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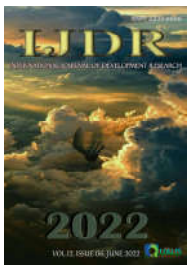

RESEARCH ARTICLE OPEN ACCESS

ASSISTIVE TECHNOLOGY: POSSIBILITIES AND WEAKNESSES MATHEMATICS FOR STUDENTS WITH VISUAL DISABILITIES

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ABSTRACT

This study aims to investigate the possibilities and weaknesses of assistive technology in the teaching and learning mathematics process to students with visual impairment. A systematic review was used in the literature in theses, dissertations and articles available in the databases of the Brazilian Digital Library of Theses and Dissertations (BDTD) and Scielo in the period between 2010 and 2020. The descriptors used were: assistive technology manipulable in mathematics teaching, tactile assistive technology for the blind, assistive technology and visual impairment. Twenty-eight studies were located. Based on inclusion and exclusion criteria, three studies were selected. The results show that among the AT used in studies by people with visual disabilities, it was possible to: i) teach physics and mathematics, to collaborate in the use of tactile exploration in learning this knowledge; ii) teach and learn tactile spatial geometry; iii) interaction with virtual environments through touch and feedback. On the other hand, the studies have shown weaknesses in relation to the AT developed: i) they need further reformulations for practical application; ii) to think of an application based on the universal design, where everyone can access; iii) to expand technical reformulations. In general, there was a low rate of production.

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INTRODUCTION

Studies show that the use of the Assistive Technology – AT has expanded the accessibility and independence of students with visual impairment[1] in various environments, to be considered in this study the teaching educational environments (Bersch, 2017; Borges; Tartuci, 2017). From the convention and approval on the human rights of people with disabilities, among other policies that rule Special Education, the means for accessibility have been increased in an inclusive perspective, to consider resources involving the use of AT (Brasil, 2008; Brasil, 2009; Brasil, 2015; Brasil, 2020). Before this scenario, there was a significant increase in the number of students with visual impairment enrolled in the regular education network, considering that the Law of National Education Guidelines and Bases – LDBEN, (Brasil, 1996), deals in its Article 4, item III, on the guarantee of free specialized educational care to students with disabilities, global developmental disorders and giftedness and high abilities, transversal at all levels, stages and modalities, preferably in the regular education network. Thus, studies show that the teaching and learning students' process with visual disabilities, specifically in mathematics, has been a great challenge to teachers, to consider that mathematics teaching has been undergoing several transformations in their curriculum, especially in terms of the methodological perspective, to expand the technological resources and instruments used in classrooms (Alvaristo *et al*., 2020; Shimazaki; silva; Viginheski, 2015). Mathematics teaching inferred that mathematics plays a decisive role in people's lives. In this sense, teaching is related to observations of the real world with representations. Thus, learning relates to understanding this meaning of representations to knowledge. However, it is emphasized that with the use of AT, the possibilities are extended for people with visual disabilities to the universe of representations in the teaching and learning process (Brasil, 2018; Brasil, 2009). Considering the importance of AT for the accessibility of people with deficiency, this study aims to investigate the possibilities and weaknesses of assistive technology in the teaching and learning mathematics process to students with visual impairment.

[1]The international classification of diseases establishes four levels of visual function "[...] normal vision, moderate visual impairment, severe visual impairment," blindness (Ottaiano, *et al.*, 2019, p. 10).

CHARACTERISTICS OF ASSISTIVE TECHNOLOGY IN THE PERSPECTIVE OF INCLUSIVE EDUCATION

AT has been widely discussed in educational environments, as it aims to provide quality access for inclusive education. Thus, AT is considered as a multidisciplinary knowledge area (Borges; Tartuci, 2017). In view of this, AT is defined as "[...] resources and services that contribute to providing or expanding the functional skills of people with disabilities and consequently promote independent life and inclusion" (Bersch, 2017, p. 4). Therefore, it is crucial that professionals working specifically in the area of education do not confuse the purpose of AT with Educational Technology – ET, to understand that TE, according to Bersch (2017), is the one in which any student, having disability or not is benefiting from the technology for learning, exemplifying, the computer tool, which can be used by all students as a technological tool applied in the educational context, in this case is not considered an AT. Therefore, AT in the educational fields of education is considered when it is used by students with disabilities, breaking sensory, motor, or cognitive barriers that limit and/or impede their development in the knowledge process, as well as, when they allow the access and autonomous and active participation of these students in the pedagogical processes (Bersch, 2017; Brasil, 2009).

The National Undersecretariat for the Promotion of the Rights of the Disabled person, shows that AT in education or other areas includes, "[...] products, resources, methodologies, strategies, practices and services that aim to promote the functionality, related to activity and participation, of people with disabilities, incapacities or reduced mobility" (Brasil, 2009, p. 9), aiming at quality of life and inclusion.

The National Policy of Special Education from the perspective of Inclusive Education (Brasil, 2008) assures the public of Special Education, to guide educational systems to promote:

> [...] transversality of special education from childhood education to higher education; specialized educational care; continuity of schooling at higher levels of education; teacher training for specialized educational care and other education professionals for school inclusion; urban, architectural, furniture and equipment accessibility, transportation, communication and information; and intersectoral articulation in the implementation of public policies (Brasil, 2008, p. 8). Therefore, it is considered that AT is implemented together with the policy that provides for the provision of special education to target public students in quality ofInclusive education. Special education is a teaching modality that goes through all levels and stages, to perform Specialized Educational Assistance (ESA), thus, has the objective "[...] to elaborate and organize pedagogical and accessibility resources that eliminate the barriers to the students' full participation, considering their specific needs" (Brasil, 2008, p. 10).

In this sense, the TA implementation in classrooms is based on pedagogical actions of teachers who work in the ESA service, in: i) Multifunction Resource Room - SRM; ii) Specialized Educational assistance Center (CAEE);

- Support Teacher to Alternative Communication (PAC); iv) Teacher of Specialized Educational Support (PAEE) and LIBRAS Translator and Interpreter (TILS); v) Interpreting Guide and Itinerant Teacher, to consider that pedagogical actions must respect the particularities of each student. However, the teacher of regular education should seek interactions with the ESA teacher to together expand and re-signify the use of AT that best assists students in classrooms, so as to enable them greater participation, access and autonomy in the teaching and learning process.

The Statute of the Person with Disabilities (Brasil, 2015), reaffirms the application of the use of ATin educational environments and in other environments, to legalize the possibility and condition of reaching the accessibility and autonomy of these people.

Upon considering that every person with disabilities has the right to equal opportunities with other people and will not suffer discrimination of any kind. In this perspective, in its Article4, paragraph I, it is considered discrimination on the grounds of disability:

> [...] any form of distinction, restriction or exclusion, by action or omission, which has the purpose or effect of harming, preventing or nullification or impairment of the recognition or exercise of the fundamental rights and freedoms of persons with disabilities, including refusal of reasonable adaptations and supply of assistive technologies (Brasil, 2009, p. 12).

In educational environments, the elaboration, organization and application for the use of AT to students with disabilities should be thought according to the peculiarities of each, to consider any curriculum disciplines, to provide knowledge-related accessibility and equity in an inclusive manner.

METHODOLOGY

This study approached a systematic review, to be used as a data source in the literature. According to Sampaio and Mancini (2007, p. 84), this type of research "[...] provides a summary of the evidence related to a specific intervention strategy, through the application of explicit and systematized search methods, critical appraisal and synthesis of the selected information". Based on this reasoning, this study considered five stages (Sampaio and Mancini, 2007).

- Question definition: What are the possibilities and weaknesses of assistive technology in the teaching and learning mathematics process to students with visual impairment?
- Data search: two databases were chosen, the Brazilian Digital Library of Theses and Dissertations - (BDTD) with the intention of searching for theses and dissertations and the Scielo database, to consider articles. For the localization and selection of studies, the following descriptors were used: a) assistive technology manipulable in mathematics teaching; b) tactile assistive technology for the blind; c) tactile assistive technology and visual impairment.
- Selection of studies: after localization of the studies, some inclusion/exclusion criteria were established: inclusion criteria: data observation in the period between 2010 and 2020; studies in the area of education; studies that addressed the education of the blind in the use of assistive technology, in particular the area of mathematics. Exclusion criteria: duplication of studies in the database; literature review studies; study of other than educational areas; studies that did not address assistive technology for education of the blind, specifically in the area of mathematics.
- Analysis of the studies: analyzes were performed with critical assessment of the studies selected in the last ten years. For data collection, in Table 1, studies corresponding to those located and selected in the basis of Scielo BDTD. In Table 2 it was specified: author, year, type of study; title of studies, type of study, assistive technology; possibilities and weaknesses identified in the studies.
- Presentation of the results: discussion with critical appreciation of the selected studies, considering the possibilities and weaknesses of theassistive technology in the teaching and learning mathematics process to blind students. The data summary was based on Flick (2009), considering the qualitative approach.

RESULTS AND DISCUSSION

In teaching mathematics to students with visual impairment it is important to consider the remaining senses, because the lack of vision is rewarded through hearing, touch, smell and taste, these senses are paths that direct pedagogical actions to the teaching and learning process to these students (Alvaristo*et al.*, 2020).

Table 1. Localized and selected studies in BDTD and Scielo basis

SEARCH DESCRIPTORS	BDTD L= LOCALIZED S= SELECTED	SCIELO L= LOCALIZED S- SELECTED
Manipulative Assistive Technology in	L=3	L=0
Mathematics Teaching	S=1	S=0
Tactile Assistive technology for the Blind	L=10	L=1
	S= 1	S= 0
Tactile Assistive technology and	L=13	L=1
the visual impairment	S=1	S=0
Total	L=26	L=2
	S=3	S=0

Source: prepared by the authors (2021).

Table 2. Possibilities and weaknesses found in the studies

Author/Year/ Type of study	Title	Assistive technology	Possibilities	Weaknesses
ESTIVALETE, P. B. (2020) BDTD THESIS	The audio-haptic virtual environment as an instrument for Geometry Learning: study of shapes for blind students	Audio-haptic virtual environment	To enable teaching of geometric shapes for blind students, enabling interaction with virtual environments through touch and strength feedback	The existence of only one point of contact between the virtual objects and the probe attached to the Novint Falcon terminal effector, forming a kind of index finger, limits the student's perception and results in more work to identify the characteristics of the virtual objects. Context of COVID -19 pandemic
MENDES JUNIOR, J. L (2016) BDTD DISSERTATION	A hyperlinked learning object with manipulable materials for teaching spatial geometry for students with low vision in basic education	Edrons application hyperlinked to Manipulative Materials	To enable space geometry teaching and learning for people with visual disabilities (low vision)	To think of an application based on the universal design, where everyone could have access, to provide mathematics teachers with meaningful activities to the education stages
COLPES, M.K. (2014) BDTD DISSERTATION	High-relief graphics Printer for the blind: a facilitator for teaching physics and mathematics for the blind	High-relief graphics Printer for the blind	To Facilitate the teaching of mathematics and physics, to collaborate for the use of tactile exploration on the teaching of blind people's knowledge	Ink system in high-relief created for the printing of charts, it needs better reformulations, as it is not capable of reading all types of charts and diagrams

Source: prepared by the authors (2021).

Therefore, as organized in this study, based on the inclusion and exclusion criteria, it was possible to locate through the BDTD and SCIELO databases, twenty-eight (28) studies. Of these, three (3) were selected. Table 1 shows the localized and selected studies found from the descriptors:

Table 1 shows that twenty-six (26) studies were located in the BDTD database, of which three (3) were selected, two (2) dissertations and one (1) thesis. In the Scielo database, two (2) studies were located, but, were not selected, considering the criteria established in this study. Regarding the year and place of the studies selected here, a thesis defended in 2020 at Universidade Federal do Rio Grande do Sul UFRGS, 2020 was verified. (Estivalete, 2020). A dissertation defended in the year 2016 at the UniversidadeFederal de Goiás – UFG (Mendes Junior, 2016). And, in 2014, a dissertation defended at Universidade Federal do Rio Grande do Sul - UFRGS (Colpes, 2014). The studies selected addressed AT in the teaching and learning mathematics process to students with visual impairment. Table 2 shows the selected studies, pointing out the possibilities and weaknesses found in the use of AT to students with visual impairment. From Table 2, it is observed that the selected studies approached AT with the aim of providing and expanding the accessibility and active participation of students with visual impairment in the process of mathematics teaching and learning, as Brasil points out (2009). In this perspective, Colpes (2014) developed an AT called a high-relief printer, enabling the teaching of charts and diagrams to students with visual impairment through tactile perception. The study showed that, with this AT, the potential to give schools greater autonomyin relation to the adaptation of materials to students is increased,to provideproduction faster in delivery to students who need to supply their peculiarities for the process of mathematics teaching and learning. Therefore, although the study presents an innovation in the use of AT to students with visual impairment and obtaining approval from a blind student, it still lacks new reformulations for full applicability in educational fields.Mendes Junior (2016) sought through AT to improve the process of mathematic teaching and learning to students with low vision, specifically in the area of spatial geometry, to consider an application called *Edrons*, hyperlinked to manipulative materials. The results show that the AT enabled students with low vision to develop strategies of manipulation and tactile exploration of objects, thus, leveraging perceptions related to relative positions between straights in space in written activities or in virtual environment, as well as, the generalization of Euler's relationship with low vision students. Although Mendes Junior (2016), indicate pedagogical actions in the use of TA, the study shows that the Edrons application could have been thought of in order to consider a universal design, whose is one capable of impacting the greatest number of people with or without need for adaptation. In the case of Mendes Junior study (2016, p. 138), based on the TA *Edrons* application, the author points out that "[...] each screen of the application would have to present a control menu for source/brightness/contrast adjustment, an audio program describing statements, figures and animations, in addition to being an open software". Thus, the fragility found in this study was the lack of financialresources that broaden the development of this AT to be considered as a universal design. Estivalete (2020) points out that mathematics is a challenge in the formative trajectory of students, especially in Elementary School. Thus, technological resources can help to improve the teaching and learning process of mathematics. In this perspective, Estivalete (2020) addressed a discussion about the teaching of geometric shapes, using AT with virtual audio-haptic environment, reproducing mechanical signals that are usually experienced when haptically exploiting real world environments, through kinesthetic sensations emitted by the arms of blind students, i.e. haptic perception depends on cutaneous and kinesthetic sensations arising from haptic interaction with a real or virtual environment from the tactile-kinesthetic senses.

Regarding the content approached on geometry, the author based her study on the Common National Curriculum Base – BNCC (Brasil, 2018). The results show that the students investigated achieved the abstraction of the content taught in the use of the virtual audio-haptic environment. However, the existence of only one point of contact among the virtual objects, which form a kind of index finger, limited the perception, resulting in more work to identify the characteristics of the virtual objects to the participants. Another fragility pointed out by Estivalete (2020) was the context resulting from the pandemic as a result of Covid-19. The studies analyzed bring students with visual impairment, to consider blindness and low vision and mathematics teachers (Estivalete, 2020; Mendes Junior, 2016; Colpes, 2014). Regarding the methodological aspects addressed by (Estivalete, 2020; Mendes Junior, 2016; Colpes, 2014), it should be emphasized that all of them used a qualitative approach for data analysis and discussion. According to Lüdke and André (2013, 11), qualitative research "[...] presupposes the direct and prolonged contact of the researcher with the environment and the situation being investigated". Since this contact was generally understood in all the analyzed studies.

On the strategy used in the studies, Mendes Junior (2016) and Estivalete (2020), using the case study, Colpes (2014) used the exploratory strategy. Regarding the instruments and procedures adopted, the studies are based on participant observation, video recording (Estivalete, 2020); participating observations, the application of questionnaires, the recording of videos, the semi structure interviews and the activities of the workshops (Mendes Junior, 2016); observation and interpretation of materials (Colpes, 2014).Regarding the epistemological approach, Estivalete (2020) used the theory of Jean Piaget's reflective abstraction, which brings contributions to the understanding of knowledge construction; the human haptic perception from the perspective of Lederman and Klatzky. Mendes Junior (2016) based on the historical-cultural conception of Levy Seminoach Vygotsky. Colpes (2014) did not clarify the approach in his study. The studies analyzed present innovations in AT, however, there was a lack of studies addressing AT as enabling resources for learning mathematics to students with visual impairment.

FINAL CONSIDERATIONS

The importance of AT in the lives of people with disabilities is undeniable, as it facilitates accessibility processes, short communication distances breaking up insurmountable barriers, providing security and autonomy, as well as, it is crucial to emphasize that all people have the same rights and conditions of equality. But thinking AT as a resource in the teaching and learning process in mathematics is a challenge for many education professionals to reflect that the demand for AT resources in classrooms is negligible, regarding Special Education from the Perspective of Inclusive Education of people with disabilities and/or disorders. Thus, this study aims to investigate the possibilities and weaknesses of assistive technology in the teaching and learning process of mathematics to students with visual impairment. To this end, the literature was used, based on two databases, the Brazilian Digital Library of Theses and Dissertations (BDTD) and Scielo. It was verified based on the studies analyzed that, despite demonstrating possibilities in the use of AT for the teaching and learning process of mathematics to students with visual disabilities, in order to collaborate with accessibility and autonomy during the knowledge process, simultaneously, weaknesses were presented that correspond to development and the reformulations concerning theAT use practices: i) Virtual audio-haptic environment; ii) Edrons application hyperlinked to manipulative materials; iii) high-profile graphics printer (Estivalete, 2020; Mendes Junior, 2016; Colpes, 2014). Before the search in the databases, there was a low rate of production regarding the subject addressed, which causes concern for the imminent need in the AT development, to be applied to the process of teaching mathematics to students with visual disabilities, to consider the remaining senses in their learning. Therefore, it was verified the importance of researchers from the area of Special Education and Inclusive Education, who study and teach mathematics, to lead new glances to expand the demand for enabling AT in the process of teaching students with visual disabilities.

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