions for TEL in Ghana, exploring TEL within the context of Ghana's educational systems will address the unique challenges faced by students with vision impairment in resource-constrained settings. Developing context-specific solutions ensures that TEL resources are scalable, inclusive, and adaptable to the needs of students in both formal and non-formal educational environments. Addressing these identified research gaps is critical for advancing knowledge, practice and policy in TEL for students with vision impairment, particularly in science education. Each justification highlights the significance of addressing these gaps and underscores the potential benefits for students, educators, and policymakers. Therefore, to bridge Educational and Technological disciplines, there is need to integrate educational theories with technological advancements to create innovative and holistic TEL frameworks. Addressing this gap enables the development of interdisciplinary solutions that combine pedagogical best practices with assistive technologies, ensuring science learning is accessible and engaging for students with vision impairment. Evaluation of risks and barriers to TEL adoption is also crucial. Assessing the risks and barriers associated with TEL adoption, such as infrastructure deficits, digital literacy challenges, and accessibility issues is vital for designing inclusive and sustainable learning environments for vision impaired students. Hence, this research provides insights into mitigating these challenges, enabling ETEL to effectively meet the technological resource needs of students with vision impairment and thereby close existing educational gaps. In sum, filling these research gaps contribute to advancing ETEL for students with vision impairment, particularly in science education. Through addressing theoretical, empirical, methodological, practical, contextual, interdisciplinary, and critical gaps, this study provides evidence-based solutions, enhance inclusive learning, and inform policy frameworks to create equitable educational opportunities for all students. In sum, a multi-faceted approach focusing on resources required for accessibility, usability, affordability, educational relevance, fostering independence, equity, teacher training, sustainability, and cultural adaptability is required for selecting effective technology enhancement tools for students with vision impairment. While existing research provides valuable insights, significant gaps remain in addressing challenges to fulfil and integrate innovative solutions. Future studies should prioritize interdisciplinary collaborations and policy-driven approaches to develop sustainable and inclusive educational technologies.

THEORETICAL BASIS

The central concept of this theoretical framework is Technology Enhancement for Vision-impaired students, which serves as the foundation for exploring how specific technological resources can sustain specified TEL tools to improve educational outcomes. This concept is examined through the lens of four key theories: Constructivist Learning Theory, Connectivism, Cognitive Theory of Multimedia Learning, and Dual Coding Theory. Each theory highlights unique aspects of how technology supports the learning process for students with vision impairment and connects directly to specific learning outcomes. Constructivist Learning Theory emphasizes that knowledge is actively constructed by learners through their interactions with the environment and their engagement in meaningful experiences. This theory represents a paradigm shift from traditional, teacher-centered approaches to learning, which often rely on passive transmission of information. Instead, constructivism underscores the centrality of the learner in creating understanding, asserting that knowledge construction is an individualized and context-dependent process influenced by prior knowledge, experiences, and the immediate learning environment [30], [31]. Constructivist Learning Theory, rooted in the works of Jean Piaget and Lev Vygotsky, places learners at the center of the educational process, emphasizing active engagement in constructing knowledge through real-world interactions, exploration, and collaboration. Vygotsky's Zone of Proximal Development (ZPD) highlights the significance of guidance from peers or mentors, suggesting that learners can achieve advanced comprehension levels through supported learning [31]. This theory fundamentally aligns with the nature of technology enhanced education, where digital platforms offer supported learning through TEL resources in the forms of discussion boards, virtual simulations, and peer collaborations to foster knowledge construction. In technology enhanced environments, constructivist approaches, such as gamification, project-based learning, and scenario-based tasks, have been demonstrated to significantly enhance cognitive engagement, critical thinking, and academic performance [32], [33]. These methods promote self-directed learning and creativity by enabling students to interact actively with content, refine their understanding through feedback, and collaborate with peers across different contexts. The Constructivist Learning Theory is particularly relevant as it mirrors the requirements of inclusive classroom education, which demands hands-on and interactive learning. Educational technology enhanced resources employed on platforms tailored to this theory can integrate simulations of real-world scientific problems, collaborative design projects, and interactive tutorials, thus bridging the gap between theoretical knowledge and practical application. For example, vision impaired students could engage in virtual labs or participate in collaborative group assignments. Further, the study can leverage this theory to analyze how technology enhanced resources advances student engagement and achievement by creating environments that reflect active, social, and experiential learning. This aligns with the broader objectives in equipping students with employable skills, ensuring that digital platforms foster learning experiences that are both practical and impactful. Thus, Constructivist Learning Theory not only provides a foundational lens for this study but also guides the design of required technology enhanced resources interventions that are directly applicable to unique demands of education of students with vision impairment. In the context of vision-impaired students, constructivist principles are particularly salient. These students often face unique challenges in accessing information, and adaptive learning environments are essential to ensure equitable engagement. Constructivist learning environments utilize tools such as tactile models, audio descriptions, and interactive platforms to create opportunities for active participation. For example, tactile graphics can help vision-impaired students explore geometric concepts through touch, while auditory explanations supplement understanding by providing verbal context. This integration of require relevant and sustained adaptive resources which can foster meaningful engagement and reinforce the constructivist emphasis on experiential learning [34]. Social interaction plays a pivotal role in constructivist learning, aligning with Vygotsky's assertion that knowledge is co-constructed through collaborative activities. Vision-impaired students benefit significantly from peer collaboration and guided exploration, as these interactions help bridge gaps in understanding and create shared experiences that deepen comprehension. For instance, collaborative problem-solving activities in science education enable students to experiment with tactile materials while exchanging insights and ideas, thereby constructing knowledge in a supportive social context [35]. Constructivist Learning Theory also advocates for inquiry-based learning, critical thinking, and problem-solving, placing students at the center of the educational process. These principles are particularly applicable in science education for students with vision impairment. Inquiry-based approaches present TEL resources that encourage students to actively explore scientific concepts through hands-on activities and auditory feedback, promoting deeper understanding and retention. For example, using adaptive technologies like auditory simulation software, students can investigate complex phenomena that might otherwise be inaccessible due to visual limitations. These strategies not only align with constructivist principles but also reflect inclusive teaching practices that recognize and value diversity in learning needs and styles [36]. One major strength of Constructivist Learning Theory is its adaptability to diverse educational contexts. By focusing on the active role of learners and the importance of tailoring learning experiences to individual TEL resource needs, constructivism provides a robust framework for designing inclusive education for students with vision impairment. Additionally, the theory's emphasis on collaboration and interaction aligns well with modern pedagogical approaches that prioritize student-centered learning. However, constructivism is not without its limitations. Critics argue that the theory's emphasis on individualized learning can create challenges in structured settings, where standardized curricula and assessments often dominate. Furthermore, constructivist approaches may demand significant TEL resources, including specialized training for teachers and the development of adaptive TEL materials, which can be difficult to implement in resource-constrained environments [34]. Finally, without careful scaffolding, some students, particularly those with limited prior knowledge, may struggle to construct meaningful understanding independently. In conclusion, Constructivist Learning Theory offers a powerful framework for enhancing the educational experiences of vision-impaired students. By emphasizing active engagement, social collaboration, and individualized learning, the theory supports the creation of adaptive environments that empower students to construct their own knowledge. While its implementation requires careful planning and resources, constructivism remains a cornerstone of inclusive education, particularly in fostering equity and accessibility for diverse learners.

Connectivism, introduced by [37], is a contemporary learning theory emphasizing the interconnectedness of knowledge through networks, technology, and collaborative interactions. The theory argues that, learning extends beyond individual cognition and thrives in the integration of diverse digital platforms, communities, and real-time data. This approach aligns with realities of the digital age, where access to global resources and collaboration shapes learning experiences. Effectiveness of Connectivism has been validated by [38] and [39] who highlighted its potential to enhance engagement and critical thinking by leveraging interactive tools, such as discussion forums, virtual labs, and collaborative project platforms. These tools allow learners to connect with peers and experts globally, creating a networked environment conducive to deeper learning. For technology enhanced education, Connectivism is transformative as it aligns with the inherently collaborative and practical nature that require students to develop both individual competencies and team-based problem-solving skills. Through digital platforms, students can simulate real-world challenges, access diverse expert opinions, and engage in peer-to-peer learning, bridging gaps in traditional methodologies. Adopting Connectivism can redefine how students interact with content and their peers. By integrating platforms that foster connectivity such as virtual reality tools for practical simulations, digital communities for peer engagement, and resources linked to industry practices, students can cultivate skills essential for a technologically advanced workforce. This approach ensures that they are not only equipped for local industry demands but also prepared to thrive in globally connected economy, fulfilling the dual objectives of quality education and employability. Further, Cognitive

the Cognitive Theory of Multimedia Learning, developed by Richard Mayer, provides a framework for understanding how individuals process and retain information presented through multimedia formats. The theory is built on three foundational assumptions. First is the dual-channel assumption, which posits that information is processed through two primary channels, visual and auditory. For vision-impaired students, these channels extend to auditory and tactile modalities, adapting the principles of the theory to suit their specific needs. Second is the limited capacity assumption, which emphasizes that each channel has a finite capacity for processing information. This underscores the importance of designing learning materials that avoid cognitive overload. Finally, the active processing assumption highlights that meaningful learning occurs when learners actively engage with the material, organizing and integrating it into their existing knowledge structures [40]. For vision-impaired students, the principles of the Cognitive Theory of Multimedia Learning are particularly relevant in guiding the creation of adaptive educational resources. The dual-channel assumption highlights the importance of integrating audio descriptions with tactile graphics to provide complementary inputs that reinforce comprehension. For instance, tactile maps paired with auditory descriptions allow students to build a mental model of spatial relationships, facilitating deeper understanding. These materials leverage the complementary strengths of auditory and tactile modalities, creating richer and more accessible learning experiences [41]. Relative to technology enhanced resources, a key principle of this theory is the reduction of extraneous cognitive load, which refers to the unnecessary mental effort required to process, support and sustain poorly designed materials. For vision - impaired students, this means that multimedia content should be clear, concise, coherent and well sustained through required TEL resources. For example, an auditory narrative explaining a tactile diagram should avoid redundant or overly complex descriptions, allowing the student to focus on the essential information. Well-designed materials minimize distractions and maximize the cognitive resources available for active learning, ensuring that students can engage meaningfully with the content [42] steadily. The Cognitive Theory of Multimedia Learning also emphasizes the importance of segmentation and signaling in instructional design. Segmentation involves breaking down content into manageable chunks that learners can process sequentially. For example, a tactile representation of a complex scientific concept can be divided into smaller, interconnected components, with each section accompanied by an auditory explanation. Signaling, on the other hand, involves highlighting key elements to direct attention of the students. In the case of vision-impaired students, this might include using auditory cues or tactile markers to emphasize critical features of a diagram or model. These techniques help learners focus on essential elements, reducing cognitive load and promoting deeper comprehension [36]. The strengths of the Cognitive Theory of Multimedia Learning lie in its adaptability and its focus on optimizing the cognitive processes involved in learning. By emphasizing the integration of multiple modalities, the theory provides a robust framework for designing accessible educational materials that cater to diverse learning needs. Additionally, its principles of reducing extraneous cognitive load, segmentation, and signaling offer practical guidelines for creating effective instructional resources that sustain and enhance engagement with tools and retention. However, the theory has some limitations. Its reliance on the dual-channel assumption may oversimplify the complex ways in which vision -impaired students interact with multimodal content. Furthermore, while the theory provides clear design principles, it does not address the specific challenges associated with implementing these principles in resource-constrained settings. The development of high-quality tactile materials and synchronized auditory descriptions, for instance, can be time-intensive and costly, posing challenges for educators and institutions with limited resources [43]. In conclusion, the Cognitive Theory of Multimedia Learning offers valuable insights into the design of educational materials that are both accessible and effective for vision-impaired students. By adapting its principles to include tactile modalities and focusing on reducing cognitive load, segmentation, and signaling, educators can dwell on resources that sustain and foster active engagement and meaningful learning. While the theory's practical implementation may require careful planning and investment, its potential to improve educational outcomes, makes it a vital framework for inclusive education. Additionally, Dual Coding Theory, introduced by Allan Paivio, provides a cognitive framework for understanding how verbal and non-verbal information is processed through distinct but interconnected systems. This theory underscores the complementary nature of linguistic or verbal and imagistic or non-verbal representations in enhancing learning and memory. By creating multiple pathways for encoding and retrieving information, Dual Coding Theory facilitates deeper comprehension and more robust recall [41]. For vision-impaired students, Dual Coding Theory holds significant implications for the design of educational materials. The theory supports the integration of auditory and tactile modalities to provide accessible and effective learning experiences. For instance, pairing tactile maps with audio descriptions allows students to process spatial information through touch while simultaneously reinforcing it with verbal explanations. This dual-modal approach leverages the strengths of each system, creating multiple retrieval pathways that enhance understanding and retention [36]. A critical aspect of Dual Coding Theory is the alignment of verbal and non-verbal content. Educational materials designed for vision-impaired students must ensure that tactile and auditory inputs are congruent and mutually reinforcing to avoid cognitive dissonance. For example, when teaching the structure of a cell, an educator might use a tactile model to represent components of the cell while providing an auditory narrative that describes their functions. Misalignment between the verbal and tactile information could lead to confusion, reducing effectiveness of the instructional material. Ensuring coherence between these modalities enhances ability of the student to integrate and retain information effectively [42]. The principles of Dual Coding Theory also emphasize importance of tailoring educational resources to the needs of the student and the context. For students with vision impairment, this might involve simplifying tactile representations to reduce complexity while aligning them with clear, concise auditory explanations. Thus, resources should be designed to support the tools to minimize extraneous cognitive load, allowing students to focus on the essential elements of the material. For example, a tactile map might include raised lines and braille labels, complemented by a step-by-step auditory guide that describes the features of the map, enabling students to process the information systematically [43]. Dual Coding Theory has several strengths that make it valuable framework for inclusive education. It provides clear guidelines for creating multimodal instructional materials that enhance engagement and comprehension. By emphasizing the integration of verbal and non-verbal systems, the theory encourages the development of resources that cater to sustaining diverse learning needs, particularly for students with vision impairment. Thus, its focus on multiple retrieval pathways aligns with evidence-based practices in cognitive science, supporting long-term memory retention [41]. However, Dual Coding Theory also has limitations. One challenge lies in the practical implementation of its principles, particularly in resource-constrained settings. Developing high-quality tactile materials and synchronized auditory content can be time-consuming and expensive, posing barriers for educators and institutions with limited resources. Furthermore, while the theory provides a robust conceptual framework, it does not offer specific methodologies for evaluating the effectiveness of multimodal materials in diverse learning contexts [36]. In conclusion, Dual Coding Theory offers valuable insights into the design of educational resources for vision-impaired students. By integrating auditory and tactile modalities, educators can create materials that enhance engagement, comprehension, and retention. While its implementation requires careful planning and investment, principles of the theory provide a strong foundation for advancing inclusive education. By addressing its practical limitations, educators and policymakers can maximize its potential to transform learning experiences for students with vision impairment. In sum, the theoretical framework positions Technology Enhancement for Vision -impaired Learners at its core, connecting it to four foundational theories to illuminate distinct aspects of the learning process. Constructivist Learning Theory explains how technology facilitates active knowledge construction and improved learning outcomes. Connectivism theory emphasizes the interconnectedness of knowledge through networks, technology, and collaborative interactions and argues for learning that extends beyond individual cognition and thrives in integration of diverse digital platforms, communities, and real-time data. This approach aligns with realities of the digital age, where access to global resources and collaboration shapes learning experiences. Cognitive Theory of Multimedia Learning demonstrates how multimodal tools optimize information processing and retention. Dual Coding Theory highlights the role of dual-modality inputs in strengthening comprehension and recall. Together, these theories provide a comprehensive basis for understanding how technology can transform the educational experiences of vision -impaired learners, ultimately advancing equitable and inclusive education.

METHOD

The relative contexts as well as characteristics of vision-impaired students were obtained from desk study, documents and reports. Theoretical reviews of relevant theories supported desk studies towards preparations for fieldwork. Research instruments were constructed to guide the fieldwork involving collection of Primary data. Experiences of vision impaired students with TEL resources in inclusive classrooms were captured from interviews and questionnaires with checklists, focus groups discussions during practical classroom education setups.

A population of 13,950 students from 32 educational institutions were involved in inclusive classroom education in 3 regions, Eastern, Greater Accra, and Central regions of Ghana. Using multi-stage sampling technique, together with stratified sampling of only students undergoing education in purposively selected inclusive classrooms totaling 1532 persons, capable to voluntarily answer the questionnaire in person or online was done to obtain representativeness of subjects for the study. The purposive sampling approach is consistent with the concept of open sampling, and helped in selecting specific interviewees and observational sites within vision-impaired student groups in indiscriminate ways. Hence, all purposively selected groups of vision-impaired student category were justified as statistically representative cluster exposed to current educational practices and processes. The [44] procedure for selecting samples were used to verify sample size whereby, given the population of participants for the different subjects, appropriate sample sizes were obtained from established Tables. The sampling design is consistent with open sampling. Open sampling is non-probability sampling that allows open coding where indices for the study were represented by any defined variable to obtain cultural data [45]. Open sampling selects culturally specific interviewees or observational sites within a target group in indiscriminate ways to allow the collection of as much data as possible in order to obtain the desired outcome of in-depth descriptions. Within vision-impaired student groups the approach gave the desired outcome of in-depth descriptions in addition to surveys. To be able to collect data from a large, geographically spread of groups of students, for representativeness, the stratified random sampling technique was used to ensure representation across all the 32 schools selected across the 3 regions. This approach divided the population into strata, and then purposefully selected participants from each school. This method helped to capture diversity of perspectives. Focusing on students provided insight into their constraints [46] ensuring findings are relevant to addressing both immediate and systemic challenges. The large population facilitated collection of robust data, enhancing generalizability of the results. Quantitative methods employed interview guides with questionnaires and checklists. Qualitative methods employed observation checklists, focus groups discussions guide questions, application of theoretical and conceptual frameworks to obtain data on contextual experiences of vision-impaired students. Descriptive Statistics of One-Sample Statistics were employed. The target population for this study comprised students with vision impairment alongside other students in inclusive classrooms within science educational institutions implementing Technology-Enhanced Learning (TEL). This population was chosen to provide a comprehensive understanding of how TEL resource interventions impact the diverse learners, particularly those with vision-impairments. The institutions included in the study were specifically identified for their active adoption of TEL interventions, which are designed to foster inclusivity, enhance accessibility, and improve academic outcomes for students with varying levels of visual ability. By focusing on this population, the study captured the experiences, challenges, and benefits associated with TEL resources in learning environments that prioritize equity and inclusivity in education. The diverse composition of the population ensures a holistic representation of students' perspectives across different levels of vision and educational settings. The sample unit for this study comprised individual students within inclusive classrooms that actively employed Technology-Enhanced Learning (TEL) tools and strategies. These students included those who appeared fully sighted, partially sighted, and blind, ensuring a diverse and comprehensive representation of vision statuses within the sample. By focusing on this broad range of vision abilities, the study captured the nuanced experiences and perspectives of all students engaging with TEL resource interventions. This approach not only highlights the inclusivity of the research design but also provides valuable insights into how TEL resources affect students with varying levels of vision impairment. The inclusion of students across this spectrum ensures that the findings reflect the diverse realities of educational settings employing TEL resources, emphasizing the importance of equitable access and tailored support in inclusive classrooms. The sampling frame for this study encompassed inclusive classrooms within various educational institutions equipped with Technology-Enhanced Learning (TEL) resource infrastructure. This frame was systematically developed by utilizing institutional records and databases, which provided detailed lists of classrooms actively supporting vision-impaired students through TEL resources. By focusing on classrooms with established TEL resource interventions, the sampling frame ensured that the study targeted settings where the integration of technological resources into learning environments was already in practice. This approach facilitated identification of suitable classrooms that could offer rich insights into effectiveness and challenges of TEL resources in inclusive educational settings. A total of 1,532 students were surveyed as sample size. This substantial sample size was selected to ensure the collection of a comprehensive and diverse dataset, capturing a wide range of student demographics, vision statuses of fully sighted, partially sighted, and blind, and varying levels of technological resource access. Such diversity enhances the study's representativeness and allows for robust statistical analyses. The sample size also ensures sufficient statistical power to identify meaningful patterns and relationships within the data, thereby reinforcing the study's reliability and validity. Stratified Random Sampling method was utilized to guarantee equitable representation across various vision statuses of fully sighted, partially sighted, and blind and educational levels such as first-year, second-year, and third-year students. Stratification ensures that each subgroup is proportionately included in the sample, capturing a diverse range of experiences with TEL resources. This approach enables the study to comprehensively analyze the differential impacts of TEL resources on academic engagement, accessibility, and performance, thereby enhancing the depth and generalizability of the findings. To examine the essential technology enhancement resources needed to support students with vision impairment, ANOVA was adopted method of analysis since it is appropriate for outlining the availability and adequacy of resources as reported by respondents. Correlation Analysis was used to analyze how accessible and effective resources are in the learning environment because it is suitable for exploring relationships between resource accessibility and perceived effectiveness. The specific resources that address the unique needs of students with vision impairment in science education was analyzed with ANOVA, being effective method for comparing resource usefulness across different groups of students with vision impairment.

RESULTS AND DISCUSSION

Demographic Characteristics of Student Research Participants Demographic Characteristics of Research Participants are provided in Table 1. Table 1 shows that; research participants were students who appeared in three major categories of mainly Seemingly Full Sight (SFS) (60%) Partial Sight (PS) (31.6%) or Non-Sight (8.4%). This shows that, majority of students in the inclusive classrooms appeared sighted (91.6%). Vision-impairment problems of students who participated in the study were classified in terms of vision statuses in inclusive classrooms in the Education System of Ghana, as 60 % seemingly full sight students and 40% partial or full non-sight students. t-statistic of 0.47 and p-value of 0.64 showed no significant difference, indicating that students faced vision problems. This result suggests that student faced vision problems irrespective of age and sex.

Table 1 Demographic Characteristics of Student Research Participants

Variables	**Description**	**Frequency**	**Percent (%)**
Sex	Male	754	49.2
	Female	778	50.8
Age	Under 15years old	148	9.7
	15–18 years	449	29.3
	Above 18 years	935	61.0
Year of study	One	441	28.8
	Two	638	41.6
	Three	453	29.6
Vision status	Seemingly Full sight	919	60.0
	Partial sight	484	31.6
	Non-sight	129	8.4

Source: Survey Data 2023 (Annoh & Kumi 2025)

Analysis of Resources Supporting Technology-Enhanced Learning

To examine the technology enhancement resources required by students with vision impairment for advancing learning, First, Table 2 summarizes results on the resources available to support Technology-Enhanced Learning (TEL) in inclusive classrooms, providing insight into their adequacy, accessibility, and the frequency of resource-related challenges. The average rating for the adequacy of available classroom resources is 3.10, with a standard deviation of 1.140. This indicates that respondents generally perceive these resources as moderately adequate. However, the standard deviation reveals notable variability in responses, suggesting that while some students benefit from well-equipped classrooms, others may struggle with limited or insufficient resources. This disparity likely reflects differences in funding, policy implementation, or prioritization of inclusive education across schools. The frequency of experiencing issues with accessing resources is rated at an average of 3.11, with a standard deviation of 1.139. This score suggests that, students encounter such challenges moderately often. The variation in responses points to uneven experiences among classrooms, where some provide seamless access to TEL resources while others present significant obstacles. Factors such as inconsistent teacher training, infrastructure gaps, or lack of maintenance could contribute to these disparities.

Second, the accessibility of resources in inclusive classrooms is also rated at an average of 3.11, with a standard deviation of 1.098. This result implies that students find resources to be moderately accessible on average. However, the range of responses reflects differing levels of accessibility, likely influenced by infrastructural differences, resource distribution, or the availability of assistive technologies tailored to students' needs.

Overall, the results reveal moderate adequacy and accessibility of TEL resources, coupled with noticeable variability across classrooms. These results highlight the importance of addressing systemic barriers, such as unequal resource allocation and infrastructure challenges, to ensure equitable access to TEL tools for all students in inclusive classrooms. The skewness and kurtosis values for all variables fall within acceptable ranges for large samples (skewness ±1 and kurtosis ±2), indicating that the data is approximately normal and suitable for inferential analysis. Statistical methods such as correlation and regression can be employed to identify significant predictors and areas for intervention.

Table 2. Descriptive Statistics on technology enhancement resources required by students with vision impairment for advancing learning

Item	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Are classrooms equipped with the resources you need to use technology effectively	1532	3.10	1.140	-.200	.063	-.759	.125
How often do you experience issues with accessing these resources in class	1532	3.11	1.139	-.209	.063	-.757	.125
How accessible are the resources	1532	3.11	1.098	-.207	.063	-.671	.125
Valid N (listwise)	1532						

Source: Survey Data, 2024

Analysis of Relationship between Resource Accessibility and two key Variables: Frequency of Tool Usage and Perceptions on Tool Effectiveness

A correlation analysis was conducted to examine the relationship between resource accessibility and two key variables: frequency of tool usage and perceptions of tool effectiveness. The analysis in Table 3 aimed to explore whether the availability of resources significantly influences how often tools are used and how effective they are perceived in supporting learning. In Table 3, the correlation coefficient between resource accessibility and tool usage frequency is 0.02, indicating a very weak positive relationship. This near-zero correlation suggests that resource accessibility has minimal, if any, influence on how frequently students utilize technology in the classroom. Despite the expectation that better accessibility would lead to increased usage, this result implies that other factors, such as user familiarity, teacher encouragement, or the nature of classroom activities, may play a more significant role.

Similarly, Table 3 shows that, the correlation coefficient between resource accessibility and perceptions of tool effectiveness is -0.01, reflecting a very weak negative relationship. This finding suggests that resource accessibility does not significantly affect how students perceive its effectiveness. While accessibility is an important factor, this result highlights that perceptions of effectiveness may be shaped more by the quality, usability, and relevance rather than availability.

Both correlation coefficients are close to zero, indicating no meaningful relationship between resource accessibility and either tool usage frequency or perceived effectiveness. These findings suggest that while accessibility is a foundational component of TEL, it may not directly drive how often resources support tools used or how effective they are perceived to be. Other variables, such as training, individual preferences, or the integration of specific resources to support tools into pedagogical practices, likely have a more substantial impact and warrant further exploration.

Table 3. Correlations on Resource Accessibility and Frequency of Tool Usage and Perceptions on Tool Effectiveness

Metric	Correlation Coefficient
Correlation (Resource Accessibility vs. Tool Usage Frequency)	0.02
Correlation (Resource Accessibility vs. Tool Effectiveness)	-0.01

Source: Survey Data, 2024

Table 4, provides a t-test conducted to compare the perceptions of resource adequacy between fully sighted and students with vision impairment. The analysis aimed to determine whether these groups perceive the adequacy of classroom resources to support the use of technology differently. Table 4 shows that, the analysis produced a t-statistic of 0.47 and a p-value of 0.64. Since the p-value exceeds the standard significance threshold ($\alpha = 0.05$), the null hypothesis (H_0) cannot be rejected. This indicates that there is no statistically significant difference in perceptions of resource adequacy between the two groups of fully sighted and students with vision impairment. This suggests that both fully sighted and students with vision impairment share similar perspectives regarding the adequacy of classroom resources for technology use. This result is encouraging, as it indicates that efforts to provide equitable resources in inclusive classrooms may be effective to some extent. However, it is important to note that this shared perception may also reflect broader systemic challenges, such as outdated technology or insufficient resource availability, which affect all students regardless of their vision status. The absence of a significant difference in perceptions highlights a degree of equity in the provision of classroom resources. However, this result also underscores the importance of further exploration into the quality, functionality, and accessibility of resources to ensure that technology-enhanced learning resources meet the diverse needs of all categories of students. Addressing these factors can help bridge any subtle gaps in resource effectiveness and ensure that inclusive education practices continue to evolve toward greater equity and inclusivity.

Table 4. t-Test Comparing Perceptions of Resource Adequacy between Fully Sighted and Students with Vision Impairment

Metric	Statistic	p-Value
t-Test (Resource Adequacy: Fully Sighted vs. Vision-Impaired)	0.47	0.64

Source: Survey Data, 2025

Analysis of Essential Technology Enhanced Learning Resources Needed to Support Students with Vision-Impairment

Analysis of Essential Technology Enhanced Learning Resources Needed to Support Students with Vision-Impairment showed that, ETE learning resources improve speed, accuracy, scalability, and flexibility towards consistency at Coefficient of concordance (W) of Kendall, 0.434 Sig. (2-tailed) 95% CI., indicating specific effective ETE learning resources such as available high-speed internet, Accessible e-textbooks, Regular software updates, interactive multimedia content and dedicated technical supports, Cloud-based storage, Compatible screen readers, Mobile device accessibility, synchronized learning platforms and User-friendly interfaces. This result is line with notes from Sen & Leong (2020) which indicate that, use of enhancements improves parts of learning as practices or processes through facilitating fundamental learning activities which employ technology in various forms. Further, a t-statistic of 0.47 and a p-value of 0.64, and the p-value exceeding the standard significance threshold ($\alpha = 0.05$), the null hypothesis (H_0) cannot be rejected. This indicates that there is no statistically significant difference in perceptions of resource adequacy between the two groups of fully sighted and students with vision impairment. This suggests that both fully sighted and students with vision impairment share similar perspectives regarding the adequacy of classroom resources for technology use. A t-statistic of 0.47 and a p-value of 0.64 indicates no statistically significant difference in perceptions of resource adequacy between the two groups of fully sighted and students with vision impairment. In Table 5 for example, the effect of ETE learning resources on inclusive classroom education for vision impaired students shows that, Educational technology enhanced learning resources positively improve speed towards consistency. Kendall's Coefficient of concordance (W) is 0.434 Sig. (2-tailed) 95% CI. Some Educational technology enhanced learning resources that offer speed include Available of high-speed internet, Accessible e-textbooks, Regular software updates, interactive multimedia content and dedicated technical supports, Cloud-based storage, Compatible screen readers, Mobile device accessibility maintains learning resource consistency, Synchronized learning platforms and User-friendly interfaces. Responses on the stated objective were analyzed using descriptive statistics. The mean of 2.013, with a standard deviation of 0.726, suggests that the availability of high-speed internet plays a moderate role in ensuring education consistency. While not the highest mean, the relatively low standard deviation indicates that there is a degree of consensus regarding the importance of high-speed internet. Consistent access to online resources is integral to maintaining a seamless education experience. However, potential irregularities could arise due to variations in internet infrastructure and accessibility across regions, impacting the consistency of education. With a mean of 1.926 and a standard deviation of 0.736, accessible e-textbooks are perceived as an important resource for maintaining education consistency. The lower mean score suggests strong agreement regarding the significance of this resource. E-textbooks offer students the ability to access and review materials consistently. However, challenges in ensuring universally accessible formats might hinder the attainment of complete consistency. Regular software updates, with a mean of 4.006 and a standard deviation of 0.884, are regarded crucial for enhancing education resource consistency. The relatively high mean score suggests that stakeholders emphasize the importance of updated software. These updates likely improve accessibility features and address bugs, contributing to a consistent education experience. Nonetheless, exceptions could occur if updates inadvertently introduce compatibility issues or changes that disrupt established routines. The mean of 3.803, with a standard deviation of 0.868, indicates that interactive multimedia content and dedicated technical support are both significant contributors to maintaining consistent education experiences. While not the highest mean, the relatively low standard deviation implies consensus. Interactive content engages students and fosters understanding, enhancing consistency. Technical support ensures that students can navigate resources without disruptions. However, irregularities could arise if technical support is not promptly available or if multimedia content lacks accessibility features. Cloud-based storage, with a mean of 3.886 and a standard deviation of 0.967, is recognized as a resource facilitating access to consistent education materials. The mean score suggests a moderate level of importance. Cloud storage enables students to access materials from multiple devices, supporting a consistent education environment. Irregularities might emerge if cloud services experience downtime or if educations encounter difficulties in navigating cloud interfaces. Compatibility with screen readers, as reflected by a mean of 3.716 and a standard deviation of 0.951, is seen as contributing to resource consistency. The relatively moderate mean score highlights the consensus on its importance. Screen reader compatibility ensures that students with vision impairment can access materials effectively. Irregularities could arise if compatibility is not consistently maintained across various platforms and tools. Mobile device accessibility, with a mean of 3.436 and a standard deviation of 1.112, is acknowledged as playing a role in maintaining resource consistency. The lower mean suggests that opinions vary. Mobile accessibility allows education on-the-go, but challenges such as diverse mobile operating systems and accessibility features might impact the consistency of this experience. Irregularities might also arise from differences in device capabilities and user preferences. Synchronized education platforms, with a mean of 4.000 and a standard deviation of 0.918, are recognized as instrumental in supporting consistent education experiences across devices. The mean score indicates the significance of this resource. Synchronization ensures that progress, materials, and interactions are seamless across various devices. However, irregularities might occur if synchronization processes are not optimized or if technical glitches disrupt synchronization. User-friendly interfaces, with a mean of 4.170 and a standard deviation of 0.866, are viewed as significant contributors to resource availability and consistency. The high mean score indicates the consensus on the importance of intuitive interfaces. User-friendly designs enhance accessibility and usability, promoting a consistent education experience. Irregularities could arise if interfaces are not universally user-friendly or if design changes create usability challenges. Interestingly, statement 10 shares the same content as statement 1, but with a higher mean of 3.946 and a standard deviation of 0.867. This discrepancy in mean scores suggests that there might be variations in respondents' perceptions regarding the impact of high-speed internet on education consistency. This inconsistency highlights potential disparities in the importance placed on this resource across different contexts or perspectives. This perspective explains the assertion by [36] who claimed that technology does not meet the required potential for using the technology in the field.

The data presented in Table 5 demonstrates a range of educational technology enhanced learning resources that contribute to speeding up Vision-Impaired education towards consistency. While some trends are evident, such as the emphasis on user-friendly interfaces and synchronized platforms, there are irregularities related to the perceived importance of certain resources. Similar such inconsistencies were raised by [47, [36], and [48] who noted that various new technologies that are introduced in education to facilitate learning fail to meet the high expectations of users [47], [36], [48]. Additionally, there are global assumptions on use of technologies for addressing educational equity and social exclusion in learning [48]. Therefore, the implications of these findings underscore the need for a comprehensive and inclusive approach to educational technology development. Ensuring universal accessibility, addressing technical challenges, and accommodating diverse preferences will be critical in harnessing the full potential of these resources to promote consistent and effective education experiences for students with vision impairment.

In sum, Educational technology enhanced learning resources improve speed, accuracy, scalability, and flexibility towards consistency. Following the Coefficient of concordance (W) of Kendall, 0.434 Sig. (2-tailed) 95% CI. Educational Technology Enhanced (ETE) learning resources that offer speed include available high-speed internet, Accessible e-textbooks, Regular software updates, interactive multimedia content and dedicated technical supports, Cloud-based storage, Compatible screen readers, Mobile device accessibility maintains learning resource consistency, synchronized learning platforms, User-friendly interfaces. Further, ETE resources that offer accuracy include available high-speed internet, Accessible e-textbooks, Regular software updates, interactive multimedia content and dedicated technical supports, Cloud-based storage, Compatible screen readers, Mobile device accessibility maintains learning resource consistency, synchronized learning platforms, User-friendly interfaces. Also, ETE learning resources that offer scalability are available high-speed internet, Accessible e-textbooks, Regular software updates, interactive multimedia content and dedicated technical supports, Cloud-based storage, Compatible screen readers, Mobile device accessibility maintains learning resource consistency, synchronized learning platforms, User-friendly interfaces. ETE resources that offer flexibility are available high-speed internet, Accessible e-textbooks, Regular software updates, interactive multimedia content and dedicated technical supports, Cloud-based storage, Compatible screen readers, Mobile device accessibility maintains learning resource consistency, synchronized learning platforms, User-friendly interfaces. Mobile device accessibility maintains learning resource consistency, synchronized learning platforms, User-friendly interfaces at Sig. (2-tailed) 95% CI.

Table 5. Technological Resources preferred by Vision-Impaired Students in Inclusive Classrooms for Technology Enhanced Education

Statements on Preferred Resources	Mean	Std. Dev	N
Available high-speed internet	2.013	.726	1532
Accessible e-textbooks	1.926	.736	1532
Regular software updates	4.006	.884	1532
Interactive multimedia content and dedicated technical supports	3.803	.868	1532
Cloud-based storage	3.886	.967	1532
Compatibility with screen readers	3.716	.951	1532
Mobile device accessibility maintains learning resource consistency	3.436	1.112	1532
Synchronized learning platforms	4.000	.918	1532
User-friendly interfaces	4.170	.866	1532

Source: Survey Data, 2024

CONCLUSION

Educational technology enhancement resources offer significant speed, accuracy, towards consistency in scalability and flexibility in the education of vision-impaired students in inclusive classrooms. There is no statistically significant difference in perceptions of resource adequacy between groups of fully sighted and non-sight or students with vision impairment suggesting that students share similar perspectives regarding adequacy of classroom resources for technology use, reflecting equity and inclusivity in inclusive classrooms.

Appendix

1. **Questionnaire on Preferred Educational Technology Resources required to advance inclusive classroom education of vision-impaired students in Ghana.**

Introduction

Dear Participant,

You are invited to join a study called "Using Technology to Help Students with Vision Impairment Learn Science". The study focuses on discovering the role played by technology resources among students with vision impairment, specifically related to science education. We want your real opinions and experiences about how accessible, effective, difficult, and beneficial technology-enhanced learning (TEL) Resources are, for you in your education. We will use your answers to discover important approaches and obstacles for young people with vision problems that are learning science. It can contribute to the creation of stronger standards and practices in supporting students with different needs. There are five sections in the questionnaire and respondents use the Likert scale (from 1 to 5) to rate each answer. Every answer is acceptable as long as it comes from your viewpoint. All information collected will be private and only be used within the study. It is your decision whether to continue and you are allowed to withdraw whenever you wish.

Section A: Demographic Information (For Control Variables)

- Age: ____
- Gender: [ ] Male [ ] Female [ ] Other Vision impairment status [ ] Partial [ ] Severe [ ] Total
- Educational level: [ ] JHS [ ] SHS [ ] Tertiary
- Location: ______________________

Section B: Technological Resources for Science Learning by Vision-Impaired Students

1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Construct	Item No.	Question Item	1	2	3	4	5
Availability and Use of TE Resources	1	I have access to specialized technological resources designed to sustain science education.					
	2	The technological Resources support my vision impairment needs in science learning.					
	3	These resources support me to understand complex science topics more easily.					
Contribution to Learning	4	Technological resources have sustained my ability to conduct science experiments.					

	5	I can now engage more effectively in science learning through the use of assistive technological resources.					
	6	I feel more confident participating in science classes due to support from these resources.					
Selection Criteria	7	The resources I use were chosen based on my specific vision needs.					
	8	Functionality, consistency and ease of use are key reasons I prefer certain science resources					
	9	I believe schools use clear criteria to choose the best technological resources for vision-impaired students.					
	10	I feel part of the class with the use of specific technological resources					
	11	I am aware of the resources I do not like					
	12	I feel frustrated without the right technological resources					
	13	I feel neglected without technological resources					
	14	I enjoy the class without technological resources					

Section C. Technology Enhancement Resources and Student Engagement

Kindly respond to the statements below on a scale of **Strongly Disagree (1)** to **Strongly Agree (5)**.

Statement	**1**	**2**	**3**	**4**	**5**
1. TE resources make science lessons more engaging.					
2. I regularly use TE resources for group discussions.					
3. Virtual simulations make learning science easier.					
4. Online discussions help clarify difficult topics.					
5. I enjoy the flexibility TE resources offer.					
6. Online collaboration resources make group projects more efficient.					

7. Online interactive activities keep me engaged					
8. Using TE resources increase my enthusiasm for learning science subjects.					

Section D: Challenges and Solutions in Implementing TE-Learning Resources

Kindly respond to the statements below on a scale of **Strongly Disagree (1)** to **Strongly Agree (5)**.

Statement	**1**	**2**	**3**	**4**	**5**
1. Limited internet connectivity is a major challenge for my learning & participation.					
2. Lack of access to devices affects my learning & participation.					
3. Teachers need more training on TEL resources.					
4. The cost of internet data limits TE learning adoption.					
5. Technical issues frequently disrupt online sessions.					
6. TE-learning resources are not customized for my education.					
7. Students face challenges balancing TE-learning resources with other commitments.					
8. Limited availability of practical resources on TE-learning is a drawback.					
9. Students lack motivation to engage with e-learning.					
10. Parental support for TE-learning resources is inadequate.					
11. Providing free e-learning resources can improve adoption rates.					

Section E: List Technological Learning Resources Currently Applied for TEE in Inclusive Classrooms

Technological Resources currently applied for TEE	Enhancement Characteristic
●	
●	
●	
Technological Resources required for Consistency	
●	
●	
●	
Technological Resources required for Speed	
●	
●	
Technological Resources required for Accuracy	
●	
●	

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