Technology-Enhanced Inclusive Mathematics Learning: Promoting Equity and Lifelong Learning Opportunities for Vision-Impaired Students

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***Abstract*— The paper investigates the dynamic relationship between technology and inclusive mathematics education for students with vision impairments. The paper examines the transformative potential of technology integration in fostering an inclusive educational environment while acknowledging the challenges that need to be addressed. The authors highlight the imperative of teacher training, data privacy, and ethical considerations in effectively integrating technology into educational practices. The evolving role of educators in facilitating meaningful and inclusive learning experiences is emphasized. A collaborative effort involving governments, educational institutions, technology developers, and the community is indispensable in pursuing inclusive education; by collectively addressing challenges, embracing technological advancements, and adhering to ethical principles, a transformative educational landscape can be cultivated.**

Keywords*— *Vision impairment, Assistive technology (AT), Mathematics, Inclusivity, Ethics, Technology integration, Universal Design for Learning (UDL)

I. Introduction and Background

Ensuring inclusivity and equitable quality education and promoting lifelong learning opportunities for all is the central aim of SDG 4, one of the United Nations Sustainable Development Goals adopted in 2015 [1]. At the core of this goal, inclusive education seeks to break down barriers to learning, foster diversity, and create supportive environments that accommodate students' diverse abilities and backgrounds [1]. By prioritizing inclusive education, societies can empower individuals, reduce inequalities, and promote social cohesion [2]. Education becomes a powerful catalyst for sustainable development, economic growth, and social progress, preparing individuals for active citizenship and contributing to a skilled and diverse workforce [2, 3]. Achieving SDG 4 necessitates collaboration among governments, educational institutions, and international organizations, focusing on policy development, adequate funding, teacher training, and infrastructure [4, 5, 6]. By embracing inclusive and equitable education, societies can create a more just and prosperous future where every learner can thrive and contribute to a sustainable world.

A. Technology Integration in Inclusive Education and its Impact on Learning Outcomes

Technology integration in inclusive education offers advantages for both teachers and students. Using technology, personalized instruction and differentiated learning pathways can be provided to adapt to students' needs [7, 8].

To ensure inclusive education for all students, including those with disabilities, it is crucial to provide them with tools like assistive technologies (AT). These ATs enable access to education and facilitate participation and success. When integrated within the framework of universal learning design (UDL), both high-tech (e.g., educational robots or screen readers) and low-tech (e.g., Braille) AT can potentially support the learning process, making it more inclusive [9, 10, 11, 12].

Technology enhances engagement and motivation, making learning experiences more effective [13, 14]. Real-time feedback and assessment tools help identify learning gaps promptly and provide targeted support to struggling students [15].

However, challenges related to limited access to technology, teacher training, and ensuring universal accessibility must be addressed to realize the potential of technology integration [16, 17]. Research suggests that technology integration positively influences academic achievement, facilitating comprehension and knowledge [18]. Additionally, it enables a sense of belonging and self-esteem among students, leading to increased confidence in their academic abilities [19]. Technology integration can provide a more inclusive and equitable educational landscape through effective implementation and continuous research.

B. Inclusive Mathematics Education and its Fundamental Principles

Inclusive mathematics education [20] is an approach that seeks to provide equitable opportunities and access to quality mathematical education for all students, regardless of their diverse backgrounds, abilities, or learning preferences [21, 22]. The core principle of inclusive mathematics learning lies in recognizing and valuing the individual differences among

students and tailoring instructional strategies to meet their unique needs.

To achieve inclusivity, teachers must create a supportive and respectful learning environment [23] that fosters a sense of belonging and encourages active participation from every student [24]. By addressing learners' diverse cognitive, linguistic, cultural, and social characteristics [25] inclusive mathematics education aims to promote academic success and the development of critical thinking and problem-solving skills applicable to real-world situations [20, 26, 27].

Fundamental principles that support inclusive mathematics learning include differentiation [28, 29], flexible pedagogy [30], and universal design for learning (UDL) [31]. Differentiation involves tailoring instructional content, processes, and assessments to accommodate various learning styles and proficiency levels [28]. By employing flexible pedagogy, teachers can adopt various teaching approaches, such as project-based learning or collaborative group work, to engage students with educational games (serious games) [32]. UDL emphasizes the proactive curriculum and instructional materials design to provide multiple means of representation, engagement, and expression, ensuring that all students can access and participate in the mathematical learning process [33]. By adopting these principles, inclusive mathematics education potentially empowers students to develop a deep understanding of mathematical concepts and formulate a positive mindset toward the subject, promoting lifelong learners' confidence and proficiency in mathematics and problem-solving skills.

Assistive technologies have the potential to support vision-impaired students in their educational journey. They empower students to read and write in Braille, access audio-based learning materials [34] and collaborate with peers using online platforms. Additionally, assistive technologies enhance students' independence, participation, and overall learning experience, fostering a more inclusive educational environment for those with vision impairments.

II. Vision-impaired students' challenges with Mathematics Learning

Vision impaired (VI) students face many challenges in mathematics education, which necessitate careful consideration and targeted interventions; these obstacles include information accessibility, limited teacher preparation, emotional effects, and other learning barriers. Recognizing and addressing these challenges is crucial in fostering an inclusive environment that empowers VI students to excel in mathematical learning, promoting inclusivity in education.

A. Access to Information and Learning Materials

One of the primary challenges for VI students is obtaining access to information and learning materials in a format they can comprehend. Traditional textbooks and printed materials are often inaccessible to them. VI students have various means to access information, such as Braille, audio, or enlarged print [34]. Braille offers numerous advantages for blind individuals compared to other writing systems [35]. Braille materials are an essential resource, but their availability can be limited and may only cover some subjects or grade levels [36]. Converting content into Braille or alternative formats can be time-consuming and costly [35]. This lack of timely access to instructional materials can impede their learning progress. Many students with visual impairments prefer accessing their materials in electronic formats and rely on "screen readers" as a common method of access [34].

B. Limited Specialized Teacher Training

Teachers play an important role in catering to the needs of VI students, for successful inclusion, a positive teacher attitude is essential. By undergoing effective teacher training, general education teachers can acquire diverse strategies that enhance accessibility for students with visual impairment [37]. For teachers with little to no experience or no previous social contact with VI individuals, teaching a VI student in a regular classroom can be perceived as a significant challenge [38]. Inclusive classrooms require collaborative efforts from both parents and teachers to develop personalized education plans for students. When teachers are unable to provide individualized attention to students with visual impairments in regular classrooms, it can negatively impact their academic performance [39]. This lack of expertise can lead to miscommunication and misunderstandings, hindering the students' overall learning experience [38]. It is essential for students with VI that their learning requirements are not disregarded [40].

A research study [41] conducted in Spain indicates that inclusive classrooms lack appropriate teaching and learning resources for students with visual impairments. Moreover, there is a notable absence of parental engagement and collaboration in their children's education. Additionally, teachers demonstrate insufficient knowledge in implementing inclusive practices and effectively teaching students with visual impairments in such classrooms. Furthermore, another research study carried out by NORAD (Norwegian Agency for Development Cooperation) demonstrates a review of selected policy and planning documents from Nepal, Tanzania, Vietnam, and Zambia, seeking to provide initial insights into the current inclusive education policy situation in these countries. The research found that the level of education among teachers in sign language, the use of Braille materials, the preparation of hearing aids, and the creation of tactile diagrams and maps is inadequate to meet the demands of inclusive teaching effectively [42].

C. Social and Emotional Challenges

In the process of children's development, fostering social skills holds the same significance as nurturing other abilities [43]. Vision impairment can result in social and emotional challenges for students. They face social isolation, reduced self-esteem, and increased dependency on others [43]. Encouraging a supportive and inclusive school environment and counselling services can help address these students' social and emotional needs; teachers and parental support can serve as protective factors against socio-emotional challenges such as lack of social skills [44]. Research shows that students with VI have a smaller circle of friends than their sighted peers and work hard to form relationships [40]. Self-esteem plays a vital role in fostering the confidence and motivation necessary for children to excel both academically and personally [45, 46]. Encouraging self-determination in school environments may pose difficulties for students with visual impairments [40].

D. Inaccessible Learning Environments

Children with visual impairment encounter challenges in adapting to their surroundings, leading to limitations, preventing them from interacting with others [43]. Physical learning environments may only sometimes accommodate vision-impaired students. Poorly designed classroom layouts, lack of tactile markers, and inaccessible school infrastructure can hinder their mobility and independence [47, 48]. The arrangement of schools, classrooms and the accessibility of facilities are particularly crucial for VI students. School systems, cultures, and support structures for visually impaired individuals differ across various countries. Some visually impaired children attend schools specifically designed for the blind, while others are integrated into mainstream educational institutions [46]. Overall if students with VI are offered a supportive environment, effective teaching, and learning approaches, they can become empowered [48, 49].

III. Future Classrooms: Role of Technology in Advancing Mathematics Education

STEM (science, technology, engineering, and mathematics) education is also challenging for visually impaired (VI) students [50, 51]. However, potential solutions, such as text-to-speech (TTS) technologies to vocalize mathematical equations, can be considered [52]. Moreover, tactile images and hands-on experiences are valuable for enhancing their learning process and comprehension of scientific concepts [50]. Notably, research [53] focuses on the Slovakian primary school learning system, where students use Braille books with tactile images for learning mathematics, electronic notebooks for note-taking, and mechanical typewriters for calculations.

Technology offers immense potential in mathematics education to enhance learning outcomes and promote inclusivity. The authors explore technology's role in advancing mathematics education, focusing on promoting equitable access and inclusivity for all students. Technology in mathematics education offers promising opportunities for promoting equitable access, inclusivity, personalized instruction, and support for students with diverse learning needs through adaptive, assistive, and AI-driven technologies [54, 55, 56].

A. Policy Recommendations to Promote Equitable Access to Technology in Educational Environments

Equitable access to technology is essential to ensure its benefits in mathematics education [57, 58]. Policymakers must prioritize providing adequate funding and resources to schools, especially those in underserved communities, enhancing digital coverage. Implementing professional development programs for teachers to integrate technology effectively into their classrooms can ensure optimal use [59]. Collaborating with private-sector partners and using public-private partnerships can also facilitate the procurement of advanced technologies for mathematics instruction.

B. Research and Development in Technology for Inclusivity and Equity in Mathematics Education

Inclusive mathematics education is linked to research and development efforts that meet diverse learning needs [60]. Researchers should focus on creating technology-driven solutions to help learners from various cultural, linguistic [61], and socioeconomic backgrounds [60]. This involves designing educational software and platforms that provide content in multiple languages, culturally relevant examples, and real-world contexts to enhance engagement and comprehension [62, 63]. Studies must be conducted to identify potential biases in algorithms and content that may affect certain student groups, and measures should be taken to rectify such biases [64, 65].

C. Adaptive Learning Technologies for Personalized Mathematics

Adaptive learning technologies have the potential to deliver education tailored to students' strengths and weaknesses [66]. These technologies utilize AI algorithms to identify areas of difficulty and dynamically adjust the content and difficulty level of exercises to optimize learning experiences [67, 68]. Adaptive learning technologies can help bridge learning gaps and promote a deeper understanding of mathematical concepts [68]. However, it is essential to address data privacy and security concerns to ensure the responsible use of student data [69].

D. Digital Resources and Accessibility Tools for Inclusive Mathematics Learning

In the digital age, many digital resources and accessibility tools are available to enhance mathematics learning experiences for diverse students. To ensure accessibility, designers and developers should adhere to accessibility standards, making these resources usable for students with disabilities. Providing multiple formats for content presentation, such as audio, visual, and textual, can accommodate diverse learning preferences and enhance comprehension for all learners [70]. Touch screens are not always accessible and user-friendly for vision-impaired users, which prevents them from using mobile phones or tablets to study or even for entertainment. Building the interface using spatialized, non-speech sound [71] supports the inclusivity of touch screens leading to enhanced access to mathematics education online resources.

AI technologies have demonstrated transformative potential in advancing mathematics education across various domains. Robots and chatbots equipped with AI can serve as personalized tutors, offering immediate feedback and guidance to students as they engage with mathematical problems [72, 73]. Additionally, AI in Education (AIEd) platforms can analyze vast amounts of educational data to gain insights into student learning patterns and inform instructional strategies [74]. However, ethical considerations, transparency, and privacy concerns associated with using AI in mathematics education must be addressed to build trust among educators, students, and parents.

IV. Ethical Considerations and Privacy Concerns

Ethical considerations and privacy concerns are significant issues that arise with the integration of technology in education. As technology becomes more integrated in classrooms, it is imperative to address the potential implications for student data protection and the overall ethical use of educational technologies [75].

A. Changing the Educational Landscape: Embracing Technology and Artificial Intelligence

The exclusive role of the teacher as the source of knowledge has shifted. To keep up with these advances, educators today understand that they must commit to learning computer technology [76]. Artificial intelligence promises to significantly enhance learning experiences within and beyond traditional educational settings [77]. While educators can explore ways to harness these supportive technologies for enhanced learning and resource optimization, it's important to bear in mind that many of these tools lack proper field testing and have limited or no proven effectiveness [78].

B. Privacy and Ethical Considerations for AI in Education (AIED)

Privacy is a crucial issue, with potential risks for teachers' and learners' information. For example, agent-based personalized education could use past performance data for future predictions. Educational systems primarily gather user data to anticipate learning behaviors and performance [75]. The introduction of AI in educational settings sparks significant questions – for instance, regarding curriculum content and delivery, the evolving responsibilities of educators, and the ethical and societal implications of AI [69].

C. Balancing Student Data Ethics and AIEd

One major ethical concern involves the collection and usage of student data. Educational technology often requires collecting of personal information, ranging from basic identifiers to more sensitive data like learning patterns and behavioral characteristics [75]. For example, chatbots gather substantial personal data, raising worries about privacy and security. The data used to train chatbots might carry biases, impacting accuracy and potentially causing unintended discrimination [79]. As technology monitors student engagement and performance, it can inadvertently infringe upon individual privacy rights.

In addressing these ethical and privacy challenges, educational policymakers must establish clear guidelines for the responsible use of technology [75]. Teachers should educate students not just about using AI, but also about its impact on society and ethical considerations [80]. However, adopting AIEd has raised ethical concerns regarding personal data and learner autonomy [75]. AI-based systems should undergo more thorough testing before integration into education settings. Educational institutions should prioritize student and staff security, uphold privacy, and ensure transparent data collection and usage [78].

V. Conclusion

Inclusive education is a vital approach that strives to provide equal educational opportunities for all students, including those with disabilities, ensuring access to quality learning experiences. Despite its noble intentions, inclusive education still lacks comprehensive policy-related research on a global scale. To bridge this gap, promoting teacher training programs dedicated to inclusive education and adaptive strategies is imperative. Such initiatives are key in enriching the educational journey of students with vision impairments. For true inclusivity to emerge, educators must consistently engage in self-reflection, adapt their teaching practices, and evaluate their influence on student engagement, participation, and academic accomplishments.

Integrating technology into inclusive mathematics education presents immense potential to revolutionizing the learning process for students with vision impairments. By leveraging technology, barriers that hinder their learning can be dismantled, affording all students equal chances to learn and excel. However, it is essential to acknowledge the existing challenges that must be tackled to ensure the effective implementation of technology in this context. A significant aspect of fostering inclusive mathematics education lies in providing specialized tools, such as screen readers, Braille displays, and audio resources. These tools empower vision-impaired students by facilitating learning and fostering independence, enhancing their overall educational experience.

A collaborative effort involving governments, educational institutions, technology developers, and the community at large is indispensable in pursuing inclusive education; by collectively addressing challenges, embracing technological advancements, and adhering to ethical principles, a transformative educational landscape can be cultivated. A joint initiative involving governments, educational institutions, technology pioneers, and the wider community is essential in pursuing inclusive education. A transformative educational setting can be cultivated through shared actions to address challenges, embrace technological advancements, and uphold ethical principles. This environment pledges equal opportunities for students with visual impairments, enabling them to excel academically and make valuable contributions to society, ultimately shaping a future that embodies true inclusivity and empowerment for all.

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References

[1] "Goal 4," Sdgs.un.org. [Online]. Available: https://sdgs.un.org/goals/goal4.

[2] C. Raffo and H. Gunter, "Leading schools to promote social inclusion: developing a conceptual framework for analysing research, policy and practice," Journal of Education Policy, vol. 23, pp. 397–414, 2008.

[3] M. Rieckmann, Education for sustainable development goals: Learning objectives. 2017.

[4] V. Kioupi and N. Voulvoulis, "Education for sustainable development: A systemic framework for connecting the SDGs to educational outcomes," Sustainability11, vol. 21, 2019.

[5] T. Ferguson and C. G. Roofe, "SDG 4 in higher education: Challenges and opportunities," International Journal of Sustainability in Higher Education, vol. 21, pp. 959–975, 2020.

[6] D. Rad, "Pathways to inclusive and equitable quality early childhood education for achieving SDG4 goal-A scoping review," Frontiers in psychology, vol. 13, 2022.

[7] N. Abidova, "Problems of Preparing Future Defecttologists to Work in the Conditions of Inclusive Education," Journal of Pharmaceutical Negative Results, pp. 2505–2511, 2022.

[8] V. Benigno, S. Bocconi, and M. Ott, "Inclusive education: helping teachers to choose ICT resources and to use them effectively," Elearning Paper, vol. 6, 2007.

[9] M. H. Al Omoush and T. Mehigan, “Leveraging robotics to enhance accessibility and engagement in mathematics education for vision-impaired students,” in 2023 5th International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA), 2023.

[10] P. Hunt, “Inclusive education: The case for early identification and early intervention in assistive technology,” Assistive Technology, vol. 33, pp. S94–S101, 2021.

[11] D. Tamakloe, “Enhancing learning and development of young children with disabilities with assistive technology,” Assistive Technology to Support Inclusive Education, vol. 14, pp. 141–161, 2020.

[12] "Assistive technology," *www.who.int*. https://www.who.int/health-topics/assistive-technology

[13] C. A. Marcela and R. Escobar Díaz, “Educational experiences with Generation Z,” International Journal on Interactive Design and Manufacturing (IJIDeM), vol. 14, pp. 847–859, 2020.

[14] Y.-L. Chen and C.-C. Hsu, “Self-regulated mobile game-based English learning in a virtual reality environment,” Comput. Educ., vol. 154, no. 103910, p. 103910, 2020.

[15] A. G. Zhang, Y. Chen, and S. Oney, “VizProg: Identifying misunderstandings by visualizing students’ coding progress,” in Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems, 2023.

[16] K. O’Sullivan, A. McGrane, S. Long, K. Marshall, and M. Maclachlan, “Using a systems thinking approach to understand teachers perceptions and use of assistive technology in the republic of Ireland,” Disabil. Rehabil. Assist. Technol., vol. 18, no. 5, pp. 502–510, 2023.

[17] R. Patel, P. Breton, C. M. Baker, Y. N. El-Glaly, and K. Shinohara, “Why software is not accessible: Technology professionals’ perspectives and challenges,” in Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems, 2020.

[18] I. Presley, F. Mary, and D. Andrea, Assistive technology for students who are blind or visually impaired: A guide to assessment. American Foundation for the Blind. 2008.

[19] S. S. Faradiba and A. Alifiani, “Metacognitive blindness in mathematics problem-solving,” JELMaR, vol. 1, no. 2, pp. 43–49, 2020.

[20] A. Gervasoni and A. Peter-Koop, “Inclusive mathematics education,” Math. Educ. Res. J., vol. 32, no. 1, pp. 1–4, 2020.

[21] T. Hehir, “A Summary of the Evidence on Inclusive Education,” Abt Associates, 2016.

[22] K. Cologon, Inclusion in education: Towards equality for students with disability. 2013.

[23] D. G. Cole, H. L. Sugioka, and L. C. Yamagata-Lynch, “Supportive classroom environments for creativity in higher education,” J. Creat. Behav., vol. 33, no. 4, pp. 277–293, 1999.

[24] B. Dewsbury and C. J. Brame, “Inclusive teaching,” CBE Life Sci. Educ., vol. 18, no. 2, p. fe2, 2019.

[25] Vágvölgyi, Réka, et al. "A review about functional illiteracy: Definition, cognitive, linguistic, and numerical aspects." *Frontiers in psychology* (2016): 1617.

[26] A. I. Ranasinghe and D. Leisher, “The benefit of integrating technology into the classroom,” International Mathematical Forum, vol. 4, no. 40, 2009.

[27] Fox, Jillian. "A justification for mathematical modelling experiences in the preparatory classroom." (2006).

[28] G. Anthony, J. Hunter, and R. Hunter, “Working towards Equity in Mathematics Education: Is Differentiation the Answer?,” Mathematics Education Research Group of Australasia, 2019.

[29] C. Büscher, “Conceptual learning opportunities in teachers’ differentiated task designs for inclusive mathematics education,” in Eleventh Congress of the European Society for Research in Mathematics Education, 2019.

[30] N. Gordon, “Flexible pedagogies: Technology-enhanced learning,” The Higher Education Academy, vol. 1, pp. 2–14, 2014.

[31] R. Lambert, “UDL Is the What, Design Thinking Is the How,” Designing for Differentiation in Mathematics, vol. 23, pp. 54–77, 2021.

[32] M. N. Konstantinos and N. Giannakos, “Design principles for serious games in mathematics,” in Proceedings of the 18th Panhellenic Conference on Informatics, 2014.

[33] R. Lambert, “Increasing Access to Universally Designed Mathematics Classrooms,” Policy Analysis for California Education, 2020.

[34] M. Quirke, P. McCarthy, and C. Mc Guckin, Eds., See What You Mean”: Encouraging Higher Education Educators to Reflect Upon Their Teaching and Learning Practice When Engaging with Blind/ Vision Impaired Learners, vol. 10, no. 1. AISHE-J.

[35] J. Guerreiro, D. Gonçalves, D. Marques, T. Guerreiro, H. Nicolau, and K. Montague, “The today and tomorrow of Braille learning,” in Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility, 2013, pp. 1–2.

[36] M. Bitter, *Braille in mathematics education*. 2013.

[37] H. Miyauchi, “A systematic review on inclusive education of students with visual impairment,” Educ. Sci. (Basel), vol. 10, no. 11, p. 346, 2020.

[38] N. Kocyigit and P. S. Artar, “A challenge: Teaching English to visually-impaired learners,” Procedia Soc. Behav. Sci., vol. 199, pp. 689–694, 2015.

[39] S. Sikanku, “Challenges in teaching pupils with visual impairment in inclusive classrooms: The experience of Ghanaian teachers,” Research on Humanities and Social Sciences, vol. 8, no. 11, 2018.

[40] G. M. Jessup, A. C. Bundy, N. Hancock, and A. Broom, “Being noticed for the way you are: Social inclusion and high school students with vision impairment,” Br. J. Vis. Impair., vol. 36, no. 1, pp. 90–103, 2018.

[41] C. Simon, G. Echeita, M. Sandoval, and M. López, “The inclusive educational process of students with visual impairments in Spain: An analysis from the perspective of organizations,” *J. Vis. Impair. Blind.*, vol. 104, no. 9, pp. 565–570, 2010.

[42] *Report to NORAD on desk review of inclusive education policies and plans in Nepal , Tanzania , Vietnam and Zambia*. 2008.

[43] N. M. Salleh and K. Zainal, “How and why the visually impaired students socially behave the way they do,” Procedia Soc. Behav. Sci., vol. 9, pp. 859–863, 2010.

[44] I. Manitsa, F. Barlow-Brown, and M. Livanou, “Evaluating the role of social inclusion in the self-esteem and academic inclusion of adolescents with vision impairment,” British Journal of Visual Impairment, 2023.

[45] M. Ferkany, “The educational importance of self-esteem,” J. Philos. Educ., vol. 42, no. 1, pp. 119–132, 2008.

[46] L. B. Augestad, “Self-concept and self-esteem among children and young adults with visual impairment: A systematic review,” Cogent Psychol., vol. 4, no. 1, p. 1319652, 2017.

[47] C. M. Brown, T. L. Packer, and A. Passmore, “Adequacy of the regular early education classroom environment for students with visual impairment,” J. Spec. Educ., vol. 46, no. 4, pp. 223–232, 2013.

[48] C. Palmer, “Educating learners with vision impairment in inclusive settings,” *Int. Congr. Ser.*, vol. 1282, pp. 922–926, 2005.

[49] W. J. Fraser and M. O. Maguvhe, “Teaching life sciences to blind and visually impaired learners,” *J. Biol. Educ.*, vol. 42, no. 2, pp. 84–89, 2008.

[50] M. Sahin and N. Yorek, “Teaching Science to Visually Impaired Students: A Small-Scale Qualitative Study,” Online Submission, vol. 6, pp. 19–26, 2009

[51] A. Kızılaslan, S. L. Zorluoglu, and M. Sözbilir, “A hands-on classroom activity to teach science concepts for students with visual impairment,” *Science Activities*, vol. 56, pp. 130–138, 2019.

[52] W. Wongkia, K. Naruedomkul, and N. Cercone, “i-Math: Automatic math reader for Thai blind and visually impaired students,” *Comput. Math. Appl.*, vol. 64, no. 6, pp. 2128–2140, 2012.

[53] I. Kohanova, "The ways of teaching mathematics to visually impaired students." *integration* 1 (2010)

[54] C. J. Cullen, J. T. Hertel, and M. Nickels, “The roles of technology in mathematics education,” Educ. Forum, vol. 84, no. 2, pp. 166–178, 2020.

[55] C. Attard and K. Holmes, Technology-enabled mathematics education: Optimising student engagement. Routledge. 2019.

[56] G.-J. Hwang and Y.-F. Tu, “Roles and research trends of artificial intelligence in mathematics education: A bibliometric mapping analysis and systematic review,” Mathematics, vol. 9, no. 6, p. 584, 2021.

[57] C. N. Thomas, K. N. Peeples, M. J. Kennedy, and M. Decker, “Riding the special education technology wave: Policy, obstacles, recommendations, actionable ideas, and resources,” Interv. Sch. Clin., vol. 54, no. 5, pp. 295–303, 2019.

[58] M. Bashay, “Digital Skills for an Equitable Recovery: Policy Recommendations to Address the Digital Skill Needs of Workers Most Vulnerable to Displacement,” National Skills Coalition, 2020.

[59] J. L. Donath, T. Lüke, E. Graf, U. S. Tran, and T. Götz, “Does professional development effectively support the implementation of inclusive education? A meta-analysis,” Educ. Psychol. Rev., vol. 35, no. 1, 2023.

[60] A. Bakker, J. Cai, and L. Zenger, “Future themes of mathematics education research: an international survey before and during the pandemic,” Educ. Stud. Math., vol. 107, no. 1, pp. 1–24, 2021.

[61] S.-A. Robertson and M. Graven, “Language as an including or excluding factor in mathematics teaching and learning,” Math. Educ. Res. J., vol. 32, no. 1, pp. 77–101, 2020.

[62] P. Vankúš, “Influence of game-based learning in mathematics education on students’ affective domain: A systematic review,” Mathematics, vol. 9, no. 9, p. 986, 2021.

[63] K. W. H. Tai, “Translanguaging as inclusive pedagogical practices in English-medium instruction science and mathematics classrooms for linguistically and culturally diverse students,” Res. Sci. Educ., vol. 52, no. 3, pp. 975–1012, 2022.

[64] D. Martin, “Refusing Systemic Violence against Black Children: Toward a Black Liberatory Mathematics Education,” in Critical Race Theory in Mathematics Education. Routledge, 2019, pp. 32–55.

[65] R. Q. Berry III, M. Ellis, and S. Hughes, “Examining a history of failed reforms and recent stories of success: mathematics education and Black learners of mathematics in the United States,” Race Ethn. Educ., vol. 17, no. 4, pp. 540–568, 2014.

[66] A. Alam, “Employing adaptive learning and intelligent tutoring robots for virtual classrooms and smart campuses: reforming education in the age of artificial intelligence,” in Advanced Computing and Intelligent Technologies: Proceedings of ICACIT 2022, Singapore; Singapore: Springer Nature, 2022, pp. 395–406.

[67] I. Magnisalis, S. Demetriadis, and A. Karakostas, “Adaptive and intelligent systems for collaborative learning support: A review of the field,” IEEE Trans. Learn. Technol., vol. 4, no. 1, pp. 5–20, 2011.

[68] Z. Y. Dong, Y. Zhang, C. Yip, S. Swift, and K. Beswick, “Smart campus: definition, framework, technologies, and services,” IET Smart Cities, vol. 2, no. 1, pp. 43–54, 2020.

[69] C. Adams, P. Pente, G. Lemermeyer, and G. Rockwell, “Ethical principles for artificial intelligence in K-12 education,” *Computers and Education: Artificial Intelligence*, vol. 4, no. 100131, p. 100131, 2023.

[70] E. Freeman, Multimodal Feedback in HCI: Haptics, Non-Speech Audio, and Their Applications.” The Handbook of Multimodal-Multisensor Interfaces: Foundations, User Modeling, and Common Modality Combinations, vol. 1. ACM, 2017.

[71] F. Neff, T. J. Mehigan, and I. Pitt, “Accelerometer & spatial audio technology: Making touch-screen mobile devices accessible,” in Lecture Notes in Computer Science, Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 170–177.

[72] A. Alam, “Possibilities and apprehensions in the landscape of artificial intelligence in education,” in 2021 International Conference on Computational Intelligence and Computing Applications (ICCICA), 2021.

[73] E. Mercier-Laurent and G. Kayakutlu, Proceedings 7th International Workshop on Artificial Intelligence for Knowledge Management (AI4KM 2017) AI for Humans. 2017.

[74] M. J. Timms, “Letting artificial intelligence in education out of the box: Educational cobots and smart classrooms,” Int. J. Artif. Intell. Educ., vol. 26, no. 2, pp. 701–712, 2016.

[75] A. Nguyen, H. N. Ngo, Y. Hong, B. Dang, and B.-P. T. Nguyen, “Ethical principles for artificial intelligence in education,” *Educ. Inf. Technol.*, vol. 28, no. 4, pp. 4221–4241, 2023.

[76] K. Kerr, “Chapter 1: Ethical considerations when using artificial intelligence-based assistive technologies in education,” in *Ethical Use of Technology in Digital Learning Environments: Graduate Student Perspectives*, Calgary, AB, Canada: University of Calgary, 2020.

[77] M. J. Reiss, “The Use of Al in Education: Practicalities and Ethical Considerations,” *London Review of Education*, vol. 19, 2021.

[78] K. Kerr, “Chapter 1: Ethical considerations when using artificial intelligence-based assistive technologies in education,” in *Ethical Use of Technology in Digital Learning Environments: Graduate Student Perspectives*, Calgary, AB, Canada: University of Calgary, 2020.

[79] C. Kooli, “Chatbots in education and research: A critical examination of ethical implications and solutions,” Sustainability, vol. 15, no. 7, p. 5614, 2023.

[80] T. K. Ng, J. K. L. Leung, K. W. S. Chu, and M. S. Qiao, “AI literacy: Definition, teaching, evaluation and ethical issues,” *Proc. Assoc. Inf. Sci. Technol.*, vol. 58, no. 1, pp. 504–509, 2021.