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Article

Assistive Technology in Inclusive Mathematics Education for Students with Visual Impairment: A Conceptual Framework

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Abstract:

Assistive technology is recognized as a crucial facilitator of inclusive education, especially in increasing access to the mathematics curriculum for students with visual impairments. Mathematics instruction heavily relies on visual aids such as graphs, diagrams, and symbols, which can pose significant barriers for students with visual impairments in mainstream classrooms. This study aims to develop a conceptual framework to explain how assistive technology effectively improves mathematics learning outcomes for students with visual impairments in inclusive environments. The framework integrates technological factors like accessibility and usability of assistive tools with contextual elements such as teacher and institutional support. Drawing on various theoretical models, including Universal Design for Learning, Social Constructivism, the Technology Acceptance Model, and the UNESCO AI Competency Framework for Teachers, this research seeks to synthesize existing literature to identify key mechanisms behind technology-enhanced learning. Prior research indicates that accessible assistive technologies are vital for increasing student engagement in learning activities (Fernández-Batanero et al., 2022; Shoaib et al., 2023). Moreover, accessible technologies play a critical role in fostering students' independence and understanding of the world (Adnan et al., 2025; Muradyan, 2023). Ndayambaje et al. (2025) and Alimović (2024) demonstrate that teacher competence and infrastructure are crucial for the successful implementation of assistive technologies in inclusive education settings. This paradigm offers theoretical guidance for future empirical research.

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1. INTRODUCTION

Generally, education is considered one of the fundamental human rights that promotes social inclusion, economic development, and personal empowerment. In addition, educational agendas worldwide are focusing more on the concept of inclusive education to ensure equal educational opportunities for all students, including those with impairments. For instance, Sustainable Development Goal 4 of international agendas recognizes the importance of providing inclusive and equitable quality education and lifelong learning opportunities for all, regardless of physical, sensory, or cognitive disabilities (UN Office of the High Commissioner for Human Rights

[OHCHR], 2015; UNESCO, 2020). However, students with visual impairment are still facing significant barriers in accessing educational materials, especially in subjects like mathematics, which are mostly based on visual learning (Bhowmick & Hazarika, 2021; Kelly & Smith, 2022).

Mathematics education has unique challenges for students with visual impairment since mathematical concepts are often represented through symbols, diagrams, graphs, and spatial arrangements. These visual elements might hinder students' ability to understand mathematical concepts and develop spatial thinking skills, which are essential for problem-solving (Kelly & Smith, 2022). For this reason, students with visual impairment might experience difficulties in understanding mathematical concepts, lack motivation in mathematics education, and might avoid pursuing STEM-related fields of study.

The evolution of assistive technology has been significant in addressing the challenges and barriers for students with visual impairment and promoting an inclusive learning environment for students with visual impairment. For example, screen readers, refreshable Braille displays, talking calculators, and tactile graphics enable students with visual impairment to learn and understand mathematical concepts through auditory and tactile means. Recent breakthroughs in digital accessibility and AI technology have enhanced assistive technology for students with visual impairment through the automatic conversion of visual mathematical content into accessible formats and the creation of adaptive digital learning environments (Holmes et al., 2023).

However, past studies have often been centered on assessing the effectiveness of a particular technology tool rather than exploring the educational framework in which these technologies are implemented. The effectiveness of assistive technologies in enhancing the learning outcomes of students with visual impairment depends on various aspects, such as the accessibility and usability of technology, teacher preparedness, and institutional support. Despite considerable research on assistive technologies for students with visual impairment, few studies have been found to have developed an integrated conceptual framework to explain how these technologies influence mathematics learning outcomes in inclusive education settings.

In order to bridge this gap, the current study offers a conceptual framework for understanding how assistive technology promotes the learning of mathematics among students with visual impairment. This study contributes to the body of literature on assistive technology and its role in promoting the learning of mathematics among students with visual impairment in two main ways. Firstly, it offers a conceptual framework for understanding how technology accessibility, usability, teacher support, and institutional support interact with one another in promoting the learning of mathematics among students with visual impairment.The concept of assistive technology for promoting the learning of mathematics among students with visual impairment is based on the principles of Universal Design for Learning and Social Constructivism.

2. THEORETICAL BACKGROUND

This section presents the theoretical basis upon which the conceptual framework is being developed.

2.1 Assistive Technology in Inclusive Mathematics Education

Assistive technology plays a critical role in the promotion of inclusive education because it allows students with disabilities to access learning resources and participate in class activities. AT devices include screen readers, refreshable Braille displays, software for magnification, speech-to-text systems, and tactile graphics devices. These devices provide alternative access to visual content.

Research indicates that assistive technology enhances accessibility and participation for students with visual impairments. Fernández-Batanero et al. (2022) posit that assistive technology enhances inclusive education since it allows students to access learning resources and participate actively in class learning. In addition, Ali (2021) emphasizes the importance of assistive technology in mathematics learning because the learning materials used in mathematics include symbolic notation, diagrams, and graphical representations.

Mathematics is one of the subjects in which students with visual impairment find it difficult to learn, as many concepts are based on spatial and graphical understanding. Graphs, diagrams, and coordinate systems are mostly designed for visual understanding, which might affect the understanding of concepts and spatial thinking (Kelly & Smith, 2022; Shoaib et al., 2023). These problems are overcome with assistive technology, as it can easily convert visual understanding into tactile and aural understanding, enabling students to explore and understand mathematical concepts through touch and sounds (Dabi & Golga, 2023). Its effectiveness is based on the

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availability and effectiveness of assistive technology in the educational system.

2.2 Accessibility and Usability as Key Technological Dimensions

Accessibility and usability of technologies represent two technological key variables in determining the effectiveness of assistive technologies in inclusive education. In particular, accessibility focuses on the extent to which digital technologies, learning platforms, and assistive technologies are designed to accommodate the needs of disabled students and enable students with visual impairments to access learning information and actively participate in learning activities. On the other hand, usability focuses on the extent to which people can easily and effectively use technologies for learning and actively engaging in learning activities.

However, recent studies show that the availability of an accessible digital environment has a significant impact on the equal participation of students in the learning process. For instance, Kerdar et al. (2024) contend that the use of interoperability among assistive technology helps students with visual impairment to enhance their learning experience. Moreover, Sánchez et al. (2024) point out the importance of accessible learning management systems in promoting inclusive online learning for students with visual impairment. Nevertheless, despite the advancements in the accessibility of learning, there are still barriers to accessibility in learning, such as the high cost of assistive technology, the lack of infrastructure, and the absence of technological assistance, which hinder the use of technology, particularly in poor countries (Lavric et al., 2024; Zhang et al., 2024).

In addition to accessibility, usability is another factor to be considered in the use of assistive technologies. Usability has been defined by usability approaches such as ISO 9241-11, where usability is regarded as essential attributes such as effectiveness, efficiency, and user pleasure while using the system. These attributes are often measured in terms of learnability, memorability, efficiency, and prevention of errors, among others. Studies on digital accessibility have indicated that there is a need to have both accessible and user-friendly assistive technologies for people with disabilities (Lazar et al., 2015).

There are two types of usability: objective and perceived usability. Objective usability is related to various attributes of the system, such as its navigability and interoperability with assistive devices. On the other hand, perceived usability is associated with user experience and perceptions of usability. Various usability attributes of technology, such as its screen reader usability, voice clarity, and diagram clarity, have a significant effect on technology adoption and learning engagement among students with visual impairment (Nasr et al., 2025; Adnan et al., 2025; Muradyan, 2023).

2.3 Pedagogical and Institutional Enablers of Assistive Technology

Technological solutions alone cannot ensure the provision of inclusive education. Inclusive education requires supporting teaching approaches and learning environments for the effective implementation of assistive technologies. Teachers can play a key role in bridging the gap between assistive technologies and learning by incorporating assistive technologies into teaching practices.

However, there is a lack of professional expertise in the effective implementation of assistive technologies in schools. According to Ndayambaje et al. (2025), the lack of professional development opportunities affects the ability of teachers to effectively implement digital technologies in the classroom for inclusive learning. Research by Siu & Morash (2014) showed that the professional competence of teachers can be enhanced through professional learning communities.

Furthermore, there is a need for supporting learning environments for the effective implementation of assistive technologies. In order to support the implementation of assistive technologies in learning environments, there is a need to provide learning environments with the necessary resources. Accessible learning environments have been emphasized through the formulation of policies such as the National Education Policy (NEP) 2020. However, there is still a lack of learning environments in schools due to inadequate resources and lack of budget (Alimović, 2024).

2.4 Emerging Challenges in Assistive Technology Integration

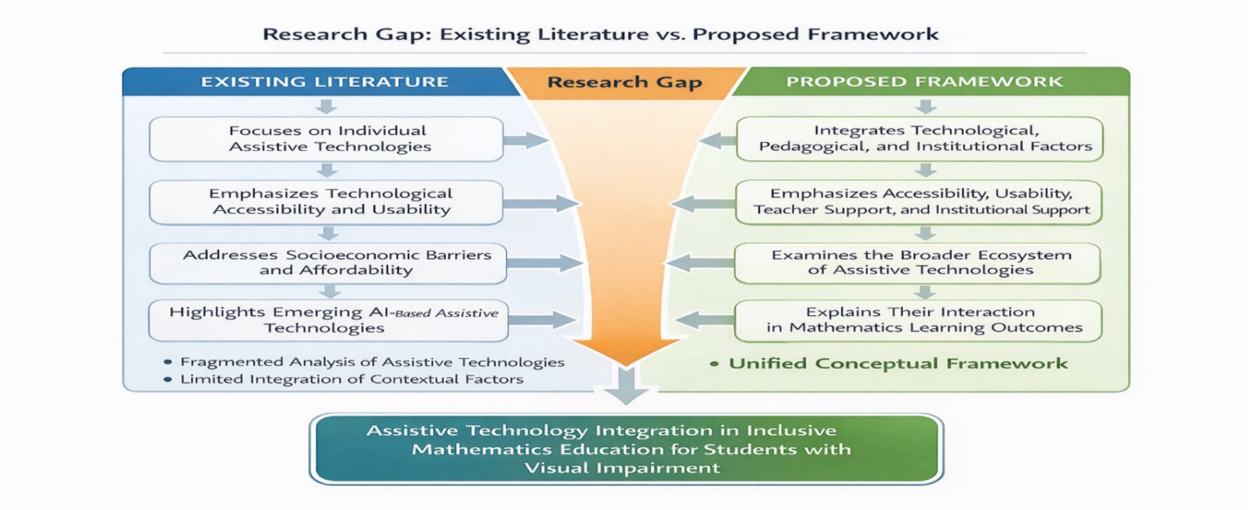
Nonetheless, a number of challenges still exist in spite of the growing adoption of assistive devices. One major disadvantage associated with assistive devices is the lack of representation of viewpoints from students with visual impairment in the design and evaluation of technology. As Shinohara and Wobbrock (2011) assert, assistive technologies are often designed without adequate regard for users' experiences.

Socioeconomic factors can be viewed as yet another challenge in the adoption of technology in educational institutions. Although assistive devices have come a long way in terms of advancement, they remain beyond the reach of many students in developing countries due to their inaccessibility because of their costly nature (Lavric et al., 2024; Alimović, 2024). In this case, students in developing countries lack access to costly technology such as refreshable Braille displays.

Furthermore, assistive technology in the form of AI devices has raised a number of ethical issues concerning bias in AI systems, data privacy, and inequalities in access to digital technology. In this case, if AI systems are designed without adequate representation of different needs in accessibility, they can be seen as a barrier in addressing inequalities in educational access.

2.5 Research Gap and Need for a Conceptual Framework

Though previous studies have emphasized the importance of assistive technology in promoting inclusive education, the majority of the studies have been based on the evaluation of a specific technology rather than the whole ecosystem for its implementation. Existing studies have shown the importance of accessibility and engagement (Fernández-Batanero et al., 2022; Shoaib et al., 2023), as well as the importance of usability and user-centered design (Adnan et al., 2025; Muradyan, 2023). However, there are still significant research gaps in the field of assistive technology for students with visual impairment, as comments from students with visual impairment on the usability of assistive technology are rarely included in the research (Shinohara & Wobbrock, 2011). In addition, despite their importance in technology implementation, the problem of socioeconomic barriers and affordability is still not adequately discussed in the field of assistive technology (Lavric et al., 2024; Alimović, 2024). Moreover, the newly developed AI-based assistive technology has raised ethical concerns about fairness in algorithms, data privacy, and digital inequality (Elshaer et al., 2025). Figure 1 illustrates the research gap identified in the literature in the field of assistive technology for students with visual impairment.



As such, it is essential to create a conceptual framework that will account for all these aspects of assistive technologies in their collective effect on mathematics learning outcomes for students with visual impairment. These aspects include technology, particularly accessibility and usability, as well as contextual issues like teacher and institutional support.

2.6 Critical Perspectives and Contextual Considerations

While the proposed paradigm highlights the significance of the technological, pedagogical, and institutional factors affecting the effectiveness of assistive technology for inclusive mathematics education, there are some basic factors that must also be taken into consideration. To begin with, there is a scarcity of students with visual impairment both during the formulation and assessment of assistive technology, which makes such technology less effective for these individuals. In fact, disability-centered design research has pointed out that such technology does not portray the actual needs and experiences of students with visual impairment (Shinohara & Wobbrock, 2011). Thus, participatory design approaches may also be an important dimension that needs to be included in the further development of the proposed paradigm.

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Second, the framework has to be considered in the broader context of the digital divide. For many educational settings, particularly in developing countries, there may be no access to even the most basic assistive technologies because of financial constraints, infrastructure, and technical support. Thus, the potential benefit of accessibility and usability improvements might be limited until the broader inequities in technology access are addressed.

Lastly, there is a need to consider the ethical aspects of new digital and AI-based assistive technologies. For example, there may be an impact of issues such as algorithmic bias and data privacy on AI use on the effectiveness of assistive technologies. Therefore, it is important to view AI ethics and design principles as essential preconditions to the effective use of assistive technologies in inclusive mathematics education.

3. METHODOLOGY

The present study utilizes a conceptual method of research to formulate a theoretical framework that describes how assistive technology supports mathematics learning for students with visual impairment. The conceptual framework is developed from a synthesis of peer-review literature, governmental publications, and scholarly research on assistive technology, inclusive education, and mathematics learning.

The research identified four key variables in assisting students with visual impairment in mathematics learning: accessibility, usability, teacher assistance, and institutional support. These variables were assessed from the theoretical perspectives of Universal Design for Learning, Social Constructivism, Technology Acceptance Model, and UNESCO AI Competency Framework for Teachers, which were used to formulate the conceptual framework.

4. CONCEPTUAL FRAMEWORK

The purpose of this study is to introduce a conceptual framework that can be used to understand the role that assistive technologies can play in improving the results that students with visual impairments obtain in the area of mathematics education in inclusive education settings. Although prior research has indicated that assistive technologies have the potential to improve the accessibility and participation of students with visual impairments, most prior research has focused on the individual technologies rather than the overall ecosystem that is required to successfully implement the technologies. In an effort to overcome the limitation that the prior paradigm has with respect to the focus on individual technologies, the new paradigm that is being proposed considers the technological, pedagogical, and institutional factors that can affect the application of assistive technologies in mathematics education. The proposed conceptual framework is based on four different theoretical perspectives that complement each other and can be used to understand the different ways that assistive technologies can improve the results that students with visual impairments obtain in the area of mathematics education.

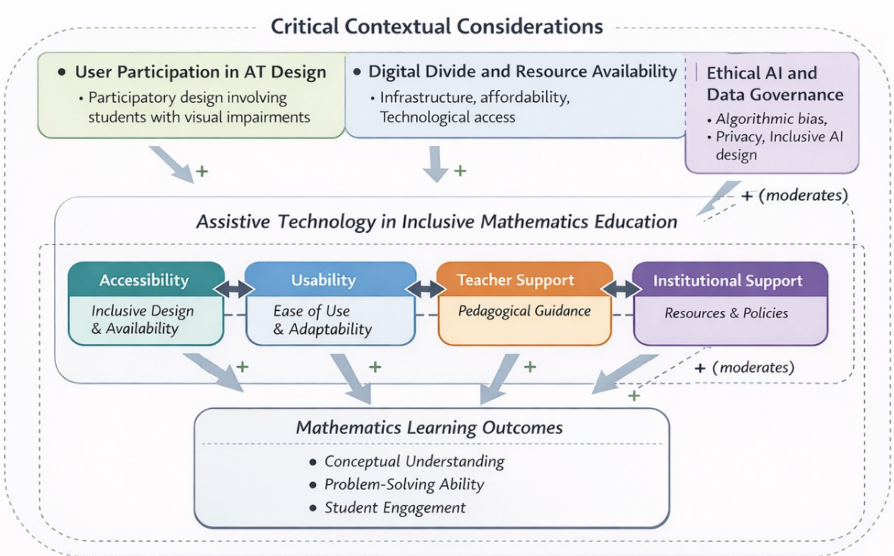

Figure 1. Conceptual framework explaining the relationships between assistive technology factors and mathematics learning outcomes for students with visual impairments. Accessibility and usability of assistive technologies directly influence mathematics learning outcomes, while teacher support and institutional support act as moderating factors that strengthen technology integration. The framework operates within broader contextual conditions including user participation in assistive technology design, digital divide considerations, and ethical AI governance.

The fundamental principle for establishing inclusive learning environments for different kinds of learners is provided by Universal Design for Learning. UDL focuses significantly on different modes of expression, participation, and representation. Students with visual impairment may be able to access mathematical concepts auditorily and tactually by means of assistive technology tools such as screen readers, Braille displays, and diagrams. Social constructivism asserts that learning takes place by means of communication and cooperation between learners. From this perspective, assistive technology tools function as mediators that enable students with visual impairment to communicate with their peers and teachers, participate in group works, and solve mathematics problems in inclusive classes.

The Technology Acceptance Model explains how users adopt technology tools. According to TAM, user adoption of technology tools is driven by their perceived usefulness and usability. By extension, accessibility and usability of assistive technology tools in mathematics classes are vital in determining their adoption by learners and teachers. The UNESCO AI Competency Framework for Teachers highlights the need to emphasize teacher competencies in integrating technology tools in teaching and learning mathematics. Furthermore, the paradigm focuses on teacher training, digital literacy, and pedagogical experience as factors that can influence the effective integration of technology in inclusive classrooms. To demonstrate the theoretical contribution of the framework, the roles of each theoretical perspective have been outlined in Table 1.

Table 1. Theoretical Foundations of the Conceptual Framework

Theoretical Lens	**Role in Framework**	**Key Contribution**
Universal Design for Learning (UDL)	Foundation for accessibility	Promotes multiple means of representation to support diverse learners
Social Constructivism	Learning process	Positions assistive technology as a mediator for interaction and collaborative learning
Technology Acceptance Model (TAM)	Technology adoption	Explains how perceived usefulness and ease of use influence technology use
UNESCO AI Competency Framework for Teachers	Teacher competency	Highlights teacher skills and institutional support for technology integration

Based on the theoretical perspectives discussed above, the framework has identified four main variables that are said to affect the results of the mathematics learning outcomes for students with visual impairment. The first variable identified is the accessibility of assistive technology. This refers to the availability and accessibility of technology instruments through which students are able to access the mathematics content. Examples of assistive technology instruments include screen readers, Braille displays, audio equation readers, and tactile diagrams. The second variable identified is the assistive technology usability. This refers to the ease through which students and educators are able to use the assistive technology instruments in the delivery of the mathematics content.

The third variable is teacher assistance, which entails the pedagogical and technological guidance offered by teachers for students to effectively utilize assistive technology in mathematics instruction. The fourth variable is institutional support, which entails infrastructure support, policy support, financial support, and training support for the long-term utilization of assistive technology in educational institutions. Accessibility and usability in this concept function as technology enablers, while teacher support and institutional support function as contextual facilitators for facilitating the utilization of assistive technology in inclusive mathematics instruction for children with visual impairment, which would eventually affect mathematics learning outcomes in terms of conceptual mastery, engagement, and problem-solving skills for these students.

5. RESEARCH QUESTIONS

The purpose of this research is to develop a conceptual framework to account for how assistive technology can facilitate students with visual impairments in learning mathematics more effectively.

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The research will cover the following questions:

RQ1: What are the effects of technology factors, namely the usability and accessibility of assistive technology, on the learning outcomes in mathematics for students with visual impairments?

RQ2: How might teacher assistance help in the appropriate integration of assistive technology in mathematics education?

RQ3: What is the impact of support on assistive technology use in inclusive learning environments?

RQ4: How do the interrelations between the institutional, pedagogical, and technology factors contribute to the learning outcomes in mathematics for students with visual impairments?

6. FINDINGS / RESULTS

The conceptual synthesis of literature reveals a number of significant links between assistive technology and mathematics learning outcomes for children with visual impairment. The findings are presented in respect to the research issues that form the basis for this study.

RQ1: What are the effects of technology factors, namely the usability and accessibility of assistive technology, on the learning outcomes in mathematics for students with visual impairments?

Accessibility and usability have been identified as key factors in the application of technology in the education of children with visual impairments in mathematics. Accessibility is essential because it gives the learner the ability to access knowledge in mathematics, which is presented in graphical form. Technologies such as screen readers and refreshable Braille displays can be used to translate visual information into auditory and touch formats, helping the learner understand the concepts and symbols presented in mathematics.

The usability of technologies has also been identified as a key factor in the education of children with visual impairments in mathematics. This is because it affects the level of interest and the nature of the experience that the learner has with the technologies and the information presented in mathematics. The usability of assistive technologies can be significant in the education of children with visual impairments because it can encourage the learner to take part in problem-solving activities and gain conceptual understanding (Adnan et al., 2025).

RQ2: How might teacher assistance help in the appropriate integration of assistive technology in mathematics education?

Teacher support is a pedagogical key factor in the effective integration of assistive technologies in the classroom. A teacher facilitates the learning of students through the adaptation of teaching strategies and the use of assistive technologies. According to research findings, educators who are technologically and pedagogically competent are effective in the integration of assistive technologies in the teaching and learning of mathematics for diverse students (Ndayambaje et al., 2025). Professional development and collaborative learning are essential in the effective use of assistive technologies. Teachers are effective in the creation of an inclusive classroom where students are encouraged to take part in the learning process (Siu & Morash, 2014).

RQ3: What is the impact of support on assistive technology use in inclusive learning environments?

Institutional support has a significant effect on the usage and longevity of assistive technologies in inclusive education settings. Educational institutions are the backbone of providing the necessary infrastructure, financial support, and policies required to integrate technology into the educational system. A study indicates that the adoption of inclusive education, including infrastructure and training programs, has a positive effect on the usage of assistive technologies (Alimović, 2024). However, some of the limitations, such as a lack of financial support, infrastructure, and training opportunities, might affect the adoption of technology in educational settings.

RQ4: How do the interrelations between the institutional, pedagogical, and technology factors contribute to the learning outcomes in mathematics for students with visual impairments?

According to literature, mathematical learning outcomes for students with visual impairments are influenced by technical, pedagogical, and institutional factors. Accessibility and usability enable learners to engage with mathematical content (Fernández-Batanero et al., 2022; Shoaib et al., 2023; Adnan et al., 2025), whereas teacher support facilitates effective integration of assistive technologies in teaching and learning (Siu & Morash, 2014; Ndayambaje et al., 2025). Institutional support also enhances teaching and learning by promoting inclusive teaching practices in mathematics for learners with visual impairments (Alimović, 2024). The above-mentioned characteristics of assistive technologies create an enabling instructional environment for learners to engage in mathematics and improve their mathematical problem-solving abilities. The conceptual framework presented in this paper integrates all these characteristics to illustrate how assistive technologies contribute to improving mathematical learning outcomes for children with visual impairments.

7. DISCUSSION

The results of this conceptual study underscored the interdependence of technical, pedagogical, and institutional issues in explaining mathematics learning outcomes for students with visual impairment. According to the suggested concept, it is not just assistive technology that will ensure inclusive learning for students with visual impairment; rather, it is the interdependence of accessible technology, teaching, and institutions that will ensure its success.

Consistent with the RQ1, technological factors such as accessibility and usability are essential in order for students with visual impairments to access the mathematical information. Graphs, diagrams, and symbols are examples of visual representations that are commonly used in the training of students in mathematics. Examples of assistive technology devices that convert visual representations into auditory and tactile feedback are screen readers and refreshable Braille displays and diagrams. They are essential in helping students understand the concepts in mathematics (Fernández-Batanero et al., 2022; Shoaib et al., 2023). Moreover, the usability of the technology is essential in determining the ease with which students are able to access the products. According to the Technology Acceptance Model (TAM), technologies perceived as valuable and user-friendly are more likely to be accepted and integrated into the activities of the students (Adnan et al., 2025; Muradyan, 2023).

In regard to RQ2, teacher assistance is important in supporting the pedagogical integration of assistive technologies. According to Social Constructivist perspectives, the teacher is seen as a mediator who helps students in effectively understanding mathematical representations and utilizing assistive technology. According to studies, teachers with high technological and pedagogical competencies are better placed to successfully integrate assistive technologies in the teaching and learning of mathematics (Ndayambaje et al., 2025). Limited opportunities for professional development often hinder teachers from using inclusive technology-based approaches in teaching and learning (Siu & Morash, 2014).

Regarding RQ3, the results provide the framework for the long-term usage of assistive technologies. In order to support the adoption of inclusive technology, there is a need for professional training and the development of digital infrastructure. This is consistent with the UNESCO AI Competency Framework for Teachers, which emphasizes the importance of teacher training and capacity building at the institutional level for the efficient use of digital technologies in the teaching profession (Lavric et al., 2024; Alimović, 2024).

Lastly, with regards to RQ4, the results revealed that the accessibility of technology, pedagogical support, and institutional readiness do have an effect on the learning outcome of the math concepts among the students with visual impairment. This perspective is in line with the concepts and principles of Universal Design for Learning (UDL), which focuses on the design of the learning environment that can accommodate different types of learners.

8. CONCLUSION

This study seeks to establish a conceptual model for the role that assistive technology plays in enhancing the results of mathematics learning for students with visual impairment in inclusive education. The model is based on two significant dimensions of technology: accessibility and usability of assistive technology, and two significant dimensions of the context: teacher and institutional support. The model is significant because it seeks to establish the role played by assistive technology through significant theoretical perspectives such as Universal Design for Learning, Social Constructivism, Technology Acceptance Model, and UNESCO's AI Competency Framework for Teachers.

The significant contribution of the paradigm, however, is its integrative nature. Unlike prior studies, which generally view assistive technology on a strictly technological basis, the paradigm considers the integration of technological factors, educational facilitation, and institutional infrastructure. The model extends the current discussion on inclusive mathematics education with its emphasis on the integrated impact of accessibility, usability, teacher qualities, and infrastructure. Moreover, the model offers a framework for exploring the link

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between assistive technology and learning outcomes for students with visual impairment.

9. IMPLICATIONS

The implications of this study are significant for educational practices, policies, and future research. Educational practices should employ inclusive teaching methods to effectively incorporate assistive technology in mathematics teaching. Professional training for teachers should be provided to enhance their technological and teaching abilities to facilitate their involvement in assisting students with visual impairment in comprehending mathematical representations.

Educational institutions should provide accessible technology to create an inclusive teaching environment for learners with disabilities. Educational institutions should promote universal design in their policies to ensure compatibility of assistive technology with digital learning systems. Governments and educational authorities must remove structural barriers for equal access to assistive technology. Financing programs for assistive technology, educational policies for inclusion, and access programs for assistive technology can all play a role in eliminating these inequities and creating more opportunities for students with visual impairment. Finally, the relationships set out in this conceptual framework must be tested in a study to assess the effectiveness and usability of assistive technology for students with visual impairment from their own perspective.

10. LIMITATIONS

The study has major drawbacks in its application. First, it is based on a conceptual model rather than empirical evidence, meaning that these hypothesized relationships have yet to be tested rigorously. Furthermore, this paradigm has yet to be validated by key stakeholders such as instructors, students with visual impairments, and developers of assistive technology. Secondly, relying on published literature might not account for all experiences in different educational environments. Differences in infrastructure, teacher training, and access to assistive technology might affect how this framework is implemented. Finally, ethical issues in artificial intelligence and digital accessibility were not adequately investigated in this study and would need further exploration in subsequent studies.

11. FUTURE DIRECTIONS

This framework also identifies avenues for future research. For this purpose, it is suggested that future research should be conducted using quantitative, qualitative, and mixed methods to examine and validate these concepts in different educational settings. For example, future research can explore the impact of accessibility and usability of assistive technology on the engagement and conceptual understanding of students with visual impairment in math, along with the role of teachers' expertise and support.

In terms of practical implications, it is suggested that there should be more emphasis on training teachers regarding assistive technology and inclusive teaching practices within teacher education programs. Furthermore, there is a need to ensure that there are accessible physical and technological resources within educational settings. Lastly, it is suggested that there should be more emphasis on accessibility, usability, and adaptability during the development of assistive technology, specifically digital aids within mathematics education. These are just some of the measures that can be taken to ensure more equitable and inclusive mathematical education for students with visual impairments.

DECLARATIONS

Author(s) Contribution

Conceptualization, Mohd Shahzad and Abhishek Panigrahi; methodology, Mohd Shahzad and Abhishek Panigrahi; software, Mohd Shahzad; validation, Mohd Shahzad, Saurabh Ray, and Abhishek Panigrahi; formal analysis, Mohd Shahzad and Abhishek Panigrahi; investigation, Mohd Shahzad and Abhishek Panigrahi; resources, Saurabh Ray; data curation, Mohd Shahzad; writing original draft, Mohd Shahzad and Abhishek Panigrahi; writing review and editing, Mohd Shahzad, Saurabh Ray, and Abhishek Panigrahi; visualization, Mohd Shahzad and Abhishek Panigrahi; supervision, Saurabh Ray; project administration, Saurabh Ray; funding acquisition, none. All authors have read and agreed to the published version of the manuscript.

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Grammarly was used for language polishing, grammar correction, and sentence restructuring during manuscript preparation. All content was reviewed, verified, and edited by the authors, who remain fully responsible for the integrity and originality of the work. The tools were not used to generate substantive scientific content, arguments, data analysis, or interpretations

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Availability of Data and Materials

The study is conceptual and based on published literature. No primary empirical datasets were generated. The bibliometric data used in the analysis are available from Scopus and can be obtained from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Clinical Trial Registration (if applicable)

Not applicable. The study did not involve any clinical trial.

Human Ethics and Consent to Participate

The study did not involve any clinical interventions or experiments requiring formal ethical approval or informed consent.

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