DIGITAL TECHNOLOGIES IN TEACHING AND LEARNING PROCESSES FOR STUDENTS WITH AUTISTIC SPECTRUM DISORDER (ASD): A SYSTEMATIC REVIEW OF THE LITERATURE

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ABSTRACT: The objective of this study was to explore existing research on the use of digital technologies in teaching mathematics to students with Autism Spectrum Disorder (ASD), highlighting the main results. This is a qualitative research, focusing on the Systematic Literature Review procedure, where a search was carried out for scientific articles in six databases (WorldCat, Scopus, Science Direct, Scielo, ERIC, and Web of Science), in the last five years, covering the themes of Digital Technology, Autism and Mathematics Education. Five articles were recovered, three from Brazil and two from Portugal. Although there was a slight growth in interest from 2022 onwards, it was noted that there is a scarcity in the number of publications related to the topic. Considering that digital technology is crucial to innovate in teaching and learning, the results of this study indicate that there is a vast field of investigation regarding the use of digital assistive technologies in the education of autistic students.

KEYWORDS: Assistive Technologies. Digital technologies. Mathematics Education. ASD.

RESUMO: O objetivo deste estudo foi explorar as pesquisas existentes sobre o uso de tecnologias digitais no ensino de matemática para estudantes com Transtorno do Espectro Autista (TEA), destacando os principais resultados. Trata-se de uma pesquisa qualitativa, com foco no procedimento da Revisão Sistemática da Literatura, onde fez-se uma busca por artigos científicos em seis bases (WorldCat, Scopus, Science Direct, Scielo, ERIC e Web of Science), nos últimos cinco anos, abarcando a temática Tecnologia Digital, Autismo e Educação Matemática. Recuperou-se cinco artigos, sendo três do Brasil e dois de Portugal. Embora percebido um tímido crescimento de interesse a partir de 2022, notou-se que há uma escassez no número de publicações relacionadas a temática. Considerando que a tecnologia digital é crucial para inovar no ensino e aprendizado, os resultados deste estudo apontam que há um vasto campo de investigação em relação ao uso de tecnologias assistivas digitais na educação de estudantes autistas.


RESUMEN: El objetivo de este estudio fue explorar las investigaciones existentes sobre el uso de tecnologías digitales en la enseñanza de matemáticas a estudiantes con Trastorno del Espectro Autista (TEA), destacando los principales resultados. Se trata de una investigación cualitativa, centrada en el procedimiento de Revisión Sistemática de Literatura, donde se realizó una búsqueda de artículos científicos en seis bases de datos (WorldCat, Scopus, Science Direct, Scielo, ERIC y Web of Science), en los últimos cinco años, abarcando los temas de Tecnología Digital, Autismo y Educación Matemática. Se recuperaron cinco artículos, tres de Brasil y dos de Portugal. Si bien hubo un ligeró crecimiento en el interés a partir de 2022, se observó que hay escasez en el número de publicaciones relacionadas con el tema. Considerando que la tecnología digital es crucial para innovar en la enseñanza y el aprendizaje, los resultados de este estudio indican que existe un vasto campo de investigación sobre el uso de tecnologías de asistencia digital en la educación de estudiantes autistas.

PALABRAS CLAVE: Tecnologías de asistencia. Tecnologías digitales. Educación Matemática. TEA.
Introduction

School inclusion has been discussed at significant events, with the World Declaration on Education for All (UNESCO, 1990) and the Salamanca Statement (UNESCO, 1994) serving as introductory milestones, to which Brazil became a signatory. These events led various countries to commit to the right to education for all individuals, establishing principles, policies, and practices in Special Education. Additionally, the universal document recommended the inclusion of children and young people with specific educational needs, that is, those with disabilities, in mainstream schools, bringing the concept of inclusive schools into the discussion and challenging educators to develop pedagogies that respect individual differences.

Regarding teacher training, it is essential for schools to equip teachers with Assistive Technologies (AT). This relatively new term identifies the arsenal of resources and services that contribute to providing or enhancing the functional abilities of people with specific needs, thereby promoting their independence and inclusion (Bersch, 2013). Research in this area focuses on the necessity of including these individuals for humanitarian, ethical, and legal reasons.

As mentioned, assistive technologies can reduce societal limitations that prevent individuals with disabilities from accessing school content. In the context of teaching mathematics, it is crucial to leverage digital resources to facilitate inclusion and learning, as these devices are part of our daily lives and ease everyday tasks. This study aimed to survey existing research on the use of digital technologies in teaching and learning mathematics for students with Autism Spectrum Disorder (ASD) and to highlight the outcomes reported by these studies. A bibliographic research was conducted, guided by the procedures of a systematic literature review.

Digital inclusion helps overcome physical and cognitive barriers, potentially providing equal access to the school curriculum and creating a more effective learning environment. Moreover, digital technologies can also be used to develop social skills in students with ASD, aiding in improving their communication and social interaction abilities. Thus, the relevance of this study lies in seeking teaching methodologies supported by digital assistive technologies that can promote an inclusive environment for autistic students, enabling them to actively participate in mathematics activities in the classroom.
Mathematics Learning and ASD

The teaching and learning of Mathematics have undergone numerous changes over time, similar to all regular Education, with evolving teaching and learning methodologies. According to Carvalho and Lima (2022), many possibilities have emerged with new norms and ways of thinking and responding to the educational process. Among the topics gaining prominence and serving as a field of study for teachers and researchers is the inclusion of students with disabilities—a relatively new and underexplored area for education professionals.

In Mathematics and other sciences, inclusive Education has been the subject of debate, aiming to make the teaching of these subjects more inclusive. Consequently, this action seeks to make our society more inclusive for people with disabilities, fostering their autonomy, critical thinking, and reflection, and enabling these students to genuinely learn the content, thereby promoting their overall development (Carvalho; Lima, 2022).

The right to Education for people with disabilities in Brazil is historically recent. As a result, Public Policies of Interest for People with Disabilities are enacted to effectively offer and guarantee equality (of rights and opportunities) and accessibility for these individuals. According to the Brazilian Inclusion Law (LBI) of July 2015, it is necessary to ensure the inclusion, guarantee, and promotion of equal conditions for people with disabilities so that their rights and freedoms are assured, constantly seeking their inclusion in society and citizenship (Brasil, 2015). Thus, schools are at the core of institutions with the role and capacity to include these students, offering qualified and supportive professionals, multifunctional resource rooms, appropriate materials, and support for their learning and development as students and citizens.

Special Education is a field of Education dedicated to serving students with specific educational needs, whether physical, intellectual, sensory, or emotional. Its goal is to provide specific support and resources to ensure these students can actively participate in the educational process, promoting their inclusion and maximizing their development. According to the National Education Guidelines and Framework Law, in Chapter V, Article 58, Special Education can be defined as “the mode of school education preferably offered within the regular education system for students with some specific needs” (Brasil, 1996). This encompasses the inclusion of all students as a fundamental principle, aiming to integrate students into regular educational environments whenever possible.

In the context of Policies of Interest for the Education of People with Disabilities in Brazil, it is worth highlighting the concept of Special Education presented in Article 3 of Resolution CNE/CEB No. 02/01:
Special Education is understood as an educational process defined by a pedagogical proposal that ensures specific educational resources and services are institutionally organized to support, complement, supplement, and, in some cases, replace regular educational services. This aims to guarantee school education and promote the development of the potential of students with specific educational needs at all stages and levels of basic Education (Brasil, 2001, our translation).

Additionally, “the mode of Special Education is based on the need to provide equal opportunities through the diversification of educational services to meet individual differences among students, no matter how pronounced they may be” (Mazzotta, 2005, p. 10, our translation). This involves promoting adapted pedagogical practices and creating an environment that embraces diversity, providing meaningful interactions among all students.

Regarding the inclusion of students with ASD, the focus of this study, Law No. 12.764/2012 establishes the National Policy for the Protection of the Rights of Persons with Autism Spectrum Disorder (ASD), expanding their access to regular institutions of professional Education, based on the defense of equal rights and opportunities, with the following definition:

Autistic disorder (or childhood autism) is part of a group of neurodevelopmental disorders known as Pervasive Developmental Disorders (PDDs), Invasive Developmental Disorders (IDDs), or Autism Spectrum Disorders (ASDs). This group of disorders shares core symptoms in three specific areas of development: (a) deficits in social skills, (b) deficits in communicative skills (verbal and non-verbal), and (c) the presence of restricted, repetitive, and stereotyped behaviors, interests, and/or activities (Silva; Mulick, 2009, p. 117, our translation).

Furthermore, according to Silva and Mulick (2009), the previously known nomenclatures such as Asperger’s disorder (or syndrome), childhood disintegrative disorder (or other childhood disintegrative disorder), Rett syndrome (or disorder), and pervasive developmental disorder not otherwise specified (including atypical autism)6, now fall under the term ASD, Autism Spectrum Disorder, which is more commonly used.

ASD can be defined as a range of conditions characterized by some degree of impairment in behavior, communication, language, and social skills, with a narrow range of interests and activities that are unique to the individual and carried out repetitively. The term “spectrum” was added to the name of autistic disorder in 2013 due to the diversity of symptoms and levels that individuals exhibit. Each individual with autism has their own set of

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manifestations, making them unique within the spectrum. Additionally, each individual’s recognition level encompasses behavior, communication/language, and social skills, as illustrated in Table 1.

**Table 1 – Characteristics of the Autism Spectrum**

<table>
<thead>
<tr>
<th>Levels of Autism Spectrum Disorder Characteristics</th>
<th>Behavior</th>
<th>Language and Communication</th>
<th>Sociability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not recognizing real dangers like moving vehicles or great heights</td>
<td>Lack of imaginative play</td>
<td>Qualitative impairments in reciprocal social interaction, often showing inadequate appreciation of socio-emotional cues.</td>
<td></td>
</tr>
<tr>
<td>Alterations in gaze: Absence or avoidance of eye contact, looking &quot;through&quot; others, lack of eye tracking, peripheral vision, and strabismus</td>
<td>No use or understanding of gestures</td>
<td>Lack of response to others' emotions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not using language for social communication</td>
<td>Lack of modulation of behavior</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Presence of stereotyped responses or echolalia</td>
<td>Inadequate use of social signals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alterations in speech melody</td>
<td>Poor integration of social, emotional, and communicative behaviors</td>
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<td></td>
<td>Poor integration of social, emotional, and communicative behaviors</td>
<td>Poor integration of social, emotional, and communicative behaviors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extreme verbal dominance in mild autism cases.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted by the authors (APA, 2003).

According to the APA (2003), the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders) divides autism into different levels based on certain individual conditions. It is generally categorized into grades (1, 2, and 3) or as mild, moderate, and severe autism.

- **Mild Autism** - Requires Little Support: In this degree, the main difficulties are related to communication deficits, with few comorbidities associated. Because of this, a child with mild autism is often labeled as disinterested.

- **Moderate Autism** - Requires Substantial Support: Moderate autism has more complicated aspects compared to mild autism. In this case, the lack of verbalization can be one of the individual's problems, and generally, more comorbidities are associated with the diagnosis.

- **Severe Autism** - Requires Very Substantial Support: Grade 3, or severe autism, is characterized by higher levels of neurodevelopmental impairments. In this context, problems range from socialization processes to the overall functioning of the body and mind. For this reason, the independence of a child with autism is more challenging to achieve at grade 3.
Regarding the learning process, from a neuroscience perspective, according to Pereira and Tonelli (2022), it is defined as a constant movement of brain reactions to environmental stimuli, which activate synapses that "[...] are connections between neurons through which stimuli pass" (Flor; Carvalho, 2011, p. 223). With each new stimulus or repetition of a behavior to be consolidated, new circuits are activated for information processing. As learning occurs, more changes are observed in the brain (Flor; Carvalho, 2011).

According to Amaral, Dawson, and Geschwind (2011), the brain of individuals on the spectrum may have altered neural connectivity. Some areas of the brain may have increased functional connectivity, while other areas may have reduced connectivity.

Furthermore, Amaral, Dawson, and Geschwind (2011) highlight that autism is a complex neurobiological condition and is not limited to brain differences alone. Genetic factors, environmental influences, and social interactions also play a significant role in the development of autism. Each person on the autism spectrum is unique and may present a different combination of characteristics and abilities.

Regarding the learning of mathematics, Van de Walle, Karp, and Bay-Williams (2013) highlight that the main difficulties faced by individuals with autism are: 1) Understanding abstract concepts such as numbers, mathematical operations, fractions, and geometry. Some individuals with ASD may struggle to grasp these abstract concepts and their practical application; 2) Difficulty in generalizing skills, i.e., transferring mathematical skills learned in one context to another. For example, they may find it challenging to apply a mathematical concept learned in one problem to a different problem or a real-life situation; 3) Visual-spatial processing, including pattern recognition, geometry, and spatial organization, which can affect their ability to handle mathematical problems requiring visualization and manipulation of spatial information; 4) Problem-solving skills, which require logical reasoning, analysis, synthesis, and application of strategies. An autistic student may have difficulty identifying relevant information, planning steps, and applying appropriate strategies; and finally, 5) Difficulty dealing with uncertainty and ambiguity, such as estimates and approximations. Some individuals with ASD may prefer more rigid reasoning and struggle to tolerate imprecision or lack of clarity in mathematical problems.

However, it is important to emphasize that, with adequate support, curricular accessibility, and Assistive Technologies (AT), it is possible to make mathematics education feasible for students with ASD. As Bersch and Tonolli (2006) note, AT is a relatively new term...
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used to identify the entire arsenal of resources and services that contribute to providing or enhancing the functional abilities of people with disabilities, thereby promoting autonomy and inclusion. In this context, Radabaugh (1993) states that for people without disabilities, known as typical, technology makes things easier. For people with disabilities, technology makes things possible.

According to Cook and Hussey (1995), AT involves "a range of equipment, services, strategies, and practices designed and applied to alleviate the functional problems encountered by individuals with disabilities." Within the scope of AT, Bersch (2009 apud Nickel, 2012, p. 47-48) explains that a resource can range from a simple cane to a complex computerized system, including adapted clothing, software, devices for posture adjustment, communication aids, visual aids, prosthetic materials, and many others that can assist people with disabilities in their specific needs. Services, on the other hand, involve professionals who will tailor these resources to each individual's needs. AT services are typically interdisciplinary, involving professionals from various fields, such as speech therapists, psychologists, special education educators, caregivers, and many other specialties (Bersch, 2009 apud Nickel, 2012). AT is a key element in promoting the rights of people with disabilities to exercise their autonomy and citizenship in society.

Galvão Filho (2009) corroborates that AT is an area of knowledge aimed at providing the necessary support for each person with a disability to demonstrate their potential for sociability, creativity, interaction, and educational development. Comprising a wide variety of resources, instruments, and materials used or adapted according to need, Galvão Filho (2009) explains that Digital Assistive Technologies, i.e., high-tech technologies such as computers, tablets, smartphones, screen reader programs, devices like adapted mice, audio description, etc., can be used to enhance the abilities of people with disabilities, providing autonomy, empowerment, and active participation.

Furthermore, we can include in this category Augmentative and Alternative Communication (AAC) resources for mobility, location, and signaling, and furniture that meets postural needs, among others. Thus, in the school environment, AT is understood as an essential tool that serves the right to education and the creation of more conducive learning environments, as it promotes pedagogical and architectural accessibility, as well as facilitating communication and mobility for people with disabilities (Rodrigues, 2022). It can be seen that, for people with ASD, Digital Assistive Technologies for Augmentative and Alternative
Communication (AAC) can help with the communication difficulties that affect a significant percentage of these individuals and thus contribute to the learning processes.

Several authors highlight the potential of digital technologies in mathematics education. Borin (1996) emphasizes that integrating learning applications during math classes can reduce the difficulties many students face, establishing a meaningful and enjoyable learning environment for the construction of mathematical concepts. According to Alves (2001), teaching mathematics using applications and software substantially boosts intellectual, social, and affective interactions and promotes attitudes of constructive criticism and creativity in students participating in this process.

According to Medeiros (2014), these digital tools, which also take the form of digital games, have the potential to be viable options for teaching the theoretical concepts addressed in mathematics and providing students with problem-solving skills that would not be feasible using pen and paper.

Digital technology plays an increasingly important role in mathematics education. Borba, Scucuglia, and Gadanidis (2014) summarize the use of digital technologies into four phases: characterizing the first phase as the use of software, through programming language itself, the second phase from the popularization of personal computers that fostered the creation of educational software, the third phase with the emergence of the internet as access to information sources and a means of communication, and the fourth phase, with the internet itself with its enhanced infrastructure providing faster access, integration of various multimedia devices, bringing the sensation of instant access to repositories, music, and videos.

Mathematics education, in accordance with Borba and Santos (2005), expresses concerns about the role of mathematics in society, intertwining it with the sciences and the technology that pervades our current daily lives. Their concern is not isolated and has been the keynote in books, continues Borba and Santos (2005), reinforcing their speech with authors such as Skovsmose (2001) and the theses of Jacobini (2004) and Vianna (2003), who believe that mathematics education will not survive if it does not acknowledge this multiple interaction [between Education, Mathematics, and society], running the risk of being reduced to a didactics of mathematics or, worse, to the teaching of mathematics in which it is instituted by society and how, reciprocally, it acts on individuals permeating power relations, beliefs, worldviews.

Teaching Mathematics through the use of games, educational software, and robotics education can be a strategy that favors logical reasoning and students' concentration in
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matematics learning. Furthermore, it is possible to use technology in the school environment to make learning more agile, enjoyable, as well as to expand the transmission of this content.

Considering studies in mathematics education, searches were also conducted in articles focused on Mathematics Education and ASD, identifying authors such as Tognette, Santos, and Silva (2023), Almeida and Uliana (2023), and Fleira and Fernandes (2019), where a systematic review of the literature is observed, seeking to identify what has been researched about the learning of mathematics within an inclusive perspective of students with ASD.

Methodology

This study was guided by the procedures of Systematic Literature Review, which, according to Camilo and Garrido (2019, p. 253), is characterized by "the use of explicit, rigorous, and transparent criteria that allow identifying, synthesizing, and critically evaluating all literature on a specific topic to answer a research question." Thus, the steps proposed by the authors were followed: 1) Formulation of the research question; 2) Choice of databases and selection of keywords; 3) Selection of data according to inclusion and exclusion criteria; 4) Reading; 5) Data extraction; and 6) Data synthesis and interpretation. The research was conducted from March to November 2023.

The described steps were considered to guide the selection and eligibility of articles, establishing inclusion and exclusion criteria developed based on the study by Pereira and Tonelli (2022), as shown in Table 2. The filtering resources available in the databases were used to apply these precepts. The exclusion criteria, in turn, required a preliminary reading of abstracts and full texts.

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Publication Period: 2017 to 2023</td>
<td>a) Documents that were not Review Articles or Applied Research Papers.</td>
</tr>
<tr>
<td>2. Access: Full text</td>
<td>b) Studies that did not depict direct relationships between the use of digital technologies in teaching mathematics to individuals with autism.</td>
</tr>
<tr>
<td>3. Language: Portuguese and English</td>
<td></td>
</tr>
<tr>
<td>4. Contain in the title or keywords the descriptors &quot;Autism&quot; and &quot;Mathematics&quot; and &quot;Digital Technologies&quot; (in Portuguese or English).</td>
<td></td>
</tr>
</tbody>
</table>

Source: Pereira, Tonelli (2022) - adapted by the authors.

The search resulted in the identification of 14 documents (Figure 1), including books, book chapters, interviews, conferences, review articles, and applied research. For the direction of article selection and eligibility, the exclusion criteria were applied in the second stage, as
described in Table 2. The process of searching and selecting the retrieved articles can be visualized in the flowchart of Figure 1.

**Figura 1 – Fluxograma revisão sistemática**

From institutional access to the Capes Periodicals Portal, six databases were selected for data retrieval: WorldCat, Scopus, ScienceDirect, ERIC, Scielo, and Web of Science. These databases were chosen because they encompass a considerable number of academic journals in the field of education and mathematics education, with the possibility of free access to full texts. The search was guided by the descriptors "Autism," associated by the boolean operator AND with the terms "Digital Technologies," and other variables such as "Mathematics Education," "Mathematics," and "Math." The same search was also conducted in Portuguese to expand the results. Thus, it was guided by the descriptors "Autismo," associated by the boolean operator E with the terms "Tecnologias Digitais," and other variables such as "Ensino de Estatística" and
"Matemática." Initially, inclusion criteria were applied, as described in Table 2. For this, the fields title, keyword, and abstract were used, considering the last 5 years of publication.

As shown in Figure 1, the initial search resulted in a database with fourteen documents. However, after reading the titles and applying the exclusion criteria (items a and b), nine documents were eliminated because they did not review articles or applied research, or they did not address direct relationships between the use of digital technology in teaching mathematics for individuals with autism, i.e., some articles only addressed one of the descriptors. In the end, five articles were obtained, two of which were review articles and three were applied research, which were considered relevant for analysis and discussion on the topic.

To facilitate the systematic review of the selected articles, a table (Table 3) was constructed under which the aspects characterizing the five scientific productions were analyzed, considering: the type of article, title, authorship, year, nationality, focus of study, methodology, and research subjects, in the case of applied research.

**Table 3 - Categorization of articles retrieved in the systematic review**

<table>
<thead>
<tr>
<th>Article Type</th>
<th>Title</th>
<th>Authorship</th>
<th>Country</th>
<th>Year</th>
<th>Focus of Study</th>
<th>Methodology</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>REVIEW (Total = 2)</td>
<td>O Uso da Tecnologia e suas Contribuições para a Formação Integral do Aluno com Transtorno do Espectro Autista e do Aluno com Deficiência Intelectual nas Aulas de Matemática</td>
<td>TAKINAGA; MANRIQUE</td>
<td>Portugal</td>
<td>2022</td>
<td>Comprehensive education of students with ASD and ID (Intellectual Disability)</td>
<td>Literature review</td>
<td>None</td>
</tr>
<tr>
<td>Gamificação como estratégia pedagógica para potencializar habilidades matemáticas para estudantes com Autismo: uma revisão sistemática da literatura.</td>
<td>PEREIRA; BARWALDT</td>
<td>Brazil</td>
<td>2022</td>
<td>Gamification in Mathematics Teaching</td>
<td>Review of literature</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Promover o Raciocínio Geométrico em Alunos com Perturbação do</td>
<td>SANTOS; BREDA; ALMEIDA</td>
<td>Portugal</td>
<td>2020</td>
<td>Geometric Thinking</td>
<td>Research – Tests using the digital environment LEMA</td>
<td>Autistic Students</td>
<td></td>
</tr>
</tbody>
</table>
In the following section, the analysis and discussion of the findings and contributions of assistive digital technologies in teaching mathematics to autistic individuals will be presented.

### Results

In accordance with the objective of this study, this section will present the results obtained from the systematic review regarding what has been produced on Digital Technologies and Mathematics Education and Autism, in terms of nationality, periodicity, focus of study, methodology of applied research, and target audience of participants.

Regarding the data extracted from the 3 retrieved articles, concerning the nationality of scientific productions, the country that published the most was Brazil with 3 articles (Picharillo; Postalli, 2021; Souza; Silva, 2019; Pereira; Barwaldt, 2022), followed by Portugal with 2 articles (Takinaga; Manrique, 2022; Santos; Breda; Almeida, 2020).

Although few studies focused on mathematics education and the use of digital technologies in the classroom were found, the reviewed articles showed that the use of digital technology, as assistive, can contribute to mathematics education from an inclusive perspective.
The empirical findings and conclusive remarks of the authors will be presented and discussed in the next section.

As discussed in the specialized literature (Medeiros, 2014), there are several ways in which digital technologies can alleviate problems related to mathematical learning. In the analyzed articles, the authors explored some of these pathways in their studies, which will be discussed throughout the discussion.

Takinaga and Manrique (2022) discuss the use of technology in the comprehensive education of students with autism spectrum disorder (ASD) and intellectual disability (ID) in mathematics classes. The study was conducted through bibliographic research, which selected theses, dissertations, and scientific articles from specific databases. In their review, the authors selected articles that address the use of game software for building the concept of numbers, the development of counting strategies, and the study of quantities. Other software focuses on creating a virtual environment that assists in the introduction of the concept of decimal numbering systems, simulating virtual reality, and enabling a graphical strategy for teaching mathematics to children with ASD and ID.

The analyzed works present examples of activities that use educational software, digital games, tablets, and other technological resources to teach mathematical concepts in a playful and interactive manner. The research results indicate that technology can contribute to the comprehensive education of students with ASD and ID, as it allows them to develop mathematical skills more autonomously and enjoyably, which is supported by Borin (1996), who states that within gaming situations, are possibilities to reduce the blocks presented by many students who fear Mathematics and feel unable to learn it. However, the authors point out that it is necessary to consider that each student with a disability has their particularities and that not all technologies are suitable for all cases. Finally, Takinaga and Manrique (2022) warn that the use of technology should not replace the role of the teacher, who remains fundamental in guiding and mediating the learning process.

In this direction, Santos, Breda, and Almeida (2020) present a study on how to promote geometric reasoning in students with Autism Spectrum Disorder (ASD) through a digital environment. The study evaluated the performance of responses from students with ASD in geometry activities before and after interacting with the digital environment LEMA (Learning Environment on Mathematics for Autistic Children). A software whose purpose is to stimulate the construction of meanings, favoring the learning processes and understanding of geometry in children with typical development and children with ASD. The construction of the prototype
was the theoretical basis used for data collection, whose analysis, in addition to situating the geometric thinking of the participating students, also pointed to the redesign of some of the activities implemented in the digital environment, aiming at promoting geometric thinking.

Furthermore, the results of the study by Santos, Breda, and Almeida (2020) showed that the use of technology can be effective in developing differentiated and meaningful activities for children with ASD, promoting geometric reasoning and improving visualization capacity in two-dimensional and three-dimensional figures, as well as the properties of figures and mathematical reasoning. Finally, the study was able to present the essential capacities for mathematical learning of children with typical development and how they relate to children with ASD, as well as the challenges faced by teachers when teaching mathematics to all students, regardless of their limitations.

Regarding the difficulties of autistic students with numerical representations, the study by Picharillo and Postalli (2021) aimed to evaluate the effects of teaching relationships between dictated numbers, Arabic numbers, and quantity using a computerized matching-to-sample (MTS) procedure, in which an example was presented and then participants executed what was asked. The model is based on the stimulus equivalence paradigm, aiming to assess generalization, employing assistive software and manipulable materials. The computer program used to program, present the stimuli and consequences, record responses, and store data was the Contingency Program. This program aimed to evaluate the participant's performance in the various stages of the research. The software measured the percentage of correct responses in the relationships taught and assessed during the procedure, before and after teaching. To issue selection responses to stimuli presented on the computer screen, the children used a Bigtrack model mouse, in which the roller on the top can be moved with the palm of the hand, and clicking is done by pressing a button. In the manipulable material test, nine wooden pieces were used in the form of nine cards with numerals from one to nine.

Picharillo and Postalli (2021) describe that three groups of stimuli composed of three numbers (from 1 to 9, in ascending order) were employed, and the experimental procedure consisted of blocks of twelve attempts. Each group of stimuli was conducted following the stages of teaching relationships in two different tests, with a criterion of expecting 100% correctness; emergent relations test and content generalization test. Additionally, in the test, numbers from 1 to 9 were dictated, followed by the establishment of relationships with Arabic number symbols from 1 to 9, demonstrations of the quantity represented by the symbols, and finally, the use of manipulable materials to consolidate learning.
The results indicated that the teaching procedure was effective in establishing relationships between dictated number, Arabic number, and quantity, and that the participants showed generalization to new stimuli and new forms of stimulus presentation. The use of manipulable materials and software-guided possible actions to be individually adopted with each child, considering the percentages of correct and incorrect responses extracted from the program report, proving effective for promoting the generalization of acquired knowledge (Picharillo; Postalli, 2021).

Focusing on the inclusion of students with Autism Spectrum Disorder (ASD) in regular schools, Souza and Silva (2019) investigated the difficulties faced by these students and how digital technologies can assist them in the inclusion process. According to the authors, many pedagogical actions still adhere to practices that do not consider these students' singularities, which becomes a tool of exclusion. These practices of micro exclusions have been occurring frequently in regular classrooms, generating situations of invisibility for these students and a process of dehumanization of people with disabilities (Dantas, 2011). That is, when the right to learn is denied to the student, due to their presence being considered only a form of socialization.

The research conducted by these authors involved two students with ASD who had difficulties in mathematics. After the implementation of Educational Digital Technologies (EDT) in the teaching and learning process of mathematics, as well as the use of applications and games, significant advances were observed in the development of these students. The research results indicate that the use of technological resources can represent an effective pedagogical alternative in working with these students, as their engagement with computerized activities enabled the construction of mathematical concepts that they could not previously acquire in a non-digital environment.

Pereira and Barwaldt's study (2022) explores how gamification can be used as a pedagogical strategy to assist students with Autism Spectrum Disorder (ASD) in their mathematical skills. The article presents the results of a review of 26 previous studies that investigated the use of gamification as a pedagogical strategy and its application in the classroom to engage students with ASD in mathematical activities. The most commonly used gamification strategies include digital games, software, applications, and the creation of digital environments.

Pereira and Barwaldt (2022) highlight that gamification in the classroom allows for the creation of a playful and engaging environment, the use of rewards and feedback to motivate
students, the development of individualized activities that respect the individual needs of each student, the incorporation of games and challenges to make activities more interesting, and the use of narratives that make activities more meaningful for students. In summary, the authors concluded that gamification can be an effective strategy to engage and improve the mathematical skills of students with ASD, as well as promote inclusion and social interaction in the classroom.

After observing the articles, it was noted that various approaches to digital technologies have been employed in the teaching of mathematics for students with Autism Spectrum Disorder (ASD). These tools aim to facilitate mathematical learning, emphasizing the emphasis on autonomy and pleasure provided to students. All the reviewed articles presented evidence, as indicated by the authors themselves, pointing to improvements in the development of mathematical skills in children with ASD. Additionally, the benefits of these approaches regarding the promotion of inclusion and social interaction of these students within the school environment are highlighted, contributing to a more participative and collaborative classroom environment.

**Final considerations**

Regarding the objectives of this study, through the systematic review, it was possible to identify what has been scientifically produced about the development of digital assistive technologies in mathematics education and, thus, understand how these areas directly interact in the inclusive processes of students with ASD in the school context.

In this study, the analysis of scientific productions reinforced the need to investigate the use of digital technologies in the classroom context, within the perspective of inclusive education, since technology, so present in everyone's life, proves to be a tool that can enhance learning and mastery of mathematical elements, both in students with disabilities and in typically developing students, as well as promote individualized learning. Additionally, the reviewed studies reinforced the importance of providing a playful and enjoyable classroom environment through digital games.

On pedagogical aspects, the authors reinforce the need to discuss the theme of digital technologies from an inclusive perspective, especially regarding autism, in the initial and continuing education of teachers in undergraduate courses in education. Given the complex and heterogeneous nature of ASD, educators must constantly update their skills and knowledge to
adapt to the individual needs of each student, since by understanding how the individual behaves, teachers can seek strategies, such as the use of gamification, to adapt teaching and help students have better development in the subject.

Regarding the quantitative aspects of scientific publications, a reduced number of works addressing the theme of Technologies, Mathematics Education, and Autism was observed, suggesting a fertile field for further studies, especially applied research that bridges digital technology with the classroom context.

In comparison to publications utilizing terms such as Mathematics, Mathematics Education, Statistics Education, Autism, and ASD, it is noticeable that there are more studies and works focused on the theme. Authors like Tognette, Santos, and Silva (2023), Almeida and Uliana (2023), and Fleira and Fernandes (2019) address classroom strategies for teaching mathematics to children with ASD. Therefore, it is emphasized that digital technology, as an assistive tool, shows promise as a field for applied research in the school context, focusing on teaching practices that can contribute to the development of mathematics education from an inclusive perspective. Thus, it is suggested that studies focused on pedagogical interventions can promote a deeper understanding of the applicability of digital tools and games in mathematics education for students with ASD, in order to identify significant contributions to learning.

From the five retrieved articles, a word cloud (Figure 2) was generated with the most used terms in the composition of the studies. Word clouds can address various aspects related to the use of this visual tool in different contexts, as they emerge as a visual and intuitive strategy to summarize, analyze, and communicate information effectively.

As analyzed in the articles and represented in Figure 2, the graphic resource transformed textual data into visual representations, highlighting the frequency of words and revealing semantic patterns quickly and accessibly.
As visually depicted in Figure 2, the synthesis of the five analyzed articles can be observed, identifying keywords such as Education, Mathematics, ASD, Learning, Technology, Students, Autistic, and other predominant terms for quick comprehension of key concepts.

Therefore, considering the discussions raised in this study, it reinforces the need for both teacher trainees and educators to delve into the inclusion of autistic students in order to assess their teaching practice in line with educational objectives, thus attenuating learning problems and effectively fostering inclusive education.
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