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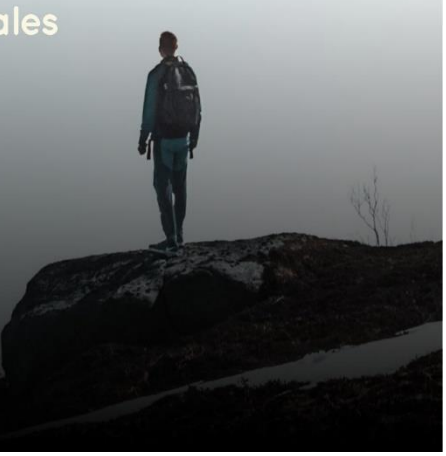

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STUDY ON THE CONSTRUCTION OF EARLY MATHEMATICAL CONCEPTS INVOLVING VISUALLY IMPAIRED STUDENTS AND ASSISTIVE TECHNOLOGY

Dra. Maria Adelina Raupp Sganzerla
Universidade Luterana do Brasil, Brasil
ORCID: 0000-0002-2956-0277
masganzerla@gmail.com
Dra. Marlise Geller
Universidade Luterana do Brasil, Brasil
ORCID: 0000-0002-9640-2666
marlise.geller@gmail.com

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Abstract

Inclusive Education in Brazil guarantees that all students have equal conditions to access school enrollment. In this context, visual impairment is one of the disabilities found in school reality. This article presents an excerpt from a doctoral investigation to reflect on the process of blind and/or low vision students' construction of early mathematical concepts with the use of Assistive Technology (AT). From a qualitative approach, the research was founded on the Discursive Textual Analysis, based on observations and interventions carried out during the attendance of five elementary school students by the Specialized Educational Service (SES). This work reports the different stages the participants underwent to understand the mathematical concepts that involve counting, recognition of quantities, numerical symbols, besides basic mathematical operations. The results suggest that visually impaired children have the same potential as sighted children concerning the construction of the concept of number. However, it is essential to use ATs and adapted materials to make this concept effective.

Keywords

Mathematics Education – Assistive Technology – Visual Disability – Inclusion

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Introduction

Inclusive Education in Brazil is based on the Federal Constitution of 1988.[1] It includes several norms, laws, and decrees that guarantee equal conditions of school enrollment for all, regardless of their physical or intellectual condition, as well as the provision of Specialized Educational Service (SES), preferably in regular education.

With the growing demand of students enrolled in regular schools, inclusive education has become a subject studied and incorporated into the daily lives of the educational institutions. Pedagogical materials enable new perspectives with adaptations for this public, and new spaces were provided, constituted of resource rooms aimed at attending these students.

Visual impairment is one of the disabilities found in school reality. According to microdata from the 2019[2] basic education school census, there were 284 blind and 3,879 low-vision students enrolled only in the state of Rio Grande do Sul. In this context, it is essential to point out that the blind children must be stimulated through their other senses - touch, hearing, smell, and taste - since the lack of vision restricts the use of certain visual aids. Thus, Assistive Technology becomes an important ally of education, offering blind and low vision students several possibilities of adaptation to the contents of the school curriculum.

This article is part of the doctoral thesis “Deficiência visual e a educação matemática: estudo sobre a implementação de Tecnologia Assistiva[3]” (Visual impairment and mathematics education: a study on the implementation of Assistive Technology), inserted in the context of inclusive mathematics education from the Graduate Program in Science and Mathematics Teaching (PPGECIM) of ULBRA, developed within the LEI - Laboratory of Inclusion Studies[4]. As a general objective, this thesis proposes to investigate the potential of Assistive Technology in the teaching of mathematical concepts, both in the regular classroom and as in the attendance carried out at the SES, besides the implementation process (involving the development, application, and evaluation) of technologies as pedagogical resources. Based on the Discursive Textual Analysis, inspired in Moraes and Galiazzi[5], this article presents some reflections about the process of construction of initial mathematical concepts with the use of AT carried out with blind and/or low vision students during attendance at the SES.

Reflections on Brazilian inclusive education

The 1988 Brazilian Federal Constitution[6] rules over equal access to school enrollment for all, regardless of their physical or intellectual condition. Thus, conditions are

[1] Brasil, Constituição da República Federativa do Brasil de 1988, availabe .at: <http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm>. (Accessed May 10, 2020)

[2] INEP/EDUCACENSO, availabe at: <http://inep.gov.br/sinopses-estatisticas-da-educacao-basica>. (Accessed May 10, 2020)

[3] Approved by the Ethics Committee under protocol number CAAE: 66101616.5.0000.5349.

[4] Developed from the research project "Tecnologias Assistivas para a Educação Matemática no Ensino Fundamental" (Assistive Technologies for Mathematics Education in Elementary School) approved in the Universal Notice - CNPq/MCTIC/SECIS No. 20/2016.

[5] Roque Moraes; Maria do Carmo Galiazzi. Análise textual discursiva (Ijuí: Inijuí, 2013).

[6] Brasil, Constituição da República Federativa do Brasil de 1988, availabe at: <http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm> (Accessed May 10, 2020).

given to ensure the other laws and decrees on school inclusion. Brazil follows the Salamanca Declaration, which establishes the legal incorporation of inclusion. The document deals with “Standard Rules on Equalization of Opportunities for Persons with Disabilities,” among which we can quote: “[...] every child has a fundamental right to education, and must be given the opportunity to achieve and maintain an acceptable level of learning; those with special educational needs must have access to a regular schools, which should accommodate them within a child-centered pedagogy, capable of meeting these needs”.[7]

In 1996, the National Education Guidelines and Framework Law (Lei de Diretrizes e Bases da Educação - LDB) No. 9.394/1996 incorporated the intentions of the Salamanca Declaration, with Chapter V aimed at Inclusive Education. Article 58 [8] states “Special education means, for the purposes of this Law, the type of school education, preferably offered in the regular school system, for students with special needs.” The Resolution[9] addresses the flexibility of a differentiated curriculum for the target audience of Special Education. With the document of the National Policy on Special Education from the perspective of Inclusive Education[10], conceptual and structural changes in the organization of the educational system were obtained. Among them, the incorporation of the Specialized Educational Service - SES (Atendimento Educational Especializado - AEE).

The Ordinance[11], which provides for the creation of the Program for the Implementation of the Multifunctional Resource Room, aims to strengthen the inclusion process in regular teaching classes, offering Specialized Educational Service.

The effective implementation of the SES regulates the multifunctional resource rooms, defined as “environments equipped with devices, furniture and didactic and pedagogical materials for the provision of specialized educational service”.[12] Currently, two types of rooms are available: Type I (Table 1) and Type II.

[7] Brasil, Declaração de Salamanca. sobre princípios, políticas e práticas na área das necessidades educativas especiais, availabe at: <http://portal.mec.gov.br/seesp/arquivos/pdf/salamanca.pdf, 1> (Accessed May 10, 2020).

[8] Brasil, LDB. Lei de Diretrizes e Bases, availabe at: <http://portal.mec.gov.br/seed/arquivos/pdf/tvescola/leis/lein9394.pdf> (Accessed May 10, 2020).

[9] Brasil, CNE/CEB N°02/2001, availabe at: <http://portal.mec.gov.br/seesp/arquivos/pdf/diretrizes.pdf> (Accessed May 20, 2020).

[10] Brasil, Decreto nº 6.571, de 18 de setembro de 2008, availabe at: <http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=428-diretrizes-publicacao&Itemid=30192> (Accessed May 20, 2020).

[11] Brasil, Portaria Normativa nº 13, availabe at: <http://portal.mec.gov.br/index.php?option=com_content&view=article&id=17430&Itemid=817> (Accessed May 20, 2020).

[12] Brasil, Decreto nº 7.611, availabe at: <http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/decreto/d7611.htm> (Accessed May 20, 2020).

Equipment	**Didactic/Pedagogical Material**
02 PCs	01 Golden Material
01 Laptop	01 Body Schema
01 Stabilizer	01 Rhythmic Band
01 Scanner	01 Memory of Numerals I
01 Laser printer	01 Embroidered Alphabet Rug
01 Beehive Keyboard	01 Alternative Communication *Software*
01 Pressure Actuator	01 Creative Bag Assembles Everything
01 Mouse with trigger for the actuator	01 Puzzle - Logical Sequence
01 Electronic Magnifier	01 Dominoes of Association of Ideas
Furniture	01 Phrase Dominoes
01 Round table	01 Animal Dominoes in Libras
04 Chairs	01 Fruit Dominoes in Libras
01 Table for Printer	01 Tactile Dominoes
Furniture	**Didactic/Pedagogical Material**
01 Closet	01 Braille Alphabet
01 Whiteboard	01 Manual Magnifier Kit
Furniture	**Didactic/Pedagogical Material**
02 Computer tables	01 Inclined Plane - support for reading
02 Chairs	01 Tactile Memory

Table 1

Type I Multifunctional Resource Room Specifications[13]

The Type II Resource Room presents all materials belonging to Type I room, plus materials for students with visual impairments (Table 2).

Didactic/Pedagogical Equipment and Materials
01 Braille printer - small size
01 Braille Typing Machine
01 Table Reglette
01 Puncture
01 Soroban
01 Subscription Guide
01 Geometric Design Kit
01 Sound Calculator

Table 2

Type II Multifunctional Resource Room Specifications[13]

[13]http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=9936-manual-orientacao-programa-implantacao-salas-recursos-multifuncionais&category_slug=fevereiro-2012-pdf&Itemid=30192.

The principles of the SES[14] are to offer special education service by identifying, developing, and organizing pedagogical and accessibility resources. The purpose is to reduce barriers so that inclusion students can actively participate in activities carried out within the school environment, and acquire some autonomy in their daily lives outside the educational institution.

Regarding the importance and purpose of the specialized service in schools, it is worth noting that "[...] it aims to guarantee students with special disabilities the possibility of learning what is different from ordinary education and develop the skills they need to be able to overcome the barriers imposed by the disability".[15]

Faced with the challenge of inclusion, improving the possibilities of using Assistive Technology (AT) made available in SES and adapted materials are deemed necessary.

Visual impairment and mathematics education

Brazilian public schools[16] received 1,250,967 students with disabilities in 2019. This number concerns basic education, comprising Early Childhood Education, Elementary Education, High School, Vocational Education and Youth and Adult Education. From the students with some disability, 6,252 are blind and 73,839 have low vision.

WHO[17] defines visual impairment as a partial or total deprivation of the ability to see. Article 5 of Decree 5.296/04 presents visual impairment as: "blindness, in which visual acuity is equal to or less than 0.05 in the best eye, with the best optical correction; low vision, which means visual acuity between 0.3 and 0.05 in the best eye, with the best optical correction; cases in which the sum of the measurement of the visual field in both eyes is equal to or less than 60°; or the simultaneous occurrence of any of the above conditions."[18]

Low vision people can see enough to carry out their main daily activities with autonomy. However, they need special lenses to read and view the computer screen and/or a television. The blind, on the other hand, need additional resources, as they may only have little light perception or total loss of vision.

As blindness does not present visual residues, the person needs resources, such as screen readers, to access the computer and writing in Braille for his/her non-verbal communication. The difficulties the visually impaired find to perform tasks due to their visual inaccuracy[19] require adaptations of time, assistance, and modifications through their other senses, which often end up becoming more acute.

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[14] Brasil, Decreto nº 6.571, availabe at: <http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=428-diretrizes-publicacao&Itemid=30192> (Accessed May 20, 2020).

[15] Maria Lúcia Sartoretto. Inclusão: da concepção à ação. (Petrópolis: Vozes, 2009.

[16] INEP/EDUCACENSO...

[17] OMS, Organização Mundial da Saúde, availabe at: <https://www.who.int/eportuguese/countries/bra/pt/> (Accessed May 10, 2020).

[18] Brasil, Decreto nº 5.296, availabe at: <http://www.planalto.gov.br/ccivil_03/_ ato2004-2006/2004/decreto/d5296.htm, 2> (Accessed May 10, 2020).

[19] Elisa Tomoe Moriya, "Tecnologia Assistiva: projetos, acessibilidade e educação a distância – rompendo barreiras na formação de educadores" (Jundiaí: Paco Editorial, 2011).

When approaching teaching visually impaired students, we must have in mind that they have the same conditions as the sighted students to learn mathematics.[20] Nevertheless, special resources and adapted materials are needed.

The learning process of visually impaired students in inclusive schools is based on their other senses: touch, hearing, smell, and taste. So, materials that facilitate discrimination and/or identification of size, texture, volume, weight, besides varied sounds are needed, as they can arouse curiosity and the desire to learn. The materials are a challenge for educators[21] since, with the absence of vision, educational resources must be tactile and simple.

The blind child "takes more time to know and recognize things and objects, as he/she handles and analyzes according to his/her needs, while the sighted child can perceive the object in its entirety and 'immersed' in a broader context".[22]

The understanding of blind and/or low vision children begins with the understanding of their basic restriction: the perceptual limitation, vision. In this way, their possibilities of perceiving the outside world are different, and it is necessary to develop other senses, such as hearing and touch, as they live in a world where the visual is much explored in education. The child constructs progressively and internally the ability to count objects[23], when he/she coordinates various actions on them, such as classification, serialization, two-way correspondence, among others. Also, knowing the number sequence "by heart" does not mean that the child incorporated the acquisition of the number.

Number learning occurs[24] when the child recognizes small numbers. With the stimulation of empirical abstraction and the construction of common object relations, the child starts to understand the higher numbers, which is then called the reflexive abstraction phase,[25] described as "constituting one of the engines of cognitive development and one of the most general processes of balancing".

In his studies, Piaget[26] shows that the process of reflective abstraction always occurs in two moments: first, the child removes something from a lower level and projects this content on a higher level (for example, from action to representation); second, she/her mentally reconstructs and reorganizes on the upper level what was transferred from the lower level.

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[20] Helen Castro Almedia Leite, "Gráficos e tabelas na ponta dos dedos: matemática para deficientes visuais" (São Paulo: Contexto, 2010).

[21] Marlise Geller y Maria Adelina Raupp Sganzerla, "Reflexões de professores sobre Tecnologias Assistivas e o processo de ensino e aprendizagem de matemática", Acta Scientiae. Canoas, Vol: 16 num 4 (2014): 116-137.

[22] Brasil, Secretaria de educação básica, availabe at: <http://pacto.mec.gov.br/images/pdf/cadernosmat/PNAIC_MAT_Educ%20Incl_pg001-096.pdf, 5> (Accessed June 10, 2020).

[23] Jean Piaget y Alina Szeminska, "A gênese do número na criança" (Rio de Janeiro: Zahar Editores, 1971).

[24] Constance Kamii, "A criança e o número implicações educacionais da teoria de Piaget para a atuação junto a escolares de 4 a 6 anos" (Campinas: Papirus, 1992).

[25] Jean Piaget, "Abstração reflexionante: Relações lógico-aritméticas e ordem das relações espaciais" (Porto Alegre: Artes Médicas, 1995).

[26] Jean Piaget, "Seis estudos de psicologia" (Rio de Janeiro: Forense Universitária, 1999).

Contextualizing Assistive Technology for visually impaired people

Although known in other countries, where it had been first used before 1900, the Assistive Technology concept in Brazil was officially created in 1988 by the Comitê de Ajudas Técnicas - CAT (Technical Support Committee).

Bersch and Toniolli present AT as an “access to the entire arsenal of resources that they need, and that will favor a more independent, productive, and inclusive life in the general social context”.[27]

On December 14, 2007, CAT[28] formalized the definition of AT in Minutes VII, as “an area of knowledge, with an interdisciplinary characteristic, which encompasses products, resources, methodology, strategies, practices and services that aim to promote functionality, related to the activity and participation of people with disabilities, impairments or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusion”.

In 2015, the Brazilian Law for the Inclusion of Persons with Disabilities passed.[29] Article 3 defines accessibility, universal design, barrier, adaptations, among others, remaining the same concepts disclosed by CAT.

Currently, there are several ATs available to assist visually impaired people in achieving autonomy to perform daily tasks. An example is the use of computers, tablets, cell phones, and records through Braille.

Louis Braille created the Braille system. It consists of six dots (Figure 1a), called a cell, which, combined, form letters, numbers, punctuation marks, musical notes, and mathematical, chemical, and physical symbols (Figure 1b). By this system, it is possible for the visually impaired person to write and read, be understood worldwide, as the system is universal.

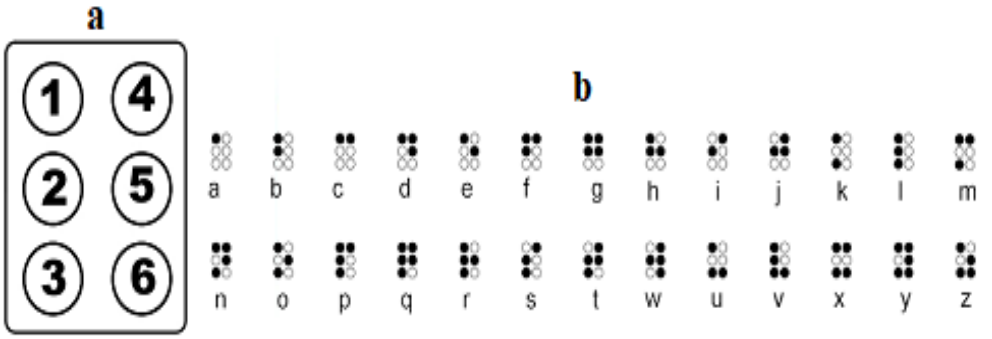


Figure 1
Braille System[30]

[27] Rita Bersch y José Toniolli, “Introdução à Tecnologia Assistiva”, (Porto Alegre: CEDI, 2008).
[28] CORDE, Comitê de ajudas técnicas – Ata VII, availabe at: <http://www.mj.gov.br/sedh/ct/corde/dpdh/corde/comite_at.asp> (Accessed June 10, 2020).
[29] Brasil, Lei nº 13.146, availabeat: <http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2015/lei/l13146.htm> (Accessed June 10, 2020).
[30] http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=9936-manual-orientacao-programa-implantacao-salas-recursos-multifuncionais&category_slug=fevereiro-2012-pdf&Itemid=30192.

To write in the Braille System, we use the slate and the stylus, or else a typewriter called Perkins.

Two types of slates are available on the Brazilian market: the conventional and the positive slate. Braille created the first version of the conventional slate in 1837.[31] Currently composed of two metal or plastic plates, adjusting the 20cm school rulers in size, fixed to each other utilizing a hinge on the left side, and with a space between them to allow the introduction of a sheet of paper weighing 120gsm or higher (Figure 2).

Figure 2
Braille writing with slate and stylus[32]

The Braille or Perkins typewriter, as it is called because of its brand, consists of 9 keys; 6 of them correspond to Braille dots, one for space, one for backspace, and one for line changes (Figure 3a). It can write up to 23 lines and 42 columns on a sheet of 120g Sulfite paper. The market offers a manual (Figure 3a) and an electric printer (Figure 3b).

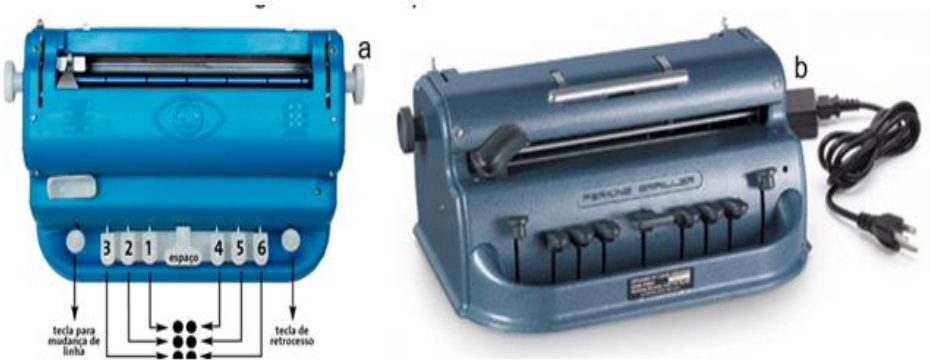


Figure 3
Braille Typewriter[33]

Both printers are used for writing with the aid of the conventional and positive slate and stylus; for the typewriter or the Braille line, it is necessary to master the Braille system.

[31] Elton Alisson, Novo instrumento reduz tempo de aprendizado de Braille" (Agência FAPESP: São Paulo, 2013).
[32] http://g1.globo.com/sp/sao-carlos-regiao/noticia/2013/05/unespprendizado-do-braille.html
[33] http://www.bengalabranca.com.br

On the other hand, the computer is a widely used resource to write and read, and to keep technical records, such as mathematical records. For its use, a screen reader is required. It consists of a software that interacts with the operational system, reproducing with a sound the events that occurs on the computer, thus reading the information, buttons, and all the events that are present in text form to the user.[34] To navigate using a screen reader, the user makes use of keyboard commands (shortcut keys).

Currently, there are three screen readers in the Brazilian market for the Windows operational system (Virtual Vision, Jaws and NVDA), and one for Linux (Orca); also, the Talkdroid for Android phones, and VoiceOver for iOS (iphone), as presented in Table 3.

Name	**Logo**	**Operational System**	**Description/Funcionalities**
Virtual Vision		Windows	Clear pronunciation in Portuguese, offered for free to blind users.
Jaws		Windows	Diferential, the simulation of the mouse trough the keyboard (left button is activated through key the bar key "/" and the right button through an asterisk "*") enabling the access to programs that do not have a textual button.
NVDA		Windows	Does not require installation on the machine, can be accessed directly from a pen drive or CD.
Orca		Linux	Open source software that is continuously being developed by the Linux community.
Talkdroid		Android	Accessibility by voice and vibration of the mobile device with Android Operating System.
VoiceOver		iOS	Based on gestures that, when enabled, allows the description of the content of the screen with a click or movements to the right and left.

Table 3
Commercially available screen readers

[34] eMAG, Tecnologia Assistiva – leitores de tela, availabe at: <http://emag.governoeletronico.gov.br/cursodesenvolvedor/introducao/tecnologia-assistiva-leitores-de-tela.html> (Accessed June 20, 2020).

Without the use of screen readers or graphical interfaces, blind people could hardly make use of computational resources. Although there are other options available on the market, in this text, we bring the most used and widespread.

Optical resources[35] are equipment or instruments that help people with low vision to improve their residual vision, usually by increasing the image with glasses or a magnifier. Vision correction through glasses (lenses) must be prescribed by an ophthalmologist. Table 4 shows the variations that low vision people use the most.

Glasses	**Image**	**Use/Vision correctio**
Bifocals		They consist of lenses to enhance the retinal image, both near and far.
Close (reading)		They assist in close reading.
Binoculars e monoculars with prisms		Consisting of positive spherical lenses and spheroprism lenses (with a prism positioned towards the nasal base in both eyes). They are indicated for people with reduced visual acuity both close and near in both eyes.
Monocular Aspherics		They are thinner lenses that reduce distortions in high degrees.

Table 4
Glasses optical features for low vision

Magnifiers are characterized by being optical instruments with lenses that increase texts, figures, or objects. Table 5 presents a selection of the most used magnifiers.

Magnifier	**Image**	**Description**
Stone-like		Manufactured with a calculated light orientation that directs all possible lighting to the object or text.
hand		5x magnification capacity.
ruler		Provide shadow-free viewing for comfortable reading over long periods of time.

Table 5
Magnifiers

[35] https://www.fcm.unicamp.br/fcm/auxilios-opticos/os-auxilios-opticos.

Besides the manual magnifiers shown in Table 5, electronic magnifiers are available on the market (Table 6), defined as[36] a CCTV-type magnifying system[37] that uses a camera to record texts and images that are reproduced on the device's screen, a television, or a computer screen.

Magnifier	**Image**	**Description**
Visolux Digital 7" HD		Wide magnification range from 2x to 22x (connected to HD TV).
Mobilux Digital 4.3" Touch HD		Portable with magnification from 4x to 12x (manual at a distance of 5cm approximately 1.9x to 4.5x).
Smartlux Digital 5"		Portable, the 5 "TFT[38] LCD screen provides 5x, 7x, 9x or 12x magnification.

Table 6
Optical features of electronic magnifiers for low vision

The operational systems responsible for controlling programs and applications on computers, mobile phones, and tablets provide native accessibility features, such as magnifying glasses. Table 7 presents a compilation of the resources most used by people with low vision.

Operational System	**Feature**	**Description**	**Example**
Windows	Screen	Possibility to increase the text on the screens, including programs and applications.	
	Magnifier	Allows you to use a function to zoom in on some content on the screen.	
	High contrast	Makes easier to view available content on the screen.	

[36] https://www.provista.com.br/lupas-eletronicas.
[37] Closed Circuit Television System - CCTV
[38] *Thin Film Transistor* ou Transistor de Película Fina

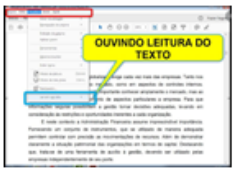
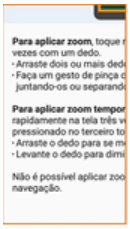
	Narrator	Reads all the elements available on the screen, besides texts, icons, buttons, among others.	
Android	Magnifying gesture	It is activated with three clicks and hold, the screen temporarily enlarges and it is possible to move the enlarged area with your finger.	
	Inversor of colours	Controls the contrast of colours of the device.	
	Magnifier	Magnifier application, increases up to 5x the texts or objects (must be installed).	
IOs	Zoom	It is like a magnifying glass on the screen, its magnification ranges from 100% to 1500% (must be installed).	
	Magnifier	The Magnifier feature turns your iPhone into a digital magnifier, using the flash to illuminate.	

Table 7
Computing resources for low vision

Besides the optical resources[39] for people with low vision, there are other possibilities to assist with studies, such as lined notebooks, adequate lighting for reading, supports for writing and reading, use of strong graphite pencils (6B), thick point pens with contrasting colors, whiteboard, among others (Table 8).

[39] Marília Costa Câmara Ferroni y Maria Elisabete Rodrigues Freire Gasparetto, Escolares com baixa visão: Percepção sobre as dificuldades visuais, opinião sobre as relações com comunidade escolar e o uso de Tecnologia Assistiva nas atividades cotidianas. Revista Brasileira de Educação Especial, Marília, 2012.

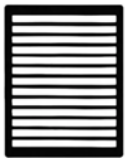
Feature	Image	Description
Notebook lines		Notebook with lines in enlarged size.
Writing guide		Guide in A4 size for writing.
Support to read and write		It has clips to hold the sheets, and 5 levels of inclination.

Table 8
Non-optical features for low vision

With the help of the ATs, visually impaired students are more likely to become autonomous to write and read their records.

Methodology

This is a qualitative research, with direct exploration through participant observation, which, according to Marconi and Lakatos,[40] consists of real participation of the researchers with their subjects, in which they experience their reality and propose alternatives. In this case, the researchers experienced the SES practice for three years, observing the students' needs and offering activities using the ATs to teach mathematical concepts.

Table 9 presents a summary of the research, covering the main authors, data collection, and methodology.

Introduction to the research	
Main authors of the theoretical framework	- GELMAN; GALLISTEL (1987). - BERSCH (2008; 2013; 2017). - KAMMI (1994; 1998; 2012). - PIAGET (1952; 1972; 1977; 1979; 1999; 2013).
Methodological approach	Qualitative research.
Data collection instruments	Class observations, questionnaires, interviews, interaction with students.
Data analysis method	Discursive Textual Analysis, inspired in Moraes and Galiazzi.[41]

Table 9
Research systematization

[40] Marina de Andrade Marconi, Eva Maria Lakatos, "Fundamentos da metodologia científica" (São Paulo: Atlas, 2010).
[41] Roque Moraes, Maria do Carmo Galiazzi, "Análise textual discursiva" (Ijuí: Inijuí, 2013).

In this perspective, the Discursive Textual Analysis comprises the analysis methodology used in this research. The study sought support in Moraes and Galiazzi,[42] since "by producing the material of analysis through interviews and observations, the qualitative research aims to deepen the understanding of the phenomena that investigates from a rigorous and careful analysis of this type of information." The authors also point out that the intention is to understand, reconstruct existing knowledge on the topics investigated and not refute them at the end of the research.

The research consisted of three stages: obtaining the participants' informed consent. In the process, they learned their identities would be preserved; observation of the teachers' actions during the SES; interaction with students served and observation of the regular classroom, from the perspective of AT use focused on teaching mathematical concepts. Figure 5 shows the steps of the research.

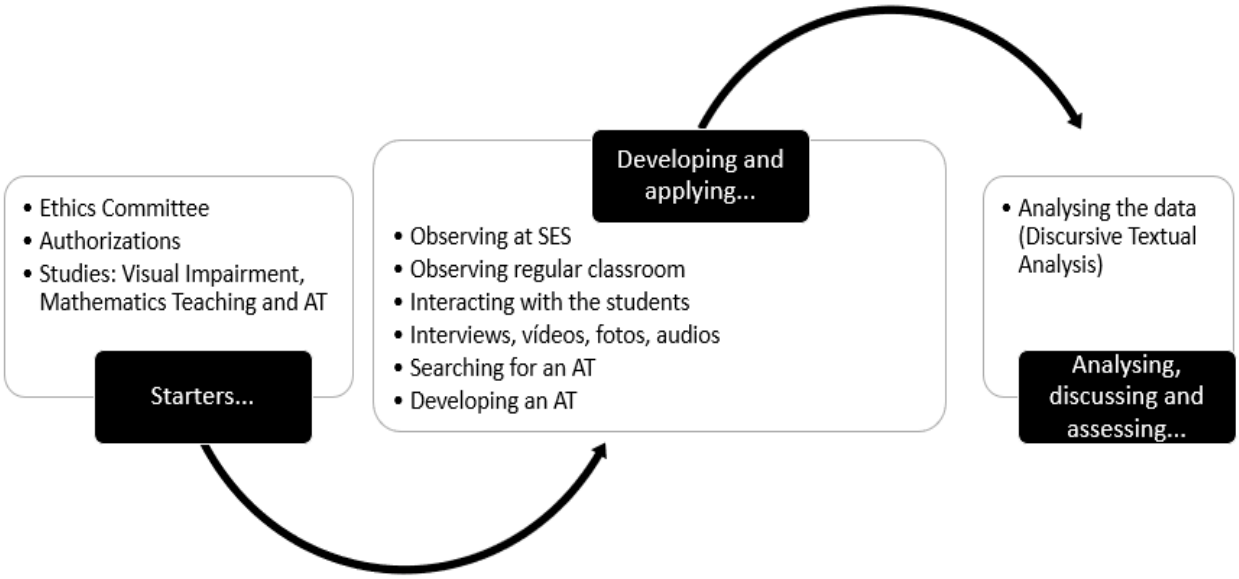


Figure 5
Steps of the research (Sganzerla, 2020)[43]

The research took place in an inclusive municipal school. It included five teachers who teach mathematics, three of the Specialized Educational Service, where they teach elementary school students and two students from regular classrooms. All teachers have pedagogical training in the area of expertise.

The research also involved the five visually impaired students enrolled in the school, all attending the SES after class, as shown in Table 10. The students' process of construction of early mathematical concepts is the central focus of this article, so it is important to note that the Mathematical Learning column refers to the point of learning at the beginning of interactions with the research subjects.

[42] Roque Moraes y Maria do Carmo Galiazzi, "Análise textual ...
[43] Maria Adelina Raupp Sganzerla, Deficiência visual e a educação matemática: estudo sobre a implementação de tecnologia assistiva (Canoas: Ulbra, 2020).

Identification	Observation period/Year	ICD[44]	Visual Impairment	Mathematics Learning
E	2015 - 2018 (1st to 4th grades)	ICD 10: Q15.0 (Congenital glaucoma) and ICD 10: H54.1 (Blindness in one eye and low vision in the other)	Legally Blind	Mathematics literacy
G	2017-2018 (5th and 6th grades)	ICD 10: H53.0 (Amblyopia due to anopsia)	Low Vision	Consolidated number and basic operations
J	2015 - 2018 (6th to 9th grades)	ICD 10: H54.0 (Blindness in both eyes)	Blind	In the process of acquiring the number
L	2015 - 2018 (2nd to 5th grade)	ICD 10: H54.2 (Subnormal vision of both eyes)	Low Vision	In the process of acquiring the number
W	2017 (1st grade)	ICD 10: H31.0 (Chorioretinal scars) and ICD 10: P31.1 (Congenital toxoplasmosis)	Low Vision	Mathematics literacy

Table 10
Students participating in the research

Discursive Textual Analysis has four focuses: (1) Disassembly of texts (deconstruction, delimitation of the “corpus” and unitarization); (2) Establishment of relationships (categorization, where two emerged: Action by teachers who teach mathematical concepts and Students’ knowledge-building processes); (3) Capture of the new emerging (construction of metatexts) and (4) A self-organized process (analysis cycle with a focus on the data collected).[45]

Based on the principle of this organization, we will present a section of the metatext through the analysis of activities belonging to the category of students, associated with concepts and arguments that seek to show the use of the ATs for the acquisition of the concept of number.

Student knowledge building processes

The research considers the students with disabilities, with global developmental disorders and with high skills/giftedness[46] as the target audience of the SES. This service must “complement or supplement schooling.” Thus, Braille teaching is one of the topics involved, as it is how the blind person carries out their records.

[44] ICD - International Classification of Diseases.
[45] Roque Moraes y Maria di Carmo Galiazzi, Análise textual ...
[46] Brasil, Decreto nº 6.571, avaliable at: <http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias= 428-diretrizes-publicacao&Itemid=30192> (Accessed June 10, 2020).

The Braille system is a code that students need to memorize; besides, "to master a notational system, the individual must develop adequate representations about how it works, i.e., about its properties".[47]

The visually impaired person keeps her/his records assisted by a specific AT, such as the slate, the stylus, the typewriter and the computer - these two being the most common and available in the SES. Gehm and Silva[48] affirm that "the Braille system is of great importance for blind people, as it is the only means by which that person has contact with written language, being able to know the structure and spelling of words".

Of the students participating in the research, W, is in the process of literacy. L, E, and G learned to read and write in the conventional process, as they have low vision, so they write in ink (enlarged); and J, who is blind, learned to read and write in Braille.

Some of the research participants' stages in literacy and mathematical literacy are reported. In this stage, the AT and the adapted materials are important, as the visually impaired person makes use of touch and hearing to acquire knowledge.

In one of the Braille writing activities, L was guided to read the storybook "The Three Little Pigs," which had been adapted to modern times. Formulated by the Dorina Nowill Foundation,[49] the adaptation inserted the mother and father in the job market, sharing the house chores. An audio CD accompanies the book, so the reader is provided with the storybook in Braille, and can hear the sounds with the description of the illustrations.

Freitas[50] defines audio description as a resource that translates images into words, allowing blind or low vision people to understand audiovisual content or static images, such as films, photographs, plays, among others.

After reading, L was invited to make a kind of reading sheet covering the subjects of the book, a summary and a list of the characters. Along with Braille training, activities related to Mathematics were added:

- Number of characters: the answer was 6, and an explanation followed, "*there are three little pigs + both little pigs' parents + the Big Bad Wolf*."
- Number of plates with names (each piglet has its name printed on top of their beds, both of the piglets and their parents): answer, "*there are 5, because the Big Bad Wolf 'doesn't live in the house with the pigs, so he 'doesn't have one plate*."
- Relationship between the characters: "*a mother for three children, a father for three children, a father for a mother, a mother for a father and the Bad Big Woolf for all? Because he wanted to bring down the house!*"

Checking L's responses, we can infer that he knows quantities and notions of relationships, being in the phase of logical-mathematical knowledge.

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[47] Andréa Galvão y Telma Ferraz Leal, "Há lugar ainda para métodos de alfabetização? conversa com professores(as)" (Belo Horizonte: Autêntica, 2005).
[48] Raquel Elisa Gehm, Alfabetização de alunos cegos: um estudo sobre pesquisas relacionadas ao processo de desbrailização (Curitiba, 2013).
[49] https://www.fundacaodorina.org.br/
[50] Patrícia Freitas, "O que é audiodescrição?" avaliable at: <https://www.fundacaodorina.org.br/blog/o-que-e-audiodescricao/> (Accessed June 10, 2020).

For Piaget,[51] this knowledge goes beyond the perception of objects, as it also includes the establishment of mental relationships between them, such as comparison, correspondence, conservation, classification, hierarchical inclusion, sequencing, and serialization.

A similar activity was proposed to W. However, as he was in the literacy process, he preferred not to read the book, only to listen to it. The explanation of the concept of pair (two objects) was presented with the example of the Big Wolf's boots. W was not convinced of the concept, so new materials were used on the table: two balls, two sticks, two pens. The sticks were of different colors, so the student said they couldn't be a pair. Recalling Piaget[52] about the knowledge of physical properties that are in objects, it appears that W assimilated these properties in a unitary way. That is, because they have different colors, they could not be the same object. The teacher explained that the same objects may have some different characteristics and still form a pair.

Student W asked to typewrite number 2, always remembering that the representation of the value 2 is the same as that of b, accompanied by the number symbol (Figure 6). Continuing the activity, he was requested to write the numerals from 1 to 10 in Braille.

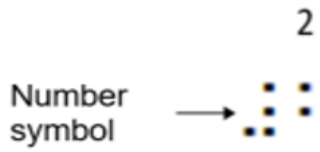

Figure 6
Representation of the number 2 in Braille

He used the concrete material to count how many pairs can be formed with the value 10. W took the sticks and put them in twos, counted, and said that four pairs had been formed, leaving one aside. Again he was asked to count, and he used the strategy of inserting the pairs inside the delimiter, so he counted five pairs.

Five sticks were given to W to tell the teacher how many pairs it would be possible to compose. He said, "*Two or three? There is one left!*" Then, he was taught that as a pair is made up of two units, only two were possible, and one stick was left, which is the concept of the rest of the division, however, it was not explored as a division.

For J, who was still in the literacy phase, writing in Braille is a problem, as she was used to listening to the texts more than reading them. The writing activities offered to her are basic, such as composing words with four or five letters and numerals up to ten.

Bezerra and Ramos[53] affirm that the sense of hearing guides people with visual impairments "to capture the information around them, also helping them to learn. The ears start, therefore, playing the role of the eyes, mainly concerning the "reading" of the audiobooks, since the blind's learning does not happen through visualization".

[51] Jean Piaget, "Problemas de psicologia genética" (Rio de Janeiro: Forense, 1972).
[52] Jean Piaget, "A epistemologia genética". (Petrópolis: Vozes, 1971).
[53] Fernanda Antônia Bezerra, Joranaide Alves Ramos, A importância do áudio-livro para o deficiente visual no estudo de literatura (Paulo Afonso-Bahia, 2015).

J was given activities involving words from the story. First, knowledge of the dots in Braille with the use of punctured Braille (Figure 7a). Then, she was asked to compose words related to the story, such as “wolf,” “pig,” “bad,” among others, using the Braille Ruler, because, in this way, the arrangement and grouping help in the composition of such words (Figure 7b). Finally, the reading in Braille of what colleagues L and W had written (Figure 7c).

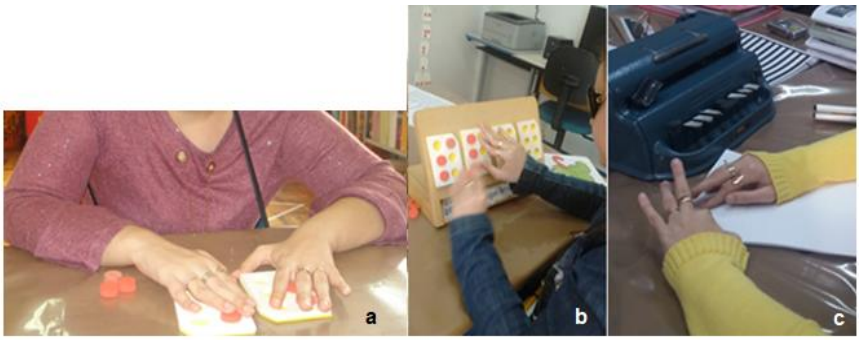

Figure 7
Activities in Braille

To train writing with the typewriter, we need to memorize the keys and master the Braille cells, recalling that the composition of the cells is different for each AT used for writing. With the conventional slater, we write from right to left and with the positive slater from left to right, in the same way as with ink. On the typewriter, the layout of the keys follows the shape of the columns from the center to the outside (Figure 8b).

Figure 8
Memorization activities in Braille

All resource rooms are equipped with accessible computers, with text readers installed, headsets, and, in some cases, the Braille keyboard. At school, the Braille keyboard is not used, because, according to the teachers and students, it disturbs those who have low vision, as they keep observing the symbols and not memorizing the position of the keys. Esperança,[54] who is blind, explains how the visually impaired memorize the keyboard: “check your keyboard for the existence of three dots, at the “F”, “J” and the “5” on the calculator. These raised dots help to memorize the position of the other keys; (d is on the left side of f, m is below and on the right side of j, and so on)”.

[54] Fabiano Boghossian Esperança, “Como nós cegos usamos o computador”, avaliable at: <http://intervox.nce.ufrj.br/~fabiano/pc.htm> (Accessed June 10, 2020).

The alphanumeric keyboard is the same as that of desktops (Figure 9b) and notebooks; however, the numeric keyboard is different, depending on the model. This often causes some inconvenience to use of notebooks (Figure 9a), since the numeric keyboard is placed above the alphanumeric keyboard, so it is necessary to memorize both ways.

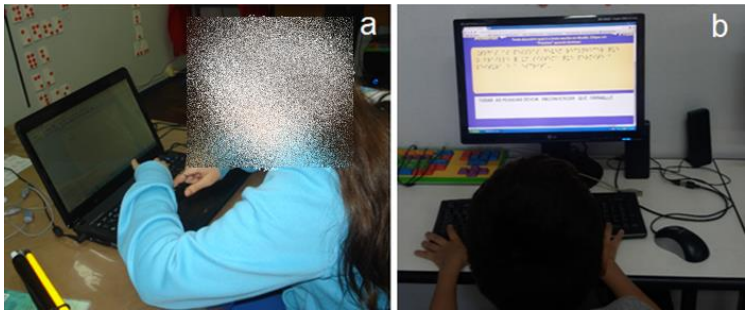

Figure 9
Use of computers

Computers, in general, are used for records, writing texts, Internet searches. The games, widely used in education, are still scarce resources for accessibility, leaving as one of the options the games available in DosVox.

Borges and Mendes[55] report that ATs for low vision students help "to carry out the tasks desired, using the visual residue and the remaining skills." Thus, SES provides low vision students with manual and electronic magnifiers. Figure 10 shows E using it to elaborate tasks requested in the regular classroom. Even with the font enlarged, a magnifying glass for reading and viewing objects is needed.

Figure 10
The use of the magnifying glass

The use of ATs to calculate, such as the enlarged and the talking calculator, to verify the results and enhance the understanding of the concepts of the four operations are resources provided during the attendance. Pesente, Olgin, and Groenwald[56] defend the idea "that the calculator has potential to develop some mathematical content, where this resource helps the student to develop and understand." Considering a blind student who organizes mathematical operations mentally, the calculator becomes an appropriate resource for the development of learning mathematical concepts.

[55] Wanessa Ferreira Borges y Enicéia Gonçalves Mendes, "Usabilidade de aplicativos de Tecnologia Assistiva por pessoas com baixa visão" (Bauru, 2018).
[56] Ilisandro Pesente; Clarissa de Assis Olgin y Cláudia Lisete Oliveira Groenwald, "Explorando os recursos da calculadora em sala de aula no ensino fundamental" (Curitiba: XIENEM, 2013.

Figure 11 shows E using the enlarged and the talking calculator. The enlarged calculator (Figure 11a) makes it easier to perform mathematical operations as it displays the values in an augmented size. Still, even so, E needs to be at a minimum distance to recognized them. The talking calculator (Figure 11b) has small buttons in comparison to the enlarged calculator. Hence, its viewing depends on a magnifying glass. When the students press the buttons, the calculator emits the audible value, which would not be necessary to visualize it. Because it was one of E's first contact with this AT, the magnifying glass helped her to memorize the position of the buttons.

Figure 11
Mathematical calculations using calculators

The acquisition of the numerical sequence does not occur in a linear and progressive manner but based on the "nodes," which are the numbers formed by the base 10 powers, such as 100, 1000, 10000, among others, besides the multiples of ten and one hundred.[57]

Two ATs developed with the LEI, Contátil[58] and Math Touch[59], were used with students during the consultations at various times, whether for counting, for recognizing the positional value, or for basic mathematical operations involving the four operations.

In the process of acquiring the number, W was introduced to several counting materials, such as diversified objects (balls, circles, and toys) and the golden material because "it is through the various manipulations of objects that children gradually develop the notion of natural number."[60] In some counting manipulations, he counted the objects more than once, which may have happened because they were separated. By having the units, tens, and hundreds grouped, Contátil makes this tactile experience more assertive.

Figure 12 shows W in one of the counting activities involving units and tens. The question of the units being grouped (Figure 12a) makes counting easier, as none of the pieces will move or be counted twice by returning to the delimiter, for example. W counted the units up to 9; then, other unit values were activated to check if he had abstracted them. The result was positive, even though in some moments, he "forgot" a value.

[57] Delia Lerner y Patrícia Sadovspy, "O sistema de numeração: um problema didático". (Porto Alegre: Artes Médicas, 1996).
[58] http://www.ppgecim.ulbra.br/teses/index.php/ppgecim/article/view/202
[59] https://editora.sepq.org.br/index.php/rpq/article/view/235/130
[60] ERMEL, Institut Nacional de Recherche Pédagogique. "Aprendissages numériques etrésolution des problèmes" (Paris: Hatier, 1991).

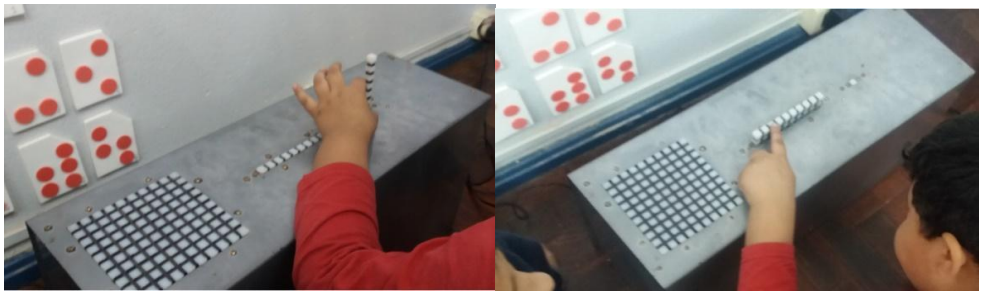

Figure 12
Contátil to recognize units and dozens

As the recognition of number ten as a quantity was still being constructed, it took W several counts of that quantity (Figure 12b) to actually consolidate the value 10. By using the Contátil, he could touch each of the units without removing them (Figure 12a), thus guaranteeing a unique count. Due to its horizontal arrangement, the counting strategy for the tens was to place the finger in each unit. However, his finger often passed from one unit to the other without being recited. Another activity carried out with students L and G was a kind of competition, where one would trigger Contátil with a value (with the sound off), while the other had to identify it. In this way, both exercised the recognition of the hundreds, tens, and units, and the positional value, because in several moments, some of the houses were zero (Figure 13). The average of correct answers for both was almost 100%.

Figure 13
Contátil in units, tens and hundreds

During the manipulation of Contátil, E questioned if that was, in fact, the golden material. She wanted to know whether the quantities were the same, especially concerning the hundreds, as she was used to receiving them on a plate containing 10 tens, and, in the Contátil, the plates were grouped. The solution was to present the two versions and ask her to count the plate (Figure 14a) of the golden material and the tens (Figure 14b) of the Contátil.

Figure 14
Contátil x Golden Material

As Math Touch presented mathematical challenges involving the four basic operations in easy, medium, and difficult modalities, it was used with students in attendance at different times, such as exercises and also to check the count.

Due to its layout, the Math Touch presents an advantage for low vision students' counting. The order of the buttons and its brightness helps not only to activate it, but also to identify what had already been selected, enabling the student to recount the buttons (Figure 15).

Figure 15
Math Touch and counting

The activities are audible, i.e., the user listens to the challenge and responds using the buttons according to the result. To know the correct answers, you just press the green button (round, not to be confused with the 5x5 matrix, which is squares), and the answer will be recited: "Congratulations" for the correct answer and "Let's try again" for the error.

The activities were made available according to the student's knowledge. Something noteworthy is that the students paid more attention to the audio activities and, whenever possible, solved the operations mentally, since the numerical universe was 25 (5x5 matrix).

Figure 16
Student J interacting with Math Touch

Student J found it a little challenging to handle with the AT Math Touch, as her numerical universe was reduced, and she still had some limitations with mental operations. The activity proposed was that she should recognize the matrix (Figure 16), the button counting, and the numerical representation activities. The exercises containing the four operations at that time were withdrawn.

Discussing the results

Dionisio and Vectore[61] state about learning how to read and write in Braille: "it must not start when the child goes to school, but from diagnosis, in the case of babies and sensory and visual stimulation." The authors also say that sighted children are stimulated from birth with written texts viewed in different places where they attend, and add, talking about visually impaired students that "they have contact with Braille only in the literacy phase."

In the mathematics area, Braille is responsible for the records both for personal use (class notes) and in assessments (tests, schoolwork). The AT responsible for writing has different characteristics; however, each student can adapt better to one method than the other, so it is important to make all resources available.

By observing the students' interaction with the conventional and the positive slates, we could draw a kind of diagnosis for each. We report below some of the situations using examples of mathematical records.

The conventional slate, used by most visually impaired people because it is one of the first ATs developed for writing, is quite difficult to understand, as described below. The writing is done "backwards," the person must write (punch the dots) from right to left, and with the positions of the dots also in reverse; when the slate is removed, it is possible to read the text normally from left to right. For a blind student who learned in this way, it is relatively easy because he/she has already assimilated the process, except that for the typewriter the writing is different. For low vision people or those who have become blind (already literate) and are having initial contact with Braille, there may be difficulties in the process, due to the reverse order of writing.

For example, a student that is given a mathematical operation or an activity where he/she should write the values in full in Braille cannot write the answer at the end of the line, because once the slate is removed, the paper replacement may "crumple" the dots, making reading difficult. Another factor is that, while the slate is positioned, it is not possible to read what is written, as it must be removed so that the dots can be felt. These are some of the restrictions found with the use of the slate during the research with the visually impaired students.

With the positive slate, however, writing is from left to right, which makes reading easier for those who are already literate. Another positive factor is that the writing of the dots is the same as for their representation, rather than backwards, as it happens with the conventional slate. However, the reading and replacement restrictions are the same as for conventional slates.

With the typewriter, the replacement on the line has the same restrictions as the slates. The writing method is different because the machine has six keys representing the six cells of the Braille system, but its position is not in columns, but in lines and from the center to the end, as previously described. The positive point is that during writing, it is possible to read, as the markings are made from left to right, and the paper is on the machine roll, so it is possible to read what is being written by touching it.

[61] Ana Maria Pereira Dionisio y Celia Vectore, Intervenção mediacional na aprendizagem do Braille: um estudo com crianças deficientes visuais (Maringá, 2017).

Another writing method is the use of text editors and printing in Braille with the Braille printer or reading through screen readers.

The presentation of the various ATs for writing gives visually impaired students the possibility to choose the one that best adapts to their writing pace and situation. We could observe that the typewriter is the resource that best suits students, as it was the first AT they used.

Also, we could verify that the use of diversified materials of tactile counting is necessary for the construction of the concept of number. The understanding that the two is part of the one plus itself (1 + 1 = 2), that the three is part of the two and one more (2 + 1 = 3) is provided by contact with such materials. The golden material is one of the most used ATs in this research.

For visually impaired students, counting activities using the golden material or other objects without the use of a delimiter can make them count twice the same object; also, some objects can even be out of their tactile reach. Figure 17 shows a counting organization with the delimiter in which it is possible to observe that the student has some cubes in his hand. He had not counted yet and, on the right, inside the limiter, the cubes were organized in rows, placed against the delimiter wall. This mode guarantees a correct counting, i.e., with only one object counted.

Figure 17
Counting strategies

The use of ATs constructed to teach mathematical concepts, besides having been idealized for visually impaired people, for example, the Contátil and Math Touch, arouse students' curiosity. This is often an impulse to seek knowledge.

The activities with Contátil presented positive points. One of them is that the pieces are grouped, so the delimiter is not necessary, and the right quantity is guaranteed. The fact that the values are presented in tactile and audio mode has enriched their abstraction. In some of the activities, the audio was removed, so that only the tactile would be verified, enhancing the counting strategies, and the tactile representation.

At Math Touch, audio is critical, because the activities are presented with sound, and students must represent the answers in concrete, by pressing the buttons.

Observations and interactions during the research deepened and brought recognition to the use of ATs in the teaching of mathematical concepts to visually impaired students, confirming its relevance to teach and construct the concept of number.

Final considerations

During the investigation, the objective was to understand the process of construction of the students' initial mathematical concepts, mediated by Assistive Technology. What could be observed during the research was the great help the ATs are for visually impaired people in some essential situations such as writing, where some AT is necessary to represent the Braille system. The adapted and tactile materials also constitute a range of possibilities in the teaching of mathematical concepts.

The Assistive Technology, developed to teach mathematical concepts to visually impaired children, such as Contátil and Math Touch, proved essential to their understanding. We observed that when a new technology is presented, the students tend to interact and participate with greater interest since something new usually arouses curiosity. During interactions with the ATs, we realized that they created activities and situations with each other, which fostered learning among peers.

Regarding the construction of the concept of number by the visually impaired children, it is possible to affirm that they have the same potential as sighted children. However, it is essential to use the AT and adapted materials to make this concept useful.

As for the development of the number concepts, W, a 1st-grade student, participating throughout the first year of the research, recognized the number and the process of acquiring it. The counting was still unstable, as well as the recognition of quantities and numerical symbols. In the following year, for family reasons, W was transferred to another municipal school, close to his residence, ceasing to be served by an SES with a Type II room.

Student L participated in the research over three years (from the 2nd to the 5th grade), starting from the process of acquiring the number and quickly moving on to consolidation and abstraction in counting, symbol recognition, and basic mathematical operations. His process was gradual, evidenced by each interaction and observation.

J started participating in the research in the 6th grade, and is still in the process of presenting and recognizing the number. Her numerical universe was reduced, and in the end, after three years of monitoring throughout the research, in the 9th grade, she still found it difficult to count, recognize and understand the units, tens and hundreds. The numerical abstraction was in the initial process. It should be noted that J was still in the process of literacy in Braille, which makes it difficult for the student to recognize the numeric symbol and its mathematical records. Another fact is that most of the time, the contents of the other subjects are approached only in audio form to J, so that she does not need to read in Braille. Nevertheless, the graphic representation is fundamental in mathematics.

During two school years (5th and 6th grades), student G presented the consolidation and abstraction of the concept of number, which can be evidenced by counting activities, mathematical calculations, and the mathematical relations he presented. The ATs and their resources were present in all stages of the participants' acquisition of the concept of number.

They were allied to the presentation of concepts, through interactions with mathematical symbols in Braille, quantities with tactile and diversified materials, in the consolidation with the use of calculators and other calculation resources and abstraction, when they represented the quantities and operations with mental calculations with the help of Math Touch. The recognition and understanding of the units, tens, and hundreds with activities carried out with the Contátil and the golden material were also evidenced.

The use of ATs can be a starting point for planning, considering the students' needs and potential.

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