Systematic literature review on Inclusive Education and Assistive Technologies: Educational Development of Children with Autism

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Abstract: Inclusive education, combined with assistive technologies, offers a promising direction to support the educational development of children with ASD. Designing an environment adapted to their needs makes these approaches favorable for academic learning, as well as contributing to the social and emotional development of these children. The purpose of this article is to present a Systematic Literature Review (SLR) using the StArt tool, on inclusive education and assistive technologies for autistic children in the school context, with the aim of understanding the data and synthesis of existing academic studies and research that address the effectiveness, impact and best practices in the use of assistive technologies to support the education of autistic children in inclusive environments. Using the time frame of the last ten years (2013-2022) of research related to this topic. 223 relevant articles were identified in pre-selected scientific databases, and after applying inclusion and exclusion criteria, 10 articles were selected for more detailed analysis, considering the proposal of this review.

Keywords: Assistive technologies; Autism spectrum disorder; Inclusive education; Inclusive pedagogical practices; Inclusive strategies.

Revisão sistemática da literatura sobre Educação Inclusiva e Tecnologias Assistivas: Desenvolvimento Educativo de Crianças com Autismo

Resumo: A educação inclusiva, aliada às tecnologias assistivas, oferece uma direção promissora para apoiar o desenvolvimento educativo de crianças com TEA. Elaborar um ambiente adaptado às suas necessidades, tornam estas abordagens favoráveis para a aprendizagem acadêmica, além de contribuir para o desenvolvimento social e emocional dessas crianças. Este artigo tem como finalidade apresentar uma Revisão Sistemática de Literatura (RSL) através da ferramenta StArt[*] sobre educação inclusiva e tecnologias assistivas para autistas no contexto escolar, visando compreender os dados e síntese dos estudos acadêmicos e pesquisas existentes que abordem a eficácia, o impacto e as melhores práticas no uso de tecnologias assistivas para apoiar a educação de crianças autistas em ambientes inclusivos. Utilizando o marco temporal dos últimos dez anos (2013-2022) de pesquisas relacionadas a esta temática. Foram identificados 223 artigos relevantes em bases de dados científicas pré-selecionadas, e após aplicação de critérios de inclusão e exclusão, foram selecionados 10 artigos para análise mais detalhada, considerando a proposta desta revisão.

Palavras-chave: Tecnologias assistivas; Transtorno do espectro do autismo; Educação inclusiva; Práticas pedagógicas inclusivas;

1. Introduction

Inclusive education is an educational approach that seeks to ensure the right to education for all students, regardless of their individual differences, including those with disabilities or special educational needs (Silveira, 2020). When it comes to the learning of students with Autism Spectrum Disorder (ASD), it is important to emphasize the significance of including all students with disabilities/needs within an educational institution. (Orrú, 2012) defines autism as a health condition characterized by deficits

[*] State of Art Tool ⟨https://www.lapes.ufscar.br/resources/tools-1/start-1⟩.

in social communication (both verbal and non-verbal) and behavior (restricted interests and repetitive movements). The categorization of the levels of ASD is based on these deficits, which can range from mild to severe (Dornelas and Lima, 2023). In education, these diagnosed levels are crucial for planning the types of methodologies and assistive technologies to be used with these students, aiming to address and improve their limitations, ultimately facilitating their inclusion in society.

According to (Brasil, 2009), Assistive Technology (AT) involves the application of technological advances in established areas. It is a discipline mastered by professionals from various fields of knowledge who collaborate to restore human function. Thus, assistive technology relates to the research, manufacture, use of equipment, resources, or strategies designed to enhance the functional abilities of people with disabilities (Silva *et al.*, 2019). In the educational context, these technologies can be employed to support the learning of students with autism, helping them overcome barriers and participate more fully in the school environment.

This systematic literature review (SLR) primarily aims to analyze and synthesize academic studies and existing research addressing the effectiveness, impact, and best practices in using assistive technologies to support the education of autistic children in inclusive settings. The review was based on three main research questions, utilizing the StArt tool to assist in the SLR process. Four databases were used for this review: Scielo, IEEE, Scopus, and PubMed. The search string was designed to capture all terms related to the key themes of inclusive education, assistive technology, and autism. This article is organized into four sections (introduction, methodology, interpretation of results, and conclusion) to present an SLR focusing on the intersection of inclusive education and the use of assistive technologies for the educational development of children with autism.

2. Methodology

In this work, the systematic literature review (SLR) on inclusive education and assistive technologies for autistic individuals was divided into three main stages: (1) planning, (2) execution, and (3) summarization. Each stage was further divided into three sub-stages, totaling eight sub-stages, as shown in Figure 1. In our study, we utilized the StArt program (a free tool developed in the Software Engineering Research Laboratory at UFSCar) to assist in the SLR. This research methodology is a type of secondary study that uses literature as a data source to rigorously and impartially identify, evaluate, and synthesize all relevant evidence regarding a specific question (Kitchenham, 2004; Sendacz; Isotani and Lima, 2022). According to Figure 1, the main stages of the SLR process are: defining the research question, developing a protocol, systematic search, study selection, data extraction, data synthesis, and interpretation of results.

2.1. Planning

The planning phase was divided into two stages: the first involves creating the research protocol manual, and the second consists of data extraction based on the defined protocol. The databases are filled with various articles found on the web and populate the "`.BIB`" database, which will later be used in the stages of the SLR process.

During this phase, five research questions were proposed to guide the SLR process. To answer them, we first executed data mining methods (i.e., data clustering approaches) and identified the articles with the most similar characteristics. (P1) What is the importance of assistive devices and technologies for the teaching-learning process of children with Autism Spectrum Disorder (ASD)? (P2) What technologies are currently available that assist children with ASD in the school context? (P3) What skills are most

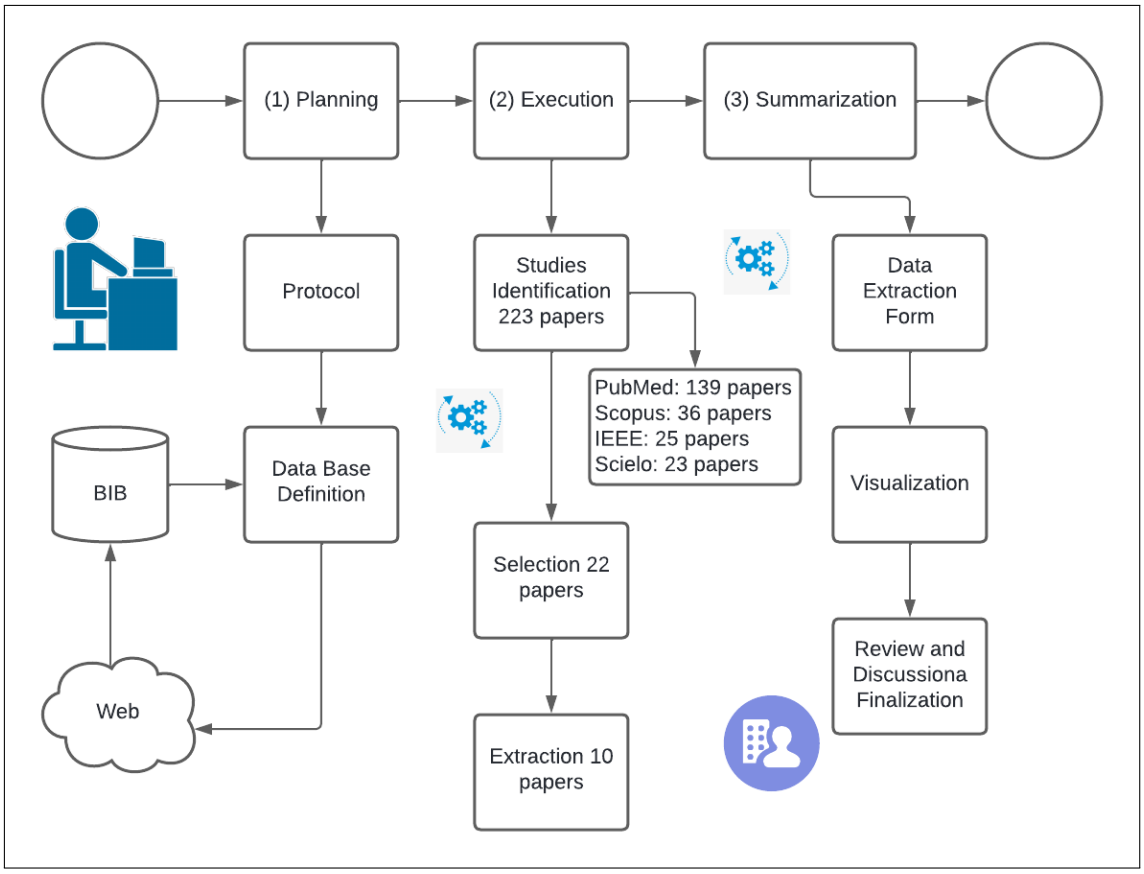

Figura 1. Process for carrying out a systematic literature review, the doll icons represent the manually executed parts, while the other parts represent the automatic executions.

frequently addressed with children with ASD in the classroom? (P4) What barriers and challenges are faced in the implementation and use of assistive technologies in inclusive educational contexts? (P5) What are the best practices and strategies for the effective integration of assistive technologies in the inclusive education of children with autism?

2.1.1. Protocol

The planning phase includes the sub-stage of creating the research protocol to be used for the execution of the SLR. We adopted the following databases as search tools: Scielo, IEEE, Scopus, and PubMed. Thus, the search string was defined as "(Asperger's syndrome OR autism OR autism spectrum disorder) AND (inclusion process OR inclusive apps OR inclusive education OR inclusive learning OR inclusive pedagogical practices OR inclusive strategies) AND (assistive features OR assistive technologies OR skills development OR educational apps OR serious games)" to capture all terms that correlate with the main keywords (in English) of the TAK (title, abstract, and keywords), considering only articles published between 2013 and 2022 (the last 10 years). Additionally, we created a form for data extraction to facilitate the discussion of results.

In this regard, we considered the following 12 items: (1) What is the concept of assistive technology according to the authors? (2) What was the overall objective of the research? (3) Type of research = Qualitative, Quantitative, Quali-quantitative (4) What is the population involved in the study? = [Early childhood education, Elementary education, High school, Technical education, Higher education, Youth and adult education, Special education] (5) Data collection technique = [Interviews,

Questionnaires, Observation, Focus groups, Journals and records, Panel interviews, Psychometric tests, Participatory techniques, Ethnographic interviews, Biometric data collection, Others, No collections] (6) What countries are the authors of the article from? (7) What was the research method? = [Case study, Experimental research, Non-experimental research, Field research, Laboratory research, Action research] (8) What barriers and challenges are faced in the use of assistive technologies? (9) What are the benefits and best practices in using assistive technologies in inclusive education? (10) What were the main assistive technologies presented in the article? (11) What are the outcomes of the article? = Positive, Negative, Neutral, Not mentioned (12) What were the main conclusions of the authors?

2.1.2. Database inclusion and exclusion criteria

The scientific search for articles was carried out in August 2023. All articles were then refined by StArt (which can be found and downloaded on the electronic device). In addition, at this stage the inclusion and exclusion criteria are defined. The inclusion criteria (IC) were: (IC1) Articles published between 2013 – 2022, (IC2) Articles published in English, (IC3) Peer-reviewed articles, (IC4) Articles within the context of education, (IC5) Full articles and (IC6) Primary studies. The exclusion criteria (EC) considered were: (EC1) Articles outside the time frame, (EC2) Summary articles, (EC3) Non-peer-reviewed articles, (EC4) Articles not in English, (EC5) Gray literature studies and (EC6) Studies outside the scope.

2.2. Execution

The execution phase was divided into 3 distinct parts: (i) identify the studies, (ii) select the articles by reading the TAK through the inclusion and exclusion criteria assessment. Finally, (iii) extract articles based on their complete reading. Each of these phases will be detailed in the following subsections.

2.2.1. Study identification

In the study identification phase, the four databases chosen for information extraction were selected, totaling 223 resulting articles according to the items described in the protocol. Initially, duplicate articles were identified across the databases, as illustrated in Figure 2. This redundancy required careful examination to ensure the integrity of our dataset.

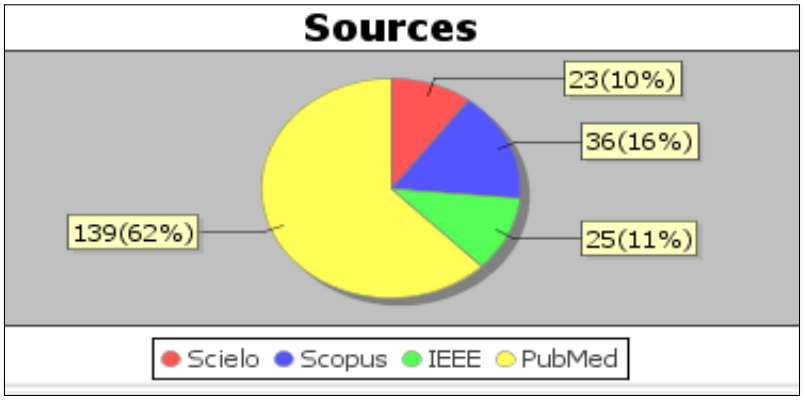

Figura 2. Databases used in SLR.

2.2.2. Selection

After identifying the 223 articles, the selection stage with greater refinement in the classification of articles is carried out. In this stage, illustrated as in Figure 3, 22 articles (10%) were accepted based on the inclusion criteria, 194 articles (87%) were rejected based on the exclusion criteria and 7 articles (3%) were duplicates, although the title was different, the duplication was detected manually. Thus, of the 22 articles selected as accepted, the reading priority was characterized as: very high, high, low and very low. All accepted articles had an automatic evaluation Score by the StArt tool. As well as the configuration to evaluate each article with a score between (0 - 5) for each time the keywords of the search string appeared in the TAK (being, T = 5, A = 3, K = 2 points) for each item.

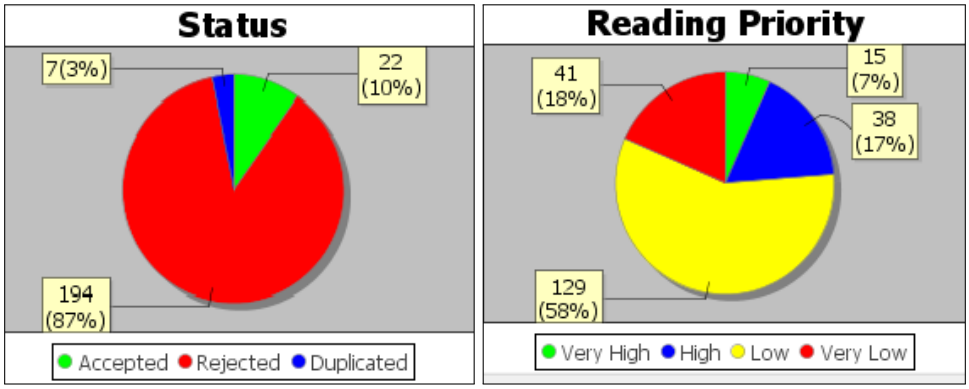

Figura 3. RSL selection status and reading priority.

2.2.3. Extraction

The extraction stage can be seen in Figure 4. In this case, of the 223 articles, only 22 were selected in the previous stage, serving as input for the final extraction stage. As a result, a total of 10 articles (45%) were accepted in the extraction stage and 12 articles (55%) were rejected in this stage. For the reading priority stage, the StArt values were configured (the same as in the selection stage). In this phase of the work, which consists of extracting articles with high, very high, low and very low priority in this stage, they were read in full, so that the summarization could begin. Thus, the fields of the data extraction form were filled out based on the reading of each of the articles and saved in the StArt platform.

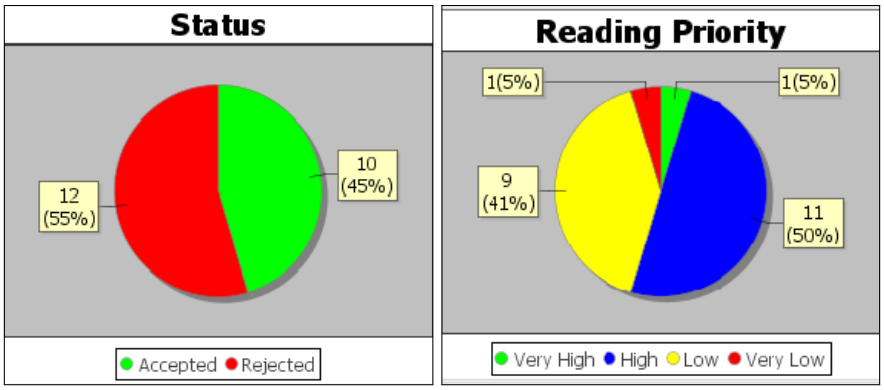

Figura 4. RSL extraction status and reading priority.

2.3. Summarization

In this last stage of the methodology, we can see that the 10 accepted articles had their studies carried out in different countries, as shown in the Figure 5. The green and red colors highlighted on the world map represent the nationalities of the research, which cover North America, Europe, Africa and Asia. We highlight a word cloud, as shown in

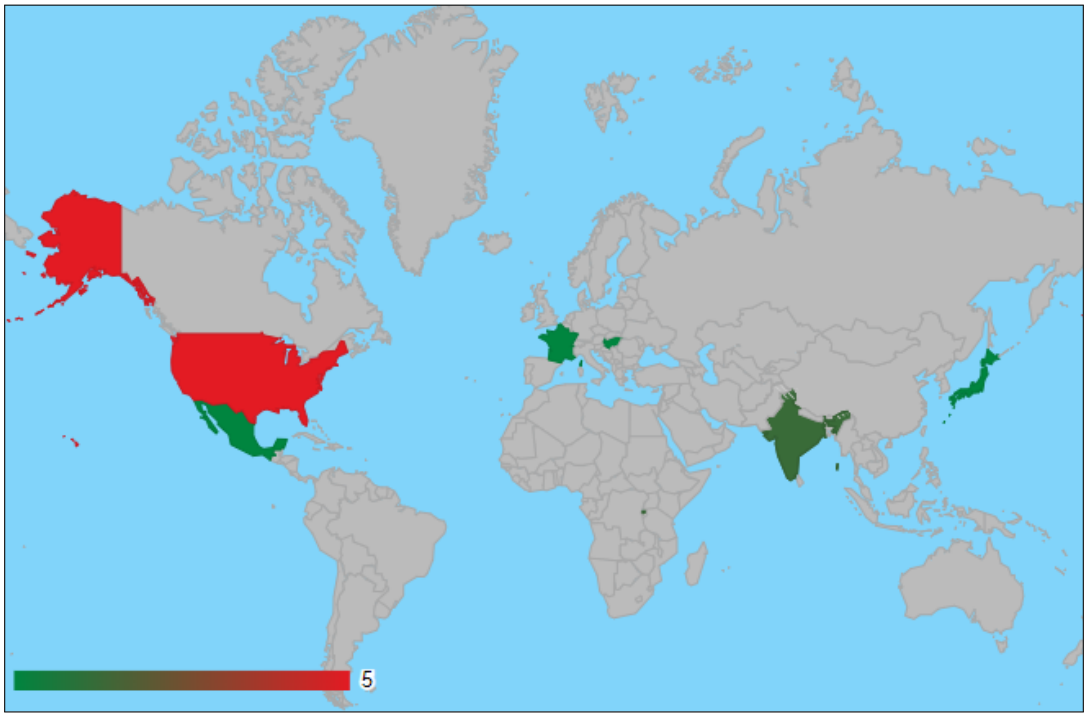

Figura 5. Map of countries extracted from RSL.

Figure 6 as a way of presenting the content items of abstracts of articles accepted in the extraction phase.

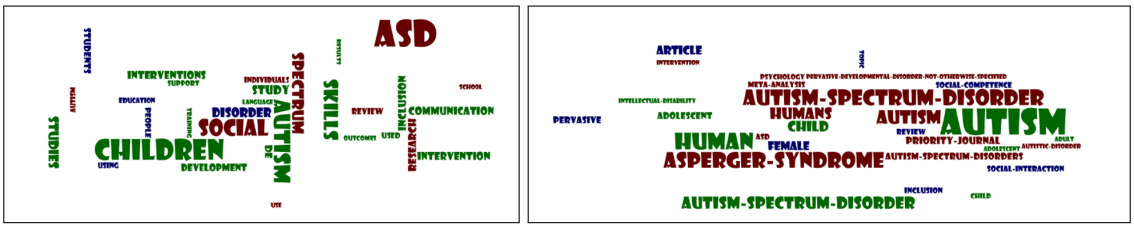

Figura 6. Word cloud of RSL articles.

The Table 1 below presents important data from each of the 10 articles and a brief summary of each. Each column represents data from the articles: (a) Article ID, (b) Authors, (c) Year of publication, (d) Country where the study was conducted, (e) StArt score, (f) Reading priority, (g) Article approach and (h) Overview. The rows in the table demonstrate that the years 2017 and 2019 are tied in number of studies, both with 3 studies each produced. In addition, it is worth noting that all articles had a positive approach.

2.3.1. Discussion and results

In this section, we will present the analyses of each of the selected articles based on the SLR methodology, according to the order in Table 1 above.

Article (1) by (Leme; Oki and Suzuki, 2021) presents a portable interactive projection device to visually support children with Autism Spectrum Disorder (ASD).

Tabela 1. Summarizing of results considering the articles were extracted and results of StArt.

ID	AUTHORS	YEAR	COUNTRY	SCORE	PRIORITY	OVERVIEW
1	Leme; Oki and Suzuki	2021	Canadá	6	Low	Positive
2	Vullamparthi *et al.*	2013	Índia	8	High	Positive
3	Singh; Mathur and Hasteer	2019	Índia	16	High	Positive
4	Hulusic and Pistoljevic	2017	France, USA	28	Low	Positive
5	Carreño-León *et al.*	2020	México	11	High	Positive
6	Ntalindwa *et al.*	2021	Rwanda	4	High	Positive
7	Yakkundi *et al.*	2017	Irlanda do Norte	10	Low	Positive
8	Watkins *et al.*	2019	EUA	12	Low	Positive
9	Mengoni *et al.*	2017	Reino Unido	0	Low	Positive
10	Ntalindwa *et al.*	2019	Rwanda	12	High	Positive

This device addresses challenges like limited communication and social interaction. Its effectiveness was tested in a simulated environment, utilizing a projector, fish-eye lens camera, and facial detection software. Twelve tests assessed facial detection stability under varying lighting and mask usage. The device shows promise for interactive support, but its success hinges on ongoing software improvements and user-specific adaptations. Article (2) by (Vullamparthi *et al.*, 2013) explores Augmented Reality (AR) as an educational tool for children with autism and mild intellectual disabilities. Implemented in 12 special schools in Andhra Pradesh and Bangalore, the AR-based content aims to enhance engagement and personalization in learning. The study highlights innovative applications but also notes the need for improved 3D model support and usability enhancements. Article (3) by (Singh; Mathur and Hasteer, 2019) focuses on the Android application AutistiCare, designed for children with ASD aged 4 to 12. It offers a fun learning platform with health tips and recipes, featuring functionalities like Our Surroundings, Fun Learning, Relaxation Videos, and Health Care. AutistiCare is beneficial for developing motor skills, and future updates could include GPS tracking and caregiver accounts for better activity management.

Article (4) by (Hulusic and Pistoljevic, 2017) details a curriculum developed for final-year Computer Science (CS) students focused on creating serious games for children with Autism Spectrum Disorder (ASD). Tested in special education centers, these games were effective, highlighting technology's potential in education for children with disabilities. The curriculum serves as a model for other CS courses and could have socioeconomic impacts, especially in resource-limited countries. Article (5) by (Carreño-León *et al.*, 2020) describes a technological prototype that supports learning for children with autism through tangible user interfaces (TUI) and gamified applications. Evaluated by special education experts and tested with an autistic child, the prototype showed positive results, proving to be an innovative tool for educators and therapists.

Article (6) by (Ntalindwa *et al.*, 2021) discusses using information and communication technologies (ICT) to aid children with ASD in low- and middle-income countries, specifically through a mobile app designed to enhance numeracy skills in Rwanda. Involving 40 children with ASD, 5 teachers, and 10 parents, the study emphasizes community involvement in developing educational tools and suggests the app could improve children's numerical skills and support a competency-based curriculum. Article (7) by (Yakkundi *et al.*, 2017) examines user-centered reading interventions for individuals with autism and intellectual disabilities (ID). It addresses their challenges in reading comprehension and advocates for appropriate academic instruction. The authors recommend Applied Behavior Analysis (ABA) principles as effective pedagogical tools,

concluding that ABA-based interventions and computer-assisted programs like HER improve reading and comprehension skills for this population.

Article (8) by (Watkins *et al.*, 2019) examines whether structured, interest-based interventions with adult guidance can enhance social interactions between children with ASD and their typical peers. Involving four children with ASD and four typical children, the study found that interest-based activities effectively fostered social engagement in inclusive settings. Article (9) by (Mengoni *et al.*, 2017) investigates the feasibility of a randomized clinical trial to assess the impact of a robot-assisted intervention (Kaspar) on social skills in children with ASD. The study involved 40 children aged 5 to 10 and included six weekly sessions focused on games that promoted joint attention, imitation, turn-taking, and collaboration. The findings suggest that using a humanoid robot could significantly enhance social skills and inform clinical practices and health policies. Finally, article (10) by (Ntalindwa *et al.*, 2019) discusses the rising prevalence of Autism Spectrum Disorder and the role of information and communication technologies in educating children with ASD in Rwanda. This qualitative study involved 54 participants (teachers, parents, and students) and concluded that integrating ICT into Rwandan schools is crucial for supporting children with ASD, along with raising awareness and motivating teachers to reduce stigma and improve inclusion.

3. Interpretation of results

The final phase of the RSL included 10 scientific articles, considering the theme of inclusive education and assistive technologies for autistic people. Based on the research objects and their results, it can be concluded that all the technologies presented, when used appropriately, provide benefits that help improve the cognitive ability, learning and social interaction of the autistic population. Correlating the authors Ntalindwa *et al.* and Singh; Mathur and Hasteer, both address mobile applications for children with ASD and see this positive technology, emphasizing the importance of a collaborative approach between professionals and the community, always attentive to adapting to the specific needs of these children. Authors Carreño-León *et al.* and Leme; Oki and Suzuki Leme compare their research on interactive programs as a tool to support learning for children with ASD. Despite using more advanced technology, both highlight technological diversity and its importance for the innovation of effective and accessible educational tools. Mengoni *et al.* and Vullamparthi *et al.* link their research on augmented reality and robot-assisted therapy. These two techniques have qualifying attributes to support teaching and skill development in children with ASD. These technologies enhance traditional methods by offering new models of engagement and interactive learning for this audience.

Following the authors Watkins *et al.* and Yakkundi *et al.*, the two investigate interventions for reading and social interaction in children with ASD. Both use Applied Behavior Analysis (ABA) as a basis and recognize the role of technology (computer-assisted instruction and use of iPads) as a facilitator. Finally, Hulusic and Pistoljevic and Ntalindwa *et al.* highlight technologies as educational support; both studies highlight that children with ASD have a greater affinity with technological devices, such as games and videos, than with traditional social or playful activities. They also emphasize the importance of adapting technological content to the cultural and linguistic context of children. Despite financial barriers and the lack of infrastructure in schools, these technologies are seen as a powerhouse for education. This RSL concludes that reconciling inclusive education with assistive technologies enhances the educational experience for students with autism. Continuous adaptation of these practices is essential due to various factors that require personalized teaching.

3.1. Answers to research questions

Technical support and assistive technologies in the teaching-learning process of children with ASD are relevant tools that can significantly improve the quality of life and educational experience of these children, promoting inclusion and the right to socialization. Currently, there are several technologies designed for use in the classroom, ranging from simple applications to advanced augmented reality and robotics devices. The skills most worked on in children with ASD generally include social interaction, communication and behavior skills, as well as motor and academic skills. It is worth noting that these are individualized approaches adapted to the specific needs of each child. The barriers and challenges to implementing these technologies are diverse, but we highlight the lack of financial resources, inadequate infrastructure and lack of training and qualification of personnel, as well as the fear of developing content. This intensifies the challenges in using these instruments, such as: acceptance, adaptation, perceptions, personalization and expectations. Therefore, it is necessary to outline strategies to overcome these barriers, such as adopting public policies, acting to comply with accessibility/inclusion in public environments and carrying out actions to promote professional training and development. The effective integration of assistive technologies in the inclusive education of children with ASD involves the adoption of several practices and strategies, from the perspective of carrying out a prudent individualized assessment, with an appropriate selection of methodology, according to the knowledge of the students. The typification and monitoring of the progress of these students must be incorporated into the lesson plans so that there is a measurement of evolution. In addition, the inclusive environment must receive support and regular maintenance of the tools so that their development and continuous learning is executable.

3.2. Limitations

A significant limitation of the SLR is the short period of the included studies, covering only the last ten years (2013-2022). Focusing on recent research ensures the relevance of the results, but may exclude important previous studies that provide fundamental information or show long-term trends. Furthermore, the distribution of studies in this period is uneven, with only one study published in 2013 and more in 2017 and 2019, with three publications each. This incongruent distribution may introduce distortions and affect the comprehensiveness of the review. The lack of studies in certain years may indicate gaps in research or in publication patterns, relevant to understanding the evolution of the topic. Another deficiency is the lack of studies in South America, especially Brazil. This may be caused by the choice of language when creating the search string. Therefore, although the chosen time frame provides a focused view of recent developments, it may limit the depth and breadth of the SLR's conclusions.

4. Conclusions

Given the results of this RSL, it is concluded that the use of assistive technologies in inclusive education has a positive impact on the learning and social interaction of children with autism. The studies analyzed demonstrate that when these technologies are applied appropriately, they offer benefits that contribute to cognitive development, improvement of learning skills and improvement in the social interaction of this group. However, it is important to highlight the need for investment in these assistive instruments, which ranges from the financial and intellectual basis to their methodological application with professionals and students. In the future, this study will need to be adapted to the Brazilian context, since there is no specific research that addresses the local reality.

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