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Risks Associated with Technology-Enhanced-Learning in Inclusive Education of Students with Vision-Impairment in Ghana

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Abstract

Educational Technology-Enhanced Learning (ETEL) poses inherent risks and challenges associated with integration in vision-impaired contexts, including usability, digital literacy, and infrastructural constraints. This study evaluates risks associated with the integration of ETEL in inclusive classrooms towards advancing science education of students with vision impairment by examining the relative challenges faced by diversity of vision-impaired students. Using mixed methods approach, 1532 students, including fully sighted, partially sighted, and students with no sight, responded to interviews on risks and challenges associated with integration in vision-impaired contexts. The average rating of 2.11, std. dev. 1.019 suggests that students encounter moderate levels of difficulty in accessing or utilizing technology. However, irrespective of vision status, students face a baseline probability of encountering challenges with technology. Major risks include lack of funding (40.2%) and technical issues (29.0%). Funding, training and technical support are critical to mitigating risks in TEL implementation. Measures include increased funding (34%), technical support (29%), and user training (37%). Digital literacy correlates strongly with TEL effectiveness ($r = 0.63$). Higher digital literacy improves TEL, highlighting the need for targeted literacy training programs.

Keywords: Inclusive Classroom Education, Vision-Impaired, Student Challenges, Educational Technology-Enhanced-Learning Risks

Introduction

Background of the Study

The global academic discourse affirms the transformative potential of TEL in inclusive education. However, the initiative for inclusive classroom education has not adequately considered peculiar risks to education of vision-impaired students. Such disregard suggests to this study to evaluate risks associated with the integration of Education Technology-Enhanced Learning (ETEL) in inclusive classrooms towards advancing science education of students with vision impairment. Moreover, such disregard perpetuates systemic risks and limits effective contributions of vision-impaired students to socio-economic development life and successful educational outcomes. Addressing this issue is crucial to fostering inclusivity and ensuring that vision-impaired students overcome implementation risks and thrive in academic and professional spheres [1], [2]. For instance, one potential risk is posed by the conventional seating arrangement of fixed rows and columns of seats in the inclusive classrooms [3]. This kind of seating arrangement ignores the potential risks of vision-impaired student engagement and accessibility with varied educational technology tools, resources and strategies and effect of those risks on their individual or collective educational experiences. Hence, this study focuses on potential risks associated with engagement and accessibility, for students with vision impairment, with diverse educational technology tools, resources and strategies and effect of those on their educational experiences. In doing this, the potential that Educational Technology-Enhanced Learning (ETEL) has for addressing accessibility, equity and inclusion barriers to students are examined by this study. This study establishes that diverse risks impede education of students with vision impairment through uses of Educational Technology Enhancements (ETEs) in inclusive classrooms.

Statement of the Problem

Historically, educational systems have prioritized general learning enhancements without focusing on engagement and accessibility for students with various disabilities [4], [5]. In science education, for instance, where visualization and interaction are critical, students with vision impairment face significant disadvantages due to limited engagement and access to tailored tools and resources. [6] highlight the absence of inclusive design approaches in TEL environments, which prevents students with vision impairment from fully engaging with digital learning platforms, but in this context focusing on engagement in the inclusive classroom. The current state of TEL in Ghana reveals infrastructural gaps, inadequate teacher training, and limited resource allocation for inclusive education [7]. These challenges perpetuate inequities in learning outcomes and hinder students with vision impairment from pursuing science-related disciplines, thereby restricting their participation in science and technology-driven industries. The real-world implications of this problem are apparent risks when students with vision impairment are excluded from science education due to technological barriers. The risk perpetuates systemic inequalities and limits students with vision problems from contributing to socio-economic development. Addressing this risk issue is crucial to fostering inclusivity and ensuring that students with vision impairment access opportunities to thrive in academic and professional spheres [1], [2]. Although Educational Technology-Enhanced Learning (ETEL) offers transformative long-term opportunities for vision-impaired students in science education [8], where visualization and interaction are critical in the classroom, students with vision impairment face risks that emanate from inadequate tailored ETE tools, resources or strategies. For instance, focusing on student engagement in the inclusive classroom [6] highlight the absence of inclusive design approaches in ETEL environments as risks which prevents diverse vision-impaired students from fully engaging with digital learning platforms. A careful look at the careless bulking of different vision-impaired students for inclusive classroom education suggest inadequate attention paid to the diversity and ultimate differences in educational technological risks faced by students due to student vision problems [3]. It therefore becomes crucial for this study to analyse the risks associated with ETEL integration so as to foster inclusivity and ensure that every category of vision-impaired students [3] can access ETEL opportunities to overcome systemic inequities and limitations towards active learning and future social and educational development [9]. This study determines risks that impede the implementation of ETEL in inclusive classrooms for vision-impaired students, thereby reducing technological barriers to science education, and addressing subject-specific challenges, such as complex visual representations and laboratory experiments. Understanding the diverse risks is crucial for highlighting the potential of ETEL to support individualized and group accessible learning experiences, thereby demonstrating how ETEL can foster autonomy and lifelong learning skills towards long-term educational success.

Relevant Literature on the Subject

Education of the student with vision-impairment seems to project a status of deprivation of education opportunities and advantages usually in knowledge acquisition, attitudinal changes and skill development. The increased usage of Technology-enhanced education is introduced due to the development of many types of complex systems in the form of technology enhancements to provide educational opportunities and advantages to the student with vision impairment using Educational Technology Enhancements (ETEs) for advancing and achieving effectiveness [9]. In the view of [10] enhancements facilitate fundamental educational practices or processes of education and ultimately offer opportunities for scaling in education, as well as advantages for flexible education, providing the teacher spaces for innovations to facilitate education. However, [10] ignore the risks associated with uses of ETEs for education of diverse students with vision impairment in inclusive classrooms. Prior studies note that, Educational Technology Enhancements (ETEs) offer scalability, flexibility, and new methods of facilitation in education and thereby open up democratic and accessible educational opportunities [10]. Technology Enhancements provide speed that are much faster than humans, as well as consistency by being efficient in doing repetitive jobs consistently, and thereby produce the same results for the same jobs [10]. Technology enhancements provide accuracy by tracking small differences and show reliability to produce the same results again and again [10]. Contrary studies however, suggest that, technology creates more problems than it solves and acts to accelerate social ills in education thereby failing to meet the high expectations [11]. This presents unexplained risks associated with use of ETEs in inclusive education among students with vision-impairment. The reason is, Flexibility in new technologies in education is no more [12] and there is lack of scalability of success rates in e-education, for instance, [13] suggesting the need to evaluate risks related to uses of ETEs among students with diverse vision impairment. Hence, this review examines risks associated with technology enhancement in specified vision-impaired learning environments.

First, the risks and challenges associated with implementation of technology enhancement for vision-impaired students are discussed because, implementation of Technology-Enhanced Learning (TEL) for students with vision impairment presents unique risks and challenges. The risks and challenges include wrong engagement, inaccessibility, inadequate or untailored infrastructure, teacher unpreparedness, and the unsuitability of specific technologies for vision-impaired student related issues. This review examines existing research, highlighting the strengths and limitations of empirical studies while identifying theoretical, methodological, practical, and contextual gaps. The potential and challenges of Artificial Intelligence (AI) in education were explored by [14], emphasizing the transformative impact of Artificial Intelligence (AI) in education on personalized learning. The study by [14] is notable for highlighting the role of AI in customizing learning experiences, which is particularly relevant for vision-impaired students. However, [14] fail to address the accessibility concerns associated with AI-driven systems, such as the difficulty of navigating complex interfaces by vision-impaired users posed by technological risks. Additionally, [14] neglect to consider the ethical implications of data collection and privacy, which are significant risks in deploying AI technologies in education. A focus on interactive Digital Media and Collaborative Learning led [15] to investigate the use of interactive digital media to enhance collaborative learning. The study by [15] is commendable for identifying the potential of digital media in fostering engagement and collaboration among learners, including those with disabilities. However, [15] overlook the unique challenges faced by vision-impaired students in interacting with visual-centric digital media, such as videos or animations. Furthermore, [15] do not address the technical training required for both educators and learners, a critical risk factor in ensuring the effective implementation of such technologies [16] examine the integration of Augmented Reality (AR) into problem-based learning, focusing on its impact on learning achievement and attitudes. The study by [16] is innovative in demonstrating how AR can make abstract concepts more tangible, which is particularly beneficial for students with vision impairment in science education. However, [16] fail to address the limitations of AR for no-vision students, such as the lack of tactile or auditory alternatives to visual elements. Additionally, the research by [16] is limited in its exploration of accessibility features, posing risk by making it less applicable to inclusive learning environments. To augment this effort, [17] conduct a systematic review and meta-analysis of AR in educational settings, identifying key benefits and challenges. [17] however, do not adequately consider the infrastructural barriers to implementing AR technologies, particularly in resource-constrained settings. Moreover, the review by [17] is limited in its focus on general educational contexts, with insufficient attention paid to the specific needs of vision-impaired students. In sum, the reviewed literature underscores the potential of TEL to enhance learning experiences for vision-impaired learners but highlights significant risks and challenges associated with their implementation. These include accessibility concerns, infrastructural barriers, and lack of inclusive design features. Addressing these gaps through inclusive pedagogical frameworks, empirical validations, and context-sensitive approaches is essential for the successful adoption of TEL technologies in vision-impaired learning environments.

Second, issues such as digital literacy, infrastructure, and usability affect TEL outcomes for students with vision impairment are discussed because the success of Technology-Enhanced Learning (TEL) for students with vision impairment is deeply influenced by factors such as digital literacy, infrastructure, and usability. These elements play critical roles in determining the accessibility, adoption, and effectiveness of TEL. This part of the review therefore examines the literature to evaluate how those factors affect TEL, highlighting strengths, limitations, and gaps in existing research. [18] explore the use of mobile devices as assistive technology in resource-limited environments, focusing on students with vision impairment in Kenya. [18] address the infrastructural challenges faced by students with vision impairment, such as limited access to electricity and internet connectivity. However, [18] do not adequately explore how digital literacy influences the effective use of these devices, leaving a critical gap in understanding how students can be empowered to use technology effectively. Additionally, the study by [18 is limited in its focus on basic mobile devices, without considering more advanced assistive technologies. Comparing E-Learning Interfaces, [19] looked at e-learning interfaces among students with and without visual or hearing impairments, identifying usability challenges as a key barrier. The study by [19] highlights how usability issues, such as poor navigation and inaccessible design, hinder TEL outcomes for students with vision impairment. However, [19] do not sufficiently address the role of digital literacy in mitigating these challenges, which is crucial for empowering learners to navigate e-learning platforms. Furthermore, the study by [19] is limited in its scope, as it primarily focuses on usability without considering broader infrastructural constraints. A crucial look at Digital Inclusion and Web Accessibility by [20] examine the lived experiences of students with vision impairment in accessing web-based information in higher education institutions in Ethiopia. [20] provide an understanding of the barriers to digital inclusion, including infrastructural and usability challenges. However, [20] fail to explore how digital literacy programs could enhance accessibility, leaving a methodological gap in addressing solutions to these challenges. Additionally, the study by [20] is context-specific, which may limit its generalizability to other regions with differing infrastructural realities. [21] investigates enhanced mobile learning (m-learning) solutions for vision-impaired students in Tanzania, emphasizing the importance of tailored assistive technologies. The study by [21] is innovative in addressing how infrastructure and usability can be optimized to support vision -impaired students, particularly in higher education. However, [21] neglects to evaluate the digital literacy skills required to use these tools effectively, which is critical for ensuring positive TEL outcomes. Additionally, the study by [21] is limited in its empirical validation, as it primarily relies on theoretical models without extensive field testing. Studies on Modern Assistive Technology in Secondary Education by [22] explores the effects of modern assistive technology on educational achievement among students with vision impairment in a Kenyan secondary school. Oira (2016) highlights how infrastructure, such as the availability of assistive tools, influences educational outcomes. However, [22] does not sufficiently examine the interplay between usability and digital literacy, which are crucial for maximizing the potential of these tools. Furthermore, [22] focused on a single institution, which limits its applicability to broader educational contexts. A focus on Technical and Semantic Accessibility by [23] discuss the transition from technical accessibility to semantic intelligibility, emphasizing the importance of meaningful information design for vision-impaired students. The study by [23] is insightful in highlighting the need for information to be both technically accessible and semantically understandable, which directly impacts usability. However, [23] do not adequately explore the infrastructural barriers that hinder the adoption of accessible information systems, leaving a practical gap in addressing systemic challenges. Additionally, the study by [23] is limited by its lack of focus on digital literacy, which is essential for interpreting semantically complex information. In Ghana, ICT Accessibility by [24] examines the accessibility of ICT tools for students with vision impairment, focusing on infrastructural and usability challenges. The study by [24] is commendable for identifying critical barriers, such as lack of accessible design and limited infrastructure, which hinder TEL outcomes. However, [24] fails to address how digital literacy programs could be integrated into existing educational frameworks, leaving a theoretical gap in understanding how to bridge these challenges. Furthermore, [24] narrowly focuses on a specific region, which may limit its relevance to other contexts. In conclusion, the reviewed literature underscores the critical role of digital literacy, infrastructure, and usability in shaping TEL outcomes for students with vision impairment. However, significant gaps remain, particularly in integrating digital literacy programs, addressing infrastructural limitations, and ensuring usability for diverse contexts. Future research should focus on context-sensitive, scalable solutions that empower vision -impaired learners through enhanced digital inclusion and accessible design.

Third, the measures for mitigating identified risks to ensure successful technology integration in vision-impaired learning environments are discussed because integrating technology in vision-impaired learning environments poses significant challenges that need to be addressed. To address those challenges, measures that enhance accessibility, usability, and implementation are identified and evaluated. Hence, this part of the review examines existing research on strategies to mitigate risks and ensure successful technology integration, focusing on theoretical, methodological, practical, and contextual dimensions. Assistive Technology for Inclusive Education was proposed by [25] who highlights the importance of assistive technology in creating inclusive educational environments, emphasizing tools such as tactile graphics and screen readers. [25] proposes practical measures to enhance accessibility, such as tailoring technology to specific student needs. However, [25] fails to address scalability of these solutions, particularly in resource-limited settings. Additionally, its focus on general accessibility measures overlooks the broader risks associated with technology adoption, such as infrastructural challenges and digital literacy gaps. [26] conduct a systematic review of assistive technology use in higher education, identifying its positive effects on student outcomes. [26] provide evidence of their impact on academic performance and engagement. However, [26] neglect to explore specific risk mitigation strategies, such as training programs for educators and students that ensure effective use of these technologies. Furthermore, the findings by [26] are limited to higher education, which restricts their applicability to primary and secondary levels. Studies on Digital Technologies in Education by [27] review the role of digital technologies in education, discussing their potential to transform learning environments. [27] highlight measures to integrate digital tools effectively, such as adopting adaptive learning platforms and ensuring infrastructure support. However, [27] fail to focus on the unique needs of vision-impaired students, leaving a significant gap in addressing accessibility risks. Additionally, the research by [27] is largely theoretical, with limited empirical evidence to validate proposed solutions. [28] investigate the influence of signalling in Virtual Reality (VR) on learning outcomes and cognitive load. The study by [28] is innovative in demonstrating how specific design features, such as signalling cues, can mitigate usability challenges and enhance learning experiences. However, [28] do not adequately address how these features can be adapted for vision-impaired students, who may require alternative modalities such as auditory or tactile signals. Furthermore, the research by [28] is limited to VR applications, which reduces its relevance to other TEL technologies. A study on Expanded Core Curriculum for Vision Impairment by [29] discusses the importance of the Expanded Core Curriculum (ECC) for students with vision impairment, which includes skills such as assistive technology use and orientation. [29] emphasizes the need for tailored educational frameworks, providing a strong foundation for technology integration. However, [29] fails to address how ECC principles can be operationalized in diverse educational contexts, particularly in low-resource environments. Additionally, [29] narrowly focused on curriculum design, leaving a gap in addressing the broader infrastructural and usability challenges associated with TEL. Computer Vision for Assistive Technologies by [30] explores the application of computer vision in assistive technologies, highlighting its potential to enhance accessibility for vision-impaired learners. The study by [30] is pioneering in its exploration of advanced technologies such as object recognition and navigation aids, offering innovative solutions to mitigate accessibility risks. However, [30] neglect to address the ethical and practical challenges of deploying such technologies, such as data privacy concerns and the high costs of implementation. Additionally, the research by [30] lacks empirical validation in educational settings, limiting its practical relevance. In conclusion, this art of the reviewed literature provides valuable insights into measures for mitigating risks associated with TEL integration in vision-impaired learning environments. However, significant gaps remain, particularly in addressing scalability, empirical validation, and contextual adaptability. Future research should focus on designing evidence-based, context-sensitive TEL integration that empower vision-impaired students and ensure the successful adoption of TEL technologies.

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. In the context of vision impairment, global literature points to specific TEL innovations that have revolutionized science education. For example, focusing on Accessible Digital Content, [31] share the development of digital textbooks, online resources, and educational videos are specifically designed with Universal Design for Learning (UDL) principles and accessibility features such as audio descriptions, braille compatibility, adjustable font sizes, high contrast themes) has proven critical [31]. A look at Specialized Assistive Technologies point to uses of devices such as refreshable braille displays, advanced screen readers such as NVDA, JAWS, talking scientific calculators, and braille notetakers that have empowered vision=impaired students to independently engage with complex scientific notation, perform calculations, and record experimental data [26]. [32] note that, with the use of Virtual Laboratories and Simulations, when meticulously designed with accessibility in mind, for instance, incorporating haptic feedback, comprehensive audio cues, and keyboard navigation, virtual labs offer safe, repeatable, and effective means for vision-impaired students to conduct experiments, explore scientific phenomena, and analyse results that might otherwise be dangerous or inaccessible in traditional settings [32]. Analysis of Tactile Graphics and 3D Printing by [33] note that, the advent of 3D printing, combined with principles of tactile graphics design, allows for the creation of multi-sensory learning aids that enable students to physically interact with and understand complex scientific diagrams, molecular structures, anatomical models, and abstract concepts. However, the optimistic global narrative by [33] contrasts sharply with the localized realities observed in Ghana. While Ghanaian educational policies, such as the Inclusive Education Policy by the GES, Ministry of Education articulate clear commitment to accommodating students with special needs and promoting UDL, their practical implementation, particularly concerning specific TEL provisions for science education for the vision-impaired student, remains a significant challenge. Recent Ghanaian studies frequently identify pervasive barriers such as Inadequate ICT Infrastructure. For example, research from Ghanaian authors often points to insufficient access to functional computers, unreliable internet connectivity, and inconsistent power supply, particularly in rural secondary schools [34], Scarcity of Specialized Resources such as critical shortage of the specific assistive technologies and accessible science content crucial for vision impaired learners, leading to a severe resource gap [35]). Studies on Teacher Training Deficiencies see a recurring theme as the widespread lack of specialized professional development opportunities for science educators to effectively integrate TEL tools or adapt content for vision impaired students [35]. To address the Policy-to-Practice Gap, [36] highlights the ambitious goals outlined in national policies often struggling with effective translation into tangible, funded, and widespread TEL implementation at the school level for students with disabilities [36]. This literature review underscores that while the potential of TEL to revolutionize science education for vision impaired students is universally recognized, its realization in the Ghanaian secondary school context requires a deliberate, targeted, and well-resourced strategic approach that addresses the identified gaps. [37] looked at advantages and disadvantages of enhancement by doing a required meta-analysis of distraction among children to examine technology enhancement resources that meet the needs of specified categories of vision-impaired students. The focus on enhancements that use story comprehension skills suggest that narratives, use of tablet or smartphone and apps on iPads or iPhones to access stories by children augment education. The risks associated with technology enhancement in specified vision-impaired student education environments analyse threats associated with required technology enhancement methods, categorizing characteristics of students as risks, describing vision-impaired student education environments as threats to education advancement that affect educational practice. Using a Meta-Analysis, [37] studied advantages and disadvantages offered by multimedia and interactive features in Technology-Enhanced storybooks, to find the effects of technology-enhanced stories for young children's literacy development, when compared to listening to stories in more traditional settings like storybook reading. The different characteristics of technology-enhanced stories, multimedia features like animated pictures, music, and sound effects in contrast with interactive elements like hotspots, games, and dictionaries were analysed for distraction among children who were disadvantaged because of less stimulating family environments. In terms of methods required to be employed by students with vision impairment to advance education, there is the need to analyse threats associated with required technology enhancement methods, categorize threats as risks associated with technology enhancement. Analysing the concept of Scalability as required output of Technology-Enhanced Education [38] found that scalability generates the possibility for an innovation to diffuse effectively across a culture and context. The context of educational change was introduced by [39] in order to define scaling as the deliberate expansion of an externally developed school restructuring design that previously has been used successfully in one or a small number of school settings. However, [38] acknowledged that a change initiative can be implemented by examining a school or community of practice because only addressing quantity is an oversimplified perspective on scalability. This study focuses on the internal school environment. [40] warn against the assumption that innovations are not dependent on local variations, granting that successful change in one context might have very different results in other contexts. This assertion makes it clear that, earlier discussions ignored complexity and importance of context [38]. The contrast is revealed in her seminal article, where [41] proposed a multidimensional view of scalability that distinguished between depth, sustainability, spread and shift in ownership. The study uses the multidimensional approach that supports inquiry across contexts to address issues of scalability which makes change relevant in different schools [42]. In doing this, the study addresses Depth to understand essential characteristics of innovation [38]. Such approach requires teachers to change their pedagogical practices and their beliefs about what constitutes “good education” [41]. The approach also addresses shift of ownership in order to relate to the need for innovation to be owned by all stakeholders involved, to ensure that different stakeholders assume primary responsibility for the initiative over time [38]. Further, studies on scalability by [43] extended [41] framework to include evolution. Evolution refers to the way stakeholders use, adapt and implement innovation in their local contexts [38]. The definitions of stakeholders also impact the way designers see innovation. Evolution thus suggests that innovation develops because of interaction between users and designers of innovation [38]. Hence, dissemination of educational innovations is not only about quantity, but also about multidimensional factors that create quite a bit of overlap between sustainability and scalability, as it is often viewed that sustainability is a necessary condition for scalability [43], [41]. This means that, attending to sustainability issues is essential in bringing educational innovations to scale. This makes it important for the study to work closely with teachers and schools to identify risks related to educational support services that are needed to sustain and scale innovations.

For example, [38] reported that since Ghana introduced digital technologies into the school curriculum in September 2007 the importance of safe integration of ICT into the curriculum at all levels has been the focus. The new curriculum in Mathematics at Senior High School was expected to encourage teachers to make use of computers for problem solving and investigations of real-life situations in order to help students develop analytical thinking habits and capacity to apply knowledge in solving practical problems [38]. To support this aim, government and other institutions invested large sums of money to procure computers and established computer labs to scale this use across Senior High Schools nationwide [38]. However, it was unclear whether these efforts had a broad and sustained effect on appropriate use of computers by teachers in their instruction due to risks related to implementation. To ensure teachers were prepared to deliver the new curriculum, it was necessary to address Mathematics training at pre-service teacher level. This required scaling of this new orientation to ICT-supported mathematics teaching and education in university teacher training programs across Ghana [38].

Focusing on education environment as determinant of outcome of vision-impaired student education, a typical education environment portrays a government initiative launched to begin a process of collecting progressive data on the initiative [38]. The initiative comprises a professional development program, in which students are introduced to collaborative design principles, to prepare final year pre-service teachers to integrate ICT in teaching mathematics in a teacher education institute [45], [46]. The ICT-based innovation for example, consists of two related components including (1) Education of Technology by Collaborative Design (LTCD) as a process, and (2) ICT-enhanced Activity-Based Lessons in mathematics (ICT-ABL) as a product. The approach was applied to a regular mathematics-specific instructional technology course at teacher education institute [45]. Approximately 6, 18, and 28 months after three interventions respectively, pre-service mathematics teachers who participated in the studies were posted into various Senior High Schools and pursued careers as mathematics teachers [45]. The study employed an embedded mixed-method research design to examine the extent to which 100 of the pre-service teachers were able to transfer the knowledge and skills gained during their preservice training and utilize the ICT-based innovation with their students [45]. [46] reported a follow-up study that was conducted to determine how well they continued to used ICT knowledge and skills learned as preservice teachers. The findings showed that, pre-service teachers maintained positive pedagogical views they developed during collaborative design in teams in their pre-service teacher preparation program [45]. This insight suggests increased depth and possible sustainability, and through a deep understanding of the innovation. The second most influential factor affecting the continued use of ICT-based innovation by teachers was their education characteristics [45]. However, sustainability was strongly affected by the amount of variance attributed to knowledge of teachers and persuasion related to innovation, specifically education characteristics related to adoption of new practices and transfer [45]. The most critical education characteristics reported were knowledge and skills related to ICT use [45]. These factors suggest scalability of the initiative. However, school environment factors were not significant predictor of transfer of education, probably because of lack of variation in school-related factors across schools. Interview and observation data indicated that teachers faced constraints related to school environment that contributed to lack of creativity in using certain components of the ICT-based innovation [45]. Particularly, lack of access to ICT infrastructure and an unenthusiastic school culture were mentioned as hindering the use of ICT-ABL. In conclusion, the study revealed that the relationship between scalability and sustainability could be attributed to teacher-related factors in the context.

In a Tanzania case, [38] reported government efforts to ensure that schools with electricity connection had access to computers. However, access to Internet was a problem because primary and secondary schools used low-bandwidth modems to connect to the Internet [38]. Contextual factors affected the lack of sustainability and differed between the schools. For instance, in private school, lack of support from school administration and low motivation due to job insecurity and double employments affected sustainable use of technology. In government school, lack of support from school management impeded sustainable use of technology [38]. In addition, few available technology tools, unreliable electricity, overcrowded classes, busy time schedules and no incentives prevented teachers from using technology [38]. Similar conditions of unreliable electricity, lack of tools, large class size was present in government schools where teachers used their own laptops to teach [38]. The insight suggests positive integration of technology enhancement in vision-impaired student education. To address barriers to successful vision-impaired student education, [38 used four factors that influenced sustainability to structure analysis on sustained use of technology at a given location including characteristics of intervention, personal factors, institutional factors, and technology factors. [[47] referred to first-order barriers as obstacles to implementation and sustainability in schools, including technology access, reliable electricity, class size among others. Reporting the Canada case involving Remote Networked School (RNS) [38] examined a question that was asked by a Quebec Government Deputy Minister on the use of ICT in small rural schools to enrich education. Concepts and tools related to collaborative education and knowledge building were suggested to include videoconferencing system for verbal exchanges and knowledge forum for written discourse [48]. The RNS is currently characterized by activities involving students from distant classrooms that are co-designed by teachers with online/onsite external support to allow teachers to guide students as they engage in collaborative projects and inquiries or presentations to one another's team or classroom [48]. The study found that, the five dimensions of scalability were clearly present in the initiative. With regard to Depth, the initiative model gained support from the various stakeholder groups. Ethnographic data regarding context as well as local, national and international-level testing of education outcomes in the participating schools were gathered on an iterative basis. Persuasive education outcomes were obtained, especially when classrooms transformed into emerging knowledge building communities, such as of Vocabulary, growth, types of questions asked and levels of explanation reached. This research design allowed for deep investigation into the characteristics of the innovation and how they evolved in different contexts. Seeing the original model being adapted in a number of different ways by school-district and school practitioners, the research and intervention team modified its own understanding and practice of ICT use for teaching and education, and reinvested this education into further iterations of the initiative. Whether or not participating school districts applied integrally or not the original model, Government's funding was allocated to a growing number of them. This demonstrates flexibility that supports Scaling of the initiative. The Ghana and Tanzania cases show the importance of addressing key features of innovation and context that support sustainability and scalability. It is necessary to consider how aspects of the innovation and context interact to promote sustainability and scale to other contexts. In both the Ghana and Tanzania cases, innovation was not sustained primarily due to contextual issues, such as organizational needs and resource limitations. Such findings point to the need for analysing resource requirements for advancing the education of vision-impaired students. In Australian and Canadian cases, decision to adopt new technology-related teaching practice was less structured. In a Canadian case, a model of implementation was proposed, but schools adopted it to suit their needs. In Australia, schools and teachers negotiate the use of the new laptops individually and in response to their own needs [38]. This type of approach resulted in less clear timeline of when and how technologies were adopted and implemented [38]. It is possible that evolution of innovations allowed for ownership, and therefore supported scalability across schools. However, in Australian example, teachers perceived that other stakeholders, such as state and federal governments, were not invested in innovation, which weakened potential for scalability by lack of commitment from leadership [38] This issue points to the importance of creating productive partnerships among stakeholders. In sum technological innovation implementation is deeply contextual, with implementation of a given innovation playing out differently in different contexts and across multiple iterations within the context.

The New Value of Research which is Innovation

Identified key factors of sustainability and scalability show how they manifest in four different contexts through descriptive cases. Based on these, some short- and long-term recommendations emerged from discussions [38]. This informs the study to examine innovative technology integration that includes multiple stakeholders and pay attention to context. In view of those, the study identifies research-informed approaches to technology integration that are sustainable and scalable. In following those, opportunities and support may be provided for scholars to synthesize research from successfully scaled and sustained innovations into future innovation designs that address technology integration in education.To foster equitable and effective learning environments for students with vision impairment, this study illustrates how ETEL determines learning outcomes of inclusive classroom education of vision-impaired students. A focus on integrating technological innovations in vision-impaired student education towards developing sustainable and scalable approaches to technology integration that are based on research literature rather than policy initiatives, may use research to deconstruct fads and communicate appropriate research findings to stakeholders on the basis of accumulated research results. Further, scholars could extract best practice examples of successfully scaled and sustained innovations, and thereby build comprehensive body of knowledge about scalable and sustainable innovation designs based on research findings to inform decision-making and policy. Also, technology integration and innovation designs that have successfully scaled and sustained may be built on or adapted. While sustainability and scalability are challenging and complex phenomena, and school change is notoriously difficult challenge, meaningful integration of technology can and will change the ways that we think about teaching, education and schooling. The reason is, multiple interacting factors influence the change process, and challenges are often encountered when implementing curricular and pedagogical innovations that integrate technologies, which can be daunting. The ultimate goal is to integrate classroom technology use that is more meaningful, purposeful and relevant to students. Hence, establishing productive partnerships among stakeholders, identifying research informed approaches to technology integration that are sustainable and scalable, and developing sustainable and scalable approaches to technology integration that are based on research literature rather than policy initiatives can help inform this process. For instance, [13] studied the perspectives of scalability of success rates in e-education. This was due to lack of achievement of scalability of numbers instead of scalability of success rates in e-education, which presented a mismatch that created worry to investors and bad reputation to Open and Distance Education (ODL). The study by [13] is relevant for highlighting potentials of e-education. This study examines ability of e-education to improve quality of education, access to education and training, reduce cost of education, and improve cost-effectiveness of education, in specified context, using achievement of high success rate as one element of cost-effectiveness of education. Studies on models of determinants of vision-impaired technology-facilitated education provide insights from [13], which point to the need to develop models that determine vision-impaired technology-facilitated education of students. This is because, models are useful to explain requirements of specified technology enhancement that advance education of vision-impaired students, and establish contributions made by technology enhancements such as computerized technologies towards vision-impaired technology-facilitated education. This establishes relationship between technology-facilitated education devices and educational requirements for vision-impaired student education that is important to the study discipline of technology enhanced education, which focuses on achievement of scalability. Scalability of success rates shows direct measure of quantitative performance outcome of the institution thereby addressing shortfalls of conventional institutions in provision of education to as many people as possible regardless of their inherent differences. The discussion by [13] allows analysis of factors that influence vision-impaired student success rates in e-education technologies as technology enhancements for education which take considerations of education characteristics. This implies that, the discussion has implications for direct outcome and describes the characteristics of students with vision impairment in order to categorize them relative to relevant technology enhancements for advancing their education.

THEORETICAL BASIS

The theoretical grounding is based on the chain of response Model in order to explain barriers to advancing vision-impaired student education through technological enhancements in education. Based on classification of education barriers as situational, institutional and dispositional and epistemological, the framework examines factors such as, technological enhancement, education support services, demographic profile, institutional framework, pressure group and success measures [13] the chain of response Model is useful to explain vision-impaired student barriers to advancing education through uses of technological enhancements in education. This is because, education support services, demographic profile, institutional framework, pressure group and success measures as well as the interactive nature of these factors makes it difficult to determine a single causal explanation for scaling up success or decreasing attrition rate. [13] explain the implications for scaling success rates to include timely enhancement and production of human capacity for national wealth creation; enhancing the reputation of institutions, reducing cost of education and training, increasing revenue base of institutions to attract students and increasing market opportunities for promotion and mobility of educations to affect educational practice. The discussion by [13] provides insights on use of the Chain of Response Model to explain barriers to Outcomes of vision-impaired Technology-Enhanced Education. Further, the subject area of Technology-Facilitated Education (TFL) is underpinned by Constructionism with the basis on constructivist education theory and theory of instruction. Constructivism is an approach to education that holds that people actively construct or make their own knowledge and that reality is determined by the experiences of the education [49]. The theory states that building knowledge occurs best through building things that are tangible and sharable [50]. Constructionism in the context of education is the idea that people learn effectively through making things [51]. This implies that, to use tools, resources and strategies to acquire knowledge and skills the student could face risks associated with the practice or process in education. Hence this study examines risks and difficulties in engaging technology enhancements for advancing effective education by vision-impaired students.

The study draws on the Activity Theory by [52] as framework for qualitative analysis of risks faced by students in the use of technology enhancements. The Activity Theory is a useful theoretical framework for areas of research such as, information systems development, information systems in organizations, health care, and education [52]. Activity Theory is a theoretical framework for analysis and understanding of human interaction through their use of tools and artefacts. The Theory offers a holistic and contextual method of discovery that can be used to support qualitative and interpretative research [52]. Activity Theory is particularly relevant in situations that have a significant historical and cultural context and where the participants, their purposes and their tools are in a process of rapid and constant change. Activity theory as a conceptual framework is based on the idea that activity is primary, that doing precedes thinking, that goals, images, cognitive models, intentions, and abstract notions like "definition" and "determinant" grow out of people doing things [52]. The Theory uses the whole work activity as the unit of analysis, where the activity is broken into the analytical components of subject, tool and object, the subject becomes the person being studied, the object is the intended activity, and the tool is the mediating device by which the action is executed [52]. Additional units of analysis, which have an implicit effect on work activities are rules, that constitute sets of conditions that help to determine how and why individuals may act, and are a result of social conditioning. or division of labour, which provides for distribution of actions and operations among a community of workers [52] The two elements affect a new plane of reality known as community, and through this, groups of activities and teams of workers are anchored, and can be analysed. Activity theory sees the integration of technology as tools which mediate social action. These tools, or artefacts, include instruments, signs, language, machines and computers. Further, the relation between the individual and their environment is considered through the component of community. The relation between subject and community is mediated by rules and the relationship between object and community is mediated by the division of labour [52]. [52] explain that, due to the fact that the tools which have been incorporated into the social system have been created and transformed by humans during the development of the activity itself they will carry with them remnants of the cultural and historical evolution, mediation through tools and technology is therefore not a neutral process, the tools will have an influence over the interaction between the subject and the object [52]. This phenomenon is referred to as "ring structure", a combination of three code terminating elements – subject, activity, and object – where the subject is not primary and where the object completes the circle by influencing the subject, making an activity the basic unit of analysis to understand individual actions. It is only when viewing the larger activity that individual actions are comprehensible [52]. So, the activity will have a motive, the action will have a goal, and the operation will have conditions. Activity Theory is a valuable tool for researchers to incorporate into their repertoire as it enables a means of discovering human activity without the express explication of tasks by participants, instead, through the mediated study of the participant's tools an understanding of activity is revealed which includes tacit and explicit actions [52]. Activity Theory as a practical framework can be used to underpin the complex and dynamic problems of human research and practice [52]. Hence, the Practical Value of Activity Theory stems from the analysis of the individual, in pursuance of their activity and objective through an examination of their tools and its mediation through rules, community and history. Consequently, the tool is known as the mediating artefact. The assumption is that, the artefact "attains its qualities of function, aesthetics, and ethics as it is integrated into the actual activity; only in practice does it become a tool. Hence to become a tool is to become part of someone's activity. While observation and interviewing may reveal the explicit aspects of the participant's actions, they will not assist in the understanding the implicit motivation. Activity Theory, however, through the examination of artefacts can render explicit the more tacit elements of an action. In these ways, Activity Theory inspires theoretical reflection in a variety of fields, for example in psychology, education, management, culture, and information systems, which in general incorporate approaches involving human activity. Many researchers recognize this theory as being holistically rich in terms of understanding how people do things together with the assistance of sophisticated tools in such intricate and dynamic environments.

One attribute of Activity Theory is its focus on argumentative and dialectic analysis on the interaction between people or human and their mediated tools or artefacts as purpose which have been shaped by human activity such as technical elements [52]. An activity comprises set of actions which aim for specific goals and operations, and these actions are indicated clearly in the information systems domain and can be found in the routines and cognitive or behavioural processes which are a common element of activities involving information systems.

The human side of Information Systems is commonly referred to as Human-Computer Interaction. This interaction involves the juxtaposition of the computer and its suite of supporting tools such as software applications and communications tools such as the Internet to ease and improve human working activities and communication processes [52], Activity Theory can be used to analyse levels of interaction using a tertiary tool in the knowledge creation processes which is focused on interaction between activities of information technology developers and the activities of users of their products. Activity Theory may not only be merely a methodology, but a theoretical framework valuable in the analysis of human practices on the multiple dimensions of individual activities and social interaction. Hence, Activity Theory is geared towards a practice which embodies a qualitative approach that offers a different lens for analysing education processes and their outcomes. Activity Theory is a suitable framework which involves models of knowledge building, perspectives and artefacts to guide the design of computer-supported collaborative education activities. Activity Theory is able to clarify the nature of the collaborative activities, and indicate how people can socially participate while interacting with the technology. This enables a more optimum design of tools to support computer-supported collaborative education activities effectively in various contexts, and develop methods to put them into practice. Activity Theory is an appropriate theory to use in understanding and solving problems involving e-education systems and the associated environment. For example, research by [53] presents a conceptual framework and design method for the analysis of a Mobile Computer-Supported Collaborative Education system using Activity Theory. Thus, the Activity Theory framework is useful in describing the multi-faceted system of information and its users regardless of its contextual environment, because the theory insists that activity is mediated by tools, which helps to explain relationships between the user and the tool. Activity theory views activity not as a simple individual action but as being culturally and historically located. The study applies the Activity theory to describe the mediation role of risks associated with technology enhancements in vision-impaired student education.

Further, Cognitive Theory of Multimedia Education and the Dual Coding theory are employed to examine associated risks and difficulties in engaging technology enhancement for advancing effective education by students with vision impairment [37]. The cognitive theory of multimedia education by [54] proposes that deeper education occurs when information is presented both verbally and nonverbally. The Dual Coding Theory by [55] indicates that, verbal and nonverbal information are processed in two separate but interconnected channels. Thus, processing the two kinds of stimuli simultaneously does not result in cognitive overload but, on the contrary, facilitates education. The reason is, illustrations and narration mostly complement each other in picture storybooks, the nonverbal information may support comprehension of verbal information and, vice versa, verbal information may support the interpretation of illustrations and other nonverbal information [37]

METHOD

To examine risks and challenges associated with implementation of technology enhancement for students with vision impairment, Descriptive Statistics was adopted method of analysis because it is suitable for summarizing the frequency and severity of challenges reported by respondents. Correlation Analysis was used to show how issues such as digital literacy, infrastructure, and usability affect TEL for students with vision impairment. The reason for method adoption is that, it is useful for exploring the relationships between these issues and TEL. The measures that can mitigate the identified risks to ensure successful technology integration in learning environments for students with vision impairment were analysed with Logistic Regression, because it is effective for assessing the likelihood of risk mitigation measures improving TEL. Research instruments were constructed to guide the fieldwork involving collection of Primary data [56]. Experiences of vision-impaired students with TEL risks and difficulties 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 [57] 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 together with 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 risks impact diverse vision-impaired students. The institutions were specifically identified for their active adoption of TEL, which are designed to foster inclusivity, enhance accessibility, and improve academic studies for students with varying levels of visual ability. By focusing on this population, the study aimed to capture risk experiences and challenges 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 implement TEL. These students included those who were full sight, partial sight, 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 risky environments of TEL implementation 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, emphasizing the importance of equitable access and tailored support services 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. 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 ETEL risk 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 full sight, partial sight, and no sight and varying levels of technology access were considered. 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. This approach enables the study to comprehensively analyse the differential impacts of ETEL risk on academic engagement, accessibility, and performance, thereby enhancing the depth and generalizability of the findings.

RESULTS & DISCUSSION

Analysis of risks associated with technology enhancement in specified vision-impaired learning envirnments is shown in Table 1. This section explores the risks and challenges associated with using technology in learning environments designed for students with vision impairment, providing insights into their prevalence and impact on learning experiences. In Table 1, the challenges faced by students in using technology have an average rating of 2.11, with a standard deviation of 1.019. This suggests that students encounter moderate levels of difficulty in accessing or utilizing technology. The variability in responses indicates that while some students may face significant obstacles, others experience fewer challenges. These differences could stem from factors such as varying levels of digital literacy, disparities in resource availability, or inconsistent teacher support. Table 1 shows that, the severity of these challenges in hindering learning is rated at 3.10 on average, with a standard deviation of 1.150. This reflects a moderate-to-high severity level, suggesting that challenges related to accessibility, functionality, or resource adequacy can have a substantial impact on learning outcomes for some students. Such challenges may limit students' ability to fully engage with or benefit from technology-enhanced learning tools. The frequency of these challenges is rated slightly higher, at an average of 3.15, with a standard deviation of 1.112 in Table 1. This indicates that students encounter these issues moderately often, highlighting the recurring nature of barriers such as inadequate training, unreliable tools, or limited access to necessary technologies. Addressing these challenges is essential to ensure a more seamless integration of technology into inclusive classrooms. Table 1 further shows the frequency of disruptions caused by technical issues, such as malfunctioning devices or internet outages, is rated at 3.10, with a standard deviation of 1.156. This shows that technical problems are a regular occurrence for many students, posing significant risks to their learning continuity. Such disruptions may be particularly detrimental in subjects requiring consistent interaction with assistive tools or online resources. Overall, these findings highlight the persistent challenges and risks associated with technology use in vision -impaired learning environments. The moderate-to-high ratings for severity and frequency underscore the need for targeted interventions, such as improved resource management, enhanced technical support, and teacher training, to mitigate these issues and create more effective, reliable, and inclusive learning experiences for students with vision impairment. The skewness and kurtosis values for all variables are within acceptable ranges for large samples (skewness ±1 and kurtosis ±2), indicating that the data is approximately normal and suitable for inferential statistical analyses, such as correlation and regression. The variability observed in responses suggests the need for further exploration into the factors contributing to these challenges and their impact on learning. Such analyses can help identify areas for intervention to reduce risks and improve the technological experience for students with vision impairment. Funding limitations and technical issues are the primary risks identified in implementing TEL. The result highlights the need for targeted interventions to address systemic barriers and ensure the sustainability of TEL initiatives and confirms findings by [14], but expands on the role of funding limitations as a unique challenge in the study's context.

Table 1 Descriptive Statistics on Risks Associated with Technology Enhancement in Specified Vision-Impaired Learning Environments.

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error

What challenges have you faced when using technology in your learning? (Select all that apply)	1532	2.11	1.019	.327	.063	-1.161	.125
How severe are these challenges in hindering your learning?	1532	3.10	1.150	-.178	.063	-.817	.125
How frequently do these challenges occur?	1532	3.15	1.112	-.259	.063	-.634	.125
How often do technical issues (e.g., malfunctioning tools, internet outages) disrupt your learning?	1532	3.10	1.156	-.197	.063	-.789	.125
Valid N (listwise)	1532						

Source: Survey Data 2024

Table 2 provides the specific challenges experienced by students with vision impairment when utilizing technology for learning, shedding light on key barriers that hinder the effective use of technology-enhanced tools in educational settings. In Table 2, the most frequently reported challenge is difficulty in accessing tools, indicated by 37.3% of respondents. This highlights a significant barrier, suggesting that many students struggle to obtain the assistive technologies necessary for effective learning. Contributing factors could include physical unavailability of tools, logistical constraints, or insufficient classroom infrastructure, all of which hinder equitable access to learning resources. The second most common challenge in Table 2, reported by 24.0% of respondents, is a lack of training on how to use the tools. This underscores the critical need for both students and educators to receive adequate training in the use of technology-enhanced learning tools. Without such training, even the most advanced tools may fail to deliver their intended benefits, leaving students unable to fully utilize the available resources. Table 2 shows that, Technical issues, including malfunctions or software glitches, were reported by 29.0% of respondents. These findings indicate that unreliable tools and insufficient technical support are persistent obstacles in the integration of technology into learning environments. Solutions to these issues could include improving the design and functionality of tools, implementing regular maintenance protocols, and ensuring the availability of responsive technical support teams. 9.7% of respondents reported facing no challenges when using technology, in Table 2. This minority likely benefits from well-implemented technology-enhanced learning environments, where tools are accessible, reliable, and supported by effective training and infrastructure. These instances serve as examples of the potential success that can be achieved when the right conditions are met. While a small portion of students experience seamless integration of technology, a proportion face apparent challenge. Among these, difficulties in accessing tools and lack of training emerge as the most prominent issues. Addressing these barriers is essential to ensuring that technology-enhanced learning environments are inclusive, equitable, and capable of meeting the diverse needs of students with vision impairment. Digital literacy is a significant factor influencing TEL outcomes, alongside infrastructure and usability barriers. Highlights the interplay between digital literacy and infrastructure as crucial elements in ensuring effective TEL implementation. The result aligns with [58] who emphasized the importance of digital literacy but uniquely identifies infrastructural barriers in resource-constrained environments.

Table 2 What challenges have you faced when using technology in your learning? (Select all that apply)			
		Frequency	**Percent**
Valid	Difficulty in accessing tools	572	37.3
	Lack of training on how to use tools	367	24.0
	Technical issues with tools	445	29.0
	None	148	9.7
	Total	1532	100.0

Source: Survey Data 2024

Table 3 presents a logistic regression analysis conducted to explore the relationship between vision status and the likelihood of experiencing challenges with using technology for learning. The analysis aimed to determine whether vision status significantly predicts the probability of encountering such challenges. In Table 3, the constant term in the model has a coefficient of 0.31, which represents the baseline log odds of encountering challenges when vision status is not considered. The z-value of 2.32 and a p-value of 0.02 indicate that the constant is statistically significant at the 5% level. This finding suggests that, irrespective of vision status, students face a baseline probability of encountering challenges with technology.
The coefficient for vision status is 0.14 in Table 3, indicating that for each unit increase in vision status (e.g., moving from fully sighted to partially sighted or from partially sighted to blind), the log odds of encountering challenges increase by 0.14. However, the z-value of 1.72 and a p-value of 0.09 show that this relationship is not statistically significant at the 5% threshold. The 95% confidence interval for this coefficient ranges from -0.02 to 0.30, which includes zero, further reinforcing the lack of statistical significance. These results in Table 3 indicate that, vision status does not significantly predict the likelihood of encountering challenges with technology use. While the positive coefficient suggests a slight increase in challenges as vision status changes, this effect is not statistically meaningful. This finding implies that the difficulties students face in using technology are not primarily determined by their vision status and are likely influenced by other factors, such as resource availability, technical support, or training opportunities. The analysis in Table 3 underscores the importance of addressing broader systemic and contextual issues in ensuring equitable access to and effective use of technology for learning, regardless of students' vision status. Increased funding, technical support, and user training are critical measures to address TEL risks. This result demonstrates the importance of systemic interventions to ensure successful and sustainable TEL integration. The result supports [59] who highlighted funding and training as essential measures, but adds emphasis on technical support as a key mitigating factor. Further research could explore these additional factors to provide a more comprehensive understanding of the challenges faced in technology-enhanced learning environments.

Table 3 Logistic Regression

	Coef.	**Std. Err.**	**z**	**P>|z|**	**[0.025**	**0.975]**
Constant	0.31	0.13	2.32	0.02	0.05	0.57
Vision Status	0.14	0.08	1.72	0.09	-0.02	0.30

Source: Survey Data, 2024

A Chi-Square test was conducted to investigate the relationship between the frequency of challenges faced by students and the reliability of the tools they use. The objective was to determine whether tool reliability significantly influences how often students encounter challenges in using technology for learning. In Table 4, the test yielded a Chi-Square statistic of 17.77 and a p-value of 0.34. Since the p-value exceeds the standard significance threshold of 0.05, the null hypothesis (H0) cannot be rejected. This result in Table 4 indicates that there is no statistically significant association between the frequency of challenges and the reliability of the tools. The result in Table 4 suggest that the frequency of challenges students experience is not meaningfully influenced by their perceptions of tool reliability. This lack of association indicates that other factors may play a more significant role in determining how often challenges occur. For instance, issues such as accessibility barriers, insufficient training, or the availability of technical support might exert a stronger influence on the challenge students face when using technology. These results highlight that while tool reliability is an important consideration, it alone does not appear to drive the frequency of challenges faced by students. To improve the overall experience of technology-enhanced learning, a broader focus on addressing systemic issues, such as improving resource availability, offering adequate training, and establishing robust support systems, is necessary. Addressing these multifaceted issues will be critical in creating more inclusive and effective learning environments for students with vision impairment.

Table 4 Chi-square

Metric	Statistic	p-Value
Chi-Square (Challenge Frequency vs. Tool Reliability)	17.77	0.34

Source: Survey Data, 2024

Appendix
Questionnaire on Risks Associated with Technology-Enhanced-Learning Support-Services for Inclusive Classroom Education of Vision-Impaired Students in Ghana.
Introduction
Dear Participant,
You are invited to join a study on ‘Risks Associated with Technology-Enhanced-Learning Support-Services for Inclusive Classroom Education of Vision-Impaired Students”. The study focuses on examining Risks Associated with Technology-Enhanced-Learning Support-Services for Inclusive Classroom Education of Vision-Impaired Students, specifically related to science education. We want your real opinions and experiences about how integration of ETEL support services pose inherent risks and challenges in vision-impaired contexts, including usability, digital literacy, and infrastructural constraints, for you in your education. We will use your answers to discover important approaches and obstacles for young people with vision problems that are learning science. It can contribute to the creation of stronger standards and practices in supporting students with different needs. There are two sections in the questionnaire and respondents use the Likert scale (from 1 to 5) to rate each answer. Every answer is acceptable as long as it comes from your viewpoint. All information collected will be private and only be used within the study. It is your decision whether to continue and you are allowed to withdraw whenever you wish.

Section A: Demographic Information (For Control Variables)

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

Section B:
Educational Technology Enhanced Science Learning Risks for Students
1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Construct	Item No.	Question Item	1	2	3	4	5
Challenges faced when using technology in learning	1	I face difficulty in accessing or utilizing technology. I benefit from technology-enhanced learning tools.					
Severity of challenges in hindering your learning.	2	I face barriers such as: • inadequate training, • unreliable tools, • limited access to necessary technologies.					
Frequency of challenges occurrence	3	My challenges are frequent • frequent disruptions caused by technical issues, • malfunctioning devices					
Technical issues (e.g., malfunctioning tools, internet outages) disrupt your learning?	4	I face: • internet outages, • difficulty in accessing technical tools, • unavailability of tools, • logistical constraints • malfunctions or software glitches • unreliable tools • insufficient technical support • no challenges when using technology,					

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