Mathematics Accessibility in Primary Education: Enhancing Mathematics Learning Skills and Overcoming Barriers for Visually Impaired Primary Students

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Abstract. This paper describes a qualitative study concerning the experiences of blind and visually impaired students learning mathematics in primary schools in Ireland, along with a thematic analysis of the findings. It investigates the instructional challenges and teaching techniques that facilitate an inclusive learning environment through flexible assessment plans. Key focus areas include adapting class collaboration activities, using digital and non-digital materials, and deploying specialized strategies to boost learning skills. This study identified significant barriers, including technology accessibility, classroom mobility, and the need for supportive educational aids such as tactile materials and Braille resources. This paper also discusses the importance of support and assistance, including teacher training, parental involvement, and peer support processes. Based on expert opinions, the study identifies gaps in current solutions and suggests future research and development directions. These include the advancement of User-Centred Design (UCD), the integration of multimodal techniques, and the improvement of collaborative and interactive learning solutions. Furthermore, this study recommends reforming educational policy and comprehensive training programs for educators to ensure that visually impaired students receive an equitable mathematics education. This study lays the groundwork for future advancements in teaching methodologies and assistive technologies, aiming to remove educational barriers and foster academic excellence within blind and visually impaired students.

Keywords: Mathematic, Barriers, Primary, Accessibility, Blind, Visually-Impaired

1 Introduction and background

Educational inclusion is still a cornerstone of equal schooling. The unique academic requirements of blind and visually-impaired children are often not adequately met during primary education. This study presents a thematic analysis that investigates three main areas: the mathematical learning experiences of blind and visually-

impaired students, the pedagogical approaches of teachers, and expert viewpoints on accessible educational solutions in primary schools.

1. Mathematical learning experiences of blind and visually-impaired students

The first area of attention concerns the unique challenges and techniques of mathematics learning for blind and visually impaired students. Previous research includes many studies focusing on specific teaching strategies for these students and identifying several key aspects of mathematics learning. Maćkowski & Brzoza introduced a tutoring platform developed for visually impaired children. The platform utilizes audio-tactile visuals to enhance the learning process for mathematics topics. The efficiency of this platform was examined through quantitative and qualitative research with students from primary and secondary schools. The study attempts to improve learning effectiveness through tailored audio explanations and exercises, catering specifically to the educational needs of visually impaired students[1]. Hayes et al. examine the issues faced by students with visual impairments during standard scientific and mathematics instruction. They stress the significance of classroom adjustments, such as hands-on experiences and extra instructional time, to promote their learning. They also highlighted findings concerning educational policies and practices, i.e., effective adaptation of teaching materials and helping students acquire skills that enhance their independent learning [2]. Steinbach addressed the obstacles students with visual impairments face in obtaining and understanding the mathematics curriculum. It examines several techniques of conveying mathematical information to these children, such as auditory, tactile, and multi-sensory approaches. This study also underlines the need to adjust instructional strategies and resources to suit the needs of visually impaired students, concentrating on boosting their engagement and understanding of mathematical ideas. The study highlights the need for inclusive educational approaches and the development of appropriate multi-sensory solutions to help the mathematical education of visually impaired children[3]. Drijvers & Sinclair reviewed how digital technologies were employed in mathematics instruction. They created a framework encompassing five aims for employing DTs: increasing learning, understanding learning processes, designing for learning, guaranteeing equal access, and influencing curriculum and teaching practices. They address various theoretical foundations, methodologies, and outcomes relevant to these aims, illustrating the evolving nature of research on this topic and the rising relationship between digital technology and mathematical education. The article underlines the significant impact of DTs on the nature of mathematics education and learning[4]. Bobomurod focused on the educational obstacles and methods of teaching mathematics to visually impaired students. This study highlights the need to understand children's attitudes toward mathematics learning from an early age to prevent the development of negative opinions about this subject. Moreover, it examines the content and objectives of the mathematics course, highlighting the need for corrective and developmental conditions, particular techniques, and cognitive activity development. It underlines the significance of adjusting educational methodologies to accommodate the specific demands of visually impaired students, trying for their optimal growth and social adaptation [5].

2. Investigation of teachers' experiences while teaching mathematics to Blind and visually impaired students

The second area of attention is teachers' experiences when educating blind and visually impaired students. The literature shows that teachers are essential in designing inclusive education. They often experience unique pedagogical problems and lack proper preparation. Rushahu conducted a study focusing on the issues and skills of lecturers in Tanzanian higher education institutions to serve visually impaired pupils. A qualitative method was employed with interviews and focus group discussions among 40 participants, including students with visual impairments and professors. The survey demonstrates that most professors lack the abilities and knowledge to identify and address the unique learning demands of these students. It underscores the need for redesigned university curricula, adequate training for professors, and more significant state funding for inclusive education[6]. A thesis by Amanda Esmeralda Mungunda, finished in April 2023, explores the specific obstacles that secondary school mathematics teachers confront when educating learners with vision impairment. Focusing on the Khomas region in Namibia, the study adopts Bruner's idea of constructivism as its theoretical base. Utilizing qualitative research methodologies, it comprises observations and semi-structured interviews with a selected sample of teachers and visually impaired students. The study intends to improve visually impaired students' teaching and learning experiences and offers successful teaching practices, including the need for assistive technologies and instructional materials [7]. Baykaldı explored the experiences of high school mathematics teachers in teaching students with visual impairments. They investigate the challenges faced by the teachers, along with their teaching styles, curriculum preparation, assessment strategies, and ideas regarding inclusive education. The study, conducted through interviews with eight instructors, highlighted a lack of proper training and resources for inclusive education, although they demonstrated 'high teaching efficacy' generally (e.g., with non-visually-impaired students) and had high ideals regarding teaching (e.g., were highly motivated to help visually impaired students. The findings underline the need for increased teacher training and resource development to facilitate inclusive education [8]. Mbulaheni Maguvhe proposed a study focusing on the problems and opportunities in teaching science and mathematics to visually impaired children. The study is based on a case study approach, underlining the critical role of instructors and the necessity for specialized resources and training. It highlights the need to empower instructors to serve visually impaired students in various courses successfully and recognizes the vital role of inclusive education methods. The research gives valuable insights for increasing the learning abilities of visually impaired students in science and mathematics, helping the broader conversation on inclusive education [9].

3. Expert viewpoints on accessible educational solutions in primary schools

Thirdly, the study included professionals to obtain suggestions for potential solutions for these children. Integrating expert perspectives is vital in bridging the gap between theoretical knowledge and actual application. Previously, several studies were conducted without the opinion of experts or professionals. IrisMath is a web program developed to aid visually impaired people in executing mathematical operations, notably for engineering students. Inspired by Jupyter Notebooks, this system supports

multiple output formats such as LaTex, CMathML, JSON, and audio, assuring accessibility and comprehensibility for visually impaired users. The paper explores the architecture, development, and evaluation of IrisMath, showing its potential as a helpful tool for inclusive education in technical and engineering subjects [10]. Gözde et al. investigate the experiences of visually impairment children in inclusive math courses in Turkey. It focuses on the obstacles these students experience, their opinions on learning methods, and the usefulness of the resources adopted. The study underlines the gap between these children's social and academic demands, underlining a shortage of teacher preparation and reservations towards inclusive education. It emphasizes the need for increased teacher training and creating resources to help visually impaired children in mathematics [11]. Karshmer and Gupta conducted a study on building tools to help visually challenged children learn mathematics. They address the issue of writing and reading complicated mathematical formulas for children. The project at New Mexico State University includes developing logic programming-based systems and interfaces to improve the utilization of mathematical information. This includes building a method for converting Nemeth Code to LaTeX and vice versa, boosting collaboration among blind students and sighted lecturers. The research also discusses employing encoded musical notes and signals of sound to express mathematical concepts, seeking to complete the education cycle with accessible resources for visually impaired children [12].

In this article, we have explored the challenges of blind and visually impaired primary school students. A study was conducted with teachers intended to add depth to this knowledge by examining the lived experiences of teaching in primary schools. Find out the viewpoints of professionals and expert persons. Their thoughts can help researchers and developers build more prosperous, inclusive educational platforms for blind and visually impaired students. This thematic analysis contributes to the ongoing conversation about inclusive education. It strives not only to expose the existing obstacles and opportunities in teaching mathematics to blind and visually impaired primary students but also to provide actionable ideas for improvement, pulling from both academic and practical domains. The remaining article is organized as follows: Section 2 explains the methodology; Section 3 illustrates the results in the form of extracted themes; Section 4 concludes this article and provides recommendations for future work.

2. Methodology

The research employed a qualitative study design, employing semi-structured interviews for data collection. Thematic analysis was used to analyze the gathered data.

2.1 Participants

This study involved nineteen participants divided into three categories: students, teachers, and domain experts. Firstly, this study included five visually-impaired participants from various primary schools, two males and three females. These individuals were recruited from different primary schools. Their ages ranged from 9 to 12

years, with a mean age of 10.80 (Std. Deviation = 1.3 and Variance = 1.7). Student participants in the study met the criteria for legal blindness (visual acuity 20/400 or less). Among the participants, three were completely blind (P1, P2, and P4), and two participants (P3 and P5) had low vision. Most students identified as Republic of Ireland nationals (4), and EU national (1), Secondly, nine primary school teachers (P6-P14) took part in this study. They have diverse roles within the primary school context, including class teachers (1), Support teachers (2), and Special Educational Needs teachers (6), boasting experience ranging from 3 to 22 years. The age range of participants spanned from 26 to 54 years, with a notable gender difference (7 females, 2 males). The majority of participants identified as Republic of Ireland nationals (4), EU National (2), Asian (2), or United Kingdom (1), aligning with broader demographic trends in the teaching profession. Thirdly, five focus group persons (P15-P19) from several organizations, i.e., National Disability Authority (1), National Council for Special Education (1), Saint John of God (1), and VisitEDUfinn Ltd (2), participated in this study. The age range of participants spanned from 40 to 58 years, with a notable gender difference (3 females, 2 males). Their professional experience ranges from 5 to 20 years. The majority of participants identified as Republic of Ireland nationals (2) and EU National (2), United Kingdom (1), aligning with broader demographic trends in their professional careers. Overall, teachers and focus group participants ages ranged from 26 to 58 years, with a mean age of 43.64 (Std. Deviation = 9.44 and Variance = 89.02). Their experience ranges from 3 to 22 years, with a mean experience of 13 (Std. Deviation = 6.28 and Variance = 39.39). For additional demographic details, refer to Table 1 and Table 2. Table 1 provides participant details, including participant ID, age, gender, nationality, a description of vision impairment, blind or low vision, and Educational arrangements. Table 2 provides participant details, including participant ID, age, gender, nationality, and experience in number of years.

Table 1 Detailed information of student participants

Participants ID	Age	Gender	Nationality	Description of vision-impaired	Educational Arrangments
P1	12	Female	EU Country	Blind	Special education class
P2	10	Male	EU Country	Blind	General education along with special education
P3	11	Female	EU Country	Low Vision	General education along with special education
P4	9	Male	Republic of Ireland	Blind	General education along with special education
P5	12	Female	Republic of Ireland	Vow Vision	General education along with special education

Table 2. Detailed information of Teachers and Focus group participants

Participants ID	Age	Gender	Nationality	Experience in No. of Years
P6	52	Female	Asian	20
P7	42	Female	EU Country	19
P8	26	Female	Asian	3
P9	29	Female	EU Country	18
P10	45	Male	United Kingdom	10
P11	37	Male	Republic of Ireland	14
P12	43	Female	Republic of Ireland	22
P13	54	Female	Republic of Ireland	7
P14	44	Female	Republic of Ireland	10
P15	43	Female	EU Country	13
P16	58	Male	EU Country	15
P17	40	Male	United Kingdom	5
P18	57	Female	Republic of Ireland	20
P19	41	Female	Republic of Ireland	6

2.2 Data analysis

One technique for finding, examining, and summarizing patterns in qualitative data is thematic analysis. Using this methodology, data can be transformed into rich, in-depth knowledge through text analysis. Thematic analysis is a tool for identifying and explaining facts and capturing crucial details related to the data and research question. Thematic analysis is an iterative and distinctive approach to text evaluation that offers a specific understanding and interpretation of the study issue, according to researchers [13-14]. Thus, in the current study, the concerns of visually impaired students and teachers were identified and extracted using thematic analysis.

The data was examined using the inductive thematic analysis procedure outlined by Braun and Clarke[15]. Thematic analysis was chosen for its adaptability and capacity to yield insightful, interpretative comments [16]. This approach is not theory-driven but instead data-driven, enabling the researcher to uncover unforeseen insights. The analysis adhered to Braun and Clarke's six-step method. Firstly, the researchers read and familiarized themselves with the data. Secondly, codes were manually generated on the transcripts' margins based on the entire dataset. The same unit of text could be encompassed in more than one code, and relevant data for each code were compiled. Thirdly, the coded data were systematically reviewed, cross-checked, and organized into themes. Fourthly, themes were cross-checked against the coded data and the entire dataset and concluded by creating a thematic 'map.' Fifthly, themes were defined and labeled. Finally, the themes underwent in-depth analysis, with selected data extracts examined in relation to the research question, existing literature, and the subsequent report.

3 Results

3.1 A thematic analysis of Mathematics learning of Blind and visually impaired students in primary schools perceptions of learning Challenges, strategies, support, resources

After examining the five transcripts, five prominent themes concerning students' viewpoints were found. Figure 1 presents a comprehensive visual representation of the factors affecting the learning process of visually impaired students in mathematics. The diagram also represents a thematic analysis related to the mathematics learning of blind and visually impaired students in primary schools. It is structured around a central theme, "Investigating Mathematics learning of Blind and visually impaired students in primary schools", with related factors branching out into specific categories such as: "Mathematics Topics", "Class Collaboration Activities", "Challenges, Obstacles, and Issues", "Techniques and Methods to Fulfill Learning Needs", and "Assistance and Support".

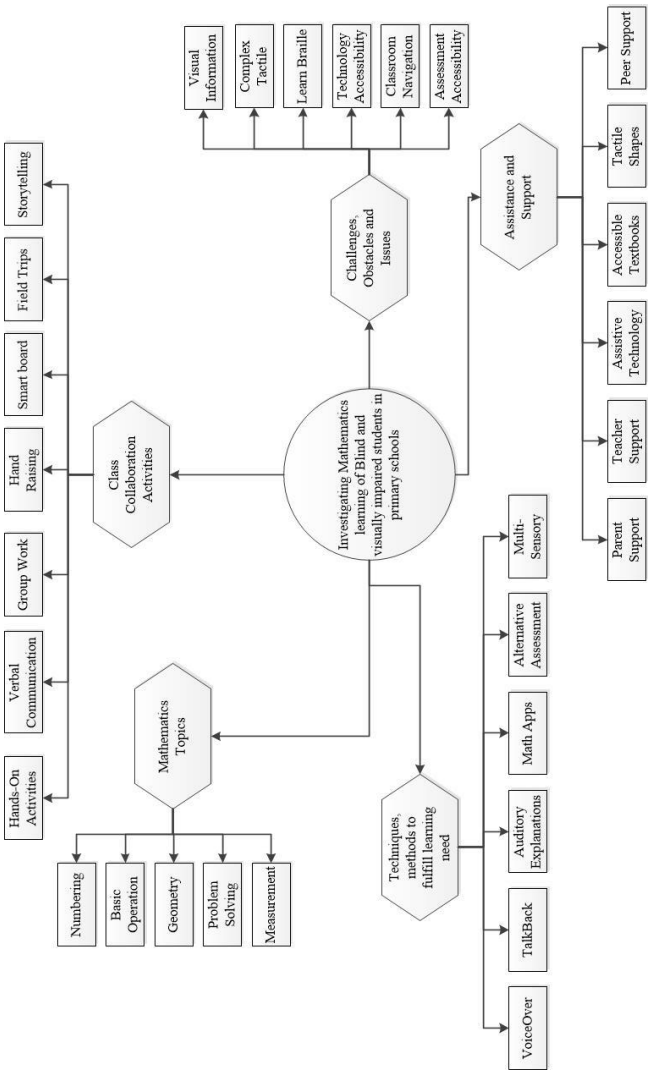

Fig. 1. A thematic analysis of Mathematics learning of Blind and visually impaired students

3.2 Investigation of teacher experiences while teaching mathematics to Blind and visually impaired students in primary schools

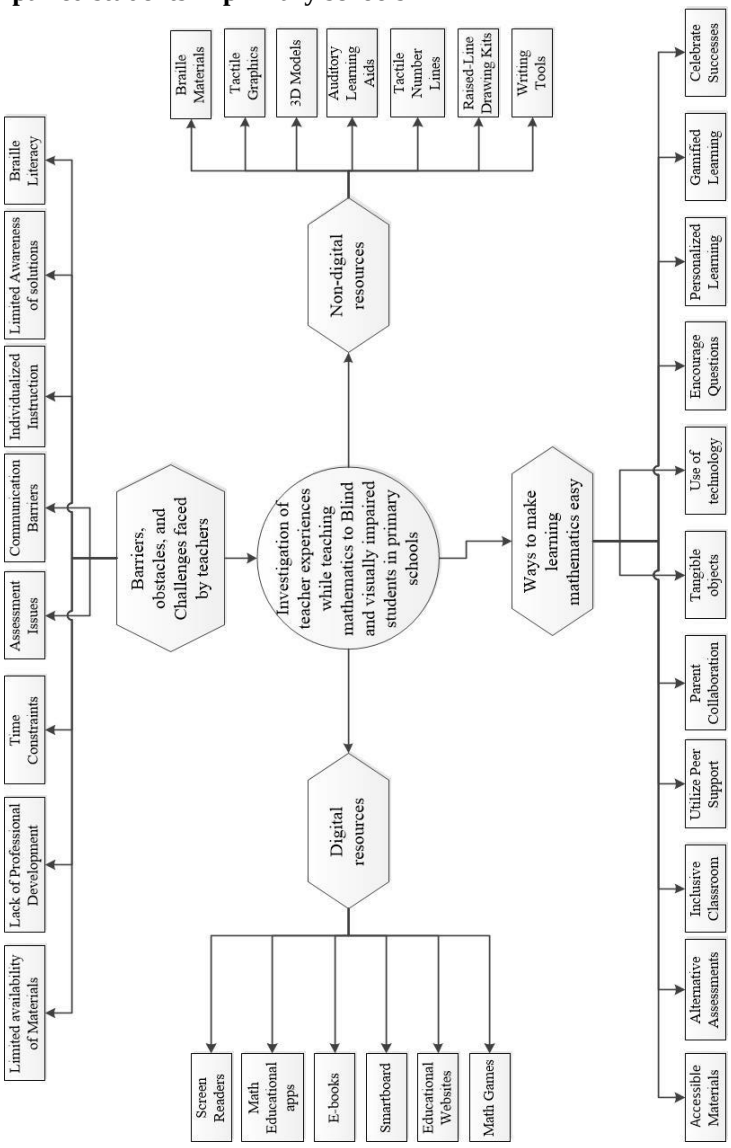

Fig. 2. A thematic analysis of teachers' experiences

An analysis of nine transcripts revealed four leading themes concerning teachers' viewpoints. Figure 2 presents a comprehensive analysis of the various factors affecting the teaching process and the potential strategies to overcome challenges, facilitating a better learning experience for visually impaired students in primary schools. This diagram also represents the thematic analysis of teacher experiences while teaching mathematics to blind and visually impaired students in primary schools. Here's an

explanation of its structure: The central theme of the diagram is the "Investigation of teacher experiences while teaching mathematics to Blind and visually impaired students in primary schools." Branching out from this central theme are four main categories: "Barriers, obstacles, and Challenges faced by teachers", "Digital resources", "Non-digital resources", and "Ways to make learning mathematics easy".

3.3. Opinions of expert persons to introduce accessible solutions for Blind and visually impaired students.

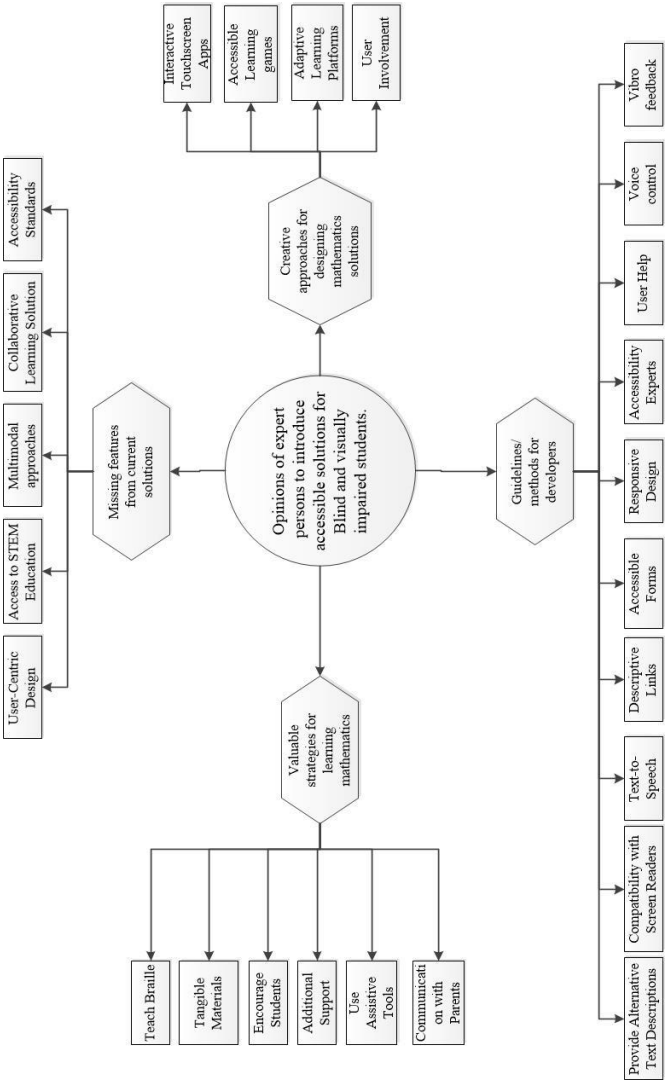

Fig. 3. A thematic analysis of professional experts to introduce accessible solutions

After the exploration of five transcripts disclosed four leading themes concerning focus group persons' viewpoints, figure 3 serves as a comprehensive representation of expert perspectives on creating a more inclusive and accessible learning environment for blind and visually impaired students, particularly in the context of mathematics education. It suggests a multi-faceted approach that includes both the refinement of existing solutions and the development of new strategies and tools. This diagram also represents a thematic analysis of the opinions of experts on introducing accessible solutions for blind and visually impaired students. It organizes these opinions into several categories, named: "Valuable strategies for learning mathematics", "Missing features from current solutions", "Creative approaches for designing mathematics solutions", and "Guidelines/methods for developers".

4. Conclusion and Future Work

The thematic analysis provided in this study emphasizes the challenging task of offering an accessible educational setting for blind and visually impaired primary school learners, especially in mathematics. Our research has identified several significant areas of attention, such as the material available for mathematics education, assistance and support for blind and visually impaired students, mathematics topics that require attention, class collaboration activities that are useful for learning, pedagogical methodologies, challenges/obstacles and issues encountered by students and teachers, available essential technologies and approaches to fulfilling learning need, ways to make learning mathematics easier, guidelines/methods for developers, more effective strategies for learning mathematics, missing features from current solutions, creative approaches for designing mathematics solutions and an overall support system encompassing both digital and non-digital resources. Through comprehensive investigation, it is evident that while there are multiple challenges (ranging from the availability of resources and technology integration to the necessity for ongoing professional development of teachers), there are also many approaches that might reduce these challenges and obstacles. Effective strategies such as using tactile resources, Braille understanding, and using assistive technology have emerged as solid enablers in learning.

Moreover, this study has underlined the importance of multimodel approaches in educational tools and the demand to develop UCD-based accessible solutions. The insights from expert perspectives have supported the notion that a team effort is essential to build inventive and flexible math solutions that are interactive and enjoyable for blind and visually impaired students. Due to the ongoing progress of technology, the concept of assistive technology is evolving over time. Because of this, a key component in improving mathematics education for visually impaired pupils is determining how best to adopt and integrate assistive technology in schools in order to provide access to the curriculum. Considering our analysis, we recommend the implementation of extensive training initiatives for teachers that provide them with the knowledge and abilities essential to effectively implement assistive technology-based solutions in classrooms. For the training purpose, attention to policy reform is neces-

sary to ensure that the current frameworks guarantee the training of teachers for inclusive learning experiences to better support blind and visually impaired students. The collaborative activities inside classrooms, together with personalized instruction and assistance of parents and classmates, comprise a comprehensive strategy that may significantly improve the educational experience of visually impaired students. Implementing these findings needs an intense effort that includes continual development and evaluation of methods of instruction, resources, and assistive technologies.

This research has created a platform for further investigation into the improvement of mathematics teaching for blind and visually impaired children. Additional studies should attempt to verify the impact of the suggested strategies on student learning skills. We intend to expand on these findings by introducing an inclusive educational platform with innovative digital learning features. The primary objective of this platform is obvious: minimize challenges and promote a learning atmosphere in which blind and visually impaired students can succeed in mathematics education. This can ensure that these learners are enabled and fully integrated into the structure of educational excellence. In this educational platform, researchers and developers should use touch gestures, audio feedback, and vibro feedback to assist blind and visually impaired students. The development of interactive learning games could allow blind and visually impaired students to learn more easily, just as the use of text-to-speech functionality could allow users to hear mathematical content and resources. Developers should provide customizable content with accessible features, catering to individual needs.

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