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Ensino de álgebra para deficientes visuais: contribuições das situações desencadeadoras de aprendizagem

Teaching algebra to the visually impaired: contributions of learning-triggering Situations

Enseñanza de álgebra para personas con discapacidad visual: contribuciones de las situaciones desencadenantes de aprendizaje

Enseignement de l'algèbre pour les déficients visuels : contributions des situations déclenchantes d'apprentissage

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Abstract

Considering the need to combine theory and practice in planning teaching situations for visually impaired students, this research adopted the assumptions of the Historical-Cultural Theory and the Activity Theory, and was based on the Teaching Guiding Activity. Learning triggering situations for algebraic knowledge were developed, and interventions carried out with a 7th-grade student and another from 8th grade, both visually impaired and attending the multifunctional resource room of a public school in the state network, were analyzed. The aim of this article is to recognize the appropriation of algebraic knowledge by visually impaired students from learning triggering situations. To this end, the data were organized into two categories: manifestations of conceptual nexuses and manifestations of thought and language. These two categories allow understanding the phenomenon of "appropriation of algebraic knowledge" from the situations presented to the students. At the end of the study, it is highlighted that the elaborated situations allowed symbolic and instrumental mediation, enabling the appropriation of the conceptual nexuses of algebra (variation, variation field, and

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fluency) and of some selected school contents (recognition of unknowns, dependency of variables, and operations with monomials and polynomials). It should be noted that the proposed triggering situations achieved these results through a teaching organization process that considered the conditions for accessibility of the students served.

Keywords: Algebra teaching, Visual impairment, Historical-cultural theory, Teaching guiding activity, Learning triggering situations.

Resumen

Considerando la necesidad de combinar teoría y práctica en la planificación de situaciones de enseñanza para estudiantes con discapacidad visual, esta investigación adoptó los supuestos de la Teoría Histórico-Cultural y de la Teoría de la Actividad, y se basó en la Actividad Orientadora de Enseñanza. Se desarrollaron situaciones desencadenantes del aprendizaje de conocimientos algebraicos y se analizaron intervenciones realizadas con un estudiante de 7º grado y otro de 8º grado, ambos con discapacidad visual y asistiendo al aula de recursos multifuncionales de una escuela pública de la red estatal. El objetivo de este artículo es reconocer la apropiación de conocimientos algebraicos por parte de personas con discapacidad visual a partir de situaciones desencadenantes de aprendizaje. Para ello, se organizaron los datos en dos categorías: manifestaciones de nexos conceptuales y manifestaciones del pensamiento y del lenguaje. Estas dos categorías permiten comprender el fenómeno de "apropiación de los conocimientos algebraicos" a partir de las situaciones presentadas a los estudiantes. Al final del estudio, se destaca que las situaciones elaboradas permitieron la mediación simbólica e instrumental, posibilitando la apropiación de los nexos conceptuales del álgebra (variación, campo de variación y fluidez) y de algunos contenidos escolares seleccionados (reconocimiento de incógnitas, dependencia de variables y operaciones con monomios y polinomios). Cabe resaltar que las situaciones desencadenantes propuestas lograron estos resultados a través de un proceso de organización de la enseñanza que consideró las condiciones para la accesibilidad de los estudiantes atendidos.

Palabras clave: Enseñanza de álgebra, Discapacidad visual, Teoría histórico-cultural, Actividad orientadora de enseñanza, Situaciones desencadenantes de aprendizaje.

Résumé

Considérant la nécessité de combiner théorie et pratique dans la planification des situations d'enseignement pour les étudiants déficients visuels, cette recherche a adopté les postulats de la Théorie Historico-Culturelle et de la Théorie de l'Activité, et s'est fondée sur l'Activité

Ordinatrice d'Enseignement. Des situations déclenchantes d'apprentissage des connaissances algébriques ont été élaborées, et des interventions réalisées avec un élève de 7e année et un autre de 8e année, tous deux déficients visuels et fréquentant la salle de ressources multifonctionnelles d'une école publique du réseau d'État, ont été analysées. L'objectif de cet article est de reconnaître l'appropriation des connaissances algébriques par les déficients visuels à partir de situations déclenchantes d'apprentissage. Pour cela, les données ont été organisées en deux catégories : manifestations des liens conceptuels et manifestations de la pensée et du langage. Ces deux catégories permettent de comprendre le phénomène "d'appropriation des connaissances algébriques" à partir des situations présentées aux élèves. À la fin de l'étude, il est souligné que les situations élaborées ont permis une médiation symbolique et instrumentale, permettant l'appropriation des liens conceptuels de l'algèbre (variation, champ de variation et fluidité) et de certains contenus scolaires sélectionnés (reconnaissance des inconnues, dépendance des variables et opérations avec les monômes et polynômes). Il convient de noter que les situations déclenchantes proposées ont atteint ces résultats grâce à un processus d'organisation de l'enseignement qui a pris en compte les conditions d'accessibilité des élèves servis.

Mots-clés : Enseignement de l'algèbre, Déficience visuelle, Théorie historico-culturelle. Activité ordinatrice d'enseignement, Situations déclenchantes d'apprentissage.

Resumo

Considerando-se a necessidade de aliar teoria e prática no planejamento de situações de ensino para estudantes deficientes visuais, esta pesquisa adotou os pressupostos da Teoria Histórico-Cultural e da Teoria da Atividade e fundamentou-se na Atividade Orientadora de Ensino. Foram elaboradas situações desencadeadoras de aprendizagem de conhecimentos algébricos e analisaram-se intervenções realizadas com um estudante de 7º e outro do 8º ano, ambos deficientes visuais e frequentando a sala de recursos multifuncionais de uma escola pública da rede estadual. O objetivo deste artigo é reconhecer a apropriação de conhecimentos algébricos por deficientes visuais a partir de situações desencadeadoras de aprendizagem. Para tal, organizaram-se os dados em dois isolados: manifestações dos nexos conceituais e manifestações do pensamento e da linguagem. Estes dois isolados permitem compreender o fenômeno “apropriação dos conhecimentos algébricos” a partir das situações apresentadas aos estudantes. Ao fim do estudo, destaca-se que as situações elaboradas permitiram mediação simbólica e instrumental, possibilitando a apropriação dos nexos conceituais da álgebra (variação, campo de variação e fluência) e de alguns conteúdos escolares selecionados (reconhecimento de incógnitas, dependência de variáveis e operações com monômios e polinômios). Cabe ressaltar que as situações desencadeadoras propostas alcançaram estes resultados a partir de um processo de organização do ensino que considerou as condições para a acessibilidade dos estudantes atendidos.

Palavras-chave: Ensino de álgebra, Deficiência visual, Teoria histórico-cultural, Atividade orientadora de ensino, Situações desencadeadoras de aprendizagem.

Teaching algebra to the visually impaired: contributions of learning-triggering situations

Since the promulgation of the Brazilian Federal Constitution (Brasil, 1988) and the Law of Guidelines and Bases of National Education (Lei de Diretrizes e Bases da Educação Nacional – LDB – Brasil, 1996), inclusion has progressively permeated discussions on the right of access to education, becoming an agenda in schools and teacher education. However, we must pay attention to the methodological organization of classes, which should not be limited to producing differentiated materials for the included students. Planning the possibilities for student interaction and discussion is part of the school inclusion process.

In this way, considering the need to articulate theory and practice in the inclusion of visually impaired people and based on the organization of teaching based on the assumptions of the teaching guiding activity, in this research, we seek to analyze how situations that trigger learning help in the appropriation of algebraic knowledge for visually impaired students.

This research is based on a work focused on the contributions of situations that trigger algebra learning in regular non-inclusive classes (Panossian, 2008; Alves, 2016; Cedro, 2004) and on Lucion's investigations (2015), which showed subsidies to this form of organizing mathematics teaching for inclusion in the initial years of elementary education.

Considering the research objective, we created algebra teaching situations involving content such as variables, the field of variation, recognition of unknowns, dependence of variables, and operations with monomials and polynomials. These situations were developed with two visually impaired students, one attending the 7th grade and the other attending the 8th grade. The analysis used isolates (Caraça, 1951), i.e., sections of the entire phenomenon, to understand its relationships of interdependence and movement:

> In the impossibility of embracing the entirety of the universe, the observer highlights a set of beings and facts from this totality, abstracting from all the related others. We will call such a set an isolate; therefore, an isolate is a section of reality arbitrarily cut out from it. (CARAÇA, 1989, p. 112).

This research presents the study of the phenomenon of appropriation of algebraic concepts by visually impaired students based on the proposed learning-triggering situations. Therefore, we consider it necessary to discuss inclusion, the process of organizing teaching with situations that trigger learning, the situations created, and the results of interventions with students.

This research was approved by the Research Ethics Committee of the Federal University of Technology of Paraná (CAAE: 12565419.0.0000.5547, número do parecer: 3.392.138).

Inclusion in education

Discussions about inclusive education have been intensifying worldwide since the 1990s, with the "World Declaration of Education for All" (Unesco, 1998) approved in Jontien, Thailand (March 5 to 9, 1990), a major milestone in this movement. We highlight the following items from Article 3 of the document:

> 1. All children, young people, and adults are entitled to basic education. To this end, it is necessary to universalize it, improve its quality, and take effective measures to reduce inequalities. [...]
>
> 5. The basic learning needs of people with disabilities require special attention. Measures are necessary to guarantee equal access to education for people with any disability as an integral part of the educational system. (Unesco, 1990, p. 4).

Around a decade earlier, the right to universal access to education was established by Article 6 of the Brazilian Constitution, being reinforced as a duty of the State in other sections:

> Art. 23. It is a joint competence of the Union, the States, the Federal District, and the Municipalities to:
>
> [...] V - provide means of access to culture, education, science, technology, research, and innovation; (Brasil, 1988).

The concept of special education, however, had already been defined as a means to guarantee the right to education for people with disabilities:

> [...] a pedagogical proposal that ensures special educational resources and services, institutionally organized to support, complement, supplement and, in some cases, replace regular educational services, to guarantee school education and promote the development of the potential of students with special educational needs in all stages and modalities of basic education. (Brasil, 2001, p. 1).

It is important to highlight that the special education model is only provided for in cases where inclusion in regular classrooms is not possible. Article 58 of the Basic Guidelines Law (Lei de Diretrizes de Bases - LDB) also states that education must be offered "preferably in the regular education network." (Brasil, 1996). The National Special Education Policy (Política Nacional de Educação Especial), enacted in 2020, reinforces this guidance:

> It is worth noting that, as is very clear in the LDB, educational services should preferably be provided at inclusive regular schools –which does not mean exclusively there. The adjective "regular," as stated in the LDB, is synonymous with "standard" or "conventional," in contrast to "special" or "specialized." (Brasil, 2020, p. 19).

However, considering classes with students with and without disabilities working collectively and having their needs met is a recent idea in the history of education (Pacheco & Alves, 2007).

Pacheco and Alves (2007), when analyzing how people with disabilities have been treated throughout history, indicate that their abilities were not recognized until the 19th century. According to the authors, in Antiquity, each culture had an attitude towards people with disabilities, ranging from total exclusion to a protectionist, not inclusive, aspect. With the rise of Christianity in the Middle Ages, the welfare aspect gained strength:

> [...] Even with the increased attention to people with disabilities and the continuous creation of hospitals, these still did not show a humanitarian and social equity character. After all, in our view, these hospitals proved to be repositories of people who were not socially valued and only attended to in terms of their organic needs, disregarding the psychosocial aspect of the human being. (Pacheco & Alves, 2007, p. 243).

During the First Industrial Revolution, according to Pacheco and Alves (2007), the need for a workforce made the productive potential of people with disabilities began to be valued: “In this way, from the second half of the 19th century, there was great concern about the work potential of people with disabilities, which contributed to the creation of several organizations that still exist today for this purpose.” (Pacheco & Alves, 2007, p. 244).

The paradigm of integrating disabled people, enabling access to education and work activities, but segregating them from social life, lasted for almost a century. Throughout the 19th century, with the new demand for workers due to World War I and World War II, the integration paradigm strengthened based on the idea of rehabilitation, especially for people with physical disabilities (Pacheco & Alves, 2007). Briefly, “integration can be understood as the process by which a person with a disability adapts to the current social environment, which differs from inclusion, which occurs when society prepares to receive this person.” (Kaleff et al., 2013, p. 208).

Under pressure from other countries, Brazil began to include people with disabilities in educational policies in the second half of the 20th century (Pacheco & Alves, 2007). At this time, the possibilities for including them socially and caring for their psychosocial development began to be discussed. Despite this, the inclusion paradigm only strengthened in the 1990s and still faces several barriers.

One of these barriers is the fact that social inclusion is a bilateral movement: society and individuals mobilize to make changes happen:

> This author [Bartalotti] states that respecting diversity and difference does not mean denying them and the special needs of people with disabilities. Thus, to truly respect people with disabilities, society must offer possibilities for development, and its participation must be concurrent with rehabilitation programs and the efforts of the person with disabilities. (Pacheco & Alves, 2007, p. 245-246)

To guarantee these rights (of development, social participation, and diversity) to people with disabilities, we must ensure accessibility; i.e., that everyone, with or without disabilities, can make use, safely and independently, of all spaces, furniture, transport, means of communication, systems and technologies, and services and facilities open to the public (Brasil, 2015).

On the other hand, to guarantee accessibility, we must analyze and eliminate existing barriers, to be specific, any obstacle or attitude that impedes the person's social participation and accessibility (Brasil, 2015). One way to overcome this is to create products with a universal design concept: products/spaces that people with or without disabilities can use without specific adaptations (Brasil, 2015).

Universal design, therefore, encompasses the environment (classroom), materials (teaching), and the teacher's teaching methodology, as it is the right of people with specific educational needs, according to Article 59 of the LDB, "curricula, methods, specific techniques, educational resources, and organization, to meet their needs" (Brasil, 1996). Such modifications and reformulations are the responsibilities of teachers and education systems (Brasil, 1996). It is essential to highlight that inclusion is not just about significant structural changes but that:

> Small changes in the organization of the classroom and the class itself already bring a significant difference to the blind student, such as the arrangement of tables and chairs; instead of organizing students in rows, as is commonly done, one can gather them in small groups, thus creating greater interaction, helping students to have contact with different learning perspectives, allowing for greater socialization, where one supports the other. (Dias, 2018, p. 23).

For such reorganization in the planning of their classes, the teacher must know students' needs, in the case of this study, related to visual impairment. Decree-Law n. 5.396 (Brasil, 2004) defines people with visual impairment as follows:

> i. People are blind when visual acuity is equal to or less than 0.05 in the best eye with the best optical correction and;
>
> ii. They have low vision when visual acuity is between 0.05 and 0.3 in the better eye with the best optical correction.

Visual acuity is the eye's ability to distinguish contours, shapes, and details. Thus, a blind person with visual acuity equal to or less than 0.05 (1/20) sees at 1 meter or less away what a fully sighted person would see at 20 meters away, reaching cases of total blindness in which they cannot even see a shadow of the object.

Therefore, to include a student with visual impairment, the first step is to know how much they can see and what instruments they use in their routine (Braille, soroban, digital resources, etc.). To this end, the teacher can count on the support, in the case of visual impairment, from the resource rooms:

> Specific and multifunctional resource rooms are spaces organized in basic education schools, specialized educational service centers, or partner institutions with qualified professionals, adequate teaching materials in accessible formats, equipment, and assistive technology resources. (Brasil, 2020, p. 76).

The specific resource rooms are focused on a single disability, while multifunctional resource rooms serve "students with disabilities, global developmental disorders, and high abilities or giftedness." (Brasil, 2020, p. 76).

In this way, the inclusion process is both social and educational, and coordination between regular and resource classroom teachers is essential. In order to break away from the integration paradigm, students must be offered actual inclusion opportunities that respect each student's time and needs. In this process, specialist teachers and resource room materials become essential allies in the development process of children and adolescents with disabilities (Dias, 2018). However, for this to happen, both teachers need to work cooperatively:

> The role of the [specialist] teacher, then, is not only to provide service within the resource room; it is quite comprehensive, as it involves interaction with the entire school community; that is, the student's inclusion implies the inclusion of the teacher of the resource room into the school. Work flows well when there is rapport between the parties involved. (Hilsdorf, 2014, p. 24).

This broad role of the specialist teacher in the resource room allows us to investigate aspects that the regular teacher cannot reach, such as those relating to the student's family life. In this way, the teacher and the student must prepare the teaching plans together, considering students' needs, both psychosocial and resulting from disability, and their appropriation of specific content.

> Planning, in a broad sense, is a process that aims to provide answers to a problem by establishing ends and means that aim to overcome it, to achieve previously foreseen objectives, thinking and necessarily predicting the future but without disregarding the conditions of the present situation and past experiences, considering the contexts and

> philosophical, cultural, economic, and political assumptions of those who plan and with whom they plan. (Padilha, 2001, p. 63).

From this, each teacher can rethink their teaching strategies and the resources they will use in the classroom, a process that, in this work, considers the principles of guiding teaching activity.

Teaching Guiding Activity

Theoretically and methodologically, this study is based on the Teaching Guiding Activity (Moura et al., 2016). From this perspective, teachers and students are active subjects (Leontiev, 1986); therefore, they perform actions and operations based on their conditions, values, and affection to achieve personal or collective objectives (Moura et al., 2016).

Recognizing that teachers' objective is to guide the appropriation of scientific knowledge grounded on theoretical forms of thinking, we understand that they are subjects in the teaching activity (Moura et al., 2016). As such, they organize content and actions in the classroom, ensuring that their students are engaged in the learning activities. To awaken students' yearning to learn, teachers can organize actions in the classroom based on situations that trigger learning, i.e., a teaching situation created considering the elements of the mental process of the activity, since:

> In TGA, the needs, motives, objectives, actions, and operations of the teacher and students are initially mobilized through the situation that triggers learning. The teacher organizes this based on their teaching objectives, which, as we said, translates into content to be appropriated by students in the learning space. (Moura et al., 2016, p. 188).

Games, virtual stories of the concept, or emergent everyday circumstances are examples of situations that may trigger learning as a central action of the teaching guiding activity (Moura & Lanner de Moura, 1998). They share some essential characteristics: teachers must consider the historical-logical dialectical movement of the knowledge to be taught (Moura et al., 2016) and pose a triggering problem (Moura. 2006). Then, the objective is to develop theoretical thinking based on appropriate situation knowledge (Moura et al., 2016).

> We do not mean that it is necessary to remake history, but rather that it is necessary to give social meaning so that subjects can appropriate knowledge in order to attribute personal meaning. And to do this is to be in tune with their needs as individuals and subjects living in a specific place and time. [...] Combining the reasons for learning mathematics for subjects in need of social development should be the main reason for the school's existence. (Moura, 2006, p. 405).

The situations that trigger learning are potentially interesting, but their results in the classroom depend on the forms of mediation organized by the teacher. Based on Vygotsky (1997), we understand mediation as the intervention of an element (sign or instrument) in a previously unequivocal relationship. The relationship between the student and a problem can be unequivocal when the problem is merely presented to the child. On the other hand, this relationship between the student and a problem can be mediated by instruments, such as concrete materials, drawings, and other representations, and signs, such as concepts already appropriated by the student and the communication with the teacher.

This work recognizes that teachers can carry out instrumental mediation using the materials they make available to their students and that mediation through signs takes place through guidance during the class.

We must, however, differentiate between these two forms of mediation. The instruments used to solve a problem, whether offered by the teacher or created by students, preserve their function, always used with the same objective for which they were created (Luria, 2017). Mediation through signs, as it occurs on a psychological level, allows the subject to reorganize their reasoning and to refer to elements that are not present. It is expected that, in some moments of mediation by signs, an external mark is necessary, i.e., a sign, drawing, object, or action that refers to the internalized sign (Luria, 2017).

According to Vygotsky (2017), mediation is essential for human learning, as it occurs socio-historically-culturally mediated by culture, social institutions, customs, etc. Likewise, school learning provided by collective discussions depends on the teacher's guidance and mediation, the mediation of a subject who has already acquired this scientific knowledge.

Algebraic concepts

From the perspective of Teaching Guiding Activity, understanding algebraic concepts is recognizing that they were historically constituted in contexts in which they were necessary, albeit with different representations.

> In the historical movement of algebra, in turn, we can recognize the movements of objective reality being expressed in Antiquity by rhetorical algebra, through words, when symbols had not yet been created; by geometric algebra (figure variable); by syncopated algebra (numeral variable) in which abbreviations are used and, later, by symbolic algebra (letter variable). (Sousa, 2004 *Apud* Sousa, Panossian & Cedro, 2014, p. 118).

From the study of the historical and logical movement of algebraic knowledge, Sousa, Panossian, and Cedro (2014) explain that concepts such as fluency, number, variable, and fields of variation are essential in this form of knowledge.

> These concepts, which we call conceptual nexuses of algebra, constitute the substantial, the movement of algebraic reasoning with a view to the search for relativized truth. They are the basis for the various algebras, structurally elaborated from time to time by mathematicians from different civilizations, to describe and formalize the different movements present in our world. (Sousa, Panossian & Cedro, 2014, p. 121).

Furthermore, Panossian, Sousa, and Moura (2017) highlight some essential relationships in the movement of the historical development of algebraic knowledge: the recognition of quantities (related to the concept of numbers), the movement of numerical fields to control quantities (related to the field of variation), form and content of algebraic knowledge (related to fluency), the recognition of variable quantities (linked to the concept of variable) and the generalization of mathematical objects and methods.

This last relationship refers to one of the conceptions of algebra highlighted by Usiskin (1995) and Fiorentini, Miorin, and Miguel (1993), presented in Figure 1:

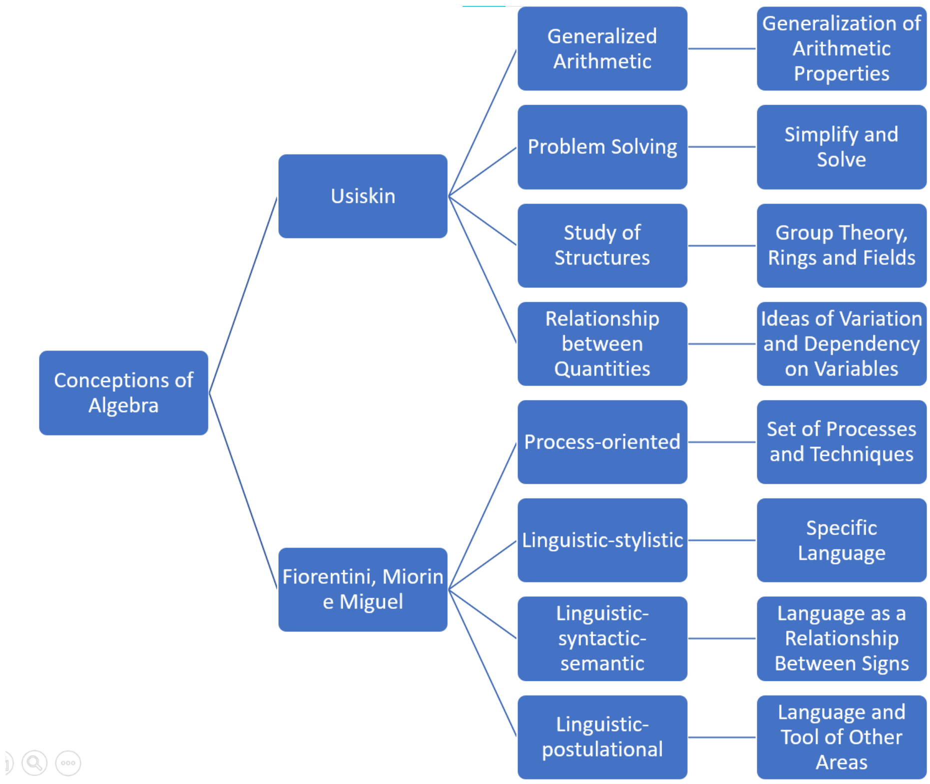

Figure 1.

Conceptions of algebra (OLIVEIRA, 2020, p. 37).

Thus, among the various authors who write about algebra, Usiskin (1995) highlights four general conceptions about the purpose of algebraic knowledge: as a generalization of arithmetic, as a problem-solving tool, as a field of study of mathematical structures, and as a relationship between quantities. This work emphasizes the last conception, considering that, from the study of the essential relationships of algebra, "[...] the establishment of the quantitative relationship between variable quantities, in general, was considered a stable relationship (essence, general entity or cell) of algebraic knowledge." (Panossian, Sousa & Moura, 2017, p. 155).

Regarding the character of algebraic knowledge, Fiorentini, Miorin, and Miguel (1993) also indicate four general conceptions: algebra as a collection of processes and techniques, as a specific language of mathematics as a relationship between signs, and as a linguistic tool for other areas of knowledge. What stands out in this work is the conception of algebra as a language that relates signs with a view to their meaning, taking into account the historical movement exposed by Sousa, Panossian, and Cedro:

> Algebraic concepts and contents, fundamentally, deal with mathematical operations considered in an abstract and generalized way. The development of algebraic language is not as natural as one would like to suppose. It also occurs from social pressures and

> human needs of each era (Aleksandrov et al. 1956[1988]). Considering the use of words, letters, signs, and symbols, tracing a path of algebraic language is possible. (Sousa, Panossian & Cedro, 2014, p. 101).

Thus, we understand that, throughout human history, algebra was used and developed based on the need to represent (in reasoning and language) relationships between variable quantities. From this conception of algebra, we consider that the appropriation of the conceptual links of algebraic knowledge enables the creation of personal meanings and apprehension of content meaning, allowing the development of theoretical forms of thinking in students.

> Thus, understanding the historical and logical development of the concept of variable [conceptual nexus] makes it possible to understand the meaning it carries that is not explicit to students and, therefore, depends on the appropriation process enhanced by the organization of school teaching. (Panossian, Sousa & Moura, 2017, p. 146-147).

Such conceptual links should not take up a specific moment in teaching; on the contrary, they should guide work with school content, enabling the understanding of the teaching object "algebra" as an area of knowledge:

> Taking the historical and logical movement of concepts as a point of analysis, we understand that this allows us to identify essential elements inherent to a certain form of knowledge, thus constituting a 'teaching object'. This 'teaching object', in turn, can and should be present in various 'teaching contents' or 'teaching topics' in the school curriculum organization. [...] In the particular case of algebraic knowledge, it is essential to this form of knowledge to "establish the relationship between variable quantities in general" (PANOSSIAN, 2014, p. 8), which can be accomplished through various teaching contents, such as sequences, equations, functions, etc. In this sense, the concept of variables should be central in algebraic teaching and learning processes. (Panossian, Moretti & Souza, 2017, p. 139).

Considering that the field research was carried out with two students, one in the 7th grade and the other in the 8th of a public school in Curitiba (Paraná - Brasil), we decided to highlight content from the yearly plan of their regular mathematics teacher. The teacher's plan was organized at the beginning of 2019 and guided by the contents of the National Common Curriculum Base (Brasil, 2018) and the Paraná Curriculum Reference (Paraná, 2018). The content related to algebra covered in the second and third quarters was:

Table 1.

Mathematical content

	7th grade (Marcelo)	8th grade (Cláudia)
2nd quarter	-Algebraic expressions; - 1st degree equation	- Quadrilaterals; - Monomials
3rd quarter	- 1st degree equation - Ratio and proportion;	- Polynomials.

In this way, linked to the conceptual nexuses of fluency, variable, and field of variation, the contents of algebraic expressions, 1st degree equation, monomials, and polynomials were defined as the teaching objective of the interventions. From this, we created situations to trigger the learning of algebraic concepts, presented below.

Methodology

As the objective of the work was to recognize the appropriation of algebraic knowledge by students with visual impairment based on situations that trigger learning, we used the space of the multifunctional resource room of a public school in Curitiba (PR). The research participants were a 7th-grade student, from now on called Marcelo, with low vision, and an 8th-grade student, here called Cláudia, with congenital blindness and hearing impairment. They were chosen because they were the only students in the resource room attending the 7th and 8th grades –when the National Common Curriculum Base (Brasil, 2018) indicates the beginning of solving equations.

Before the interventions, the regular teacher was consulted about each student's relationship with mathematics: Cláudia handled well the operationalization of algorithms, i.e., performing calculations mentally, such as multiplications and divisions, but had difficulties with long texts in contextualized situations; on the other hand, Marcelo had difficulty with algorithms but was very interested in the themes of the situations, being very curious about them. Thus, if the mathematics teaching situation was contextualized with dinosaurs, Marcelo could ask everything about these animals, but he would not need to work too hard on the calculations.

In conversations with the resource room teacher, in an attempt to recognize the students' needs considering their disability, we identified that despite having low vision, Marcelo did not use enlarged fonts but rather the computer's voice program (DOSVOX); even so, he paid close attention to the contrast of colors present in the materials. Cláudia, in turn, used the same text-reading program as Marcelo. However, because she was also hearing impaired, she had difficulty understanding the reading of very long texts or in noisy environments. The concern that noise in the regular classroom could interfere with the student's understanding, the need to give students time to solve the situation, and the fact that the students were from different classes led the researcher to choose the resource room as the research space.

Considering both students' needs and characteristics, we created two situations to trigger learning: a virtual story of the concept called "Tax Collection in Egypt" and a game called "Target Dicing."

All interventions with students were organized in the same order: presenting the situation, discussing the elements of the situation, collectively solving the questionnaire, and resuming. They were recorded in audio and video and registered in the researcher's logbook; the DOSVOX program collected the students' computer registers.

The potentialities of the situations were analyzed based on two isolates: manifestations of conceptual links and manifestations of reasoning and language. We understand that these two isolates allow us to apprehend the "appropriation of algebraic knowledge" phenomenon based on the situations presented to students.

Virtual history - Tax collection in Egypt

This learning-triggering situation (Table 2), identified as the virtual history of the concept, was created based on the character of a situation for teaching rational numbers created by Moura (2015), called "Cordasmil."

The objective of this situation was to discuss the concept of variables. As it was the first situation proposed, it also identified students' difficulties with algebraic knowledge. The pupils received three materials: the narrative of the virtual story, the related questionnaire, and a manipulative material designed to aid a three-dimensional understanding of the situation.

Table 2.

Tax collection in Egypt (Own authorship)

Located in a desert region, Egyptian civilization developed along the fertile banks of the Nile River, occupying its entire length approximately 10 to 20 kilometers from the waters. It was extremely dependent on the river, both for the maintenance of agricultural and livestock activities and for the transport of goods and communication between the cities. Navigation between the various regions bathed by the Nile was so appropriate that the Egyptians did not need to build roads. The Egyptian calendar was divided according to the phases of the Nile, namely: flood, planting, and harvest. During the flood, the waters of the Nile invaded the

land of each of the residents, which, with the drop in water levels during the planting season, became very fertile (since they had been in contact with the water for months). As the Egyptian economy was based on exchanging goods, taxes were collected in the form of cereals. The governors annually evaluated the cereal collection that year, basing their calculations on the surface area of each piece of land.

Thus, the main element to be analyzed in the story is the movement of the Nile River. However, considering that the students were visually impaired, there was a possibility that they would not understand how the floods occurred. To meet this need, we created a model using crepe paper representing the waters of the Nile (Figure 2).

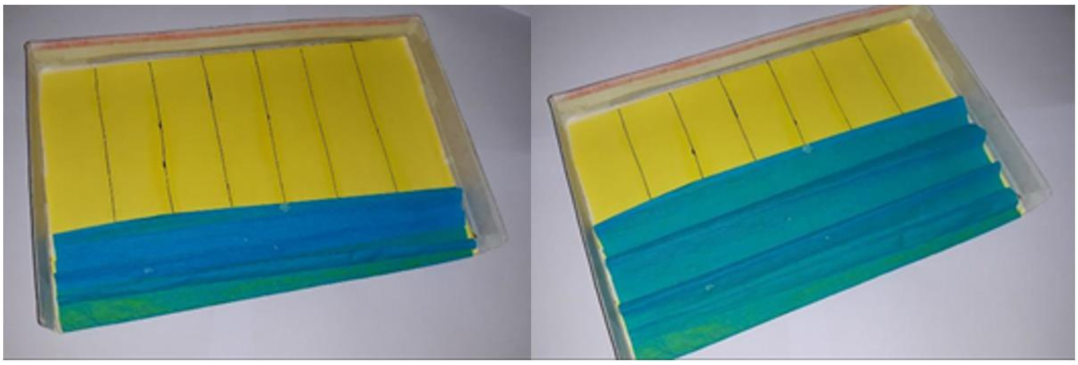

Figure 2.

Model with the Nile River at planting and harvesting times (Own authorship).

Furthermore, we took the question: “What would the land area look like during the high and low waters of the Nile River?” as a triggering problem. To start the discussions, we used a questionnaire (Table 3) for two reasons: first, to know how much the students were used to interacting with teachers and each other, and second, to identify whether the difficulties were related to capturing information from a text, interpretation, or mathematical knowledge.

Table 3.

Virtual history questionnaire (Own authorship)

1. Was each resident’s land on the banks of the Nile River the same size throughout the year?
2. How can we measure land? What aspects should we consider?
3. Which aspects are related to the difference in total size throughout the year? Why?
4. Are there fixed measurements on these lands?
5. Suppose a piece of land is 15 meters wide and 20 meters long during the peak flood season. How can we represent its dimensions after the river has receded?
6. How would we represent the area of this land during the flood? And during a streamflow recession?
7. Are there other things/characteristics we can measure? Which of these things/characteristics can vary?

This situation was addressed in just one intervention, and its results guided the development of the game “Target Dicing”, presented below.

Game - Target Dicing

This game was created based on an unnamed game without a theoretical grounding a teacher presented in the video “Brincando com a álgebra na matemática” [Playing with algebra in mathematics], available on the YouTube platform[3].

It was adapted to students’ needs, with contrasts in colors and textures, to mathematical needs, with more types of pieces, and to become a triggering situation, with goal setting.

The concepts and operations to be worked on in this game are: representation of different variables; addition of monomials and binomials; replacing a variable with a value from its variation field; field of variation; representing and solving equations with monomials and binomials.

The Target Dicing game is built with a circular board divided into four circular crowns (strips): two red ones made of smooth EVA and two white ones made of fuzzy EVA. The strips are divided by cardboard so that the pieces do not change sections when touched. The game has two types of pieces: in the first phase, they are blue marbles, and in the second phase, they are dice with three types of textures on their faces (Figure 3).

Figure 3.

Target Dicing elements (Own authorship).

The name of the game, Target Dicing, comes from the board, which has the shape of a target. For each round, the players throw a handful of dice onto the board and count, observing the texture of the dice and the type of strip into which it fell.

3 https://www.youtube.com/watch?v=139CkqAivCQ

To facilitate the organization of the pieces, if necessary, we created a cash register as a possible mediating tool (Figure 4).

Figure 4.

Cash register (Own authorship).

Below (Table 4) are the rules of the game in the second phase:

Table 4.

Rules of the second phase of the game (Own authorship)

The game has three rounds; in each round, both players have their turn to get a score. Each player must, in turn, draw a handful of dice and throw them on the board. Then, they must count how many dice of each type there are in each strip of the board, observe the relief of the strip, and write down the amount on their computer. After finishing all the strips, the player must do the math on the computer and announce their score to the opponent. After each round, one of the players must draw three cards with numbers from 1 to 6; each will be the value of a type of dice. Whoever has the highest score wins the round, and whoever wins the most out of the three rounds wins the game.

Cards with numbers from 1 to 6 were only used the first time each phase was played, and from then on, students were asked to represent the results for any card value and stipulate cases in which each one would win. The questionnaire used in the second phase of the game is presented in Table 5.

Table 5.

Questions for the second phase of the game (Own authorship)

1. What elements affect the result? Do these elements have fixed values?
2. How many and what are the game variables?
3. How and between what values does this variation occur? Are there boundaries?
4. One player tells the other that he or she scored 30 points, but the opponent forgot how much the crepe paper face was worth in this round. The total was 22, but there are still two crepe paper dice left to count on the positive side of the board. How can we express this problem mathematically? And what is the face value of crepe paper?
5. In the previous question, could the crepe paper-face value change, or was it unique? In this case, is the crepe paper face a game variable? Why?

The game was worked on over three interventions to discuss the questions (Table 5) and several specific cases of sums of monomials and polynomials in each round.

Analysis of the appropriation of algebraic knowledge by students with visual impairments

The analyses of the appropriation of algebraic knowledge were divided into manifestations of conceptual links and manifestations of reasoning and language, presented below.

Manifestations of conceptual nexuses

Initially worked on in virtual history, the first situation presented to the students, the conceptual links "variable," "field of variation," and "fluency" were discussed collectively. In the game, we addressed conceptual connections within the school content: algebraic expressions, 1st degree equation, and operations with monomials and polynomials.

The students' first difficulty with virtual history was spatially understanding the "sides" of the lands mentioned, which is why the model and the researcher's explanation were essential to start the discussions. Even though the students recognized through tact and history that one side did not have a fixed measure, representing it was very challenging.

With the researcher's support, the students could establish the measurements of the land as 15 meters wide (fixed) and 20 + x meters long (variable). However, it became clear that using the symbol "x" was just a student convention to represent something unknown without analyzing its variation in the situation, which was highlighted when, in the following questions, students could not recognize "20+x" as the representation of a numerical value.

After these discussions, an extra question asked them how they would make this representation or explain what happens to the dimensions of the land if they did not know any of the measurements. In the answers (Figure 5), it is clear that Cláudia uses "length + x," showing the difference between the elements: what should be known is in rhetorical language (support in the mother tongue), and what was studied as a variable is in symbolic language.

```
During the river's low tide, the length increases, and the width remains the same.

Width

Length + x

Width times Length + x
```

Figure 5.

Cláudia's answer (Research data).

Marcelo, in turn, just explained the movement (Figure 6) but did not write the expression even after the collective summing up with the researcher, indicating that his colleague's answer was also correct.

Extra: The width never changes, and the length always changes:
during high tide it decreases, and during low tide it increases!

Figure 6.

Marcelo's answer (Research data).

After some discussions to recognize elements that "varied" or not in everyday life, a subject that arose at the time of the intervention, an advance was noticed. When asked about what a variable is, Cláudia promptly replied: "Things that vary." During the game, her understanding of the unknown was:

Researcher: [...] So, why doesn't ["x" in 4.x = 20] vary?

Cláudia: Because what comes before, do you have a value that is equal to that?

The student understood that the difference between unknown and variable depended on the expression in which the symbol was, i.e., in an equation, there are one or more unknowns (an unknown value), and in an algebraic expression, there is a variable (which can take on different values).

This knowledge was revisited in the first phase of the game, mainly in the questions "What elements affect the result? Do these elements have fixed values?" and "These elements that vary are called variables. How many and what are the game variables?"

Regarding the first question, the students had no difficulty recognizing the elements, attributing the symbol "x'" to the unknown value of the marble. However, it was necessary to explain that "x" influences the result, but it would not influence the winner at specific values in the variation field.

When asked to remember what a variable was, they responded: "Things that vary." Cláudia remembered that the land had a variable size, and Marcelo remembered that its height varies. In this way, identifying the elements that vary (number of marbles and value of the marble) did not require much time.

It is important to remember that the game was worked on in three interventions, and, in all, the concept of variables and unknowns was discussed, as we believe the notion is central to the understanding of algebraic expressions and equations. On the last day of working with the game, Cláudia differentiated these elements better: "The variable changes and the unknown doesn’t change, but you also don’t know the value.” Despite being a relatively simple answer, it shows a gradual evolution depending on the interventions, a process of reformulating the concept. This differentiation was used so that students understood that not every expression with an “x” symbol, for example, is a problem to solve. In the case of virtual history, the answer was the expression. We think it is necessary to “break with” the understanding that only positive integers can answer a problem, paving the way for future discussions, especially regarding the set of real numbers and functions.

During the first phase, the idea that “x” -the point value assigned to each marble- could be a numerical value at the end of the game confused the students a little. Opportunely, there was a round in which Marcelo’s score was 0x. When the researcher asked them if they already knew who had won the game, the students quickly responded that it would be Cláudia because “any value is greater than zero,” as they said. As the students already knew negative numbers, the researcher asked them what would happen if there was a letter with the value “-1” to replace “x.” At this point, the students understood that the winner would be Marcelo because the winner depends on the value of “x,” i.e., the card drawn at the end of the round.

> Researcher: Let me ask you another question: if Marcelo scored zero points and Cláudia scored x points, but x is a value between 1 and 6, can I already know who won?
>
> Students: Yes.
>
> Researcher: Who?
>
> Claudia: I did.
>
> Researcher: Great! Do you need to get the ‘card’?
>
> Marcelo: No.

After this moment, the game continued with the researcher asking each round who would win if the value of “x” was positive, null, or negative, no longer using cards with values. At the end of the game, students recognized the fields of variation in the number of marbles and their scores based on the tactile material.

We understand that the conceptual nexus “fluency” was worked on by realizing a variable representing a movement of objective reality, even if this relationship was not explicitly defined with the students.

The selected curriculum content (algebraic expressions, 1st degree equation, and operations with monomials and polynomials) were worked only in the game. Throughout the rounds, the representation of monomials (in the first phase) and polynomials (in the second phase) was approached.

Cláudia had already studied how to solve equations, so she answered questions related to calculus more easily. Even so, it was possible to notice that some answers from both were automatic: when the researcher presented the game pieces in the first phase, the marbles, and explained that the value was unknown, she expected the students to represent the value by “marbles” or “ b.” However, they associated the unknown directly with the letter “x,” realizing the need to use different letters in the second round of the game when different pieces should be represented.

In general, students demonstrated some ease in working with monomials, only needing guidance to organize the information on the board on the computer. Marcelo presented the most difficulties in the questions involving the resolution of an equation. To follow this process, we analyzed the manifestations of the student’s thinking in the next topic.

In this way, we recognize that the situations that trigger learning enabled students to appropriate the conceptual nexus “fluency,” “variation,” and “field of variation” and the contents of algebraic expressions, 1st degree equation, and operations with monomials, requiring more interventions to ensure that students could perform operations with polynomials. Furthermore, the researcher’s symbolic mediations were fundamental for understanding. Such a conclusion was expected, considering that this is one of the theoretical principles according to which the situations were created. We also highlight that the concrete materials produced from the universal design perspective were essential to facilitate communication between the researcher (teacher) and students, becoming a critical mediating tool.

Manifestations of reasoning and language

Given the impossibility of grasping the movement of human thinking, we sought to analyze moments of student learning based on their statements and difficulties throughout the interventions.

At the beginning of the first phase of the game, both students wrote down the points on each track on the computer board and then carried out the operations. They used mental calculation. Throughout the rounds, they felt the need to optimize this process because it was time-consuming, and the other player had to wait without knowing what was happening (with four hands feeling around, the board became easily disorganized). Marcelo and Cláudia devised different strategies to speed up the counting process: Marcelo grouped all the pieces from negative strips into a single negative strip, did the same process with the pieces from the positive ones, and subtracted the number of negatives from the positives, removing the pairs that would be taken out from the board. Marcelo only counted the pieces that remained on the board. In turn, Cláudia grouped the negative pieces and counted them, carried out the same process for the positive pieces, and mentally performed the subtraction, removing all the pieces from the board together.

In the first phase of the game, the students were challenged by the question: "In one round, the player scored 20 points; 7 fell in the positive sector and 3 in the negative region. Register and give the value of the marble." They represented: "7x - 3x" but did not recognize that this expression was equal to 20 or could be simplified as "4x". The researcher's intervention was necessary, helping them write about equality and explaining that it already existed when they played. Even though she had difficulty understanding the existence of this equation, Cláudia solved it mentally by saying that x was equal to 5. Marcelo did not show any concerns about the emergence of the equation.

In this way, students established new processes during the first phase of the game. However, in the second phase, as there were more types of pieces, students needed to note down their scores during this process. For the second phase, two interventions were used, the first with just Marcelo and the second with both students.

Without Cláudia's presence, Marcelo had more difficulties answering the questions, as he sometimes relied on his colleague's statements to formulate his understanding. This situation was anticipated, considering that Marcelo was in the 7th grade and Cláudia was in the 8th grade.

When faced with the game with more pieces, Marcelo expressed the need to register his score with different letters, choosing M, W, and G, as, according to him, it was the acronym for

"Marcelo Wins the Game[4]." When trying to count the points in the same way as in the first phase, he realized that he could not perform all the calculations together, so he started grouping the pieces by type. He felt around the entire board looking for the "M" pieces, counted and registered them, then moved on to the "W" pieces, and so on.

His first register was "-3.M-3W-2G+1.M+2.G", but when asked if there was a way to simplify the result, he replied that there was nothing to do, as they were "from different families." The researcher asked him to look more closely, to which he exclaimed, "Ah, now I understand; I can add those in the same families!" However, he still did not do the math and used the cash register.

With the cash register pieces, the student had to feel them, putting the positive and negative pieces of the same type together in his hands (Figure 7). They were pieces represented by "G," and only then Marcelo concluded that the result was "0.G", still waiting for confirmation of the process.

Figure 7.

Marcelo's grouping of pieces (Research data).

He needed to be reminded a few times that 0.G = 0 and that it would not need to be registered in the expression. Marcelo used this counting process in the first round with the cash register, then realized that "joining" was "adding" and stopped doing that. On the second day of intervention, Marcelo stopped using the cash register, probably because Cláudia did not want to use it.

Cláudia had already adopted the solution with inverse operations in questions with equations, while Marcelo refused to use them. From one of the problems, he understood that he would need to solve "2.x+22=30", but he solved it using the logic and operations of the equation: "c = 4, because 4 times 2 equals 8, and 8 plus 22 equals 30".

4 The initial of the student's name was replaced by the initial of his fictitious name to preserve his identity.

After several explanations about “undoing” the game’s actions, the student was still unconvinced about the need to use inverse operations. This need was created with the intervention of the researcher, who presented the equation 20 = 4.a – 10. The solution to this equation is not a whole number, which made visual control more difficult. In addition to recording the equation, the researcher also dictated, as he was used to, “What number ‘a’ do I multiply by 4, subtract 10, and get 20?” but the student remained silent, trying to solve it. After a few minutes, he reported only getting to “4.a = 30” but was unable to explain how he did so. When there was help and instruction, he could solve it, but on his own, he found it hard to get started.

In this way, it is noteworthy that the game created enabled discussions about content and connections. Nevertheless, once again, the researcher’s mediation was crucial for developing students’ mathematical thinking. We also understand that introducing cards with negative values and questions with non-integer values could expand game discussions, considering that they only occurred due to specific moves and difficulties and may not occur with other students.

Final considerations

Considering, from the Teaching Guiding Activity (Moura et al., 2016), that the purpose of teaching is the theoretical appropriation of concepts, in this case, algebraic ones, we had to understand how situations that trigger learning can also influence this process with visually impaired students. We sought to analyze these contributions to the apprehension of variables, field of variation, fluency, unknowns, equations, monomials, polynomials, and how to represent these elements. We cut out two isolates to do this: manifestations of conceptual nexuses and manifestations of reasoning and language.

At the end of the study, we understand that the situations that trigger learning contributed to the acquisition of the concepts of variable, field of variation, and dependence of variables. However, more time and interaction with students are needed so that they may learn how to solve equations. It is important to emphasize that learning is a process that depends on many factors, including time. Precisely for this reason, time flexibility is one of the characteristics of the resource room space:

> The professional who works in the resource room must pay attention to each student so as not to get lost in the line of reasoning followed, both in the content and the activity developed, especially considering that there is an interval between one service and another, as they are not attended to every day. It is not always possible to complete an activity in one meeting, so it can be resumed in the next meeting until it is completed, thus following a coherent line that does not confuse the student. (Hilsdorf, 2014, p. 95).

The game enabled the correct use of the cash register. This instrument facilitated and gave meaning to grouping terms in a polynomial, allowing a better organization of information to carry out mental calculations. Likewise, the model representing the virtual story allowed the attribution of meanings to the variability of the measurements. Thus, the situations enabled symbolic and instrumental mediation, which is essential for students' understanding.

It is worth highlighting that the results presented in this research, even if they seek generalizations, are still unique. The triggering situations presented can be developed at other times with other students and by other teachers. The chosen route and the researcher's mediation are specific to the research period, considering the characteristics of each subject involved since the planning of the situations.

Finally, we must understand that every teaching situation depends on its organization. We hope this research can subsidize the search for potential triggering situations in teaching algebra to students with visual impairment and for new research that may emerge in the field.

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