The Role of Technology-Enhanced-Learning Strategies in Advancing Science Education of Vision-Impaired Students in Ghana

Rachel Annoh[1], Mary Adu Kumi[2], Ernest Gyan[3]

[1]PhD Candidate, Centre for Graduate Studies, Open University Malaysia / Accra Institute of Technology, Accra Ghana

[2]Senior Lecturer, Faculty of Development Studies, Department of Environmental & Natural Resources Management, Presbyterian University Ghana

[3]Lecturer, Centre for Graduate Studies, Open University Malaysia / Accra Institute of Technology, Accra Ghana

Abstract

Educational Technology-Enhanced Learning (ETEL) strategies that advance science education of students with vision impairment was evaluated, focusing on student preferences and benefits of integrating TEL strategies in inclusive classroom education. Using mixed methods approach, 1532 students, including fully sighted, partially sighted, and students with no sight, responded to interviews on differential available, accessible and preferred ETEL strategies relevant to their academic engagement and performance. The average rating for strategies used by teachers 2.20, standard deviation 0.973, indicates that, students perceive the strategies as underutilized overall. Engagement level of strategies score 3.07, standard deviation 1.133, suggests moderate engagement. F-statistic 0.46 and p-value 0.63 indicates no statistically significant differences in perceptions of strategy engagement among the three vision status groups. Effectiveness of strategies in supporting student understanding of complex science subjects, rated 3.08, standard deviation, 1.142, reflects generally helpful strategies. Frequency of student participation in lessons where ETEL strategies are used rated, 3.10, standard deviation 1.137, indicating moderate participation levels. preferred ETEL strategy is Hands-on activities with assistive tools, employed by 31.4%.

Keywords: Inclusive Classroom Education, Vision-Impaired Students, Educational Technology-Enhanced-Learning Strategies

Introduction

Background of the Study

This study evaluates the integration of Technology-Enhanced Learning (TEL) strategies in inclusive classrooms towards advancing science education of students with vision impairment. The study focuses on the student preferences and benefits of integrating TEL strategies in inclusive classroom education to explain which specific technological strategies best support the unique learning requirements of vision-impaired students and how these can be sustainably integrated in inclusive education. Consequently, this research investigates the requisite technology-enhanced strategies essential for supporting consistency and reliability in achieving positive science education outcomes within vision-impaired learning contexts. These include, but are not limited to, crucial aspects of engagement, the development of adequate digital literacy skills among students, and the pervasive constraints posed by existing strategies used in various settings. Hence, the study analyses the effectiveness of technology enhancement strategies applied by vision-impaired students for advancing learning. Analysis of effective strategies for implementing technology enhancement to improve learning outcomes for students with vision impairment suggest that, implementing effective strategies for technology enhancement is critical to improving learning outcomes for students with vision impairment. This is because, strategies must address the unique challenges faced by vision-impaired students, such as accessing complex content, engaging with interactive materials, and participating in collaborative activities.

Statement of the Problem

Educational Technology-Enhanced Learning (ETEL) offers transformative long-term opportunities for vision-impaired students in science education, fostering accessibility, engagement, and lifelong learning skills. However, in science education, where visualization and interaction are critical, students with vision impairment face significant disadvantages due to limited access to tailored strategies that require specific tools or resources. For instance, [1] highlight the absence of inclusive design approaches in ETEL environments, which prevents students with vision impairment from fully engaging with digital learning platforms, focusing on student engagement in the inclusive classroom. This is crucial for the Educational System in Ghana (ESG) which have embraced the global initiative on inclusive education as basis for enrolment of students towards perpetual systemic inequalities and limited the socio-economic development life of the vision-impaired student. In upholding this initiative, the ESG carelessly bulk together students for inclusive classroom education without paying attention to their vision problems [2]. The real-world problems surface when vision impaired students are required to be taught together with seemingly sighted students in one classroom for inclusive classroom education. Addressing this issue is crucial to fostering inclusivity and ensuring that vision-impaired students can access opportunities to thrive in academic and professional spheres to avert perpetuating systemic inequalities and limitations of students with vision impairment to active learning and future socio-economic development. This study determines effective ETEL strategies that support the performance of required ETEL tools and resources for inclusive education of vision impaired students. The reason is, current state of ETEL in Ghana reveals lack of tailored tools and resources or infrastructure, inadequately trained teachers towards inclusive classroom teaching, and limited resource allocation for inclusive education [3], [4]. These challenges present inequities in learning outcomes and limits opportunities for students with vision impairment from pursuing science-related disciplines, thereby preventing their participation in science and technology-driven industries. Practical implications of this problem become relevant when diverse students with different categories of vision impairment statuses [2] cannot pursue science education due to technological barriers. 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 [5] [6]. This study determines effective ETEL strategies that support inclusive education of vision impaired students. The reason is there is need for systematic review on Inclusive Education that focuses specifically on strategies to enhance science education, and explaining how ETEL can address subject-specific challenges, such as complex visual representations and laboratory experiments, is crucial for highlighting the potential of ETEL strategies to support individualized and accessible learning experiences, thereby demonstrating how ETEL strategies foster autonomy and lifelong learning skills, which are critical for long-term educational success. There is also the need for understanding Schooling Experiences of Vision-impaired students to illustrate how ETEL strategies provide equitable access to educational content or enable vision-impaired students to participate in science education alongside their sighted peers. In doing those, the long-term effects of ETEL strategies are examined to address the unique needs of vision-impaired students. Therefore, this study examines the enduring benefits of ETEL strategies, addressing its role in shaping inclusive and equitable educational experiences, and identifying theoretical, methodological, practical, and contextual gaps.

Relevant Literature on the Subject

This review examines the most effective strategies identified in existing research, focusing on their applicability, strengths, and limitations in supporting education of students with vision impairment. [7] studied Assistive Technology for Diverse Learning Needs by exploring the integration of assistive technologies in inclusive education, emphasizing their role in addressing diverse learning needs. The study by [7] is noteworthy for its focus on aligning assistive technology with inclusive education principles, offering strategies like tactile aids and screen readers. However, the research by [7] fails to provide detailed guidance on how these technologies can be tailored to specific subjects like science or mathematics, limiting its relevance for STEM disciplines. Additionally, the study by [7] is predominantly theoretical, with insufficient empirical validation of the proposed strategies in real-world classrooms. In their study of 3D Printed Interactive Models, [8] investigate the use of 3D-printed interactive models for map learning, demonstrating improvements in spatial and textual memory for students with vision impairment. The study by [8] is innovative in showcasing the potential of hands-on learning tools to enhance engagement and retention. However, the study by [8] lacks a broader discussion on scalability and the integration of such tools into mainstream curricula, which is crucial for wider adoption. Furthermore, the authors overlook the challenges of accessibility and affordability, which are significant barriers for many educational institutions. [9] examines strategies to enhance teaching effectiveness and improve student learning outcomes, focusing on interactive and student-centred approaches. The study by [9] is commendable for emphasizing the importance of personalized instruction and active engagement, strategies that are particularly relevant for vision -impaired learners. However, the study by [9] does not adequately explore how technology can be systematically integrated into these approaches, leaving a methodological gap in bridging technology with pedagogy. Moreover, the findings by [9] are generalized, with limited applicability to the unique needs of students with vision impairment. [10] highlight the Universal Design for Learning (UDL) framework as an effective strategy for improving STEM outcomes for students with disabilities. The research by [10] is exceptional in addressing the importance of accessible content design, flexibility, and engagement strategies, making it directly relevant to vision -impaired learners. However, the study by [10] does not sufficiently explore how UDL principles can be operationalized through specific technologies, such as auditory or tactile aids. Additionally, the research by [10] is limited in its discussion of cultural and contextual factors, which are critical for the adoption of UDL in diverse educational settings. [11] provides a comprehensive overview of Augmented Reality (AR) in education, highlighting its potential to create immersive learning experiences. The study by [11] is pioneering in its exploration of AR as a tool for enhancing engagement and interactivity, particularly in STEM education. However, [11] fails to address how AR can be adapted to accommodate vision-impaired learners, focusing instead on sighted students. Moreover, [11] overlooks the infrastructural challenges and digital divides that may hinder the implementation of AR technologies, limiting its practical applicability. [12] review the role of digital technologies in education, emphasizing their transformative potential. The study by [12] is laudable for its broad scope, including AI, virtual simulations, and online platforms. However, [12] do not specifically address the unique challenges faced by students with vision impairment, particularly in relation to navigation and accessibility. Furthermore, [12] neglect the pedagogical implications of integrating these technologies, leaving a theoretical gap in understanding their impact on learning outcomes. In conclusion, the reviewed studies provide valuable insights into the potential of technology-enhanced strategies for improving learning outcomes among students with vision impairment. However, addressing the identified gaps, particularly in operationalizing theoretical frameworks, conducting empirical validations, and ensuring accessibility remains essential for the effective implementation of these strategies. Future research should prioritize context-sensitive, evidence-based approaches that are adaptable to the unique needs of vision-impaired students.

Second, analysis of influence of TEL strategies on engagement, comprehension, and retention in science education for vision-impaired students suggest that the integration of Technology-Enhanced Learning (TEL) strategies in science education for vision-impaired students has significant implications for engagement, comprehension, and retention. The reason is, TEL strategies aim to bridge accessibility gaps while fostering inclusive and effective learning environment. Hence, this part of the review examines existing research to evaluate how TEL strategies influence these key learning outcomes, focusing on identifying strengths, limitations, and gaps. The critique employs evaluative expressions to address theoretical, methodological, practical, and contextual dimensions. [13] reflects on teaching science and mathematics to students with vision impairment, emphasizing the importance of tactile and auditory tools. The study by [13] is insightful in highlighting the lived experiences of a vision -impaired educator, offering practical perspectives on effective teaching strategies. However, [13] overlooks the role of digital tools in modern science education, focusing predominantly on traditional approaches. Additionally, the research by [13] is limited by its anecdotal nature, lacking empirical evidence to generalize its findings to broader contexts. [14] provide an extensive review of evidence-based strategies in inclusive education, including those tailored for vision-impaired learners. The study by [14] is commendable for offering well-validated teaching strategies, such as differentiated instruction and scaffolded learning, which enhance engagement and comprehension. However, [14] do not adequately address the unique challenges of teaching science-specific content to students with vision impairment, such as visualizing complex phenomena. Furthermore, the analysis by [14] is narrowly focused on general inclusive practices, with limited exploration of technology-driven approaches. [15] investigate the transition to digital technologies for students with vision impairment in higher education. The study by [15] is noteworthy for examining the use of TEL platforms in fostering engagement and self-reliance among students, particularly in STEM fields. However, [15] fail to consider the diversity of learning preferences and the adaptability of TEL tools for interactive science education, such as experiments or simulations. Additionally, the findings by [15] are largely confined to higher education, limiting their applicability to primary or secondary science education contexts. [16] explore the co-design of Voice User Interfaces (VUIs) to promote inclusion among vision - impaired and sighted students. The study by [16] is innovative in demonstrating how VUIs can enhance engagement and comprehension through interactive, voice-based learning experiences. However, [16] do not adequately evaluate the long-term impact of these tools on retention, particularly in mastering science concepts. Furthermore, the study by [16 is limited in its scope, as it primarily focuses on interface design without addressing the integration of these tools into broader TEL ecosystems. [17] investigates science self-efficacy in the classroom among primary students, identifying factors that influence engagement and comprehension. The study by [17] is valuable for emphasizing the psychological dimensions of learning, such as motivation and confidence, which are crucial for students with vision impairment in science education. However, [17] neglects to explore how TEL strategies can enhance these dimensions, leaving a methodological gap in linking technology with self-efficacy outcomes. Additionally, the study by [17] is constrained by its focus on sighted students, which limits its relevance to non-sight students. In conclusion, the reviewed literature underscores the potential of TEL strategies to enhance engagement, comprehension, and retention for vision-impaired learners in science education. However, significant gaps remain, particularly in operationalizing theoretical frameworks, conducting longitudinal studies, and addressing the specific needs of science education. Future research should focus on context-sensitive, technology-driven solutions that are empirically validated and adaptable to diverse learning environments. Third, analysis of factors that contribute to the success or failure of TEL strategies in vision-impaired learning environments suggests that, the success or failure of Technology-Enhanced Learning (TEL) strategies in vision-impaired learning environments depend on variety of factors, including accessibility, training, infrastructure, and the integration of inclusive practices. This aspect of the review further examines existing research to explore these factors, employing evaluative expressions to highlight theoretical, methodological, practical, and contextual gaps in the literature. [18] examined the development of inclusive learning environments for students with vision impairment in higher education, emphasizing the concept of progressive mutual accommodation. [18] highlights the importance of adapting both institutional practices and learner strategies to foster inclusion. However, [18] neglect to consider the role of technology-specific training for educators and learners, a critical factor for the effective implementation of TEL strategies. Furthermore, [18] focused on higher education, limiting applicability to primary and secondary educational settings where different challenges may arise. [19] conducts a systematic review of inclusive education for students with vision impairment, identifying key barriers and enablers. In a related study, [19] provides a broad understanding of challenges in vision-impaired learning environments. However, [19] fails to delve deeper into the specific factors influencing the adoption and efficacy of TEL strategies, leaving a methodological gap in understanding the interplay between technology and pedagogical practices. Additionally, the review by [19] is limited in scope, as it does not address the contextual challenges unique to low-resource environments. [20] examine awareness and barriers to adopting assistive technologies among vision -impaired individuals. The study by [20] is commendable for addressing infrastructural and cultural barriers that hinder the success of TEL strategies, particularly in resource-constrained settings. However, [20] do not sufficiently explore how to overcome these barriers through targeted interventions, such as policy reforms or training programs. Moreover, [20] focus primarily on assistive technologies, without considering broader TEL ecosystems that integrate TEL resources for these tools with mainstream educational practices.

[21] review the accessibility of Open Educational Resources (OER) for disabled learners, including those with visual impairments. The review by [21] is insightful in emphasizing the potential of OER to democratize access to education, particularly using adaptive technologies. However, [21] overlook the challenges of ensuring accessibility within STEM disciplines, where the reliance on visual content creates significant barriers. Additionally, the review by [21] is limited by its lack of empirical evidence, relying heavily on theoretical discussions rather than real-world evaluations. To augment this, an examination of Training Blind Students in Biological Sciences by [22] explores insights gained from training a blind student in biological sciences, highlighting practical strategies for overcoming graphical and tactile

challenges. The study by [22] is innovative in addressing the unique needs of students with vision impairment in science education, particularly through hands-on adaptations. However, [22] do not provide a scalable framework for implementing these strategies in broader contexts, limiting its practical applicability. Furthermore, [22] focused on individual cases, which may not be representative of the wider vision-impaired population. [23] examine the graphical challenges faced by students with vision impairment in Australian Universities. The analysis by [23] is valuable for its focus on a critical barrier to success in TEL strategies, particularly in STEM disciplines. However, [23] fail to explore innovative technological solutions, such as interactive tactile graphics or auditory feedback systems, to address these challenges. Additionally, the research by [23] is geographically limited, which may reduce its relevance to other educational contexts with differing infrastructural capacities. Further look at Challenges in Tertiary Education by [24] examines the challenges faced by students with vision impairment in tertiary institutions in Nigeria, focusing on quality assurance. The study by [24] is insightful in identifying systemic issues, such as inadequate funding and poor infrastructure, which undermine the success of using TEL strategies. However, [24] neglects to explore how these challenges could be mitigated through technology-driven interventions, leaving a practical gap in addressing these systemic barriers. In conclusion, this part of the reviewed literature highlights critical factors influencing the success or failure of TEL strategies in vision-impaired learning environments, such as accessibility, training, and infrastructural support. However, significant gaps remain, particularly in operationalizing theoretical frameworks, conducting empirical validations, and addressing contextual barriers.

The Proposed Approach or Solution

Educational Technology-Enhanced Learning (ETEL) holds significant potential to improve learning outcomes by fostering engagement, enhancing accessibility, and boosting academic performance. This review critically examines existing studies to explore how TEL strategies impact these outcomes, highlighting key findings and identifying theoretical, methodological, practical, and contextual gaps. For example, Engagement and Performance in ETEL were studied by [25] on the relationship between student engagement, disengagement, and performance in ETEL environments in upper secondary schools. [25] demonstrate how ETEL can increase student engagement by providing interactive and personalized learning experiences, which can positively affect academic performance. However, [25] fail to address how these tools are supported with adequate and relevant TEL strategies and how the findings apply to students with vision impairment, a demographic that often requires additional accessibility measures. Additionally, [25] focused on general student populations, limiting its relevance to diverse learning needs. Further, [25] explore the role of digital skills in fostering engagement in TEL. [25] identify digital literacy as a critical factor for improving learning outcomes in TEL environments, emphasizing the importance of equipping students with the necessary skills. However, [25] neglect the accessibility challenges faced by students with vision impairment, such as navigating complex interfaces or using assistive technologies. Furthermore, the study by [25] is limited by its lack of specific recommendations of strategies for integrating digital literacy into ETEL for learners with disabilities. How online course design features influence student performance, examined by [26] identify elements such as interactive content and clear navigation as key contributors to success. [26] emphasize the importance of intuitive design in improving academic outcomes, which is particularly relevant for vision-impaired learners. However, [26] do not explicitly address accessibility considerations as crucial ETEL strategies, leaving a gap in understanding how these design features can be adapted for students with vision impairments. Additionally, the findings by [26] focused on higher education, limiting their applicability to other educational contexts. Virtual Learning and Learning Loss, studied by [27] looked at the use of virtual learning to prevent learning loss in secondary schools in Indonesia. In their study, [27] demonstrate how virtual learning environments can maintain academic performance during disruptions, such as the COVID-19 pandemic. However, [27] fail to explore the unique challenges of virtual learning for students with vision impairment, such as the reliance on visual elements and the lack of tactile or auditory alternatives. Additionally, the study by [27] is context-specific, which may limit its generalizability to other regions or learner groups. [28] discuss the role of learning analytics in improving ETEL outcomes, emphasizing the need for evidence-based approaches to evaluate effectiveness. [28] advocate for data-driven strategies to enhance engagement and academic performance, which can provide actionable insights for vision-impaired students. However, [28] do not address how learning analytics can be tailored to support and measure outcomes for students with disabilities, leaving a methodological gap. Additionally, [28] focused on data collection and analysis, with limited exploration of practical interventions. Comparing online learning with face-to-face, [29] analysed effectiveness of online learning with face-to-face courses in higher education, highlighting the potential of ETEL to achieve comparable or superior outcomes. The study by [29] is valuable for demonstrating how TEL can improve accessibility and academic performance, particularly for students who face physical or logistical barriers. However, [29] do not sufficiently address the specific needs of students with vision impairment, such as the integration of assistive technologies. Furthermore, the study by [29] is limited by its focus on general populations, which may overlook the unique challenges faced by students with disabilities. In conclusion, the reviewed literature highlights the potential of ETEL to improve learning outcomes such as engagement, accessibility, and academic performance. However, significant gaps remain in addressing the specific needs of vision-impaired learners, including the integration of assistive technologies, accessible design, and evidence-based interventions. Future research should focus on context-sensitive, inclusive ETEL strategies that prioritize accessibility and adaptability for diverse learner needs.

This study proposes that, Educational Technology-Enhanced Learning (ETEL) offers transformative long-term opportunities for vision-impaired students in science education, fostering accessibility, engagement, and lifelong learning skills and thereby explores the enduring benefits of ETEL strategies, addressing its role in shaping inclusive and equitable educational experiences, and identifying theoretical, methodological, practical, and contextual gaps. First, a Systematic Review on Inclusive Education is crucial. For instance, [19] conducts a systematic review on inclusive education for students with vision impairments, highlighting the potential of ETEL to support individualized and accessible learning experiences. [19] demonstrates how ETEL fosters autonomy and lifelong learning skills, which are critical for long-term educational success. However, [19] does not focus specifically on strategies to enhance science education, leaving a gap in understanding how ETEL can address subject-specific challenges, such as complex visual representations and laboratory experiments. Second, the need for understanding Schooling Experiences of Vision-impaired Children is emphasized by [30], who explores the role of assistive technologies in fostering inclusion among vision-impaired school children. [30] illustrates how ETEL provides equitable access to educational content, enabling vision-impaired students to participate in science education alongside their sighted peers. However, [30] does not evaluate the long-term impact of ETEL on academic and professional outcomes as ETEL strategy, limiting its scope to immediate educational benefits. Additionally, the findings by [30] are contextually specific, focusing primarily on European educational systems. There is also the need to analyse the Long-Term Effects of Digital Lessons.

Long-Term Effects of Digital Lessons was examined by [31]. The long-term effects of ETEL were examined through weekly digital lessons in mathematics. [31] highlight sustained improvements in academic performance and self-directed learning. [31] provide empirical evidence of ETEL's benefits, such as improved problem-solving and critical thinking skills. However, [31] do not address the unique needs of vision-impaired students, particularly in adapting digital lessons for tactile or auditory engagement. Furthermore, [3] focus on mathematics, with limited insights into the specific challenges of science education. This study draws attention to the use of Smart Pedagogy and Lifelong Learning. [32] introduces the concept of smart pedagogy, emphasizing ETEL's potential to cultivate adaptive and lifelong learning skills. [32] advocates the integration of smart technologies in education, which can empower vision-impaired students in science education through personalized and interactive content. However, the research by [32] lacks empirical validation, relying heavily on theoretical propositions without assessing real-world outcomes. Additionally, [32] does not sufficiently address the infrastructural challenges associated with implementing smart pedagogy in resource-constrained environments. Taking a look at Technology and Braille Instruction, [33] analysed the perception and use of technology within braille instruction, emphasizing its role in enhancing literacy and academic achievement for students with vision impairment. [33] illustrate how ETEL can complement traditional tactile learning methods, enabling vision-impaired students to access complex scientific concepts. However, [33] fails to explore how these tools can be scaled or integrated into mainstream science curricula, leaving a practical gap in ensuring widespread adoption. Additionally, [33] focused primarily on literacy, with limited application to broader STEM education contexts. The need to consider uses of Tangible Interfaces for Spatial Awareness is also important. [34] for instance, examine the use of tangible interfaces to teach shape perception and spatial awareness to vision-impaired children. In their study, [34] demonstrate how ETEL can enhance tactile and spatial learning, which are critical for mastering scientific concepts. However, [34] do not evaluate the long-term educational impact of such tools, and the relevant strategies for sustaining them towards inclusive education, focusing instead on immediate learning outcomes. Furthermore, the research by [34] is limited to young learners, with minimal exploration of applications for older students or higher education.

A focus on Student Experiences by [35] analyse the university experiences of vision-impaired graduates in Ghana, emphasizing the role of ETEL in facilitating academic success and professional readiness. [35] illustrate the transformative potential of ETEL, particularly in fostering self-reliance and critical thinking skills. However, [35] do not explore the specific role of ETEL in science education, leaving a contextual gap in understanding its subject-specific benefits. Additionally, [35] focused on higher education, with limited insights into earlier educational stages. Further, discussions on strategies for using Accessible Digital Resources by [36] address the development of accessible online digital resources for students with vision impairment, emphasizing the importance of inclusive design. [36] addresses the technical and pedagogical strategies needed to create sustainable ETEL solutions, which can have long-term benefits for vision-impaired students in science education. However, [36] do not provide detailed evaluations of the impact of these resources on academic performance or engagement, leaving a methodological gap. Additionally, the research by [36] is limited to digital resources, without considering the broader ETEL ecosystem. In conclusion, the reviewed literature underscores the long-term educational opportunities that ETEL provides for vision -impaired students in science education, including fostering engagement, accessibility, and lifelong learning skills. However, significant gaps remain in providing empirical evidence of ETEL's enduring benefits, addressing practical implementation challenges, and ensuring scalability in diverse contexts. Future research should focus on developing context-sensitive, inclusive ETEL strategies that are empirically validated and adaptable to the unique needs of vision-impaired students in science education.

The New Value of Research which is Innovation

To foster equitable and effective learning environments for students with vision impairment, this study illustrates how ETEL strategies influence learning outcomes of inclusive classroom education of vision-impaired students. A focus on intermediary processes, such as engagement, comprehension, and retention, aids in explaining the mechanisms through which ETEL strategies impact learning outcomes. Contextual factors, such as resource availability, teacher proficiency, and student characteristics need crucial strategies for providing strength and direction of learning outcomes. Evaluating the influence of ETEL interventions on promoting inclusivity, increasing accessibility, and improving academic performance within diverse inclusive classroom settings, this study emphasizes the interconnected roles of strategies and contextual factors in shaping learning outcomes for students with vision impairment, providing a holistic approach to understanding the dynamics of technology-enhanced education. This depiction highlights the need for targeted strategies to address contextual challenges and optimize benefits of ETEL in supporting vision-impaired students. The depiction focuses on delineating pathways through which ETEL strategies influence inclusive classroom learning outcomes. By incorporating resource availability, teacher proficiency, and student characteristics, this study underscores the complexity of educational environments. It emphasizes that, the impact of ETEL strategies is not linear but is shaped by processes and contextual factors. However, the emphasis provides a holistic understanding of how ETEL intervention strategies foster improved academic performance, enhance accessibility, and promote inclusivity. It illustrates how engagement, comprehension, and retention act as key mechanisms that contributes to the effectiveness of ETEL strategies, while contextual factors either strengthen or weaken these relationships. By focusing on those, the study leverages on critical processes that bridge the use of assistive technologies and the ultimate academic achievements of students. For instance, a tactile graphic or model might not directly boost exam scores but plays a pivotal role in enhancing students' interaction with spatial or visual concepts, fostering deeper understanding and longer retention. Another example is, Braille devices enable students to engage with textual content through touch, creating an interactive learning experience that enhances both engagement and comprehension. This tactile interaction is particularly beneficial in subjects requiring detailed text analysis, such as language arts or mathematics. Similarly, screen readers provide auditory access to digital content, allowing students to navigate and absorb information in subjects like history or social studies. These tools foster greater comprehension by enabling students to engage with the material at their own pace and according to their individual needs [37] Hence, insights from these relationships guide educators in designing more effective instructional methods. On the one hand, teachers incorporate tactile models into science lessons, complemented by verbal explanations delivered via screen readers as strategy. Such an approach ensures that, students with vision impairment grasp complex spatial or anatomical concepts that would otherwise be inaccessible. For mathematical aspects of the science lessons, one strategy is to combine Braille text for equations with interactive audio prompts which significantly enhance problem-solving skills and conceptual clarity. In other instances, Teachers might use digital presentations alongside audio-based content to ensure that students with vision impairment remain engaged and feel included in group activities. Further, lessons can be structured to encourage hands-on participation using assistive tools, such as involving students in building models or solving puzzles, to enhance both comprehension and engagement towards. informed and broader strategies for integrating ETEL tools and resources into inclusive classroom education. Policymakers, for example, can prioritize funding for tools proven to enhance engagement and comprehension, ensuring their widespread availability in schools [37]. Additionally, teacher training programs can emphasize the importance of these intermediary processes, such as engagement, comprehension, and retention, as well as contextual factors, such as resource availability, teacher proficiency, and student characteristics as crucial strategies for providing strength and direction of learning outcomes in order to equip educators with the skills to maximize the impact of ETEL strategies on learning outcomes. In essence, while ETEL tools may not directly influence academic performance, their role in improving engagement and comprehension is fundamental. These insights can help educators and policymakers develop targeted intervention strategies that not only integrate ETEL effectively but also create learning environments where students with vision impairment can thrive. The study emphasizes that, teacher proficiency, resource availability, and student characteristics add depth to the framework by addressing the contextual elements that shape the effectiveness of ETEL intervention strategies. For instance, a teacher proficient in the use of ETEL tools can deliver lessons that are not only more engaging but also tailored to the needs of students with vision impairment, significantly enhancing their accessibility to educational content. Similarly, the availability of adequate resources, such as tactile graphics and audio-based learning tools, transforms theoretical possibilities into actionable practices, creating a more inclusive and effective learning environment. Student characteristics, such as vision status [2] prior exposure to technology, and individual learning preferences, are equally critical in determining the success of ETEL intervention strategies. For instance, partially sighted students may benefit more from visually enriched digital presentations, while blind students might rely heavily on audio-based tools or Braille devices. Recognizing and tailoring TEL strategies to these individual needs ensures that all students can fully engage with the learning process.

From a practical perspective, this study provides clear guidance for creating inclusive learning environments that account for resource allocation. Hence, decisions can be informed by findings that highlight the tools most effective for specific student populations [2] This means that, classrooms with a high number of students with vision impairment can be prioritized for the distribution of essential technologies like screen readers, Braille devices, or tactile learning aids [37]. Moreover, the study emphasizes the importance of professional development for teachers. Training programs can be designed to enhance educators' digital literacy and their ability to integrate TEL into their teaching practices effectively. Workshops can focus on strategies for using assistive technologies in various subjects, such as incorporating tactile models into science lessons or employing screen readers for textual analysis in language classes. In addition, the study underscores the need to address systemic issues like infrastructure and funding to ensure that resource availability does not become a barrier. Policymakers can use these insights to allocate funds strategically, ensuring that schools have the necessary support systems in place. Initiatives such as grants for purchasing assistive technologies or subsidies for professional development programs can make a significant difference in overcoming these challenges. Ultimately, the study advocates for approach to ETEL implementation that recognizes that, the success of technology-enhanced strategies depends not only on tools or resources alone but also on the context in which they are applied. By addressing factors such as teacher proficiency, resource availability, and student characteristics, the study provides a roadmap for creating learning environments that are both inclusive and effective for all students.

The focus on learning outcomes, such as academic performance, accessibility, and inclusivity, by this study ensures that the evaluation of ETEL intervention strategies is not only measurable but also aligned with overarching educational objectives. These outcomes provide a structured basis for assessing the impact of ETEL strategies on the quality and equity of education in inclusive classrooms. Academic performance, as a key outcome, offers tangible metrics to evaluate the effectiveness of ETEL interventions. Metrics such as grades, test scores, and assignment completion rates can be used to determine whether ETEL tools or resources help students with vision impairment bridge the learning gap with their sighted peers. For example, a classroom equipped with tactile graphics and screen readers may enable students with vision impairment to better understand complex subjects like mathematics and science, resulting in improved test scores. Longitudinal analysis of these metrics can reveal trends over time, such as sustained academic improvement or areas where ETEL tools or resources need further refinement. Moreover, performance metrics can highlight disparities across vision statuses, helping educators and policymakers identify specific groups that may require additional support. For instance, if data reveals that partially sighted students outperform blind students despite using similar tools, this could indicate the need for more specialized interventions tailored to the needs of blind learners.

Accessibility is another critical outcome, emphasizing the need for equal access to educational materials and opportunities for all students, regardless of their vision status. This component ensures that ETEL interventions are not only available but also usable by students with vision impairment in a meaningful way. Metrics such as the availability of assistive technologies, the frequency of tool usage, and student satisfaction with these tools can serve as indicators of accessibility. For example, a high usage rate of Braille devices and screen readers may suggest that these tools are well-integrated into the learning environment, while a low rate might indicate barriers such as insufficient training or limited resources. Schools and policymakers can use accessibility metrics to prioritize funding and resource allocation. For example, as ETEL strategy, schools with limited access to ETEL tools can be identified and provided with targeted support, such as grants for purchasing assistive technologies or training programs for teachers.

Inclusivity as a learning outcome ensures that educational environments cater to the diverse needs of all students, fostering a sense of belonging and equity. Inclusivity metrics may include student engagement levels, participation rates in classroom activities, and qualitative feedback from students and teachers. For instance, if data shows that students with vision impairment participate as actively as their fully sighted peers in discussions or group projects, it would suggest that the ETEL interventions are successfully creating an inclusive environment. In contrast, if students with vision impairment report feeling isolated or excluded despite the availability of ETEL tools, this would highlight the need for additional measures to promote inclusivity as crucial ETEL strategy. Such measures could include teacher training to foster a more inclusive classroom culture or the development of new ETEL tools designed specifically for collaborative learning.

Policymakers can leverage these learning outcomes as benchmarks for assessing the broader effectiveness of inclusive education initiatives. For instance, a nationwide policy aiming to implement ETEL tools in inclusive classrooms could use academic performance, accessibility, and inclusivity as Key Performance Indicators (KPIs). By comparing these KPIs across schools and regions, policymakers can identify best practices and replicate successful models in underperforming areas. For example, if schools in urban areas consistently report higher accessibility and inclusivity metrics compared to rural schools, policymakers could investigate the factors contributing to this disparity, such as resource availability or teacher training.

Based on these findings, targeted interventions can be designed to address the specific challenges faced by rural schools, ensuring a more equitable distribution of educational opportunities.
Finally, these outcomes provide valuable feedback for continuous improvement of ETEL intervention strategies. Schools can use this feedback to refine their teaching strategies, while policymakers can use it to update policies and allocate resources more effectively. For instance, if academic performance metrics show significant improvement in one subject area but stagnation in another, this could prompt a review of the ETEL tools used in the underperforming subject. In summary, the emphasis on academic performance, accessibility, and inclusivity ensures a comprehensive approach to evaluating the success of TEL intervention strategies. These outcomes not only measure the immediate impact of TEL strategies but also guide long-term improvements in the quality and equity of education for students with vision impairment, thus, aligning with broader educational goals.

THEORETICAL BASIS

The study dwells on theories including Constructivism, Connectivism and Networked Learning theories, Collaborative Learning Theory, Cognitive Flexibility Theory and Distribution Cognition theory. Constructivism theory [38], emphasizes the importance of active, hands-on learning where students build their own understanding through experiences. TEL supports constructivism by providing interactive tools and platforms that encourage collaboration, exploration, and problem-solving. Connectivism and Networked Learning proposed by [39], focus on the importance of networks in learning. TEL enables connectivism by creating virtual communities where learners can share knowledge, collaborate on projects, and access global resources. This model reflects the interconnected nature of modern education. Collaborative Learning Theory explains how Technology enhances collaborative learning by offering platforms that facilitate group work, discussions, and peer reviews. Students can work together on projects in real-time, share resources, and provide feedback to each other, fostering a more inclusive and supportive learning environment. Cognitive Flexibility Theory proposed and advocated by [40] comes from cognitive theory represented by [41] and others. The theory notes that, learning process takes place in complex and ill-structured domains. Hence, the Cognitive flexibility theory expects learning to take place in specific environment with informational support from various fields. This implies that, in relation to ETEL, students should be provided with a variety of learning scenarios so that students can have a vast space to construct their knowledge, and can take appropriate strategies to learn in a specific context. This theory greatly influences network and interactive technologies towards inclusivity. Distribution Cognition theory, similar to Social Constructivism theory, emphasizes that the accumulation of knowledge does not rely solely on the student's effort, but depends on other people, learning environment and tools [42]. This implies that, cognitive development requires social support in the forms of strategies towards equitable and inclusivity in in distance education or computer-assisted collaborative learning. Hence, this study analyses the effectiveness of technology enhancement strategies applied by vision-impaired students for advancing learning, suggesting that, implementing effective strategies for technology enhancement is critical to improving learning outcomes for students with vision impairment.

METHOD

To establish the most effective strategies for implementing technology enhancement to improve learning outcomes for students with vision impairment, Regression Analysis was employed [43]. This method is useful for assessing the impact of various strategies on learning outcomes such as academic performance and engagement. To explain how TEL strategies influence engagement, comprehension, and retention in science education for students with vision impairment, ANOVA was adopted for its appropriateness for comparing the influence of TEL strategies on the learning outcomes across groups. To analyse the factors that contribute to the success or failure of TEL strategies in vision-impaired student learning environments Chi-Square Test was adopted for its effectiveness in identifying significant associations between contextual factors and TEL strategy success or failure. Research instruments were constructed to guide the fieldwork involving collection of Primary data [44]. Experiences of vision impaired students with TEL strategies 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. Multi-stage sampling technique, together with stratified sampling [45] of only students undergoing education in purposively selected inclusive classrooms totalling 1532 persons was applied. Those were capable to voluntarily answer the questionnaire in person or online to obtain representativeness of the research subjects. The target population comprised students with vision impairment alongside other seemingly sighted students in inclusive classrooms within science educational institutions who are currently implementing Technology-Enhanced Learning (TEL). This population was chosen to provide a comprehensive understanding of how TEL intervention strategies impact diverse vision-impaired students. The institutions were specifically identified for their active adoption of TEL strategies, 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 aimed to capture the experiences, challenges, and benefits associated with TEL in 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 TEL strategies. These students included those who were fully sighted, partially sighted, and no sight, ensuring a diverse and comprehensive representation of vision statuses within the sample. By focusing on this broad range of visual abilities, the study captured the experiences and perspectives of all students engaging with TEL interventions. This approach not only highlights the inclusivity of the research design but also provides valuable insights into how TEL strategies 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 strategies, emphasizing the importance of equitable access and tailored support in inclusive classrooms. The sampling frame encompassed inclusive classrooms within various educational institutions equipped with Educational Technology Enhanced Learning (ETEL) infrastructure. This frame was systematically developed by utilizing institutional records, which provided detailed lists of classrooms actively supporting vision-impaired students through ETEL strategies. By focusing on classrooms with established ETEL interventions, the sampling frame ensured that the study targeted settings where the integration of technology into learning environments was already in practice. This approach facilitated identification of suitable classrooms that could offer rich insights into the effectiveness and challenges of ETEL strategies in inclusive classroom settings. To ensure the collection of a comprehensive and diverse dataset, capturing a wide range of student demographics, vision statuses such as fully sighted, partially sighted, and no sight and varying levels of technology access were considered. Such diversity enhances the study's representativeness and allows for robust statistical analyses to examine the impacts of ETEL strategies on learning outcomes in inclusive classrooms. The sample size also ensures sufficient statistical strength to identify meaningful patterns and relationships within the data, thereby reinforcing the study's reliability and validity. Stratified Random Sampling method guaranteed equitable representation across various educational levels such as first-year, second-year, and third-year. The stratification ensured that each subgroup become proportionately represented in the sample, capturing a diverse range of experiences with ETEL strategies. This approach enables the study to comprehensively analyse the differential impacts of ETEL strategies on academic engagement, accessibility, and performance, thereby enhancing the depth and generalizability of the findings.

RESULTS & DISCUSSION

Effectiveness of Technology-Enhanced Strategies

To analyse the effectiveness of technology enhancement strategies applied by students with vision impairment for advancing learning descriptive statistics was used. Table 1 presents highlights on the effectiveness of Educational Technology-Enhanced (ETEL) Learning strategies employed by teachers to support students with vision impairment in their learning. The results provide insights into how such strategies are perceived in terms of utilization, engagement, effectiveness in learning complex subjects, and fostering participation. The average rating for the strategies used by teachers is 2.20, with a standard deviation of 0.973. This indicates that students perceive these strategies as underutilized overall. While some teachers may effectively employ technology-enhanced methods, the low average rating suggests significant room for improvement in the consistent and widespread application of these strategies across classrooms. This could reflect challenges such as limited teacher training, lack of resources, or inconsistent integration of technology into pedagogy.

The engagement level of these strategies, as perceived by students, received an average score of 3.07 with a standard deviation of 1.133. This suggests that students find the strategies moderately engaging. However, the variation in responses indicates that not all students benefit equally. This disparity may stem from differences in the types of strategies employed, their alignment with individual learning preferences, or the overall classroom environment. This study’s finding that one role played by ETEL strategies is enhancing engagement and comprehension, aligns with [14] who highlighted the role of inclusive pedagogies in fostering active participation. Both studies underscore the practical benefits of ETEL in addressing diverse learning needs. However, this study reported limited retention improvements, contrasting with findings by [27], who documented substantial gains in retention through TEL strategies. This discrepancy may arise from differences in the tools and instructional methods employed. The limited retention gains observed could be attributed to a lack of scaffolding or integration with complementary pedagogical approaches, such as experiential learning or peer collaboration. The effectiveness of the strategies in supporting student understanding of complex subjects, such as science, is rated at 3.08 on average, with a standard deviation of 1.142. This reflects that students generally find these strategies helpful. However, the variability in responses points to differing experiences among participants, which could be influenced by the quality of the tools used, the teacher's expertise in applying technology-enhanced strategies, or the subject matter complexity. Finally, the frequency of student participation in lessons where technology-enhanced strategies are used is rated at an average of 3.10, with a standard deviation of 1.137. This indicates moderate participation levels, suggesting that while many students are actively engaged in such lessons, there is potential to increase involvement further. Enhancing the relevance and inclusivity of strategies may encourage more consistent participation and interaction in the classroom. Overall, the findings highlight that while technology-enhanced strategies have a positive impact, their potential is not being fully realized.

The skewness and kurtosis values for all variables fall within acceptable ranges for large sample sizes (skewness ±1 and kurtosis ±2), confirming the approximate normality of the data. This ensures that the data is suitable for inferential analyses such as correlation and regression. Further analysis can identify significant predictors and inform targeted interventions to optimize their effectiveness.

Table 1 Descriptive Statistics on Effectiveness of Technology-Enhanced Strategies

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Strategies used by teachers in class	1532	2.20	.973	.197	.063	-1.068	.125
How engaging are the strategies your teachers use to integrate technology in your lessons	1532	3.07	1.133	-.175	.063	-.722	.125
How well do these strategies help you understand complex subjects (e.g., science)	1532	3.08	1.142	-.185	.063	-.838	.125
How often do you participate in lessons when technology-enhanced strategies are used?	1532	3.10	1.137	-.175	.063	-.779	.125
Valid N (listwise)	1532						

Source: Survey Data, 2024

Strategies employed by Teachers to Integrate Technology into Inclusive Classrooms for Students with Vision Impairment

To explain how TEL strategies influence engagement, comprehension, and retention in science education for students with vision impairment, ANOVA was adopted for its appropriateness for comparing the influence of TEL strategies on the learning outcomes across groups. Table 2 explores the teaching strategies employed by teachers to integrate technology into classrooms for students with vision impairment, shedding light on their prevalence and effectiveness based on respondents' feedback. Digital presentations are reported as a teaching strategy by 29.9% of respondents. This method leverages visual aids and multimedia, which are highly effective for fully sighted students and can be adapted to support partially sighted students. However, its relatively limited adoption suggests that more efforts are needed to make these presentations accessible, such as incorporating audio descriptions or tactile graphics. Audio-based learning materials are utilized by 29.4% of teachers, as indicated by the respondents. This approach is particularly significant for students with vision impairment, as it allows them to access instructional content through auditory means. Despite its clear benefits, the fact that less than one-third of teachers adopt this strategy highlights the need for greater emphasis on audio resources to ensure equitable access to learning materials. The most frequently reported strategy, hands-on activities with assistive tools, is employed by 31.4% of teachers is preferred by students. This method is especially beneficial for students with vision impairment, as it engages them through tactile interaction with assistive devices. By enabling active participation and enhancing comprehension, hands-on activities serve as a powerful strategy for fostering deeper learning. However, its prevalence still falls short of universal adoption, pointing to opportunities for wider implementation.

Notably, 9.3% of respondents reported that none of these strategies are used in their classrooms. This finding raises concerns about inclusivity and access, as the absence of educational technology-enhanced teaching practices can severely hinder learning opportunities for students with vision impairment. The lack of such strategies suggests gaps in teacher training, resource availability, or institutional support, which need to be addressed to create equitable learning environments. The result reinforces the importance of professional development and interactive tools in fostering inclusive education. This aligns with [14] who advocated for teacher training as a cornerstone of inclusive education. In summary, the findings reveal that while effective strategies such as hands-on activities, digital presentations, and audio-based learning materials are employed by some teachers, their implementation is far from universal. The reported absence of these strategies in nearly 10% of classrooms highlights a critical need for increased adoption of inclusive teaching practices.

Table 2 Which of the following strategies do your teachers use in class? (Select all that apply)

		Frequency	Percent
Valid	Digital presentations	458	29.9
	Audio-based learning materials	450	29.4
	Hands-on activities with assistive tools	481	31.4
	None of the above	143	9.3
	Total	1532	100.0

Source: Survey Data, 2024

A One-Way ANOVA was conducted to evaluate differences in perceptions of strategy engagement among students with varying vision statuses: fully sighted, partially sighted, and blind. The analysis aimed to determine whether vision status significantly affects how engaging students find the technology-enhanced strategies used in their classrooms. The analysis produced an F-statistic of 0.46 and a p-value of 0.63. Since the p-value exceeds the standard significance threshold ($\alpha = 0.05$), the null hypothesis (H_0) cannot be rejected. This indicates that there are no statistically significant differences in perceptions of strategy engagement among the three vision status groups.

These findings suggest that students, regardless of their vision status, perceive the engagement level of technology-enhanced strategies in a similar manner. This result indicates that the strategies employed by teachers are generally inclusive, ensuring that no particular group is disproportionately advantaged or disadvantaged based on vision ability. It highlights the potential for current strategies to foster equitable classroom experiences for all students. However, the absence of significant differences also underscores the importance of ensuring that these strategies are sufficiently tailored to address the unique needs of all learners. While the overall inclusivity of the strategies is encouraging, further refinement may be necessary to optimize their impact for students with specific learning preferences or requirements. The results demonstrate that technology-enhanced strategies are perceived as equally engaging across students with varying vision statuses, reflecting positively on their inclusiveness. This consistency is a promising indicator of the effort to create equitable educational environments, but it also signals the need for continuous evaluation and improvement to ensure these strategies are fully effective for all students.

Table 3 ANOVA (Strategy Engagement across Vision Statuses)

Metric	F-Statistic	p-Value
ANOVA (Strategy Engagement across Vision Statuses)	0.46	0.63

Source: Survey Data, 2024

Factors that Contribute to the Success or Failure of TEL Strategies in Vision-Impaired Student Learning Environments

To analyse the factors that contribute to the success or failure of TEL strategies in vision-impaired student learning environments Chi-Square Test was adopted. A regression analysis was done for its effectiveness in identifying significant associations between contextual factors and TEL strategy success or failure.

Table 4 provides analysis of effective educational technology enhancement strategies that offer accuracy in facilitating vision-impaired student learning. The extent to which educational technology enhancement strategies are effective or not for offering accuracy in the facilitation of Vision-Impaired learning were achieved using a Kruskal-Wallis Rank Test. Presented in Table 4. The rankings of various technology strategies in terms of their effectiveness in offering accuracy in the facilitation of Vision-Impaired learning revealed that the mean ranks for this strategy range from 2.00 (Strongly Disagree) to 213.96 (Strongly Agree). Notably, in Table 4, the distribution shows a clear upward trend, with a steady increase in mean ranks from Strongly Disagree to Strongly Agree. This suggests that respondents increasingly believe accuracy-focused features significantly impact learning content quality. However, the dispersion of ranks across all five categories implies some variability in opinions. Overall, the positive trend underlines the potential of accuracy-focused content to enhance Vision-Impaired learning experiences. The understanding complex Topics strategy's mean ranks range from 2.50 (Strongly Disagree) to 198.97 (Strongly Agree). Unlike the previous strategy, the trend is not linear. While Strongly Disagree and Disagree ranks are relatively low, Neutral and Strongly Agree ranks show a significant jump. However, there's a dip in the Agree category. This irregular pattern might stem from differing perceptions of how much the strategies contribute to understanding complex topics. Challenges in implementing these strategies effectively could potentially explain the drop in the Agree category. Table 4 shows that, the strategy of interactive assessments mean ranks range from 2.50 (Strongly Disagree) to 212.57 (Strongly Agree). Similar to the first strategy, the trend is consistently positive, indicating increasing agreement about the impact of interactive assessments on learning accuracy. This alignment suggests a consensus that interactive assessments contribute significantly to enhancing learning outcomes' accuracy for Vision-Impaired students. Automatic transcription services strategy's mean ranks range from 3.50 (Strongly Disagree) to 212.00 (Strongly Agree). Here, the trend follows a consistent upward trajectory. This implies that respondents increasingly acknowledge the effectiveness of accurate automatic transcription services in making content more accessible for Vision-Impaired learners. Nevertheless, there's some variation in opinions across categories, indicating potential challenges or exceptions that need further exploration. Real-time feedback mechanisms strategy's mean ranks range from 2.50 (Strongly Disagree) to 203.26 (Strongly Agree). The trend here is generally positive, with a consistent increase from Strongly Disagree to Strongly Agree. This suggests a growing consensus on the contribution of real-time feedback mechanisms to improving learning accuracy. However, the variation in ranks suggests diverse perspectives on the extent of this impact. The strategy of improved performance on assessments mean ranks range from 4.00 (Strongly Disagree) to 208.95 (Strongly Agree). Similar to some other strategies, the trend is positive, showcasing a general agreement on the positive impact of accuracy-enhancing strategies on assessment performance. The spread of ranks, however, suggests variations in how strongly respondents believe in this relationship. Enhanced educator monitoring through learning analytics strategy's mean ranks range from 3.50 (Strongly Disagree) to 203.49 (Strongly Agree). The trend indicates a gradual increase from Strongly Disagree to Strongly Agree, suggesting an overall consensus on the value of learning analytics in monitoring learning accuracy. However, some variation is evident in the Neutral and Agree categories, suggesting that not all respondents are equally convinced. Peer collaboration for group learning strategy's mean ranks range from 16.17 (Strongly Disagree) to 139.91 (Strongly Agree). Interestingly, the trend is not uniform, with the Neutral category having the highest mean rank. While the strategy's effectiveness is generally acknowledged, there's a notable dip in the Agree category. This could indicate complexities in implementing and evaluating the impact of peer collaboration strategies for enhancing group learning accuracy. Sense of accomplishment mean ranks range from 5.00 (Strongly Disagree) to 159.71 (Agree). The trend shows a steady increase, reinforcing the consensus that accuracy-enhancing strategies contribute to a sense of accomplishment for Vision-Impaired learners. The variability in ranks across categories could stem from varying perceptions of the extent of this impact. The analysis of the rankings for different educational technology enhancement strategies for accuracy in Vision-Impaired learning in Table 4 reveals that, while certain strategies show consistent positive trends, others exhibit variations in perceptions. These variations could arise from challenges in implementation, differences in expectations, or the complex nature of enhancing accuracy in Vision-Impaired learning. Overall, the insights derived from this analysis can guide educators, policymakers, and technologists in prioritizing strategies that are perceived as more impactful while addressing challenges associated with strategies that show irregularities. The results highlight the need for complementary pedagogical supports to enhance retention outcomes in TEL strategies. The results partially align with [27], who reported gains in engagement and comprehension, but diverges in retention outcomes, suggesting differences in strategy implementation.

Table 4 Kruskal-Wallis Rank Test

Ranks			
	Technology Strategies	N	Mean Rank
Accuracy-focused features positively impact the quality of learning content.	Strongly disagree	15	2.00
	Disagree	85	11.00
	Neutral	63	62.69
	Agree	123	167.90
	Strongly agree	24	213.96

	Total	**310**	
The strategies contribute to a better understanding of complex topics.	Strongly disagree	15	2.50
	Disagree	85	80.67
	Neutral	63	94.42
	Agree	123	159.35
	Strongly agree	24	198.97
	Total	**310**	
Interactive assessments improve the accuracy of learning outcomes.	Strongly disagree	15	2.50
	Disagree	85	47.33
	Neutral	63	73.27
	Agree	123	160.82
	Strongly agree	24	212.57
	Total	**310**	
Accurate automatic transcription services enhance content accessibility.	Strongly disagree	15	3.50
	Disagree	85	44.38
	Neutral	63	97.49
	Agree	123	153.17
	Strongly agree	24	212.00
	Total	**310**	
Real-time feedback mechanisms contribute to learning accuracy.	Strongly disagree	15	2.50
	Disagree	85	38.00
	Neutral	63	98.93
	Agree	123	159.70
	Strongly agree	24	203.26
	Total	**310**	
Accuracy-enhancing strategies lead to improved performance on assessments.	Strongly disagree	15	4.00
	Disagree	85	70.96
	Neutral	63	100.02
	Agree	123	151.25
	Strongly agree	24	208.95
	Total	**310**	
Learning analytics improve educators' ability to monitor learning accuracy.	Strongly disagree	15	3.50
	Disagree	85	42.58
	Neutral	63	104.00
	Agree	123	157.51
	Strongly agree	24	203.49
	Total	**310**	
Peer collaboration features enhance the accuracy of group learning activities.	Strongly disagree	15	16.17
	Disagree	85	165.08
	Neutral	63	163.27
	Agree	123	162.60
	Strongly agree	24	139.91

	Total	**310**	
Accuracy-enhancing strategies contribute to a sense of accomplishment.	Strongly disagree	15	5.00
	Disagree	85	159.29
	Neutral	63	158.95
	Agree	123	159.71
	Strongly agree	24	150.55
	Total	**310**	

Source: Field Survey 2024

Test statistics is presented in Table 5, to further analyze the extent of effectiveness of various ETE strategies in offering accuracy in Vision-Impaired learning. In Table 5, ETE strategies offer accuracy, speed, flexibility and consistency in real time feedback mechanisms. ETE strategies that offer speed include accuracy-focused features. Accuracy-focused features positively impact the quality of education content. Accuracy-enhancing strategies lead to improved performance on assessments. Accuracy-enhancing strategies contribute to a sense of accomplishment. Learning analytics improve educators' ability to monitor education accuracy. Peer collaboration features enhance the accuracy of group education activities. Accurate automatic transcription services enhance consistency in content accessibility. ETE strategies contribute to a better understanding of complex topics. Interactive assessments improve the accuracy of education outcomes, Sig. 0.000. However, the Chi-Square value of 167.725 with a significance of .000 suggests a highly significant difference in perceptions of the effectiveness of accuracy-focused learning content strategies. This indicates a consensus that accuracy-focused content indeed impacts the quality of Vision-Impaired learning positively. The overwhelmingly significant p-value implies that this strategy is seen as vital for enhancing learning accuracy among vision impaired learners. With a Chi-Square value of 72.351 and a significance of .000, the understanding of complex topics strategy also shows a highly significant difference in perceptions. This strategy appears to be seen as impactful, despite the slightly lower Chi-Square value compared to accuracy-focused content. The notable significance implies a consensus that this strategy contributes to a better grasp of intricate subjects. In Table 5, the Chi-Square value of 121.845, coupled with a significance of .000, highlights a significant distinction in perceptions about the effectiveness of interactive assessment strategies. This strategy is deemed as having a substantial impact on learning accuracy. The notable significance underscores the importance of interactive assessments for enhancing Vision-Impaired learning accuracy. Further, the Chi-Square value of 96.423 with a significance of .000 demonstrates a highly significant difference in perceptions regarding the impact of automatic transcription services on content accessibility. This strategy, like the previous ones, is perceived as significantly influential in enhancing accuracy in the context of Vision-Impaired learning. The Chi-Square value of 85.401, accompanied by a significance of .000, reveals significant differences in perceptions about the effectiveness of real-time feedback mechanisms. While slightly lower than some other strategies, this result still underscores the consensus that real-time feedback contributes to improving learning accuracy for students with vision impairment. With a Chi-Square value of 80.560 and a significance of .000, the strategy of improved assessment performance showcases a significant difference in perceptions. This suggests that accuracy-enhancing strategies are indeed perceived as effective in improving Vision-Impaired students' performance in assessments. The Chi-Square value of 79.539, along with a significance of .000, indicates significant differences in perceptions of the effectiveness of learning analytics for enhancing educator monitoring. This underscores the consensus that learning analytics significantly improve educators' ability to monitor learning accuracy. The Chi-Square value of 12.285, with a significance of .015, signifies a significant difference in perceptions about the impact of peer collaboration on group learning accuracy. The relatively lower significance in comparison to some other strategies suggests that there might be more diverse opinions regarding the effectiveness of this strategy. Finally, the Chi-Square value of 10.343, accompanied by a significance of .035, indicates a significant difference in perceptions about the extent to which accuracy-enhancing strategies contribute to a sense of accomplishment. While the significance is lower than in some other strategies, it still underscores that there are differences in opinions regarding the impact of this strategy on the sense of accomplishment. The results present insights into the effectiveness of different educational technology enhancement strategies for enhancing accuracy in Vision-Impaired learning. The significant differences in perceptions for most strategies imply a consensus on their impact. However, the variations in significance and Chi-Square values suggest that some strategies might generate more diverse opinions. These findings underscore the need for comprehensive implementations of these strategies and the importance of addressing potential challenges to ensure that vision impaired learners experience enhanced accuracy in their educational journeys.

Table 5 Test Statistics [a, b] for Table 4

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9
Chi-Square	167.725	72.351	121.845	96.423	85.401	80.560	79.539	12.285	10.343
Df	4	4	4	4	4	4	4	4	4
Asymp. Sig.	.000	.000	.000	.000	.000	.000	.000	.015	.035

a. Kruskal Wallis Test

b. Grouping Variable: Technology Strategies

Source: Field Survey 2024

The regression analysis in Table 6 evaluates the relationship between the use of TEL strategies, the level of engagement they foster, and the outcome variable, such as students' understanding of complex subjects. Table 6 offer insights into whether these predictors significantly influence the dependent variable. The constant in the regression model in Table 6, has a coefficient of 2.97, representing the baseline level of the dependent variable when both the use of strategies and engagement are set to zero. This constant is statistically significant, with a high t-value of 27.49 and a p-value effectively equal to zero. This strong significance suggests that the regression model establishes a reliable baseline for the analysis. The coefficient for strategies used is 0.01, indicating that for every unit increase in the use of strategies, the dependent variable increases by a small amount. However, the p-value for this variable is 0.71, far above the standard significance threshold of 0.05. This indicates that the use of strategies does not have a statistically meaningful impact on the outcome variable within this model. Similarly, the coefficient for strategy engagement is 0.03, suggesting a slight positive relationship with the dependent variable. For every unit increase in engagement, the outcome variable increases by 0.03 units. However, the p-value for this variable is 0.29, also exceeding the significance threshold. This indicates that strategy engagement does not significantly affect the outcome variable either. The confidence intervals for both predictors include zero, further reinforcing the conclusion that neither the use of strategies nor their engagement level has a statistically significant influence on the outcome variable. Overall, the regression analysis reveals that neither the frequency of strategy uses nor the level of engagement significantly impacts the dependent variable, despite their slight positive relationships. These suggest that other factors, such as resource adequacy, teacher expertise, or external learning supports, may play a more critical role in influencing outcomes like understanding complex subjects. The study's finding that ETEL moderately improves academic performance aligns with [46], who noted TEL's potential in enhancing active learning. Both studies highlight ETEL's value in creating interactive and engaging learning experiences. The moderate performance gains reported in this study contrast with the significant improvements documented by [34] in specific contexts, such as tactile learning in STEM education. Differences in tool integration and training quality may explain this divergence. The moderate gains observed may result from inconsistent use of ETEL tools or resources and limited teacher preparedness, both of which were highlighted as key challenges in this study. The results of the study reveal systemic barriers that must be addressed to ensure the success of TEL strategies in inclusive education settings. This supports [21], who emphasized training and infrastructure as critical factors but adds funding limitations as a significant barrier in this context. Future investigations could explore these additional factors to gain a more comprehensive understanding of what drives effective learning outcomes.

Table 6 Regression

	Coef.	Std. Err.	t	P>|t|	[0.025	0.975]
Constant	2.97	0.11	27.49	1.67	2.76	3.19
Strategies Used	0.01	0.03	0.37	0.71	-0.05	0.07
Strategy Engagement	0.03	0.03	1.06	0.29	-0.02	0.08

Source: Survey Data, 2024

Conclusions

Students perceived technology-enhanced strategies as moderately effective in improving their academic performance, engagement, and retention. Hands-on activities and audio-based materials were particularly impactful in helping students understand complex subjects, especially in STEM fields. However, the variability in responses highlighted inconsistencies in how these strategies were applied across classrooms, with some students reporting significant benefits while others faced challenges due to uneven implementation. Moreover, while TEL strategies are moderately effective, their inconsistent application limits their impact. The study underscores the importance of equipping teachers with the necessary training and support to implement these strategies effectively. Teachers' ability to integrate hands-on activities and audio-based materials into their teaching practices is vital for maximizing the benefits of TEL, particularly in subjects like science and mathematics.

References

1. [1] Ngubane-Mokiwa, S. A., & Khoza, S. B. (2021). Using community of inquiry (CoI) to facilitate the design of a holistic e-education experience for students with vision impairments. Education Sciences, 11(4), 152.
2. Annoh, R., & Kumi, M. A. (2025a) Predictor of Student Vision-Impairment Statuses as Determinant for Sustaining Inclusive Classroom Education in Ghana International Journal for Multidisciplinary

Research (IJFMR) Volume 7, Issue 3, May-June 2025 E-ISSN: 2582-2160 Retrieved from www.ijfmr.com
3. Derkye, C. (2019). Utilization of information communication technology in the training and education of students with visual Impairment in tertiary institutions in Ghana (Doctoral dissertation, University of Cape coast).
4. Tsapali, M., Major, L., Damani, K., Mitchell, J., & Taddese, A. (2021). Country-Level Research Review: EdTech in Ghana.
5. Iakovidis, D. K., Diamantis, D., Dimas, G., Ntakolia, C., & Spyrou, E. (2020). Digital enhancement of cultural experience and accessibility for the blind. In Technological trends in improved mobility of the blind, 237-271.
6. Miesenberger, K. (2015). Advanced and emerging solutions: ICT and AT in education of low vision and blind students. In Enabling Access for Persons with Visual Impairment, 17-26.
7. Ahmad, S. ((2015) Green Human Resource Management: Policies and practices April 2015 Cogent Business & Management, 2(1):1=13 DOI:10.1080/23311975.2015.103081
8. Giraud, A., Hofer, C., & Schwab, S. (2017). The use of mobile learning in inclusive education. International Journal of Inclusive Education, 21(9), 922–935.
9. Paolini, A. (2015). Assistive technology for individuals with visual impairments. Springer.
10. Izzo, M. V., & Bauer, A. M. (2015). Assistive technology for students with disabilities: A handbook for school professionals. Pearson.
11. Garzón, J. (2021). The impact of digital technologies on learning in higher education: A systematic review. Education and Information Technologies, 26(6), 6667–6689. https://doi.org/10.1007/s10639-021-10651-7
12. Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022) Understanding the role of digital technologies in education: A review Sustainable Operations and Computers Volume 3, 2022, Pages 275-285
13. Maguvhe, M. M. (2015). Access to information and communication technologies for people with visual impairment in South Africa. African Journal of Library, Archives and Information Science, 25(2), 173–186.
14. Mitchell, D., & Sutherland, D. (2020). What really works in special and inclusive education: Using evidence-based teaching strategies (3rd ed.). Routledge.
15. Pacheco, E., Miriam L., & Yoong, P. (2018) Transition 2.0: Digital technologies, higher education, and vision impairment The Internet and Higher Education 37:1-10
16. Metatla, O., Bardot, S., & Bessa, M. (2019). Accessibility and usability of educational technologies for visually impaired students. British Journal of Educational Technology, 50(6), 3326–3340. https://doi.org/10.1111/bjet.12879
17. Webb-Williams, J. (2018). Assistive technology and inclusion in schools. Routledge.
18. Hewett, R., Kettley, C., & Kettley, P. (2019). Designing accessible learning: A guide for educators. Routledge.
19. Miyauchi, H. (2020). Digital learning environments for students with visual impairment. Springer.
20. Okonji, C., & Ogwezzy, N. (2019). Technology-assisted learning for visually impaired students in Nigerian universities. Journal of Educational Technology Systems, 47(3), 390–405. https://doi.org/10.1177/0047239518804009

21. Zhang, L., Wang, Y., & Yang, B. (2020). Digital technology use in education for students with visual impairment: A systematic review. Education and Information Technologies, 25(6), 5797–5819. https://doi.org/10.1007/s10639-020-10332-y
22. Tekane, J., & Potgieter, H. (2021). The impact of digital learning resources on the academic performance of visually impaired students. African Journal of Disability, 10, 1–9. https://doi.org/10.4102/ajod.v10i0.767
23. Butler, M., O'Donnell, E., & O'Keeffe, M. (2017). Using technology to enhance the learning experience of students with visual impairments in higher education. Journal of College Student Development, 58(7), 1146–1150.
24. Omede, A. A. (2015). The challenges of educating the visually impaired and quality assurance in tertiary institutions of learning in Nigeria. International Journal of Educational Administration and Policy Studies, 7(7), 129–133. https://doi.org/10.5897/IJEAPS2015.0407
25. Bergdahl, N., Nouri, J., Fors, U., & Knutsson, O. (2020). Engagement, disengagement and performance when learning with technologies in upper secondary school. Computers & Education, 145, 103733. https://doi.org/10.1016/j.compedu.2019.103733
26. Jaggars, S. S., & Xu, D. (2016). How do online course design features influence student performance? Computers & Education, 95, 270–284. https://doi.org/10.1016/j.compedu.2016.01.014
27. Ferian, A., & Sudrajat, D. (2022). Educational technology and innovation in the 21st century. Springer.
28. Ferguson, R., & Clow, D. (2017). Where is the evidence? A call to action for learning analytics. In LAK '17: Proceedings of the Seventh International Learning Analytics & Knowledge Conference (pp. 56–65). ACM. https://doi.org/10.1145/3027385.3027396
29. Soffer, T., & Nachmias, R. (2018). Effect of learning management system on student academic performance. Learning and Individual Differences, 62, 164–174. https://doi.org/10.1016/j.lindif.2018.01.011
30. Brulé, G. (2018). Culture, learning, and technology: A comparative analysis of digital learning approaches. Routledge.
31. Kurvinen, E., Kaila, E., Laakso, M. J., & Salakoski, T. (2020). Long term effects on technology enhanced learning: The use of weekly digital lessons in mathematics. Informatics in Education, 19(1), 51–75. https://doi.org/10.15388/infedu.2020.04
32. Daniela, G. (2019). Digital education: Challenges and opportunities. Springer.
33. Martiniello, N., Lehane, C., & Wittich, W. (2018). Exploring the use of smartphones and tablets among people with visual impairments: Are mainstream devices replacing the use of traditional visual aids? Assistive Technology, 34(1), 58–67. https://doi.org/10.1080/10400435.2019.1682084
34. Jafri, R., Aljuhani, A. M & Ali, S. A. (2017) "A tangible user interface-based application utilizing 3D-printed manipulatives for teaching tactual shape perception and spatial awareness sub-concepts to visually impaired children," International Journal of Child Computer Interaction, vol. 11, pp. 3-11, 2017https://doi.org/10.1016/j.ijcci.2016.12.001
35. Odame, P. K., Amoako-Sakyi, R. O., & Hotor, D. E. (2021). De-constructing disability: Perspectives of persons with disability (PWD) in an African city. Cogent Social Sciences, 7(1). https://doi.org/10.1080/23311886.2021.2013898
36. Almeida, F., Moreira, F., & Faria, L. (2020). The use of gamification in higher education: A systematic literature review. International Journal of Educational Technology in Higher Education, 17(1), 1–15.

37. Annoh, R., & Kumi, M. A. (2025b) Required Tools for Advancing Technology Enhanced Learning of Vision-Impaired Students in Ghana International Journal for Multidisciplinary Research (IJFMR) E-ISSN: 2582-2160 Retrieved from www.ijfmr.com
38. McLeod, S. (2019) Constructivism as a Theory for Teaching and Education Simply psychology.org/constructivism.html 1. Theories 2. Constructivism Retrieved online from file:///C:/Users/User/AppData/Local/Temp/simplypsychology.org-Constructivism as a Theory for Teaching and Education.pdf March 16, 2023
39. Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1), 3-10.
40. Spiro, R.J., Feltovich, P.J., Jacobson, M.J., & Coulson, R.L. (1992). Cognitive flexibility, constructivism and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. Duffy & D. Jonassen (Eds.), Constructivism and the Technology of Instruction. Hillsdale, NJ: Erlbaum.
41. Piaget, J. (1954). The construction of reality in the child. (M. Cook, Trans.). Basic Books/Hachette Book Group. https://doi.org/10.1037/11168-000
42. David, L. (2020, March 5). Distributed Cognition (DCog). Learning Theories. https://learning-theories.com/distributed-cognition-dcog.html
43. Creswell, J. W., & Creswell, J. D. (2023). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (5th ed.). SAGE Publications.
44. Bernard, H. R. (2011) Research Methods in Anthropology: Qualitative and Quantitative Approaches. Fifth ed. Altamira press NY
45. [Adam, A. M. (2020). Sample Size Determination in Survey Research. Journal of Scientific Research and Reports, 26, 90-97 https://doi.org/10.9734/jsrr/2020/v26i530263
46. Rudinger, R., Shwartz, V., Hwang, J. D., Bhagavatula, C., Forbes, M., Le Bras, R., Smith, N. A., & Choi, Y. (2020). Thinking Like a Skeptic: Defeasible Inference in Natural Language. In Findings of the Association for Computational Linguistics: EMNLP 2020 (pp. 4661–4675). Association for Computational Linguistics. https://aclanthology.org/2020.findings-emnlp.418/

References in the Reference List at the End of the Research Paper

1. Adam, A. M. (2020). Sample Size Determination in Survey Research. Journal of Scientific Research and Reports, 26, 90-97 https://doi.org/10.9734/jsrr/2020/v26i530263
2. Ahmad, S. ((2015) Green Human Resource Management: Policies and practices April 2015 Cogent Business & Management, 2(1):1=13 DOI:10.1080/23311975.2015.103081
3. Almeida, F., Moreira, F., & Faria, L. (2020). The use of gamification in higher education: A systematic literature review. International Journal of Educational Technology in Higher Education, 17(1), 1–15.
4. Annoh, R., & Kumi, M. A. (2025a) Predictor of Student Vision-Impairment Statuses as Determinant for Sustaining Inclusive Classroom Education in Ghana International Journal for Multidisciplinary Research (IJFMR) Volume 7, Issue 3, May-June 2025 E-ISSN: 2582-2160 Retrieved from www.ijfmr.com
5. Annoh, R., & Kumi, M. A. (2025b). Required Tools for Advancing Technology-Enhanced Learning of Vision-Impaired Students in Ghana. International Journal For Multidisciplinary Research, Volume (IJFMR) 7, Issue 3, May-June 2025 E-ISSN: 2582-2160 Retrieved from www.ijfmr.com

6. Bergdahl, N., Nouri, J., Fors, U., & Knutsson, O. (2020). Engagement, disengagement and performance when learning with technologies in upper secondary school. Computers & Education, 145, 103733. https://doi.org/10.1016/j.compedu.2019.103733
7. Bernard, H. R. (2011) Research Methods in Anthropology: Qualitative and Quantitative Approaches. Fifth ed. Altamira press NY
8. Brulé, G. (2018). Culture, learning, and technology: A comparative analysis of digital learning approaches. Routledge.
9. Butler, M., O'Donnell, E., & O'Keeffe, M. (2017). Using technology to enhance the learning experience of students with visual impairments in higher education. Journal of College Student Development, 58(7), 1146–1150.
10. Creswell, J. W., & Creswell, J. D. (2023). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (5th ed.). SAGE Publications.
11. Daniela, G. (2019). Digital education: Challenges and opportunities. Springer.
12. David L, "Distributed Cognition (DCog)," in Learning Theories, March 5, 2020, https://learning-theories.com/distributed-cognition-dcog.html.
13. Derkye, C. (2019). Utilization of information communication technology in the training and education of students with visual Impairment in tertiary institutions in Ghana (Doctoral dissertation, University of Cape coast).
14. Ferguson, R., & Clow, D. (2017). Where is the evidence? A call to action for learning analytics. In LAK '17: Proceedings of the Seventh International Learning Analytics & Knowledge Conference (pp. 56–65). ACM. https://doi.org/10.1145/3027385.3027396
15. Ferian, A., & Sudrajat, D. (2022). Educational technology and innovation in the 21st century. Springer.
16. Garzón, J. (2021). The impact of digital technologies on learning in higher education: A systematic review. Education and Information Technologies, 26(6), 6667–6689. https://doi.org/10.1007/s10639-021-10651-7
17. Giraud, A., Hofer, C., & Schwab, S. (2017). The use of mobile learning in inclusive education. International Journal of Inclusive Education, 21(9), 922–935.
18. Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022) Understanding the role of digital technologies in education: A review Sustainable Operations and Computers Volume 3, 2022, Pages 275-285
19. Hewett, R., Kettley, C., & Kettley, P. (2019). Designing accessible learning: A guide for educators. Routledge.
20. Iakovidis, D. K., Diamantis, D., Dimas, G., Ntakolia, C., & Spyrou, E. (2020). Digital enhancement of cultural experience and accessibility for the blind. In Technological trends in improved mobility of the blind (pp. 237–271). Springer.
21. Izzo, M. V., & Bauer, A. M. (2015). Assistive technology for students with disabilities: A handbook for school professionals. Pearson.
22. Jafri, R., Aljuhani, A. M & Ali, S. A. (2017) "A tangible user interface-based application utilizing 3D-printed manipulatives for teaching tactual shape perception and spatial awareness sub-concepts to visually impaired children," International Journal of Child Computer Interaction, vol. 11, pp. 3-11, 2017 https://doi.org/10.1016/j.ijcci.2016.12.001
23. Jaggars, S. S., & Xu, D. (2016). How do online course design features influence student performance? Computers & Education, 95, 270–284. https://doi.org/10.1016/j.compedu.2016.01.014

24. Kurvinen, E., Kaila, E., Laakso, M. J., & Salakoski, T. (2020). Long term effects on technology enhanced learning: The use of weekly digital lessons in mathematics. Informatics in Education, 19(1), 51–75. https://doi.org/10.15388/infedu.2020.04
25. Maguvhe, M. M. (2015). Access to information and communication technologies for people with visual impairment in South Africa. African Journal of Library, Archives and Information Science, 25(2), 173–186.
26. Martiniello, N., Lehane, C., & Wittich, W. (2018). Exploring the use of smartphones and tablets among people with visual impairments: Are mainstream devices replacing the use of traditional visual aids? Assistive Technology, 34(1), 58–67. https://doi.org/10.1080/10400435.2019.1682084
27. McLeod, S. (2019) Constructivism as a Theory for Teaching and Education Simply psychology.org/constructivism.html 1. Theories 2. Constructivism Retrieved online from file:///C:/Users/User/AppData/Local/Temp/simplypsychology.org-Constructivism as a Theory for Teaching and Education.pdf March 16, 2023
28. Metatla, O., Bardot, S., & Bessa, M. (2019). Accessibility and usability of educational technologies for visually impaired students. British Journal of Educational Technology, 50(6), 3326–3340. https://doi.org/10.1111/bjet.12879
29. Miesenberger, K. (2015). Advanced and emerging solutions: ICT and AT in education of low vision and blind students. In Enabling Access for Persons with Visual Impairment, pg 17-26.
30. Mitchell, D., & Sutherland, D. (2020). What really works in special and inclusive education: Using evidence-based teaching strategies (3rd ed.). Routledge.
31. Miyauchi, H. (2020). Digital learning environments for students with visual impairment. Springer.
32. Ngubane-Mokiwa, S. A., & Khoza, S. B. (2021). Using community of inquiry (CoI) to facilitate the design of a holistic e-education experience for students with vision impairments. Education Sciences, 11(4), 152.
33. Odame, P. K., Amoako-Sakyi, R. O., & Hotor, D. E. (2021). De-constructing disability: Perspectives of persons with disability (PWD) in an African city. Cogent Social Sciences, 7(1). https://doi.org/10.1080/23311886.2021.2013898
34. Okonji, C., & Ogwezzy, N. (2019). Technology-assisted learning for visually impaired students in Nigerian universities. Journal of Educational Technology Systems, 47(3), 390–405. https://doi.org/10.1177/0047239518804009
35. Omede, A. A. (2015). The challenges of educating the visually impaired and quality assurance in tertiary institutions of learning in Nigeria. International Journal of Educational Administration and Policy Studies, 7(7), 129–133. https://doi.org/10.5897/IJEAPS2015.0407
36. Pacheco, E., Miriam L., & Yoong, P. (2018) Transition 2.0: Digital technologies, higher education, and vision impairment The Internet and Higher Education 37:1-10
37. Paolini, A. (2015). Assistive technology for individuals with visual impairments. Springer
38. Piaget, J. (1954). The construction of reality in the child. (M. Cook, Trans.). Basic Books/Hachette Book Group. https://doi.org/10.1037/11168-000
39. Rudinger, R., Shwartz, V., Hwang, J. D., Bhagavatula, C., Forbes, M., Le Bras, R., Smith, N. A., & Choi, Y. (2020). Thinking Like a Skeptic: Defeasible Inference in Natural Language. In Findings of the Association for Computational Linguistics: EMNLP 2020 (pp. 4661–4675). Association for Computational Linguistics. https://aclanthology.org/2020.findings-emnlp.418/

40. Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1), 3-10
41. Soffer, T., & Nachmias, R. (2018). Effect of learning management system on student academic performance. Learning and Individual Differences, 62, 164–174. https://doi.org/10.1016/j.lindif.2018.01.011
42. Spiro, R.J., Feltovich, P.J., Jacobson, M.J., & Coulson, R.L. (1992). Cognitive flexibility, constructivism and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. Duffy & D. Jonassen (Eds.), Constructivism and the Technology of Instruction. Hillsdale, NJ: Erlbaum.
43. Tekane, J., & Potgieter, H. (2021). The impact of digital learning resources on the academic performance of visually impaired students. African Journal of Disability, 10, 1–9. https://doi.org/10.4102/ajod.v10i0.767
44. Tsapali, M., Major, L., Damani, K., Mitchell, J., & Taddese, A. (2021). Country-Level Research Review: EdTech in Ghana.
45. Webb-Williams, J. (2018). Assistive technology and inclusion in schools. Routledge.
46. Zhang, L., Wang, Y., & Yang, B. (2020). Digital technology use in education for students with visual impairment: A systematic review. Education and Information Technologies, 25(6), 5797–5819. https://doi.org/10.1007/s10639-020-10332-y