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Research Paper

ASSISTIVE TECHNOLOGIES AND INSTRUCTIONAL MATERIALS FOR MATHEMATICS EDUCATION OF THE VISUALLY IMPAIRED IN MEXICO

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ABSTRACT

Mathematics education for the visually impaired presents unique challenges that require specialized instructional materials and assistive technologies to ensure accessibility and effective learning. This paper provides a retrospective analysis of the development and use of assistive technologies and instructional materials for mathematics education of the visually impaired in Mexico. It examines the evolution from traditional tactile and braille-based resources to modern computer-assisted tools, including screen readers, audio-based learning systems, tactile graphics, and interactive software. The study highlights key educational initiatives, institutional efforts, and technological advancements that have contributed to improving mathematical understanding and inclusion for visually impaired learners. By analyzing past practices and technological progress, the paper identifies strengths, limitations, and gaps in existing approaches. The findings emphasize the importance of integrating pedagogical design with technological innovation to promote inclusive mathematics education. This retrospective aims to inform educators, policymakers, and researchers about effective strategies and future directions for enhancing mathematics learning opportunities for visually impaired students in Mexico.

Keywords: Mathematics education; Visually impaired learners; Assistive technologies; Accessible learning materials; Inclusive education; Computer-based instruction; Mexico

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I. INTRODUCTION

Ensuring equitable access to mathematics education for visually impaired learners remains a significant challenge worldwide, as mathematical concepts often rely heavily on visual representations such as symbols, graphs, and spatial layouts. To address these challenges, specialized teaching materials and assistive technologies have been developed to support alternative modes of learning. In Mexico, efforts to provide accessible mathematics education for visually impaired students have evolved over several decades, reflecting broader advances in inclusive education and educational technology.

Early approaches to teaching mathematics to visually impaired learners in Mexico primarily relied on tactile and braille-based materials, including embossed textbooks, tactile diagrams, and mechanical devices such as braille typewriters and abacuses. While these tools enabled foundational learning, they often posed limitations in conveying complex mathematical structures and required substantial manual effort from both students and educators. Nevertheless, these materials laid the groundwork for inclusive mathematical instruction and established the importance of tactile learning strategies.

With the advancement of computer technologies, new opportunities emerged to enhance accessibility and learning efficiency. Screen readers, audio-based mathematical notation systems, refreshable braille displays, and interactive software have increasingly been integrated into mathematics instruction for visually impaired students in Mexico. These technologies have expanded access to advanced mathematical content, facilitated independent learning, and improved communication between students and teachers.

This paper presents a retrospective examination of teaching materials and computer technologies used in mathematics education for the visually impaired in Mexico. By reviewing historical developments and technological innovations, the study aims to identify effective practices, highlight existing challenges, and inform future efforts toward more inclusive, accessible, and technology-enhanced mathematics education.

II. METHODS AND OBJECTIVE

A systematic and thorough search was conducted for data collection in printed data bases, Internet, scientific journals, graduate and postgraduate university thesis, newspaper articles, etc. The objective of this work is an exploratory bibliographic review of teaching materials and computer technologies in Mexico for teaching mathematics for visually impaired.

III. LITERATURE REVIEW

According to Costa (2004) the term visual disability refers to an irreversible state of reduced visual capacity of a person, caused by congenital (pathogenic) or environmental factors (pathologies, injuries, tumors, etc.). Even applying clinical procedures (therapies) and/or surgery, or even using conventional optical elements (glasses, contact lenses), the deficiency remains. The decrease in individual visual capacity can be classified as mild, moderate, severe, profound (those that make up the group of subnormal vision or low vision), reaching the total absence of vision (blindness).

The teaching of mathematics for visually impaired students has been the subject of debate in recent years. Studies show the importance of using manipulative teaching material or concrete material for teaching mathematics to students with or without visual impairment (Mello, Caetano & Miranda, 2017; Pereira & Oliveira, 2016; Silva, Carvalho & Pessoa, 2016; Shimazaki et al, 2015; Vita, Magina& Cazorla, 2015; Uliana, 2013; Vita, 2012; Lorenzato, 2008; Ferronato, 2002).

In recent years there has been a lot of discussion about the inclusion of people with disabilities, however, there are still few alternatives for a truly inclusive process, since we still face many difficulties, both structural and formative. We know that the inclusion process that is faced in schools is not an easy task, it is necessary for the teacher to be prepared, understand the type of disability with which they will work and look for alternatives so that they can develop the process in the best possible way. (Silva, 2015).

Development of a programable scientific calculator, that is activated in the text editor of a free program known as DOSBox, made specifically available for use by people with special needs.

Table 1. Mathematics for the Visually Impaired, Teaching Materials and Computer Technologies in the World

Author	Description	year
Alvarenga	Concludes that the manipulative didactic material "Adapted Pie Chart" is efficient and with the necessary conditions to be used in the teaching and learning process of concepts related to the "information processing" content for visually impaired students.	2019
Vigodoski	Creó el material didáctico "Productos Notables", con adaptaciones para alumnos con discapacidad visual. Después de la aplicación de las actividades, se percibió que es posible enseñar Matemáticas a estudiantes con discapacidad visual.	2013
Brito	Found that the visually impaired student appropriated the concepts related to the content Functions of the 2nd grade through the methodological procedure and appropriate mediating instrument.	2018
Dias	Analyzed the development of algebraic concepts by visually impaired students. This dissertation emphasizes the importance of teacher mediation throughout the teaching-learning process, the use of teaching materials and resources to meet the needs of students.	2020
Miranda	Presents the AlfaMateca application, which provides contributions to the teaching of Mathematics in the literacy phase of students with visual disabilities.	2019
Silveira	Presents the MATVOX application as an alternative to the lack of resources for people with visual impairment, both for teaching and for daily life in the areas of exact sciences.	2012
Lima	Investigate the use of the computer by the visually impaired in the study of mathematics.	2014
Weber	Presents a proposal for the teaching and learning of Linear Programming in Secondary. Initially, a possible methodology to present the topic for the visually impaired.	2018
Luz	Made an investigation on the potentialities and limitations of a structured didactic intervention based on the manufacture of materials for the manipulation of students with visual disabilities, aiming at the construction of the concept, systematization and learning	2018

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	of the Pythagorean Theorem.	
Alejandro	Described a multi-layer system that is designed to help students who have moderate to severe visual impairments learn algebra while manipulating algebraic equations through an interactive non-visual web-based workspace.	2012
Nazademi	A methodology for rendering technical documents, in particular, complex mathematical formula, in an audio descriptive form (Mathspeak) is presented.	2012
D'Ucco	Developed a didactic sequence using the problem solving methodology that favors the integration of a blind student in mathematics classes.	2017
Nibe	Founded that the blind student can be integrated into a frequent geometry class, if the necessary curricular adaptations are made.	2014
Jimenez	Made the proposal of a didactic material that allows blind students to work on the concept of polynomials within a regular classroom, with the purpose of addressing the needs that blind students have in the regular classroom, when working with the area of math, specifically algebra.	2014
Moreno	Proposed the way to teach students with visual limitation to obtain roots of an integer using the soroban abacus, putting the specific case of a student.	2014
Gelley	Describes Process-Driven Math, which is an all-audio method of math instruction and assessment that was created at Auburn University in Montgomery, Alabama, to meet the needs of an individual student.	2017
Prada	Development of a programmable scientific calculator, that is activated in the text editor of a free program known as dosvox, made specifically available for use by people with special needs.	2010
Brandão	Presents a study that the deals with the learning of the concepts of triangles, quadrilaterals and symmetry by students with congenitals blindness, a possible way refers to the geometry method, which proposes the use of orientation and mobility techniques in the teaching of geometry.	2010
Costa	Evaluated mathematical counting and measurement skill of visually impaired children and adolescents managed to produce a protocols to assess mathematical skill for visually impaired people.	2019
Melo	Made an investigation that provides information on visual deficiencies and on the teaching of trigonometry, in addition to presenting the pedagogical multi-plan, and excellent tool to facilitate the learning of mathematics.	2018

Campos (1995) reports that in Mexico there is no textbook for the visually impaired that contemplates the optometric characteristics of typography for letters, numbers, signs and others that are appropriate to our social context, so it proposes concrete actions that will serve as the basis for the elaboration of these.

Escalante (2018) describes the didactic proposal of the problems that people with visual disabilities face in the mathematical classroom, it seeks to solve one of these problems, which is the learning of some analytical geometry contents with a proposal of didactic material, the mathematics table for the blind (MPC) of low cost, in which some Analytical Geometry contents can be taught such as: lines and parabolas, students can make approximations of the graphs of functions which are observable, however, they can only perceive them through of touch and thus know the characteristics that these graphs present such as: maximum, minimum, concavity, increase, decrease, continuity, distance between two points, intersection with the axes, angles with respect to the axis.

Mathematics can be a great obstacle in the school education of students with visual disabilities (blind or low vision people), this due to various factors, highlighting the time they require to perform a task, and the difficulty of mathematical language in Braille. The complexity of mathematical literacy coupled with the imposition of arguments, procedures and meanings by the School Mathematical discourse excludes students with visual disabilities from the construction of mathematical knowledge. This may be one of the various reasons why no evidence of any student with this condition was found in Mexico. (Cantoral, 2021).

Due to the complexity posed by algebraic literacy through Braille, Moreno (2021) proposes different strategies for the inclusion of people with visual disabilities in the mathematics classroom. For this, an exploratory situation was designed with transversal categories for each of the degrees of interest, that is: 1) multiplicity of the root, 2) sign-root relationship, and 3) coefficient-root relationship. The situation is posed from the graphic context, which allows addressing elements such as root, ordered to the origin, slope, concavity and inflection point through a set of non-visual sensations. This context was chosen due to the importance of the haptic sense on the part of the visually impaired population, since it is the main means of interaction with their reality.

Torres, J. (2020) Concluded that visually impaired students can learn the concept of a linear equation of one variable, from a didactic sequence as a whole with a didactic material that promotes the necessary mental constructions in the students with DV. Likewise, the cognitive model for understanding the concept of linear equation of a variable based on the APOE theory (Action-Process-Object-Scheme), allowed to develop activities and a material specifically, so that students who are blind or have low vision can develop mental structures and mechanisms similar to those of someone with normal vision, and therefore have the same possibilities of acquiring the expected knowledge.

Moreno (2018) founded that the use of materials that favor the use of the haptic sense makes it easier for visually impaired students to achieve the acquisition of geometric themes, specifically in this research, volume.

Moreno &Cantoral (2021) from a socioepistemological perspective, presents reflections on how exclusion by School Mathematical discourse is reflected in students with visual disabilities from various branches of mathematics commonly studied in STEM careers, in addition to particularizing a mathematical topic that is studied from education secondary to higher level.

Moreno (2014) investigated, with a multiple qualitative methodology, based on promoting elements based on practices for the construction of the notion of root of polynomial or, of solution of a polynomial equation of small degrees, 1 to 3, in young people with visual disabilities. For this, an exploratory situation was designed with transversal categories for each of the degrees of interest, that is: 1) multiplicity of the root, 2) sign-root relationship, and 3) coefficient-root relationship. The situation is posed from the graphic context, which allows addressing elements such as root, ordered to the origin, slope, concavity and inflection point through a set of non-visual sensations.

Espinoza (2015) presents the development of three-dimensional Learning Objects developed using virtual reality technologies assisted by haptic systems.

IV. CONCLUSIONS

This retrospective study highlights the progressive development of teaching materials and computer technologies used in mathematics education for the visually impaired in Mexico. From early tactile and braille-based resources to modern digital and computer-assisted tools, each stage of advancement has contributed to improving accessibility and learning outcomes for visually impaired students. The integration of assistive technologies such as screen readers, refreshable braille displays, and interactive software has significantly expanded opportunities for independent learning and engagement with complex mathematical concepts.

Despite these advances, challenges remain in terms of resource availability, teacher training, and the consistent integration of technology into classrooms. Addressing these issues requires continued collaboration among educators, technologists, and policymakers to ensure equitable access and effective implementation. Overall, the findings underscore the importance of combining pedagogical innovation with technological development to support inclusive mathematics education and to further enhance learning opportunities for visually impaired learners in Mexico.

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