ASSISTIVE TECHNOLOGIES IN TEACHING AND LEARNING MATHEMATICS FOR BLIND STUDENTS: INVESTIGATING THE PRESENCE OF UNIVERSAL DESIGN AND UNIVERSAL DESIGN FOR LEARNING

TECNOLOGIAS ASSISTIVAS NO ENSINO E APRENDIZAGEM DE MATEMÁTICA PARA ESTUDANTE CEGO: INVESTIGANDO A PRESENÇA DO DESENHO UNIVERSAL E DO DESENHO UNIVERSAL PARA APRENDIZAGEM

TECNOLOGÍAS DE ASISTENCIA EN LA ENSEÑANZA Y EL APRENDIZAJE DE LAS MATEMÁTICAS PARA ESTUDIANTE CIEGO: INVESTIGANDO LA PRESENCIA DEL DISEÑO UNIVERSAL Y EL DISEÑO UNIVERSAL PARA EL APRENDIZAJE

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ABSTRACT: This article presents analyzes of stricto sensu researches that address assistive technologies in the teaching and learning of mathematics aimed at blind students. With that, it is verified if these resources are conceived in the perspective of Universal Design (DU) and, still, if the methodologies indicated in the research have approach of Universal Design for Learning (DUA). The research methodology is of a qualitative nature, being a systematic and integrative review research of the findings in different search sites, such as the Catalog of Theses and Dissertations of the Coordination for the Improvement of Higher Education Personnel (CAPES). The results demonstrate little amount of research in the DUA perspective. However, the practices that make use of the DUA enables blind students to effectively participate, with equity, in inclusive educational processes in the classroom environment.

KEYWORDS: Mathematics teaching. Universal design for learning. Blind student.

***RESUMO**: O presente artigo apresenta análises de pesquisas stricto sensu que abordam as tecnologias assistivas no ensino e aprendizagem de matemática voltada ao estudante cego. Com isso, verifica-se se esses recursos são concebidos na perspectiva do Desenho Universal (DU) e, ainda, se as metodologias indicadas nas pesquisas possuem abordagem do Desenho Universal para Aprendizagem (DUA). A metodologia da pesquisa é de natureza qualitativa, constituindo-se como revisão sistemática e integrativa em diferentes locais de buscas, como o*

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Catálogo de Teses e Dissertações da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). Os resultados demonstram a existência de poucas pesquisas na abordagem DUA. No entanto, as práticas que fazem uso do DUA possibilitam ao estudante cego a participação efetiva, com equidade, nos processos educacionais inclusivos no ambiente de sala de aula.

***PALAVRAS-CHAVE**: Ensino da matemática. Desenho universal para aprendizagem. Estudante cego.*

***RESUMEN**: Este artículo presenta análisis de investigaciones stricto sensu que abordan las tecnologías de asistencia en la enseñanza y el aprendizaje de las matemáticas dirigidas a estudiantes ciegos. Con eso, se verifica si estos recursos se conciben en la perspectiva del Diseño Universal (DU) y, aún, si las metodologías señaladas en la investigación tienen enfoque de Diseño Universal de Aprendizaje (DUA). La metodología de investigación es de carácter cualitativo, siendo una investigación de revisión sistemática e integradora en diferentes ubicaciones de búsqueda, como el Catálogo de Tesis y Disertaciones de la Coordinación para el Perfeccionamiento del Personal de Educación Superior (CAPES). Los resultados demuestran que hay poca investigación sobre el enfoque DUA. Pero las practicas que hacen uso de la perspectiva DUA permite a los estudiantes ciegos participar de manera efectiva, con equidad, en procesos educativos inclusivos en el ambiente del aula.*

***PALABRAS CLAVE**: Enseñanza de las matemáticas. Diseño universal de aprendizaje. Estudiante ciego.*

Intoduction

School inclusion is a discussion of important events, the most visible being the one that took place in 1994, in Spain, promoted by UNESCO, the World Conference on Special Educational Needs: Access and quality. On the occasion, one of the most important documents, the Salamanca Declaration (UNESCO, 2004), was signed by several countries, including Brazil, reaffirming the right to education of each individual, establishing principles, policy and practice in Special Education. The Salamanca Declaration also recommends the inclusion of children and young people with special educational needs in common schools, bringing the discussion of the concept of inclusive school, challenging the development of a pedagogy that respects individual differences, breaking barriers that make students momentarily incapable.

Regarding the barriers that prevent the real inclusion of students in the school environment, we are not referring only to the barriers described in Law no. 13,146 of 2015, the Brazilian Law for the Inclusion of People with Disabilities or the Statute of the Person with Disabilities, but to the resources, services and /or methodologies that cover all students

and provide an equitable teaching and learning process. The fact that students are enrolled in a so-called "regular" school institution does not necessarily guarantee educational inclusion, as it is necessary to adopt teaching resources and specialized equipment that meet the educational needs of students, with or without disabilities (MANTOAN, 2003, p. 24), as guaranteed in Brazilian legislation,

> III - pedagogical project that institutionalizes specialized educational services, as well as other services and reasonable adaptations, to meet the characteristics of students with disabilities and guarantee their full access to the curriculum on equal terms, promoting the achievement and exercise of their autonomy (BRAZIL, 2015, Art. 28).

School inclusion does not provide for the use of teaching practices to address specific learning difficulties, since it understands that "Students learn within their limits and if teaching is, in fact, of good quality, the teacher will take these into account by conveniently exploring the possibilities of each one" (MANTOAN, 2003, p. 36). Thus, when thinking about the diversity that makes up the school, there must be a curriculum that can serve everyone equally through different paths, with goals to be achieved by all students.

From this perspective, the objective of this text is to analyze stricto sensu research that presents assistive technologies for teaching and learning mathematics, used by blind students. With that, we tried to verify if these resources are conceived in the perspective of the Universal Design (UD) and, also, if the methodologies indicated in the researches have an approach of the Universal Design for Learning (UDL).

Thus, to support the discussions of the analysis, in this article, we present, below, the concepts of Universal Design and Universal Design for Learning.

Universal Design for Learning

The term Universal Design was created by architect Ron Mace in the 1980s, in the United States, to designate guidelines for architectural projects and products that meet all people, regardless of their physical conditions. The UD has seven principles that seek to break down barriers (GABRILLI, 2007): egalitarian; adaptable; obvious; noticeable; safe; without effort; and comprehensive.

As for equal use or comparable use – "they are spaces, objects and products that can be used by people with different abilities, making environments the same for everyone"

(GABRILLI, 2007, p. 12) –, as an example, "Doors with sensors that open without requiring physical force or reaching the hands of users of different heights" (GABRILLI, 2007, p. 12).

Adaptive use refers to aspects that can change its shape or are designed to suit everyone, such as scissors for use by both right and left-handers or a computer with keyboard and mouse, which help a visually impaired person to make use of microcomputers through of the use of voice synthesizer (GABRILLI, 2007).

Regarding the obvious use, also defined as simple and intuitive, it is considered an aspect that is easily recognized in a clear way, "regardless of your experience, knowledge, language skills, or level of concentration" (GABRILLI, 2007, p. 14). As an example, signs indicating women's or men's restrooms for use by people with disabilities.

Easily perceivable information is related to the idea of when information is transmitted in a way that meets the needs of the receiver. Gabrilli (2007) illustrates this principle by mentioning different means of communication, such as symbols and embossed letters, Braille, auditory signage, among others.

The safe principle considers the provision to minimize the risks and possible consequences of accidental or unintentional actions, such as elevators with sensors at different heights that allow people of different heights to make use without risk of the door being closed when they are entering or leaving the elevator. The effortless principle, on the other hand, is related to the need to minimize effort for handling, such as faucets with sensor that do not require twisting, which provides both water and physical effort savings (GABRILLI, 2007).

The last principle of the UD, called comprehensive, brings the idea of dimensioning the space for approximation and use, evaluating the appropriate extension for access, manipulation regardless of body size, posture or user mobility, such as armchairs that can be used by obese people (GABRILLI, 2007, p. 17).

Thinking about the architectural element that brings in its conception the principles of the UD, we highlight the access ramps at different levels of heights. Through this architectural element, people with limited mobility can access higher levels, as well as a person who has no limitations in their locomotion, effectively bringing accessibility.

In the school environment, in addition to the physical space, we indicate that the principles of the UD are applied to educational resources and these, in turn, must be used in methodologies that include all students.

The educational methodologies and practices that include all students make up the Universal Design for Learning (UDL) approach, developed by David Rose, Anne Meyer and

other researchers at the Center for Applied Special Technology (CAST) in the 1990s in Massachusetts. The UDL has three principles:

Principle I - Provide multiple means of engagement that encompass self-regulation, persistence and effort, and interest recruitment. Sebastian-Heredero (2020) states that learning is intertwined with people's emotions and affectivity, from which students differ noticeably in the ways in which they can be provoked and motivated to learn. Some students are interested and curious, while others show disinterest and resistance to participating in challenging activities, preferring more routine activities, choosing to work alone rather than working collectively. Such facts demonstrate that there is not a single way to work with all students, being necessary to develop multiple ways.

Principle II - Provide multiple means of representation, involving the perception, language, expression and understanding of symbols, for example, mathematicians. Some students learn faster, others learn more effectively through visual or auditory resources rather than printed text. Thus, the more learning opportunities are used, the greater the possibilities of students to make interior connections, as between concepts (SEBASTIAN-HEREDERO, 2020).

Principle III - Provide multiple means of action and expression to encompass executive function, expression and communication and physical activity. Sebastian-Heredero (2020) warns about the need to recognize the specificities of learning, emphasizing that some students express themselves from a written text and others in an oral way, which denotes different processes in the ways in which they conceive knowledge and thus express what they know. From this, it is necessary to develop different strategies for the apprehension of contents.

The UDL principles are divided into guidelines that have verification points with more detailed suggestions, presented in Figure 1, being the basis for the establishment of learning goals, applied from the recruitment of interests, perception and physical action, in order to achieve learning goals.

Figure 1 – UDL Principle and Guidelines

Source: Adapted from CAST (2019)

Therefore, it is necessary for the teacher to dedicate effort to recruit the attention and involvement of students, using other different ways and resources in the construction of learning, whether through the use of language, symbols, expression and others, enabling students to perform the tasks proposals with autonomy depending on the situations.

Once the concepts about UD and UDL are understood, the next section presents the research methodology, indicating how and which researches were selected for analysis.

Research methodology

The research is qualitative, with a systematic and integrative review, seeking scientific productions on the subject, analyzing stricto sensu research that deals with assistive technologies used in the teaching and learning of mathematics by blind students. In this way, we try to verify if these resources were conceived in the perspective of the (UD), as well as if the methodologies indicated in the research approach the UDL.

The searches for scientific productions were carried out on the website of the Graduate Program in Education: Teaching Theory and Practice (PPGE:TPEn) of the Federal University of Paraná (UFPR), where the authors of the present study are located; and in the Catalog of Theses and Dissertations of the Coordination for the Improvement of Higher Education

Personnel (CAPES). The research that gave rise to the Multiplan didactic material, widely known and used by mathematics teachers, was also sought..

On the UFPR's PPGE:TPEn website, the titles of all dissertations were analyzed, looking for those that evidence the analysis and development of didactic material for blind students, and the work of Berbetz (2019) was found, which presents the development, application and evaluation of a teaching material.

In the Catalog of Theses and Dissertations of CAPES, two searches were carried out, and in the first the descriptors used were “didactic material”, “mathematics” and “blind”, associated with the Boolean operator AND. Two works were found, and, after reading the titles and abstracts, one of them was discarded. From this search, the selected research is that of Vita (2012), in which the author evaluates the construction and the potential of a teaching material, a tactile model, built from five prototypes with a view to the apprehension of basic concepts of probability in order to to meet the learning objectives of blind students.

The second search in the CAPES catalog, whose descriptors were “assistive technology”, “mathematics” and “blind”, associated with the Boolean operator AND, resulted in the selection of four works. When analyzing the title and the summary of the findings, one of them was discarded because it was not in the area of Education or Teaching. After analyzing the titles and abstracts of the other three studies, only the one by Salvino (2017) was selected, as it presents assistive technologies used during the process of teaching mathematics by students with acquired blindness. Among the technologies presented, whether for the understanding of mathematical concepts or operations and calculations, the author highlights: the slit and punch; perkins machine; braille printer; braille line; book with tactile or audible reading; soroban; sound calculator.

As for Multiplan, this resource was developed in the teaching practice of Professor Rubens Ferronato (2002), discussed in his master's thesis, which later had a widely disseminated commercial version. Due to the benefits that Multiplan provides for teaching and learning mathematics, it is used as an educational resource for students with disabilities, especially blind people.

Thus, four are the stricto sensu studies analyzed in this study: Algebraic plates (BERBETZ, 2019); Multiplan (FERRONATO; 2002); Tactile model (VITA, 2012); and Assistive Technologies cited by Salvino (2017).

Results and analysis

The resource used by Berbetz (2019) was developed for teaching operations with polynomials, thus giving rise to the Algebraic Plates (FIGURE 2), inspired by the Golden Material by educator Maria Montessori, who developed manipulative materials intended for children to learn mathematics.

Figure 2 – Algebraic plates

Source: Berbetz (2019, p. 63)

The author indicates that the material is composed of six wooden boards with rectangular and square shapes, with Braille code and textured face, representing positive and negative boards. The Braille Code dots were represented by half a handcraft pearl, indicating the dimensions, length, width and height of the plates, variable dimensions in the proposed activities. With this, the blind student can manipulate the material through touch, perceiving the shape, size, textures, building mental images resulting from tactile perception.

Vita (2012) created a tactile model with the objective of promoting the understanding of probability concepts by blind students (FIGURE 3).

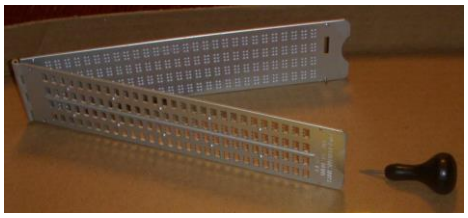
Figure 3 – Tactile mockup

Source: Vita (2012, p. 157)

Each construction followed the five steps of the User-Centered Design Methodology, a process in which the focus is on the users' needs and limitations. The instrumental analysis of each prototype related four poles of the model of situations of collective activities: blind student, tactile model, researchers and specialists. Such models were adapted, based on the ergonomics model, “on the interaction between men and technology, adapting tasks, systems, products and environments to people's physical and mental abilities and limitations” (VITA, 2012, p. 50).

Salvino (2017) presents several resources to assist the teaching and learning of blind students, such as: in Figure 4a, the “Reglete” and “Puncture” can be seen; in Figure 4b the Perkins Machine is shown; in Figure 4c you can see Soroban; Braille printer, Braille Line/Display, tactile or audible reading book and sound calculator.

Figure 4 – a) Reglete and Puncture, b) Perkins Machine, c) Soroban

a)  b) 

c) 

Source: Links in the footer[4]

Reglete and Puncture have the function of educating the visually impaired and “in terms of instruction, there are real chances of real progression like any other student who uses a notebook and pencil to write” (SALVINO, 2017, p. 15). The Perkins machine is an assistive technology that facilitates writing in Braille, reducing the effort and time that would otherwise be spent by blind students writing by hand. Soroban has the function of assisting in the development of mathematical skills in basic operations, and can also be used by people who can see. The Braille Printer follows the function of traditional printers, however, allowing printing on both sides of the paper, in addition to drawings and writing in Braille. The Braille

[4] a) Available: https://upload.wikimedia.org/wikipedia/commons/e/eb/Slate_and_Stylus_3_cropped.jpg. Access: 10 May 2021.; b) Available: https://upload.wikimedia.org/wikipedia/commons/2/29/Biblioteca_Braille_Taha_Hussein_05.jpg. Access: 10 May 2021.; c) Available: https://upload.wikimedia.org/wikipedia/commons/7/72/ Soroban.JPG. Access: 10 May 2021.

Line or Display is an electronic equipment that, when connected to a computer, has the function of reading the text displayed on the computer screen. The author also discusses the use of DOSVOX, a computer system designed to facilitate access for the visually impaired through voice synthesis, enabling students to become autonomous.

Ferronato (2002) created the Multiplan feature, as can be seen in Figure 5, initially thinking about the blind student.

Figure 5 – Commercial version of Multiplan

Fonte: Multiplan[5]

The author explains that in order to make the subject closer to the reality of the blind student, after several attempts to teach the mathematical contents, the idea of Multiplan emerged, initially made with a wooden board with several perforations, purchased at a hardware store.

In a search for more information about Multiplano, we found that in 2018 this assistive technology was approved as a pedagogical resource to compose the educational technologies guide, serving students with various learning difficulties related to Mathematics and also to some concepts of Physics.

By relating the technologies presented in this section with the DU, it is possible to verify that all of them have adequate sizes of furniture, allowing their handling, satisfying the comprehensive principle. Still, such teaching resources are safe, do not require physical effort from those who handle them and fit easily, denoting the idea of flexibility.

However, the resources presented by Salvino (2017), Reglete and punction, Perkins machine, braille printer, braille line/display and tactile reading book are assistive technologies, which do not have all the UD principles, since their use is restricted to blind students or those who understand the Braille code. Thus, with the exception of these technologies, the others allow experimentation without the requirement of prior knowledge

[5] Available: : http://multiplano.com.br. Access: 10 May 2021.

for handling, allowing the tactile exploration of the texture in relief, bringing perceptible information to students regardless of their age, referring to the idea of the obvious.

The Multiplan, the Algebraic Boards, the tactile model, the soroban, the audible book and the sound calculator comply with all the principles of the UD. Still, the Multiplano and the Algebraic Plates, allied to the methodologies exposed by the research, provide the UDL, meeting the three principles.

The principle of engagement is verified in the research by Berbetz (2019), when the author states that this technology offered opportunities for all participants to interact in different contexts, favoring the construction of knowledge. This principle is also verified in the research by Ferronato (2002, p. 74), when he informs that "even blind students, and especially blind students, were able to participate in the groups and analyze the results effectively and not as mere spectators".

The guidelines of the representation principle are explained in the comments of Berbetz (2019) and Ferronato (2000) when they state that the "abstraction of concepts and properties becomes evident when the PQ [researcher] models the representations for products according to the rules of multiplication signs" (BERBETZ, 2019, p. 87) and that the Multiplane "is a resource that helps in abstraction and, when it takes effect, it becomes expendable" (FERRONATO, 2000, p. 41).

As for the principle of action and expression, it is verified in the interaction of the blind student "with the material without barriers, accessing the previous knowledge of the associative property in relation to the operations of addition and subtraction and, still, transforming the information into knowledge" (BERBETZ, 2019, p. 82), which aroused different intrinsic abilities of the participant. Ferronato corroborates this thought by stating that "the abstraction of concepts can be facilitated when working with the concrete, with the palpable" (FERRONATO, 2000, p. 41).

It appears that these two didactic resources produced are manipulable materials, being flexible demonstration models that allow providing information about student learning in real time in the teaching-student practice, demonstrating that students can appropriate mathematical concepts from the manipulation of concrete teaching resources, seen as facilitators of the teaching and learning process through the mediation of teachers. Therefor, it is possible to affirm that the proposed activities promoted interaction between the participants, enabling the exchange of experiences and the socialization of knowledge, reinforcing that learning takes place when the individual, participant of a social group, lives with other people, causing exchanges of knowledge. information (BERBETZ, 2019, p. 74).

Such experiences are in line with the Salamanca Declaration, which provides that learning must adapt to the student and not the student adapt to learning, making inclusive education a right that must meet the specificities of students, respecting the different rhythms of learnings.

As for the research by Vita (2012), the study does not have the UDL approach, since it does not fit the principle of engagement because it took place in a space outside the regular classroom environment, without the participation of other students, restricting the experience. from the tactile mockup to the group of students in the multifunctional resource room. However, the research is considered within the theme of assistive technology, as the product was used for the autonomy and independence of students. Likewise, the research developed by Salvino (2017) portrays a case study, which allowed the author to observe the blind student in two spaces: a multifunctional resource room and the regular classroom. Although the author defends the use of assistive technology, it appears throughout the study that the researched school does not use didactic resources to promote blind student learning. The author emphasizes attention to the need for schools to prepare themselves to meet inclusion students, seeking continued training for teachers. Thus, she concludes the study by reaffirming that "as a consequence of the denial of disability, there is a denial of inclusion" (SALVINO, 2017, p. 89).

Considerações Finais

Respect for diversity in the school context directs the need to seek methodological referrals and didactic resources that meet the specifics of learning of inclusion students in proposals that go beyond preconceived concepts and discuss the breaking of existing barriers in the classroom that prevent understanding of curriculum concepts and contents by many students. It is necessary to think about these aspects, because only the insertion of students with some educational need in regular classrooms does not guarantee access to learning, and can sometimes generate segregation, signaling institutionalized exclusion.

Inclusive education has been showing progress, but still has a way to go. Thus, this study analyzed stricto sensu research that presented assistive technologies that are used by blind students for teaching and learning mathematics. Hence, we sought to verify if these resources indicated by the research are conceived in the perspective of Universal Design (UD) and, also, if the methodologies indicated in the research have an approach of Universal Design for Learning (UDL). Salvino (2017) explains that it is necessary to explore the

learning potential of students, as the learning difficulties are not exactly in the subjects, but often in the denial of access to content by teachers. In order to achieve this, teachers need to transform their internal and external world to design an education outside traditional lines, transgressing and remodeling teaching, giving the blind student a different view of the world based on a reflective pedagogical practice that enables a new model of teaching and learning from concrete materials (SALVINO, 2017). With this, it is necessary for schools to prepare themselves to serve inclusion students, seeking to offer continuing education to teachers, advising on the need to use assistive technologies that meet students' learning demands (MANTOAN, 2003). Still, it is understood that in order to effect these changes there is a need to change the look in relation to inclusion students, it is not enough to use specific assistive technologies for the target audience, because, as said, many of these technologies can sometimes, provide the segregation. It is necessary to think about technologies that serve all students, so this study sought to present the UD.

The use of assistive technologies combined with methodologies that address the UDL allows students to access curriculum content, as opposed to materials for the exclusive use of an individual, which excludes them from socialization and collective learning in the common classroom environment. On this matter, Bebertz (2019) emphasizes that for the inclusion process to be effective, it is essential that teachers understand the didactic function of each material used and provide inclusive practices with them. In line with this thought, Ferronato (2002) warns that the blind student needs appropriate situations, without precipitation and impatience on the part of those who apply the tasks, proposing that teachers use the same procedures, language, calculations, algorithms and methods that they would use. on the chalkboard/pilot with the sighted students. Reaffirming that “the teacher does not need to change their procedures when they have a visually impaired student in their classroom, but only intensify the use of concrete materials” (FERRONATO, 2002, p. 48).

Having said all that, the results presented in this study allow us to affirm that it is necessary to disseminate the UD and UDL among teachers at different levels of education, as these perspectives provide the possibility of using methodologies and the adoption of assistive technology resources that come meeting the needs of inclusive education, making all students participate effectively in educational processes with equity in the common classroom environment.

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