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# Assistive Technology in the Construction of Number Concepts: A Study Entailing Actions of Teachers and Visually Impaired Students

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## ABSTRACT

**Background:** With the constant insertion of visually impaired learners in regular basic education in Brazil, it is important to create and/or adapt methodologies and equipment capable of aiding in the intellectual and social development of these students. **Objective:** This article intends to reflect on the usage of AT (Assistive Technology) as well as the utilisation of adapted materials for visually challenged students in the early years of primary school. **Design:** With a qualitative approach, it is inspired by the Discursive Textual Analysis. **Setting and Participants:** The research included not only teachers who teach mathematics in both the Specialized Educational Service (SES) and regular classrooms, but also low-vision students in an inclusive school. **Data collection and analysis:** A snippet of the meta-text is presented, which, through the analysis of the services provided in the SES, ponders about the students' necessities and activities within AT for the teaching of number concepts. **Results:** The research results attest that the usage of AT is, indeed, imperative in the students' construction of mathematical concepts with the intention of implementing Inclusive Mathematics Education. **Conclusions:** Simple adaptations, such as providing materials in Braille for visually impaired students, are actions that classroom teachers could adopt, counting on the assistance of Specialized Educational Service professionals.

**Keywords:** Inclusive Mathematics Education; Assistive Technologies; Visual Impairment.

## Tecnologia Assistiva na Construção do Conceito de Número: Um Estudo Envolvendo Ações de Estudantes com Deficiência Visual e Professores

## RESUMO

**Contexto**: Com a constante inserção de estudantes cegos e com baixa visão nas escolas regulares do país na Educação Básica, é importante criar e/ou adaptar metodologias e equipamentos capazes de auxiliar no desenvolvimento intelectual e social desses alunos. **Objetivo**: O presente artigo buscou refletir sobre o uso de TA - Tecnologia Assistiva e materiais adaptados com estudantes com deficiência visual nos Anos Iniciais do Ensino Fundamental. **Design**: Abordagem qualitativa, inspirada na Análise Textual Discursiva. **Ambiente e participantes da pesquisa:** A pesquisa

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envolveu cinco professores que ensinam matemática na sala de aula regular e no AEE - Atendimento Educacional Especializado, além de cinco estudantes matriculados na escola, sendo dois cegos e três com baixa visão em uma escola inclusiva. **Coleta e análise de dados:** Apresenta-se um recorte do metatexto, por meio da análise de atendimentos no AEE, ponderando sobre as necessidades dos estudantes e atividades com o uso de TA para o ensino do conceito de número. **Resultados**: Com os resultados da pesquisa, pode-se inferir que a utilização de TA é fundamental no processo de construção de conceitos matemáticos por estudantes com deficiência visual, com o intuito de efetivar a Educação Matemática Inclusiva. **Conclusões**: Algumas adaptações simples, como disponibilizar o material em Braille para os cegos ou ampliado para os estudantes com baixa visão, são ações que os Educação Matemática Inclusiva professores da sala de aula regular poderiam adotar, contando com o auxílio dos profissionais do AEE.

**Palavras Chaves**: Educação Matemática Inclusiva; Tecnologia Assistiva; Deficiência Visual.

## INTRODUCTION

The 1988 Brazilian Federal Constitution regulates Inclusive Education through several norms, laws, and decrees that guarantee equal school enrollment opportunities for all, regardless of their physical or intellectual condition, and Specialized Education Service - SES (AEE in Portuguese), offered preferably in regular education (Brasil, 1988).

With the growing demand for students enrolled in regular schools, inclusive education started to be studied and incorporated into educational institutions' routine. In this perspective, pedagogical materials, curricular adaptations, and spaces such as resource rooms for students with disabilities enhance new perspectives for the teaching and learning processes.

This article addresses an excerpt from the Doctoral Thesis *Deficiência visual e a educação matemática: estudo sobre a implementação de Tecnologia Assistiva* (Visual impairment and mathematics education: a study on the implementation of Assistive Technology[1]), inserted in the context of inclusive mathematics education of the Graduate Program in Science and Mathematics Teaching (PPGECIM) in ULBRA, developed at LEI - Inclusion Studies Laboratory.[2] The general objective of this thesis is to investigate the potential of the Assistive Technology - AT (TA, in Portuguese) to teach mathematical concepts in a regular classroom and during the attendance offered by SES, and the implementation process (involving the development, application, and evaluation) of technologies as pedagogical resources. In this context, this article presents discussions on the use of the ATs in the pedagogical practice of teachers who teach the concept of number to blind and low-vision students (Sganzerla, 2020).

Visual impairment has particular characteristics and demands. Considering the blind children must be stimulated through their other senses, such as touch, hearing, smell, and taste, because the visual impairment restricts the use of some visual resources, the

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[2] 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.

adaptation of didactic materials becomes essential for these students' efficient inclusion. Thus, we understand that Assistive Technology is an ally of education in this sense because it offers the visually impaired the possibility of access to school content.

## VISUAL IMPAIRMENT AND MATHEMATICS EDUCATION

According to INEP/EDUCACENSO (2020), public schools had 1,250,967 students with disabilities enrolled in 2019. This number refers to Brazilian basic education, which comprises early childhood education, elementary education, high school, vocational education, and youth and adult education. From these, 6,252 students are blind, and 73,839 have low vision, out of which 284 blind and 3,879 low-vision students are in the state of Rio Grande do Sul.

The World Health Organization (WHO, 2019) 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 previous conditions. (Brasil, 2004, p. 2)

The decrease in visual response can be mild, moderate, or profound, making up subnormal vision or low-vision group. The image can be corrected through magnifying glasses or lens, or special glasses. Those who have no visual response at all or respond only to some light are called blind. People with low vision see enough to carry out the main activities of their daily lives with autonomy, although they need special lenses to read and see the computer screen and/or watch television. At the same time, the blind need other resources because they only have light perception or total loss of vision.

As the blindness does not present visual residues, the blind need resources such as screen readers to access the computer and writing in Braille for their non-verbal communication. Schlünzen (2011, p.197) discusses the difficulties of the visually impaired to carry out some tasks due to their visual inaccuracy, "requiring adaptations of time, help and modifications, using their other senses, which often end up becoming more acute to adapt to their daily lives."

Leite (et al., 2010) describes that any approach to teaching visually impaired students must consider that they present the same conditions as seers to learn mathematics. The author also emphasises that the syllabus must be the same as those used in the regular classroom. Cavalcante (2007) explains that teaching mathematics to people with visual impairments requires various resources and specially adapted materials.

The learning process of visually impaired students in inclusive schools is based on their other senses: touch, hearing, smell, and taste. Thus, it is necessary to use materials that facilitate discrimination and/or identification of size, texture, volume, weight, besides varied sounds, which can arouse curiosity and interest in learning. Geller and Sganzerla (2014, p.124) indicate that educators face a great challenge "mainly in the matter of materials, since that, without vision, educational resources must be tactile and simple." Assistive Technology is one of the alternatives to overcome some of the visual restrictions.

Bersch and Toniolli (2008, p.4) present AT as being "access to the entire arsenal of resources that they need and that will help them to lead a more independent, productive and inclusive life in the general social context."

To understand blind and/or low-vision children, we must understand their basic restriction, their perceptual limitation, i.e., the vision. Their possibilities of perceiving the outside world are different, so they must develop other senses. Nevertheless, it is important to note that visual resources are widely explored not only in the classroom but in different segments of society. The children's analysis of an object is not done in isolation, but rather relational or comparative through difference and equality, and, in the case of a visually challenged child, this comparison is carried out through touching. According to Piaget (1979), logical-mathematical knowledge is a construction, and it results from the child's mental action on the world and, consequently, on the concept of number.

> The blind child takes more time to know and recognise things and objects because he/she handles and analyses them according to his/her needs, while a child who sees can perceive the object in its entirety and "immersed" in a broader context. (Brasil, 2014, p. 39)

Piaget and Szeminska (1971) affirm that the child progressively and internally builds the ability to count objects when coordinating various actions such as classification, serialisation, and two-way correspondence, among others. The authors remember that knowing the sequence of the numbers "by heart" does not mean that the child has acquired the concept of number.

Kamii (1994) reports that the learning of numbers occurs when the child starts to recognise small numbers. With the stimulation of empirical abstraction and the construction of relations of ordinary objects, the child begins to understand the higher numbers, called the reflexive abstraction phase. Piaget (1999, p. 303) describes how "one of the driving forces of the cognitive development and one of the most general processes of equilibrium is constituted."

Piaget (1999) concludes that the process of reflective abstraction always occurs in two moments: the child removes something from a lower level and projects this content on a higher level (for example, from action to representation); second, he/she reconstructs and reorganises mentally on the upper level what was transferred from the lower one.

Another aspect to be considered is that children have informal knowledge that occurs in social relations of daily life. Even before attending school, they live in an environment rich in mathematical information that can give them the opportunity, together with their social group, to build essential experiences. Blind children's informal knowledge is mostly very similar to that of sighted children because the people they live with provide opportunities for counting in verbal form and also by touching (Amiralian, 1997). However, it is possible to find situations of overprotection for the blind when they are not encouraged to participate in daily life, for example, counting people in a room and seeking the necessary amount of glasses for them.

Amiralian (1997) also states that the formation of concepts, the classificatory capacity, reasoning, and mental representation constitute critical factors for the acquisition of knowledge by a visually impaired child. Based on the Piagetian framework, this study emphasises that this process occurs at the beginning of human life, in which he/she constructs reality.

In his studies, Piaget (1952) suggested that children can reason logically about quantities to understand the numerical system. But he does not discuss how children learn to count. The studies by Gelman and Gallistel (1978), on the other hand, focused on how children learn to count, starting with objects, and evolving to understand the relationships about quantities. We infer that numbers are important because they allow representing quantities and giving meaning to quantitative relationships.

## METHODOLOGY

The research presented in this article is qualitative, aiming to investigate how the Assistive Technologies impacts on the pedagogical practice of teachers who teach mathematical concepts to blind and/or low-vision students.

Flick (2009, p.21) notes that the following purposes must guide research planning: "clearly isolate causes and effects, adequately operationalise theoretical relationships, measure and quantify phenomena, develop research plans that allow the generalisation of discoveries and formulate general laws." He also states that the phenomena observed must be classified according to their frequency and distribution.

We assume, then, aiming at a direct exploration, the participant observation technique, that, according to Marconi and Lakatos (2010), consists of real participation of the researcher with their subjects, where they experience their reality and propose alternatives. Thus, throughout the research, we experienced the attendance at SES, inferring on the students' needs and suggesting activities using the ATs to teach the concept of number.

This research is qualitative, as it explores "the characteristics of individuals and scenarios that cannot be easily described numerically." Moreira and Caleffe (2006, p.75) also argue that data are collected verbally by observation, description, and recording.

Lüdke and André (1986, p.12) cite that “the material obtained is rich in personal descriptions, situations, and events,” also pointing out that the concern “with the process is much greater than with the product.”

The research lasted three years in an inclusive municipal school inserted in the metropolitan region of Porto Alegre. It involved five teachers who teach mathematics, three related to Specialized Educational Services, identified as Teacher1, Teacher2, and Teacher3, who work with elementary school students, and two teachers from the regular classroom, Teacher4, from the 4th grade (throughout 2018), and Teacher5, from the 1st grade (1st semester of 2017). Table 1 shows each teacher’s professional training profile, whose identities have been omitted.

**Table 1**
*Teachers’ characteristics.* (Sganzerla, 2020, p.35)

| Identification | Degree | Specialization | Inclusion courses |
|---|---|---|---|
| Teacher1 | Pedagogy | Inclusive Education | Libras Interpreter<br>Basic and intermediate Braille |
| Teacher2 | Language and Literature Degree | Neuroscience<br>Inclusive Education | - |
| Teacher3 | Pedagogy | Inclusive Education | Autism Course<br>Basic Libras Interpreter<br>Basic Braille |
| Teacher4 | Pedagogy | Psychopedagogy | - |
| Teacher5 | Pedagogy | Early Childhood Education | - |

This research work also involved the five visually challenged students enrolled in the school, all receiving after-class attendance at the SES, as shown in Table 2. The Mathematics Learning column refers to the point of learning at the beginning of the interactions with the research participants.

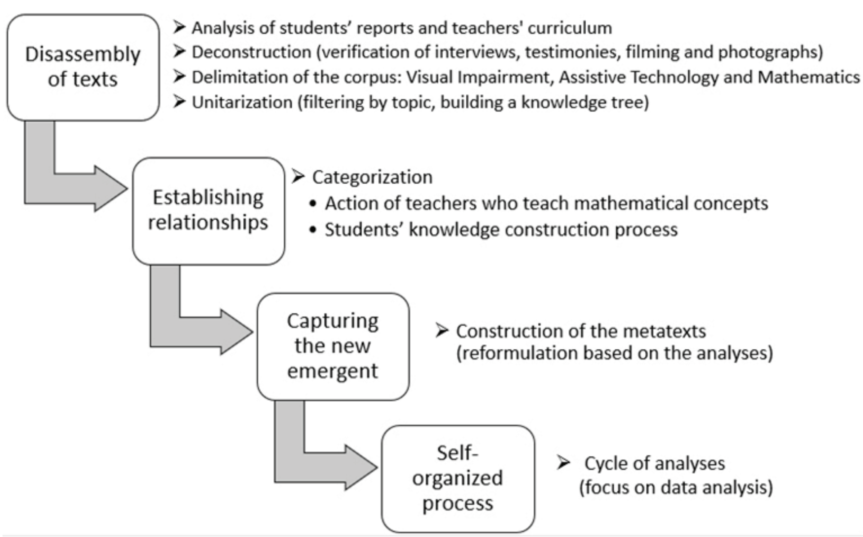
**Table 2**
*Students’ Characteristics.* (Sganzerla, 2020, p.35)

| Identification | Observation period/Year | Mathematics Learning | ICD[1] | Visual Impairment |
|---|---|---|---|---|
| E | 2015 - 2018<br>(1st to 4th grades) | Mathematics literacy | ICD 10: Q15.0 (Congenital glaucoma) and<br>ICD 10: H54.1 (Blindness in one eye and low vision in the other) | Legally Blind |
| G | 2017 - 2018<br>(5th and 6th grades) | Consolidated number and basic operations | ICD 10: H53.0 (Amblyopia due to anopsia) | Low vision |

| Identification | Observation period/Year | Mathematics Learning | ICD[1] | Visual Impairment |
|---|---|---|---|---|
| J | 2015 - 2018 (6th to 9th grades) | In the process of acquiring the number | ICD 10: H54.0 (Blindness in both eyes) | Blind |
| L | 2015 - 2018 (2nd to 5th grade) | In the process of acquiring the number | ICD 10: H54.2 (Subnormal vision of both eyes) | Low vision |
| W | 2017 (1st grade) | Mathematics literacy | ICD 10: H31.0 (Chorioretinal scars) and ICD 10: P31.1 (Congenital toxoplasmosis) | Low vision |

The research data analysis methodology was inspired by Moraes and Galiazzi's Textual Discourse Analysis (DTA) (2013), which aims to understand the phenomena based on their speeches and by delving into them. Considering the premises of textual analysis, throughout the investigation, messages, language, and discourse were analysed. Also, the non-verbal 'corpus,' referring to other symbolic representations, was also observed, because visually impaired people also express themselves by writing in Braille, by verbal communication, and, mainly, by touching to acquire knowledge. The research consisted of four steps: (a) disassembling the texts; (b) categorizing them; (c) capturing the new emergent; (d) self-organised process (Figure 1).

**Figure 1**
*Stages of the Textual Discursive Analysis.* (Sganzerla, 2020)



After organising the corpus, we understood our research objective, i.e., to analyse the use of the ATs in mathematics teaching. The unitarisation fragmented the corpus, thus identifying the significant elements observed in the speeches, interactions, and reactions of the participants, giving rise to the metatext. Based on this organisational principle, this article presents an excerpt of the metatext through the analysis of the teachers' attendance and the students' knowledge, associated with concepts and arguments that seek to highlight visually impaired children's use of the ATs to acquire the concept of number.

## ACTION OF TEACHERS WHO TEACH MATHEMATICAL CONCEPTS

For teachers to work with SES, they must have "initial training that qualifies them for the exercise of teaching and specific training in initial or continuing special education" (Mec, 2019, p. 4). The three teachers involved in the research have pedagogical training and specialisation in Inclusive Education field.

According to the special education operational guidelines on the SES (Mec, 2019, p.1), the responsible professionals have the function of "identifying, elaborating, and organising pedagogical and accessibility resources that eliminate the barriers for the full participation of students, considering their specific needs." It also argues that the services are available, aiming to complement and/or supplement the students' education for their autonomy and independence both at school and in their personal life (Brasil, 2009).

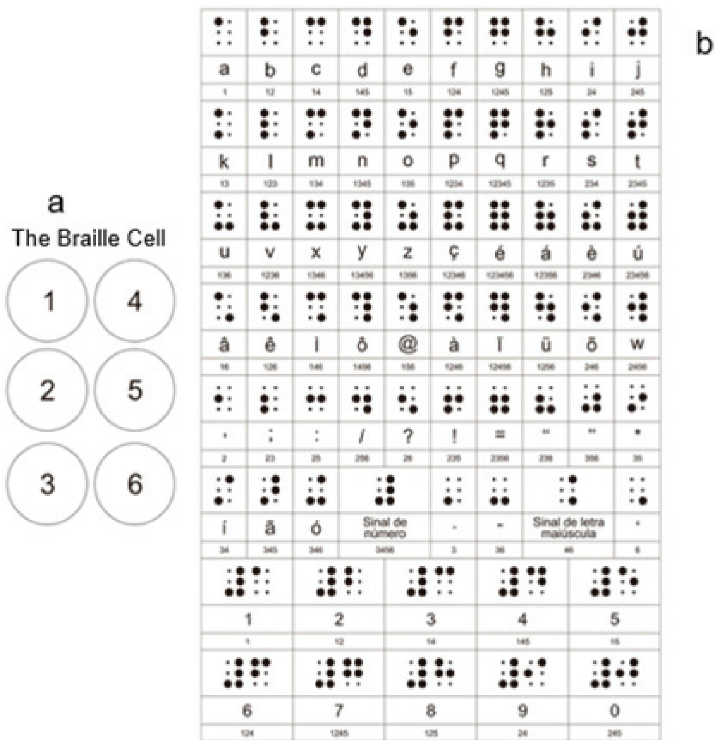
One of the tasks of the SES teachers is to develop the activities themselves, such as: "Libras, Braille, orientation and mobility, Portuguese language for deaf students; accessible computing [...]" (Brasil, 2011, n. p.).

Braille symbols are applied to text writing, mathematical and scientific symbology, music, and computing (Coelho, 2015). It is the means of written communication used by visually impaired people. Batista, Amaral, and Monteiro (2018, p.38) explain that the Braille System is a code "that needs to be memorised by the blind student." Sganzerla and Geller (2018) warn that before students start writing in Braille, they must be aware of the positions of the six cells. Bill (2017) emphasises that writing is a graphic representation of language, i. e., a transcription code of the sound units. The blind student must know the differentiation between the spoken word and its transcription through the Braille code.

Louis Braille created the Braille system, which consists of six points (Figure 2a) that are combined to form letters, numbers, punctuation marks, musical notes, and mathematical, chemical, and physical symbols (Figure 2b). It is possible for the visually challenged person to communicate worldwide in writing or reading by using this universal system.

**Figure 2**

*Braille system*. (http://www.megatimes.com.br/2015/03/sistema-braille-alfabeto-braille.html)




Ordinance No. 2.678 / 02 brings the policy for guidelines that regulate Braille use and teaching, in the production and dissemination in all types of application (Brasil, 2002). In this way, it presents unique signs (Figure 3), such as identifying a capital letter or a numeric value.

**Figure 3**

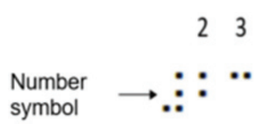
*Braille system*. (Cerqueira, 2006)

| Symbol | Meaning of indicators |
|---|---|
| ⠨ | Capital letter |
| ⠨⠨ | All letters in the word are capitalized |
| ⠒⠨⠨ | A series of words with all letters capitalized |
| ⠐ | Latin capitalization; special sign for hyphenation of mathematical expressions |
| ⠼ | Number |
| ⠡ | Exponentiation or superscript index |
| ⠌ | Subscript index |
| ⠔ | Italics, bold or underline |
| ⠐⠒ | Page change |

In parallel with the letters of the alphabet, students are introduced and taught the numbers in the Braille System.[3] As there are only 64 combinations for all representations, it is necessary to insert special symbols to represent numbers and mathematical signs. The number sign consists of cells 3 - 4 - 5 - 6 before the numerical value, which is one or more digits. Figure 4 shows number 23 written in the Braille system. We can see three consecutive cells; the first corresponds to the number symbol (cells 3 - 4 - 5 - 6), the second (cell 1 - 2), the number 2, and the third (cells 1 - 4), the number 3.

**Figure 4**

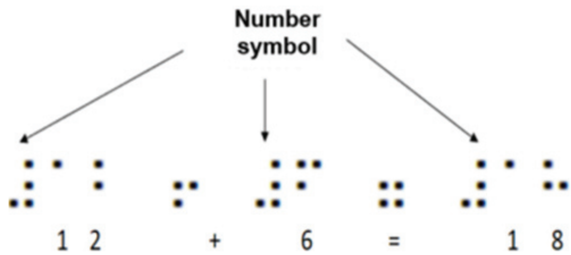
*Number 23 encoded in the Braille System*. (Sganzerla, 2020, p.114)




The concern about understanding symbols demands special attention to mathematical writing in Braille. Sganzerla and Geller (2018, p. 46) explain that "mathematical records in Braille are linear, whereas ink writing, for example, allows the representation of addition by organizing it in the specific format to solve the operation;" in Braille writing, once the first cell is positioned, the others must follow the same line, both in writing with the reglets and on the typewriter. Given the addition: 12 + 6 = 18 (Figure 5). We observe that the number symbol is inserted at each value representation.

[3] Writing in the Braille system requires the use of a reglet and a punch or else a special typewriter, called Perkins. The text can also be typed in an editor and printed on a Braille printer.

**Figure 5**
*Representation of 12 + 6 = 18*




Records are important, but their construction requires the student to understand numbers and quantities. Teacher3 always provided students with concrete materials and ATs to check and enhance the construction of the number. As the attendances were carried out with visually challenged students at various mathematical knowledge stages, it was necessary to distribute diversified tasks and materials. Figure 6 shows student L making mathematical records with the reglet, but they have other materials for counting around them, such as objects, magnifiers, and verification of numerical symbols in Braille.

**Figure 6**
*Student making mathematical records.* (Sganzerla, 2020, p.116)

Resolution no. 04, of 10/02/2009, in its Art. 13, item VII, shows that one of the tasks of the SES teacher is "to teach and use Assistive Technology to expand the students' functional skills, promoting their autonomy and participation" (Brasil, 2009, p.2). Thus, for mathematics teaching, the use of the ATs is essential, both for Braille records, as seen previously, and acquisition and construction of the number.

Piaget (2013) suggested stages or phases of evolution in the acquisition of numbers throughout life, following stages of development, with distinct characteristics, starting with the first form of intelligence, the sensorimotor, going through the beginning of the use of the symbol, concrete operations and, finally, formal operations. The first stage is marked by the reflexes that precede mental assimilation, which, during the process, are generalised to form the more complex sensorimotor systems (Piaget, 1999).

Ormelezi (2000) complements that, over time, this reality becomes a world to be perceived, differentiated, and organised in an absolutely practical way, through its manipulation. Only later, it will be replaced by thought, so, in the Piagetian perspective, there is a reflecting abstraction, considering that it is

> [...] accompanied by awareness and a formulation - actually a formalisation - of the abstracted elements. The reflected abstraction is observed from the simple verbal representation of a child's action ("I press that button, and it rings") to the formalisation of logical thinking operations, for example. (Montangero & Maurice-Naville, 1998, p. 91)

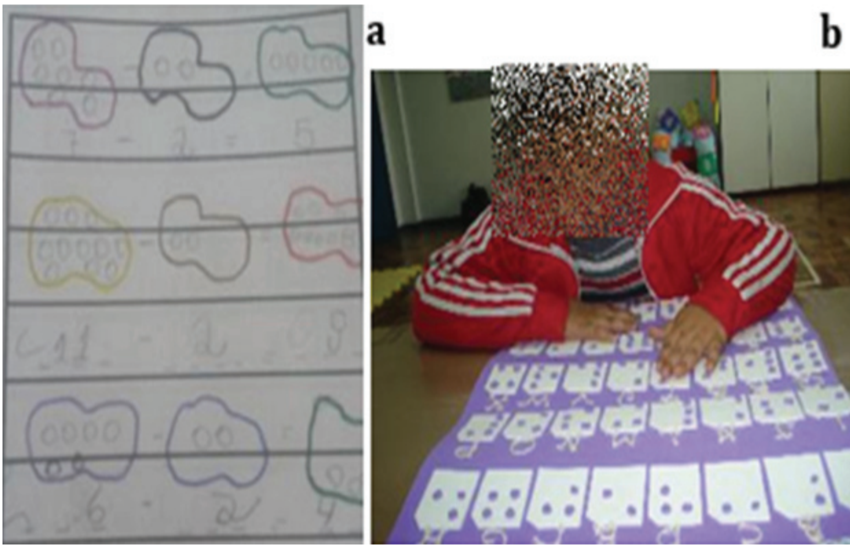
The earlier the children have contact with the world of mathematics, the sooner they will establish relationships between objects and the environment. Leonardo, Comiotto, and Miarka (2016, p.126) affirm that "fewer will be their difficulties with the related contents later," since the children will develop their logical reasoning, and, consequently, autonomy and skills to solve problems.

Many students have difficulties with mathematics. One of the reasons already mentioned is that it requires abstraction, an essential element to understand its concepts. Rodrigues and Sales (2018, p.26) indicate that "when they [students] are visually challenged, these difficulties are greater due to loss of visual acuity, whether the student is blind or had low vision."

Piaget (1979) relies on four relevant factors for the construction of the number: (1) Maturation, that refers the process in which physical and psychological growth occurs, thus influencing intellectual development; (2) Experience, understood as acting on the environment, that is, physical experience, which deals with the discovery of the observable properties in objects and together with logical-mathematics, which are the relationships between objects and their internal understanding; (3) Social, related to interactions with peers; (4) Equilibrium, an essential factor that coordinates all the others, determinant for the individual's development, the balance between the discovery of a new situation and the already existing others.

In a regular classroom, student W was doing exercises of quantities and association of values (Figure 7a). In attendance, he was given the same values, but in the Braille version (Figure 7b). In this way, student W worked in parallel the abstraction of the two forms of written numerical representation both in ink and in Braille, which contributed to the equilibrium and the acknowledgment.

**Figure 7**
Record resources. (Sganzerla, 2020, p.81)



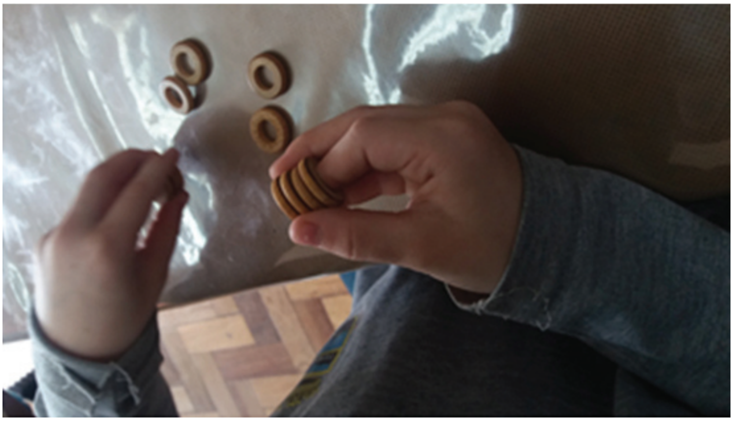

The fact that a student recites the values in a sequential order does not indicate that he/she developed the concept of number. Piaget and Szeminska (1971, p.15) reflect that "it is by no means enough for young children to know how to count 'one, two, three, etc.' verbally to be in possession of the number." They also state that the construction is part of the development of logic itself, which is associated with the construction of the pre-numeric period.

The authors also add that "[...] the number is organized, step by step, in close solidarity with the gradual elaboration of the inclusion systems (hierarchy of logical classes) and asymmetric relationships (qualitative series), with the succession of numbers, thus constituting an operational synthesis of classification and ranking" (Piaget & Szeminska, 1971, p.12).

The students were given a simple activity so that we could verify their counting. After they recited the sequential order, we checked whether they quantified the values, the quantities. Figure 8 shows the count of the circles (casters). We observed that the student used the strategy of joining the objects with his index finger to be sure he had already counted the object.

**Figure 8**

*Record resources*. (Sganzerla, 2020, p.118)



Blind people develop mental images, concepts of objects and quantities related to their experiences with the tactile world and to the form of language they use (Fernandes et al., 2006), because the formation of the number concept does not occur through numeral mechanical repetition, but through the progressive construction of the stages they experienced in their daily social and school lives.

Batista (2005, p. 8) explains that the issue of visually impaired people's acquisition of concepts "goes, first of all, with everything that refers to the acquisition of concepts by any person, with or without sensory alterations."

Teacher3 adapted the well-known domino game in an enlarged size, made with milk cartons lined with orange TNT, with the values pasted in black embossed circle shapes to intensify the touch to blind students. Such colours were chosen to provide contrast, to help low-vision students.

W3C (2019, np) states that "two colours provide good visibility if the difference in brightness and colour between the two colors is greater than a defined range." So, orange and black confer this property.

The activity with Dominoes (Figure 9) was directed by Teacher3 to check the classification. For the students, it is not enough to be able to count; they must separate the quantities arranged on one side of the piece and organise it with another of the same type, that is, with the same amount. Since all the pieces are the same size, it is possible to check the classification of groups (domino pieces) and subgroups (quantities on each side).

**Figure 9**
*Counting objects.* (Sganzerla, 2020, p.124)

Resuming Piaget (1977), the construction of the number is an operative synthesis of classification and ranking. According to Aranão (1997, p.29), the classification "is a logical operation that consists of the ability to separate objects, people, facts or ideas into classes or groups, having as criterion one or more common characteristics."

The mental construction is given in stages, in which the children go through a process of formation and acquisition of the concept of number, thus forming the logical-mathematical knowledge, since "when coordinating the relations of equal, different and more, the child it can deduce that there are more beads in the world than red beads and that there are more animals than cows. Likewise, it is by coordinating the relationship between "two" and "two" that he/she deduces that 2 + 2 = 4 and that 2 x 2 = 4" (Kamii, 2012, p.19).

The author also adds that this abstraction of the concept of number is a construction carried out by the mind from the properties of objects known to children (Kamii, 2012). That is, the ability to match words (in this case numbers) to objects.

Counting requires an aptitude, involving positional logic, grouping, and conservation of the number. For Piaget (1977), when students organise objects in rows to count, they should know that the quantity remains the same as when they group the same objects. This step is considered the conservation of the number, regardless of the organisation or properties (Kamii, 2012).

**Figure 10**

*Counting with the aid of the golden material.* (Sganzerla, 2020, p.126)

Professor3 proposed some grouping activities. Figure 10 shows student L grouping four elements in each of the nine groups, making a total of 36 objects. She requested student L to group the same objects into six groups, and, after completing the exercise, he was asked about the quantity. He answered correctly that there were the same 36 previous objects, but that they were now “in a smaller size,” referring to the number of groups.

For Piaget (1971), children understand the meaning of the number when they can make the logical relationship between serialisation, classification, and two-way relationship, understanding the equivalence relationships, with the gradual elaboration of the inclusion systems.

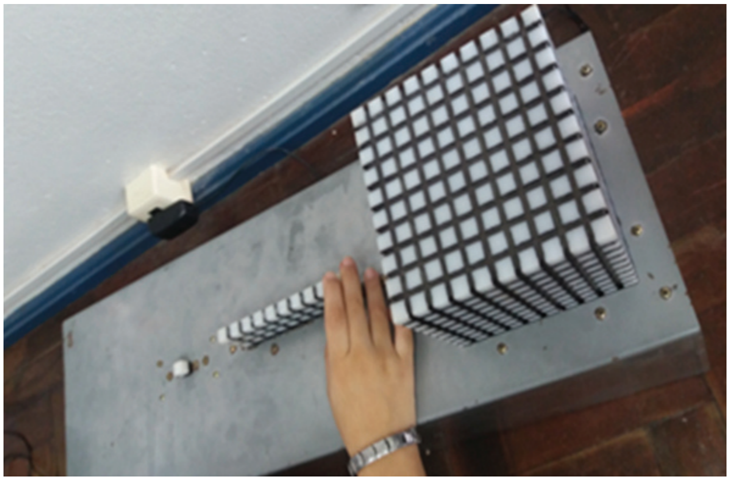
In line with the regular classroom, Teacher3, when attending the SES, works with positional values. Student E received an activity during the mathematics period that included positional values. He was requested to fill in a table to “break up” the amounts (Figure 11) in units, tens, and hundreds, which was printed in a small font. In this way, the student had to use both the magnifying glass and the gold material to verify the values.

**Figure 11**

*Activity related to the positional value.* (Sganzerla, 2020, p.128)

In parallel to the activity, the Contátil[4] The AT was manipulated to check the corresponding values, since it presents the tactile amounts of the values in the form of the golden material (Figure 12).

**Figure 12**
*Activity related to the positional value*. (Sganzerla, 2020, p.128)



One of the activities proposed was that they should verify the value 103 (Figure 13). Student L started by counting the units, and, when touching the tens, he said: "*There is nothing here!*" So, he passed to the hundreds, where he verified that the hundred was there. He was expected to express the value, so suddenly, he said: "*It's 103*." Teacher3 asked: "*Explain why it is number 103*." Realizing L's silence, she asked another question: "*Let's see why it is number 103, say how many units it has, how many tens and how many hundreds*." Immediately the answer came: "*There are three units, they are here*." At that moment, he pointed to the grouping of units, "*there are, there are, no tens - that's why it is zero?*" The value representation was correct; however, the student was still doubtful about the position of the zero. Then, the teacher explained that the zero was the placeholder, and it expressed that there were not dozens, but there were units and hundreds.

[4] Contátil: AT that mechanizes the golden material, available at: http://revistaparadigma.online/ojs/index.php/paradigma/article/view/741

**Figure 13**

*Checking the positional value 103*. (Sganzerla, 2020, p.129)

Sganzerla and Geller (2019) show that activities through visualization/touching of quantities are essential for the visually challenged to understand the positional value. In this way, the student is assisted in working the abstraction and, consequently, to execute mathematical operations correctly, using the units, tens, and hundreds in their original position.

The AT enlarged calculator (Figure 14a) and the speaker (Figure 14b) are part of the resources used in the SES. Students W and L were encouraged to work with mathematical operations with two portions.

**Figure 14**

*Enlarged calculator and speaker*. (Sganzerla, 2020, p.130)


The activity was mediated by Teacher3, who proposed that W and L make sums in calculators, given orally, or through numbers and symbols arranged on the table to visualise them (Figure 14b) after the calculation. The proposal was to confirm, through the result presented in the calculators, whether the values were correct. Thus, there was an interaction between the two students. In a moment, Teacher3 recited: "*five plus seven, how much is it?*" L calculated and said: "*12*", to which W retorted: "*13*." At that moment, Teacher3 intervened, asking them to calculate differently, without using the calculator. W requested the golden material.

In possession of the golden material, W separated five cubes in one corner of the boundary and seven units in his hand. Not sure whether the quantity separated was correct, he counted the cubes inserted in the delimiter again. He made sure that there were actually five, so he started to insert the cubes that were in his hand, counting one, two, ... up to seven. Then, he replied: "*they are not 13; they are 7*." Then student L, helping student W, separated the five units again in the corner of the delimiter and took the other seven cubes, returning them to W, saying: "*There are 5 there, already, then the next one is the six*," taking a small cube and placing it in the delimiter, "*after that, it's seven*," inserting a new unit. In the end, they had 12 cubes; W counted them all and said: "*so, it is really 12!*" L's assistance promoted an exchange of experience between students.

The AT "is fundamental for the person with disabilities, for their self-esteem" (Othero & Ayres, 2012, p.228). Thus, students can feel integrated into society because the use of technologies contributes to the construction of knowledge. Besides, the technologies arouse curiosity and interest in handling the materials. This was observed when Teacher3 proposed activities using the AT Math Touch[5] to student J.

In the first moment, student J was requested to explore the AT; given he is blind from birth, he must recognise the equipment by touch. Ochaita and Rosa (2019, np) warn us about the differences between passive and active touch, "while in the first (passive touch) tactile information is received unintentionally or passively (such as the feeling that clothing or heat produces in our skin), in the active touch, information is sought intentionally by the individual who touches it."

After using the active touch for the recognition, the student was asked what the maximum amount to be represented would be, so he started the count by selecting the buttons. Eventually, the student stated that there were nineteen buttons, so he was asked to check if this value was correct. Then he started to count again, and the answer was different: "*there are twenty-five buttons, is it correct now?*" to which the answer was "*Yes*."

After analysing the reason for the wrong answer at first, we concluded that the student had not pressed some of the buttons, as his counting strategy was random, not following a logical order, such as columns or rows. In the second verification, the following strategy was used: the selection of the buttons in the order of the rows, in this way with one hand, he checked whether there were remaining objects while, with the other hand, he counted by touching, as can be seen in the position of J's hands in Figure 15.

[5] Math Touch: AT developed to work with counting, available at: https://editora.sepq.org.br/index.php/rpq/article/view/235/130

**Figure 15**

*Interaction with Math Touch.* (Sganzerla, 2020, p.131)

Confirming the numerical universe of Math Touch, they completed the challenges. For each AT question, student J inserted the result, and the platform displayed whether it was correct, or he should try again. The student succeeded better in the first attempt, when he was more focused, and found the activities were different because they had been proposed by the AT rather than by Teacher3. The challenges proposed involved only demonstrating quantities.

Kamii (1994, p.13), based on Piaget's theory, explains that "[...] the number is constructed by each child from all types of relationships that he/she creates between objects." During the attendances, the teachers involved in the research were careful to offer several objects to the students so that they could create the relationships independently, providing the necessary abstraction for counting, since objects may have different characteristics but are part of that set.

The use of diversified ATs to count and to perform mathematical calculations/ operations, such as enlarged calculators and speakers, golden material, Contátil, and Math Touch, was emphasised during the observations mainly of Teacher3's actions, who always searched for, and experienced, different technologies and materials.

Kamii's (1994) studies also point out that although a child may "recite" the numbers orally, it does not mean that the formation process is complete. They must be able to reflexively abstract the concept of number and build the relationships of order and hierarchical inclusion.

During the observations, it was possible to verify that the use of diversified materials of tactile counting is necessary to construct the concept of number. The understanding that number two is part of the one plus itself (1 + 1 = 2), and that the three is part of two plus one (2 + 1 = 3), is provided by contact with such materials. The golden material is one of the most used ATs in this process during the research.

## CONCLUDING REMARKS

About the construction of the concept of number, it is possible to observe that visually impaired children have similar potential than sighted children. However, it is necessary to use ATs and adapted materials for this concept to become active.

The ATs and their resources were used in all stages of the participants' acquisition of the concept of number through interactions with mathematical symbols in Braille, quantities with tactile and diversified materials, or consolidation, with the use of calculators and other calculation resources, and abstraction, when they represented quantities and operations with mental calculations with the help of Math Touch. The awareness and understanding of students concerning the units, tens, and hundreds were highlighted in the activities with Contátil and the golden material.

In the mathematics field, Braille is responsible for the records for personal use (class notes) and assessments (tests, schoolwork), so it must be understood and trained. Some simple adaptations, such as making the material available in Braille for the blind or enlarged for students with low vision, are actions that teachers in the regular classroom could have as a practice, with the help of the SES professionals. We observed that not all teachers at the school realise that visually impaired students need these resources.

During the SES attendances, the teachers tried to approach the mathematical content worked during the regular classroom, in constant interaction with the conducting teachers. However, according to the current legislation, the SES should not be a school reinforcement, but a moment to learn and search for knowledge related to disability, such as teaching Braille.

In this research, considering the metatexts writing and data analysis, it is possible to extract four significant units regarding the construction of the concept of number: introducing, recognising, consolidating, and abstracting. By introducing, we mean that the students have their first interactions with the concept of number, involving its representation, quantification, and meaning. Recognising involves the relationships established through these interactions. Students E and W were at this stage at the beginning of the research. J and L were already acquiring the number, consolidating the concept, and, finally, student G had the knowledge of number consolidated and understood the basic mathematical operations, managing to abstract.

This process is often not linear, since abstraction, according to Piaget's theory, is constituted throughout the student's school life. Thus, we understand that abstraction permeates the entire process, becoming evident when the student shows a solid comprehension of the concept of number.

## CONTRIBUTION OF EACH AUTHOR

This article was prepared and organised by both authors. M.A.R.S. was responsible for the theoretical framework and data collection. M.G. was responsible for guiding the theoretical assumptions, methodological guidelines, and the monitoring of writing. The results and concluding remarks were discussed and written by both authors.

## DATA AVAILABILITY STATEMENT

The authors agree to make their data available at the reasonable request of a reader. It is up to the authors to determine whether a request is reasonable or not.

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