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Inclusive education through technology: a systematic review of types, tools and characteristics

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Technologies that contribute to inclusive education are digital tools and specialized devices that facilitate equitable access to learning for students with diverse abilities. Understanding these technologies allows for the personalization of teaching methods, the removal of barriers that limit participation for students with differences, and the promotion of a more accessible and equitable educational environment for all. This study aims to identify and analyze practices and technologies that foster the participation of students with diverse needs. A systematic review was conducted following PRISMA guidelines, gathering responses to the research questions from 159 studies. The Scopus database was utilized, with three blocks of keywords related to technology, inclusion, and education. The findings indicate that educational technologies transform the learning environment into a more inclusive and accessible one by adapting to the diverse needs of students. Tools such as mobile devices, interactive applications, and augmented reality help to remove barriers for students with disabilities or in various contexts, facilitating personalized and equitable learning. Additionally, these technologies promote the development of critical skills and encourage collaboration among students, enriching both their academic training and social integration. Thus, technological inclusion becomes a key factor in maximizing the potential of each student within a diverse educational system.

KEYWORDS

education, accessibility, inclusion, technological tools, hardware, software

1 Introduction

For Throughout history, educators have sought to develop inclusive learning societies, reconfiguring both their content approaches and pedagogical methods to improve accessibility. This constant adaptation has become an essential mindset and a fundamental mechanism that impacts not only students but also learning structures and society at large. Adaptive learning practices, designed to address the diverse needs of personal knowledge, play a crucial role in fostering inclusive participation (Mihovska et al., 2021). Given that each person learns differently and that students' needs evolve in response to technological disruptions, it is imperative to continuously adjust knowledge dissemination practices to effectively respond to these changes.

In recent years, educational reform has highlighted the importance of including all students in regular classrooms and redesigning the educational process to meet their individual needs. Inclusion, understood from the perspective of social justice and equality, involves integrating students with special educational needs into regular schools, ensuring their active participation in all educational aspects and the resulting social interactions (Karagianni and Drigas, 2023a).

Inclusive education aims to ensure that all students have access to education by adapting to their diverse needs, including those of individuals with special requirements (Buenaño-Barreno, 2024). It is based on several fundamental principles, among them that the intrinsic value of each person in modern society does not depend on their abilities or achievements; and that individuals with disabilities or special educational needs should be integrated into the educational environment (Shmeleva and Litovchenko, 2022).

Some research indicates that educational technology (ET) is a valuable tool for differentiating teaching, facilitating learning, and promoting inclusion in educational settings. Merzon et al. (2022) state, the use of digital educational technologies as a means to develop technical skills opens up broad opportunities for teachers and students, especially when it comes to inclusive education. A teacher acquires technological competence when they can understand, manage, and use digital environments to develop and disseminate their knowledge (González and Estrella, 2023).

Inclusive learning environments aim to integrate all students into the educational process, regardless of their individual differences. Their purpose is to ensure that each student has access to equitable educational experiences, respecting diversity and promoting participation without restrictions, while considering their diverse needs and learning preferences (Ghosh et al., 2022).

The use of educational software creates a dynamic learning environment, with diverse content and authentic situations that connect students to the real world, fostering active and independent learning, and allowing personalized adjustments to meet each student's needs and preferences. Additionally, technology enhances children's engagement, concentration, and learning curve (Demetriou, 2023).

Creating inclusive spaces in classrooms involves more than administrative adjustments; educators must develop pedagogical approaches that recognize and accept students' individual differences. This encourages collaboration and learning through "critical creation" in the classroom (Fernandez, 2021). As Marimuthu and Cheong (2015) mention, inclusive education depends on positive beliefs and the commitment of professionals, who must value and respect students, acknowledging that, with adequate support, students with disabilities can exceed expectations. By preparing these students for their integration into society, inclusive education has the power to transform social mindsets and promote a paradigm shift, improving their social adaptation and financial well-being through vocational training and employment.

Technology plays a crucial role in skill development for students, facilitating learning, social interaction, play, and collaboration (Berrones-Yaulema and Buenaño-Barreno, 2023). However, while students enjoy using digital media, they also show interest in real-world activities, highlighting the importance of balancing both environments. Integrating digital technology from an early age is essential for developing digital literacy and fostering inclusion and participation in the digital age. In the context of inclusive education, especially for students with disabilities, technology takes on an even more significant role (Desideri et al., 2023). The use of conventional and assistive technologies has become central in schools, helping to reduce the impact of disabilities and learning difficulties, and promoting the participation of all students in creativity, learning, and play.

"E-inclusion" pedagogy focuses on teachers' decisions to provide students with innovative learning methods and alternative means for completing their tasks, using technology in educational activities. Students with disabilities may need assistive technology to leverage their strengths and compensate for their weaknesses. Inclusive education must consider these needs for all children with disabilities. An assistive technology device can be any item, equipment, or system used to enhance a child's functional abilities. Moreover, students need training on how to use their devices (Draper, 2024).

In the context of educational technology for inclusion, the systematic review by Lynch et al. (2024) addresses the use of educational technologies to support children with disabilities in primary schools in low- and middle-income countries. This study highlights a significant disparity in the evidence base among different types of disabilities, with a focus predominantly on sensory disabilities in specialized school environments. It emphasizes the need for more inclusive and participatory research that integrates intersectional factors such as gender and geographical location, to develop technological solutions that meet the needs of all students with disabilities.

On the other hand, Toto et al. (2024) explore, through another systematic review, the impact of emerging technologies on inclusive teaching practices. They focus on the experiences of educators who have implemented innovative teaching methodologies supported by advanced technologies, such as Assistive Technology, Augmented Reality, and Artificial Intelligence. The findings suggest that these technologies can significantly enhance the inclusive educational experience, creating a more effective and engaging learning environment for all students, including those with disabilities. Although the number of publications on these technologies has increased, there is recognized need for further research in certain areas.

Furthermore, Salas-Pilco et al. (2022) reviewed 27 studies on the application of artificial intelligence and new technologies in inclusive education for minority students in regions such as the United States, Colombia, and China. The findings underscore that these technologies enhance accessibility and customization of learning, facilitating the integration of students from diverse sociocultural backgrounds. However, they face challenges such as resource scarcity and the need for adequate teacher training. The study recommends that future research should extend to more minority groups and examine emerging technologies, highlighting the importance of including educators' perspectives in the design of inclusive practices.

Additionally, Lawan et al. (2023) conducted a systematic review focused on assessing the efficacy of emerging technologies in inclusive education for students with Autism Spectrum Disorder (ASD). Through the analysis of 36 articles, they identified various technological interventions, such as mobile apps, educational robots, and augmented reality, that have proven useful in supporting these students in inclusive environments. The study emphasizes the importance of developing cost-effective and practical solutions for implementing these technologies in educational contexts, especially in resource-limited countries.

As the literature suggests, technology is currently a fundamental part of development and inclusivity for individuals, making it essential to comprehensively understand how technological tools are being implemented to support inclusion in educational settings. This research aims to identify, analyze, and synthesize existing evidence on practices and technologies that have proven effective in promoting the participation of students with diverse needs, as well as to contribute to closing knowledge gaps and identify areas where further research is needed, thereby guiding the development of future educational innovations. To address these objectives, the following research questions are proposed:

> RQ1. What are the main types of inclusion presented in the literature?
>
> RQ2. What are the most commonly used technologies in educational settings to promote inclusion?
>
> RQ3. What are the characteristics of the technologies identified in the literature for inclusive learning?
>
> RQ4. How are the diverse inclusion needs of students addressed through the use of technological tools?

2 Materials and methods

The methodology of this systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a rigorous and transparent process (Page et al., 2021). First, the inclusion and exclusion criteria for selecting relevant studies were objectively defined. Subsequently, a search was conducted in recognized academic databases using keywords related to technologies for inclusive learning. The identified studies were evaluated in multiple stages, including duplicate removal, title and abstract screening, and full-text review. Finally, data from the selected studies were extracted and analyzed to synthesize the available evidence and identify trends, knowledge gaps, and areas for improvement in the use of technologies for educational inclusion.

2.1 Eligibility criteria and information sources

For data collection, the Scopus database was selected as the source of information due to its recognition in collecting high-impact studies across various disciplines worldwide. Scopus is known for its extensive coverage and rigorous selection of scientific publications, ensuring that the included studies are relevant and of high quality (Table 1).

TABLE 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• Scopus database included. • Scientific articles, conference papers, and book chapters. • Studies from the last 5 years (2019–2024). • Studies published in any language.	• Duplicate studies. • Studies with conflicts of interest. • Books. • Studies with retraction letters or errata. • Studies that do not address at least one research question.

The inclusion criteria for this search are as follows: documents available in the Scopus database were considered, specifically scientific articles, conference papers, and book chapters. Studies published in the last 5 years (2019–2024) were included to ensure that the information is up-to-date and reflects recent developments in the field. Additionally, studies in any language were accepted to avoid limiting the search to a single language and to gain a broader perspective on the topic.

On the other hand, duplicate studies were excluded to avoid redundancies and ensure the originality of the analyzed data. Studies with conflicts of interest, books (to focus on more specialized publication formats), and those containing retraction letters or errata were also excluded, as these compromise the validity of the results. Moreover, studies that did not address at least one established research question were not included, ensuring that the selected documents are relevant to the research objectives.

2.2 Search strategies

The search process was conducted in the Scopus database, following predefined inclusion and exclusion criteria to ensure the relevance of the retrieved documents. The search strategy was organized into three main thematic blocks. The first block addressed the area of technology, the second focused on education, and the third block was oriented toward inclusion. The objective of this search structure was to ensure that the identified studies contained relevant information on the use of technology in the context of inclusive education.

Initially, a preliminary search was conducted in Scopus, setting the parameters so that the article titles included these three essential keywords. From the results obtained, we employed R Studio software to perform a text analysis and generate a keyword cloud. This cloud helped to identify additional terms frequently associated with our key terms, reflecting current trends and approaches in research. Based on this analysis, a second, more refined search string was formed, incorporating these new keywords to broaden and refine the search for relevant studies. The combination of these blocks enabled the creation of a search string that identified a total of 228 pertinent documents up to January 8, 2025. The search string was as follows:

(TITLE (tools OR technologies OR technology OR technological) AND TITLE (learning OR students OR education) AND TITLE (inclusive OR inclusivity OR diversity OR equity)) AND PUBYEAR >2018 AND PUBYEAR <2025 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ch"))

2.3 Study selection and data extraction process

The study selection and data extraction process were carried out in several stages. First, the studies retrieved from the Scopus database were individually evaluated through the analysis of their titles, abstracts, and keywords. This initial analysis aimed to identify those studies that primarily focused on the research topic and could provide answers to the research questions posed in the study.

Out of the 197 studies initially selected, 171 were accessible for a full content analysis. During this detailed analysis, 12 studies were

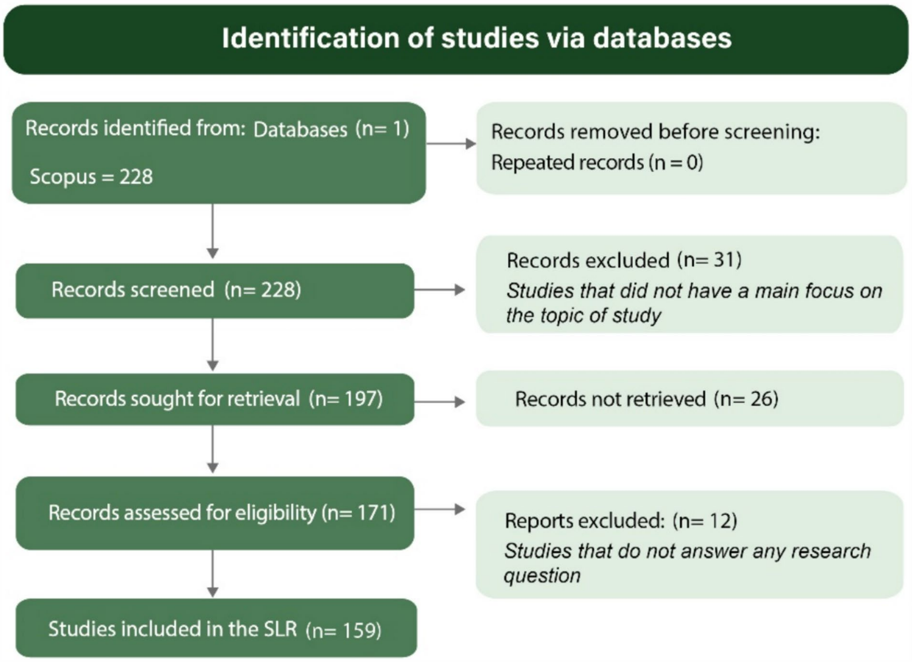

FIGURE 1
PRISMA flow diagram of the study selection process.

excluded as they did not address any of the formulated research questions, resulting in a final sample of 159 studies (see Figure 1). From these studies, the necessary characteristics and data were extracted to adequately answer the research questions.

2.4 Risk of bias assessment

The risk of bias assessment was conducted using a systematic approach to ensure the validity and reliability of the included studies. In this process, all four authors actively participated in the analysis, arbitration, and selection of each study. Standardized criteria were first applied to identify potential sources of bias, including methodological quality, transparency in reporting results, and the presence of conflicts of interest. Each study was individually evaluated by the authors, who discussed and reached a consensus on the evaluations to minimize the influence of personal or methodological biases.

The arbitration process was essential for conducting an impartial evaluation and selection. Disagreements among the authors were resolved through discussions and complementary reviews, ensuring that each study was evaluated fairly and objectively. The collective participation of all four authors enabled a rigorous assessment, significantly reducing the risk of bias and ensuring the quality and credibility of the studies included in the analysis.

2.5 Synthesis methods

The synthesis methods were carried out using an Excel matrix, which allowed for a systematic and efficient organization of the collected data. Through a detailed analysis of each study, the responses to the research questions were extracted and classified. These included the types of inclusion presented in the literature, the technologies used in educational settings to promote inclusion, and the characteristics and functions of the technologies identified for inclusive learning. Additionally, an evaluation was conducted on how these technological tools address the individual needs of students with various types of disabilities.

It is important to note that many studies did not focus on a single tool, characteristic, or approach to inclusion, but rather addressed multiple aspects. Therefore, the results were categorically presented in the analysis, thus facilitating their understanding. This categorized structure enhances the clarity of the presented information and provides an informative basis for its application in the development of strategies and practices for inclusive education. By presenting the information in this way, it ensures that readers can use it effectively to advance the implementation and improvement of inclusive education.

3 Results

3.1 RQ1. What are the main types of inclusion presented in the literature?

Educational inclusion is a broad and multifaceted concept, with each examined study addressing different forms of inclusion based on its specific context and focus. Some studies concentrate on the inclusion of students with disabilities, while others highlight the importance of including people of different ages, genders, nationalities, customs, or health conditions (see Figure 2). Given that inclusion can manifest in various ways, it is essential to identify the different types of inclusion covered in the literature to gain a more comprehensive understanding of the concept (see Table 2).

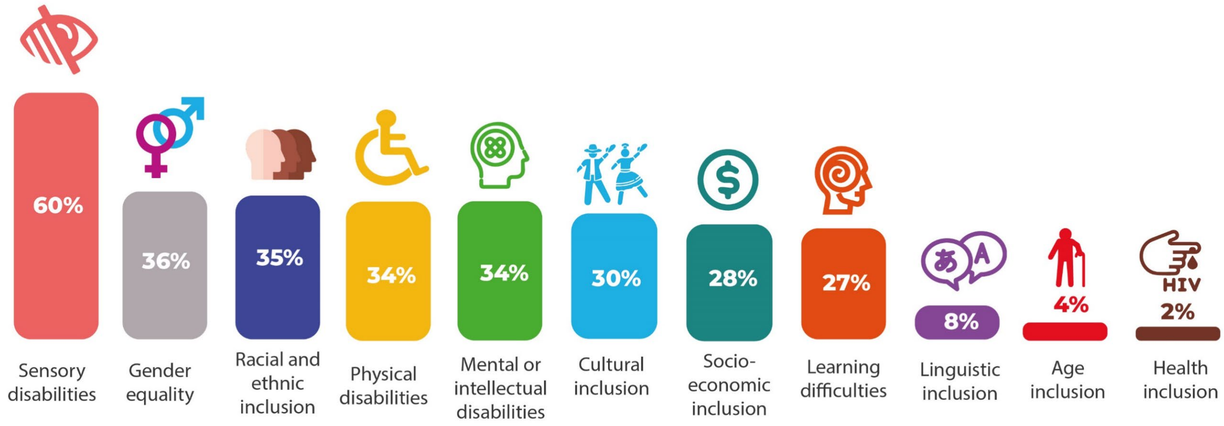

FIGURE 2
Types of inclusion identified in the studies.

This will provide insight into the breadth of what educational inclusion entails in its entirety.

The analysis of inclusion approaches in the literature highlights that sensory disabilities (60%) and gender equality (36%) are the most frequently mentioned topics, followed by racial and ethnic inclusion (35%), physical disabilities (34%), mental or intellectual disabilities (34%), and cultural inclusion (30%). These categories emphasize the need to adapt educational and social environments for individuals with sensory, mobility, or cognitive development limitations, providing equitable opportunities regardless of gender. They also advocate for valuing diversity in classrooms and social settings, actively integrating different races and ethnicities to foster an environment of mutual respect and intercultural understanding.

Additionally, socioeconomic inclusion (28%) aims to remove barriers caused by poverty, ensuring equality of resources. Learning difficulties (27%), linguistic inclusion (8%), age inclusion (4%), and health inclusion (2%) are also highlighted, underscoring the importance of equitably integrating individuals across multiple languages, all ages, and those with chronic health conditions. This comprehensive approach to inclusion reflects the importance of removing barriers to ensure a truly equitable and accessible environment.

3.2 RQ2. What are the technological tools used in educational settings to promote inclusion?

Technology plays a fundamental role in creating more inclusive educational environments, allowing students with diverse needs to access learning equitably. It is crucial to identify both software and hardware tools that have proven effective in this context, as they can facilitate personalized teaching and adaptation to different types of disabilities, learning styles, and access barriers. Understanding the available technologies broadens the possibilities for inclusion and provides educators and educational policymakers with the necessary tools to create truly inclusive and accessible learning environments for all students (Table 3).

The technological tools used in educational settings for inclusion offer multiple benefits by adapting to the diverse abilities of students, significantly enhancing their participation and learning. Physical and sensory accessibility tools, such as electronic Braille displays, adapted keyboards, and alternative mice, facilitate access to educational content for students with visual or physical disabilities, allowing for smoother interaction with the digital environment (see Figure 3). Assistive devices, such as voice output systems or robotic gloves, provide autonomy to those with motor limitations, promoting their integration in the classroom.

Accessibility software, such as screen readers and text-to-speech applications, expands learning opportunities for students with visual, auditory, or cognitive disabilities, improving their ability to process and use educational information. These tools ensure equitable access to content and foster independence in the learning process.

Educational tools, such as mobile devices, tablets, and robotics, promote personalized and adaptive learning by tailoring content to the individual needs of students. This not only enhances their understanding and retention of knowledge but also increases their motivation and active participation in the educational process.

Interaction and collaboration tools, such as digital whiteboards and augmented reality technologies, enrich the educational environment by providing immersive and visual experiences, making learning more dynamic and engaging for all students. Additionally, online collaboration platforms facilitate teamwork and communication, even remotely, which is particularly useful for those with physical or geographical limitations.

Communication technologies like Zoom and augmentative and alternative communication (AAC) devices enable students with communication challenges to interact and participate actively in the classroom. Educational games, meanwhile, combine entertainment and learning, helping to develop skills in a playful and accessible way.

3.3 RQ3. What are the characteristics of the technologies identified in the literature for inclusive learning?

Understanding the particular features of these technological tools is essential for educators to identify and select those that are most suitable for different types of inclusion. This knowledge allows

TABLE 2 Types of inclusion.

Inclusion approaches	Studies	Total	Percentage
Sensory disabilities: Limitations in one or more senses, such as vision, hearing, or speech.	Kuvshinova et al. (2019) Olivares Granados et al. (2019), Raja and Giannoumis (2019), Rasool and Smith (2019), Shestakevych et al. (2019), Chambers (2020), Du and Meier (2020), Ellis (2020), Houston-Wilson and Lieberman (2020), Rodrigo-Martín et al. (2020), Uygur et al. (2020), Wen and Castek (2020), Cruz et al. (2021), Espinosa-Castaneda and Medellin-Castillo (2021), Fernandez (2021), Gandolfi et al. (2021), Izario et al. (2021), Srivastava et al. (2021), Tomczyk et al. (2021), Tyutryumova and Pomytkina (2021), Yaskevich (2021), Alhabahbe and Alhadidi (2022), Krasnopevtseva et al. (2022), Kristén et al. (2022), Merzon et al. (2022), Palla and Vallberg Roth (2022), Rosado-Castellano et al. (2022), Sarsenbayeva et al. (2022), Shmeleva and Litovchenko (2022), Al Omoush et al. (2023), Albalhareth and Saleem (2023), Drushlyak et al. (2023), Geering and Hayhoe (2023), Karagianni and Drigas (2023a), Karagianni and Drigas (2023b), Maćkowski et al. (2023), McDonald et al. (2023), Nasyrova and Muller (2023), Richter et al. (2023), Rocha et al. (2023), Şahin et al. (2023), Tejera et al. (2023), Valdivieso and Jadán-Guerrero (2023), Yenduri et al. (2023), Acosta-Vargas et al. (2024), Alkeraida (2024), Bulathwela et al. (2024), Draper (2024), Fälth and Selenius (2024), Ge et al. (2024), Grindei et al. (2024), Horna-Saldaña et al. (2024), Horna-Saldaña and Canaleta (2024), Layachi and Pitchford (2024), Mariappan et al. (2024), Montoya et al. (2024), Puentes et al. (2024), Ramírez-Montoya et al. (2024), Šumak et al. (2024), and Toto et al. (2024)	60	43%
Gender equality: Equal opportunities, rights, and treatment in all areas of life, regardless of gender.	Asongu et al. (2019), Asongu et al. (2021), Grindei et al. (2019), Kross and Guo (2019), Lusigi (2019), Orser et al. (2019), Lim et al. (2020), Mawasi et al. (2020), Rodrigo-Martín et al. (2020), Uygur et al. (2020), Waizmann et al. (2020), Wen and Castek (2020), Brown et al. (2021), Ekeng-Itua et al. (2021), Gandolfi et al. (2021), Mihovska et al. (2021), Sandoval et al. (2021), Zeagler et al. (2021), Abiolu et al. (2022), Gordon and Leutenegger (2022), Knestis et al. (2022), Lee (2022), Sarsenbayeva et al. (2022), Burbage et al. (2023), Chawla and Sharma (2023), Gweshe and Chiware (2023), Kim and Higgs (2023), Richter et al. (2023), Tejera et al. (2023), Weisberg and Dawson (2023), Ydesen and Elfert (2023), Boatright et al. (2024), Bulathwela et al. (2024), Ge et al. (2024), Mosier et al. (2024), and Ruel and Tajmel (2024)	36	26%
Racial and ethnic inclusion: Integration and equity of people from different races, ethnicities, or nationalities.	Kross and Guo (2019), Mayfield et al. (2019), Rasool and Smith (2019), Suzianti et al. (2019), Chiu and Lim, 2020, Kormos and Julio (2020), Lim et al. (2020), Mawasi et al. (2020), Rodrigo-Martín et al. (2020), Waizmann et al. (2020), Wen and Castek (2020), Brown et al. (2021), Ekeng-Itua et al. (2021), Gandolfi et al. (2021), Sandoval et al. (2021), Yaskevich (2021), Abiolu et al. (2022), Augusthian et al. (2022), Gordon and Leutenegger (2022), Knestis et al. (2022), Mavangere et al. (2022), Smeins et al. (2022), Higgins et al. (2023), Kim and Higgs (2023), Singh-Pillay (2023), Weisberg and Dawson (2023), Ajani (2024), Cobian et al. (2024), Ge et al. (2024), Kwawukumey et al. (2024), Mosier et al. (2024), Peruzzo and Allan (2024), Ruel and Tajmel (2024), Stepanova et al. (2024), and Sunny et al. (2024)	35	25%
Physical disabilities: Limitations in mobility or bodily function.	Asongu et al. (2019), Kuvshinova et al. (2019), Olivares Granados et al. (2019), Rasool and Smith (2019), Chambers (2020), Du and Meier (2020), Ellis (2020), Houston-Wilson and Lieberman (2020), Uygur et al. (2020), Cruz et al. (2021), Diolaiuti et al. (2021), Fernandez (2021), Gandolfi et al. (2021), Hunt (2021), Izario et al. (2021), Tomczyk et al. (2021), Kirupainayagam and Sutha (2022), Krasnopevtseva et al. (2022), Kristén et al. (2022), Rosado-Castellano et al. (2022), Sarsenbayeva et al. (2022), Shmeleva and Litovchenko (2022), Blavt et al. (2023), Drushlyak et al. (2023), Karagianni and Drigas (2023b), Nasyrova and Muller (2023), Richter et al. (2023), Tejera et al. (2023), Valdivieso and Jadán-Guerrero (2023), Yenduri et al. (2023), Acosta-Vargas et al. (2024), Bulathwela et al. (2024), Fälth and Selenius (2024), and Grindei et al. (2024)	34	24%
Mental or intellectual disabilities: Conditions that affect cognitive development, reasoning, and a person's intellectual abilities.	Kuvshinova et al. (2019), McMahon and Walker (2019), Olivares Granados et al. (2019), Vishnevsky et al. (2019), Chambers (2020), Dimitrova et al. (2020), Du and Meier (2020), Houston-Wilson and Lieberman (2020), Cruz et al. (2021), Izario et al. (2021), Rizvi et al. (2021), Sandoval et al. (2021), Collazo (2022), Costa et al. (2022), Kirupainayagam and Sutha (2022), Rosado-Castellano et al. (2022), Shmeleva and Litovchenko (2022), Shumilova et al. (2022), Utami and Palacios Hidalgo (2022), Vechkanova et al. (2022), Drushlyak et al. (2023), Kapieva et al. (2023), Lawan et al. (2023), Valdivieso and Jadán-Guerrero (2023), Yang et al. (2023), Yenduri et al. (2023), Acosta-Vargas et al. (2024), Alkeraida (2024), Blavt et al. (2024), Bulathwela et al. (2024), Fang et al. (2024), Grindei et al. (2024), Materazzini et al. (2024), and Toto et al. (2024)	34	24%
Cultural inclusion: Recognizing and valuing cultural diversity, beliefs, or customs in society.	(Chiu and Lim (2020), Rodrigo-Martín et al. (2020), Uygur et al. (2020), Sandoval et al. (2021), Tomczyk et al. (2021), Augusthian et al. (2022), Kirupainayagam and Sutha (2022), Sarsenbayeva et al. (2022), Chauhan and Anand (2023), Bulathwela et al. (2024), and Cobian et al. (2024)	30	22%

(Continued)

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TABLE 2 (Continued)

Inclusion approaches	Studies	Total	Percentage
Socioeconomic inclusion: Equality of resources and opportunities, eliminating barriers associated with poverty or social class.	Asongu et al. (2019), Grindei et al. (2019), Lusigi (2019) Orser et al. (2019) Rasool and Smith (2019), Kormos and Julio (2020), Mawasi et al. (2020), Rodrigo-Martín et al. (2020), Uygur et al. (2020), Wen and Castek (2020), Ekeng-Itua et al. (2021), Gandolfi et al. (2021), Liping (2021), Sandoval et al. (2021), Abiolu et al. (2022), Sarsenbayeva et al. (2022), Coker and Mercieca (2023), Higgins et al. (2023), Kim and Higgs (2023), Weisberg and Dawson (2023), Boatright et al. (2024), Ge et al. (2024), Gupta et al. (2024), Lin and Riccomini (2024), Peruzzo and Allan (2024), Ruel and Tajmel (2024), Sunny et al. (2024), and Šumak et al. (2024)	28	20%
Learning difficulties: Disorders that impact the ability to acquire and use academic skills, such as reading, writing, or performing mathematical calculations.	Chambers (2020), Chiu (2020), Du and Meier (2020), Houston-Wilson and Lieberman (2020), Kormos and Julio (2020), Cruz et al. (2021), Rojas Pernia and Haya Salmón (2021), Wood (2021), Alcívar et al. (2022), Collazo (2022), Costa et al. (2022), Merzon et al. (2022), Rosado-Castellano et al. (2022), Utami and Palacios Hidalgo (2022), Vechkanova et al. (2022), Barbetta (2023), Demetriou (2023), Drushlyak et al. (2023) Han and Shim (2023), Karagianni and Drigas (2023a), Seale (2023), Wu et al. (2023) Yenduri et al. (2023), Fang et al. (2024), Grindei et al. (2024), Layachi and Pitchford (2024), Materazzini et al. (2024), and Toto et al. (2024)	27	19%
Linguistic inclusion: promoting equality by respecting and utilizing diverse languages and accents.	Smeins et al. (2022), Garza (2023), Kim and Higgs (2023), Singh-Pillay (2023), Ajani (2024), Kwawukumey et al. (2024), Lin et al. (2024), and Stepanova et al. (2024)	8	6%
Age inclusion: Equitable participation of people of all ages, avoiding age-based discrimination.	Kross and Guo (2019), Sandoval et al. (2021), Tomczyk et al. (2021), and Geering and Hayhoe (2023)	4	3%
Health inclusion: Inclusion of individuals with chronic or specific health conditions, such as HIV, asthma, obesity, or diabetes.	Houston-Wilson and Lieberman (2020) and Abiolu et al. (2022)	2	1%

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TABLE 3 Inclusive technological tools.

Physical and sensory accessibility tools	Electronic braille displays	Raja and Giannoumis (2019), Du and Meier (2020), Ellis (2020), Izario et al. (2021), Srivastava et al. (2021), Yaskevich (2021), Alhabahbe and Alhadidi (2022), Albalhareth and Saleem (2023), Al Omoush et al. (2023), Drushlyak et al. (2023), Karagianni and Drigas (2023b), Maćkowski et al. (2023), Şahin et al. (2023), Fälth and Selenius (2024), and Puentes et al. (2024)
	Braille keyboard	Ellis (2020), Drushlyak et al. (2023), and Layachi and Pitchford (2024)
	Adapted keyboards	Olivares Granados et al. (2019), Drushlyak et al. (2023), Karagianni and Drigas (2023a) Karagianni and Drigas (2023b), and Fälth and Selenius (2024)
	BigKeys keyboard	Daems et al. (2023)
	Foot mouse, trackball	Drushlyak et al. (2023)
	Pointing devices	McDonald et al. (2023)
	Joystick	Fälth and Selenius (2024)
	BigTrack trackball	Daems et al. (2023) and Drushlyak et al. (2023)
	Optical pen for mouth control	Drushlyak et al. (2023)
	Voice output systems	Alhabahbe and Alhadidi (2022)
	Robotic gloves	Espinosa-Castaneda and Medellin-Castillo (2021) and Kristén et al. (2022)
	Eye-tracking devices	Bulathwela et al. (2024)
	Analog and digital sensors	Blavt et al. (2023) and Daems et al. (2023)
	Braille printer	Olivares Granados et al. (2019), Izario et al. (2021), and Drushlyak et al. (2023)
	3D printer	Higgins et al. (2023), Grindei et al. (2024), Horna-Saldaña and Canaleta (2024), Horna-Saldaña et al. (2024), and Puentes et al. (2024)
Software and applications for accessibility	Screen Readers	Olivares Granados et al. (2019), Raja and Giannoumis (2019), Du and Meier (2020), Yaskevich (2021), Barbetta (2023), Drushlyak et al. (2023), and Şahin et al. (2023)
	Text-to-speech software (Screen Reader, JAWS, Thunder, Natural Reader)	Chambers (2020), Hunt (2021), Srivastava et al. (2021), Barbetta (2023), Karagianni and Drigas (2023a), Karagianni and Drigas (2023b), and Şahin et al. (2023)
	Voice synthesizer with representative images	Izario et al. (2021), Drushlyak et al. (2023), and Fälth and Selenius (2024)
	Voice writing software	Mayfield et al. (2019) and Albalhareth and Saleem (2023)
	Sign language translation software	Izario et al. (2021), Albalhareth and Saleem (2023), Hunt (2021), and Daems et al. (2023)
	Braille translation	Puentes et al. (2024)
	Descriptive video services	Karagianni and Drigas (2023b)

(Continued)

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TABLE 3 (Continued)

Educational and learning tools	Mobile devices and tablets: PC, tablet, smartphone	Asongu et al. (2019), Grindei et al. (2019), Lusigi (2019), McMahon and Walker (2019), Raja and Giannoumis (2019), Rasool and Smith (2019), Chambers (2020), Chiu and Lim (2020), Ellis (2020), Rodrigo-Martín et al. (2020), Waizmann et al. (2020), Yusuf (2020), Brown et al. (2021), Diolaiuti et al. (2021), Fernandez (2021), Gandolfi et al. (2021), Hunt (2021), Liping (2021), Tomczyk et al. (2021), Yaskevich (2021), Zeagler et al. (2021), Alcívar et al. (2022), Kirupainayagam and Sutha (2022), Knestis et al. (2022), Lee (2022), Rosado-Castellano et al. (2022), Saltanat et al. (2022), Sarsenbayeva et al. (2022), Shumilova et al. (2022), Smeins et al. (2022), Utami and Palacios Hidalgo (2022), Albalhareth and Saleem (2023), Barbetta (2023), Coker and Mercieca (2023), Daems et al. (2023), Demetriou (2023), Desideri et al. (2023), Drushlyak et al. (2023), Geering and Hayhoe (2023), Karagianni and Drigas (2023a), Karagianni and Drigas (2023b), Lawan et al. (2023), Maćkowski et al. (2023), Rocha et al. (2023), Şahin et al. (2023), Seale (2023), Singh-Pillay (2023), Valdivieso and Jadán-Guerrero (2023), Yenduri et al. (2023), Ajani (2024), Blavt et al. (2024), Castellano-Beltran et al. (2024), Draper (2024), Fälth and Selenius (2024), Fang et al. (2024), Grindei et al. (2024), Gupta et al. (2024), Layachi and Pitchford (2024), Materazzini et al. (2024), Mosier et al. (2024), Peruzzo and Allan (2024), Puentes et al. (2024), Ramírez-Montoya et al. (2024), Toto et al. (2024), Vargas Castro et al. (2024), and Vitale and Iacono (2024)
	Educational mobile applications	Raja and Giannoumis (2019), Uygur et al. (2020), Rizvi et al. (2021), Tomczyk et al. (2021), Wood (2021), Alcívar et al. (2022), Gordon and Leutenegger (2022), Kirupainayagam and Sutha (2022), Merzon et al. (2022), Rosado-Castellano et al. (2022), Barbetta (2023), Garza (2023), Han and Shim (2023), Karagianni and Drigas (2023a), Lawan et al. (2023), Maćkowski et al. (2023), Nasyrova and Muller (2023), Şahin et al. (2023), Weisberg and Dawson (2023), Yenduri et al. (2023), Acosta-Vargas et al. (2024), Castellano-Beltran et al. (2024), Cobian et al. (2024), Fang et al. (2024), Gupta et al. (2024), Mariappan et al. (2024), Ruel and Tajmel (2024), Stepanova et al. (2024), and Sunny et al. (2024)
	E-libros	McMahon and Walker (2019), Chiu (2020), Chiu and Lim (2020), Drushlyak et al. (2023), Fälth and Selenius (2024), and Ramírez-Montoya et al. (2024)
	Educational robots	Kuvshinova et al. (2019), McMahon and Walker (2019), Chambers (2020), Dimitrova et al. (2020), Du and Meier (2020), Alcívar et al. (2022), Utami and Palacios Hidalgo (2022), Al Omoush et al. (2023), Lawan et al. (2023), Şahin et al. (2023), Yenduri et al. (2023), Bulathwela et al. (2024), Huang and Lan (2024), Ramírez-Montoya et al. (2024), Sunny et al. (2024), and Vitale and Iacono (2024)
	Smart tutoring, virtual assistant	Mayfield et al. (2019), Waizmann et al. (2020), Alkeraida (2024), Kwawukumey et al. (2024), Layachi and Pitchford (2024), Lin et al. (2024), Montoya et al. (2024), Sunny et al. (2024), Šumak et al. (2024), and Vitale and Iacono (2024)
	Arduino-like	Zeagler et al. (2021) and Merzon et al. (2022)
	Chatbot	Tasker et al. (2020), Waizmann et al. (2020), Barbetta (2023), Ge et al. (2024), Lin et al. (2024), Montoya et al. (2024), Šumak et al. (2024), and Vitale and Iacono (2024)
	LEGO WeDO Education	Merzon et al. (2022) and Puentes et al. (2024)
	Hologram	Materazzini et al. (2024)
	Virtual courses/MOOCS	Kross and Guo (2019), Castellano-Beltran et al. (2024), Ge et al. (2024), Sunny et al. (2024), and Tripak et al. (2024)
Interaction and collaboration tools	Interactive digital whiteboards	Chambers (2020), Uygur et al. (2020), Alcívar et al. (2022), Utami and Palacios Hidalgo (2022), Albalhareth and Saleem (2023), Daems et al. (2023), and Karagianni and Drigas (2023a)
	Multimedia projectors	Uygur et al. (2020), Kirupainayagam and Sutha (2022), Daems et al. (2023)
	Augmented and Virtual Reality Devices and Programs: Google Glass, Google Cardboard, hologram, CleverBooks Augmented Classroom, Aurasma, AR. Vuforia	McMahon and Walker (2019), Rasool and Smith (2019), Chambers (2020), Du and Meier (2020), Brown et al. (2021), Diolaiuti et al. (2021), Espinosa-Castaneda and Medellin-Castillo (2021), Liping (2021), Mihovska et al. (2021), Shmeleva and Litovchenko (2022), Shumilova et al. (2022), Smeins et al. (2022), Albalhareth and Saleem (2023), Drushlyak et al. (2023), Gweshe and Chiware (2023), Karagianni and Drigas (2023b), Kim and Higgs (2023), Lawan et al. (2023), Maćkowski et al. (2023), Richter et al. (2023), Yenduri et al. (2023), Ge et al. (2024), Maquera-Maquera et al. (2024), Ramírez-Montoya et al. (2024), Toto et al. (2024), and Vargas Castro et al. (2024)
	Online Collaboration Tools: Google Colaboratory, Jupyter Notebook, Padlets, Miro board	Du and Meier (2020) and Srivastava et al. (2021)

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TABLE 3 (Continued)

Communication systems and devices	Social networks: Facebook y Twitter	Lusigi (2019), Kormos and Julio (2020), Mawasi et al. (2020), Gordon and Leutenegger (2022), Zeng et al. (2022), Kim and Higgs (2023), Weisberg and Dawson (2023), Castellano-Beltran et al. (2024), and Mosier et al. (2024)
	Instant messaging platforms: WhatsApp	Castellano-Beltran et al. (2024) and Maquera-Maquera et al. (2024)
	Zoom	Sarsenbayeva et al. (2022), Shmeleva and Litovchenko (2022), Seale (2023), Draper (2024), and Mariappan et al. (2024)
	Augmentative and Alternative Communication (AAC) devices	Şahin et al. (2023) and Draper (2024)
Analysis and monitoring tools	Optical character recognition (OCR) technologies	Raja and Giannoumis (2019), Du and Meier (2020), Drushlyak et al. (2023), Karagianni and Drigas (2023b), and Şahin et al. (2023).
	Emotion recognition technologies	Şahin et al. (2023)
	Educational Tracking and Analysis Systems: Spell-check software, speech training and development software, word processing tools	Shestakevych et al. (2019), Du and Meier (2020), and Drushlyak et al. (2023)
Didactic materials and educational games	Virtual games	Suzianti et al. (2019), Chiu and Lim (2020), Du and Meier (2020), Diolaiuti et al. (2021), Espinosa-Castaneda and Medellin-Castillo (2021), Gandolfi et al. (2021), Izario et al. (2021), Tyutryumova and Pomytkina (2021), Alcívar et al. (2022), Collazo (2022), Costa et al. (2022), Knestis et al. (2022), Merzon et al. (2022), Shmeleva and Litovchenko (2022), Smeins et al. (2022), Vechkanova et al. (2022), Barbetta (2023), Daems et al. (2023), Drushlyak et al. (2023), Karagianni and Drigas (2023a), Nasyrova and Muller (2023), Fälth and Selenius (2024), Puentes et al. (2024), Toto et al. (2024), Tripak et al. (2024), and Vargas Castro et al. (2024)
	Minecraft, Roblox	(Yenduri et al., 2023)
	Book Creator	Nasyrova and Muller (2023) and Cobian et al. (2024)
	StoryJumper	Barbetta (2023)
	LEGO Braille Bricks, Kurzweil 3,000	Merzon et al. (2022) and Puentes et al. (2024)
	Sketchfab	Rasool and Smith (2019)

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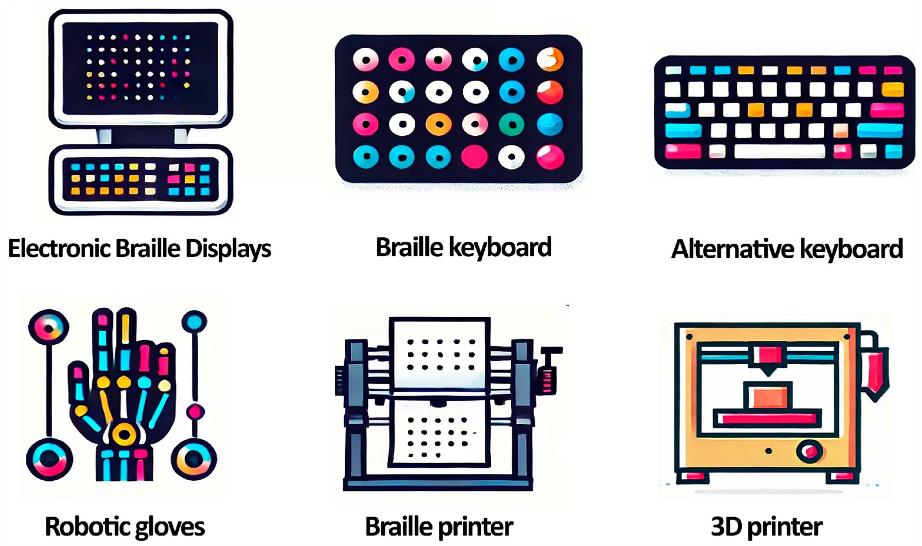

FIGURE 3
Physical and sensory accessibility tools.

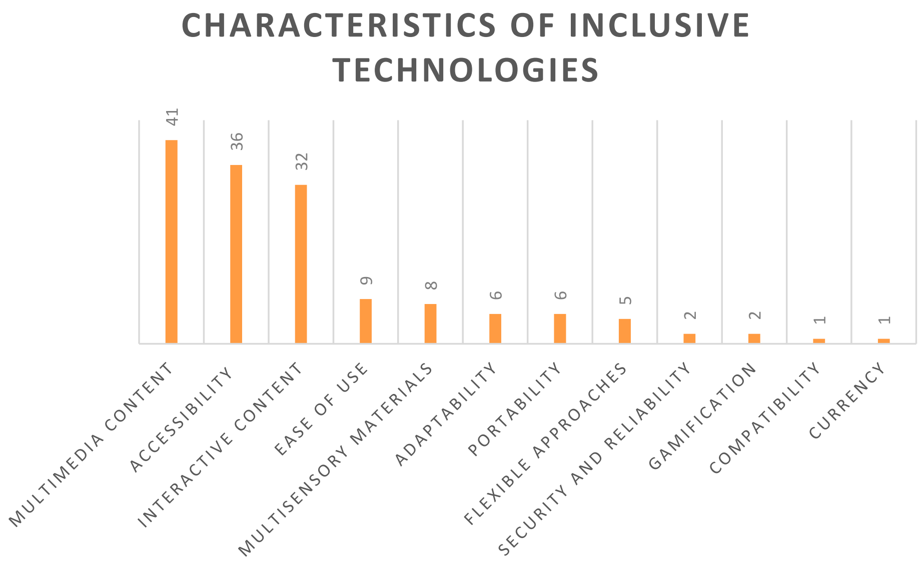

FIGURE 4
Main characteristics of technologies in inclusive education.

educators to explore the characteristics that make these technologies effective in supporting students with diverse needs, thus promoting a more accessible and equitable learning environment. Understanding these functionalities can contribute to the adaptation of pedagogical strategies, thereby facilitating the creation of personalized educational experiences that take into account the individual differences of students and foster their full participation in the educational process. Figure 4 presents the most notable characteristics of inclusive technologies.

The results of the analysis show that the most frequently mentioned characteristics in the literature on technologies for inclusive learning are multimedia content, interactive content, and accessibility, highlighting their importance in creating educational environments that promote inclusion. Multimedia content, highlighted in 41 studies, facilitates understanding by integrating various formats, such as images, videos, and audio, adapting to different learning styles. Accessibility, mentioned in 36 studies, emphasizes the importance of designing educational technologies to be usable by students with a wide range of disabilities, including physical, cognitive, or sensory disabilities. Similarly, interactive content, mentioned in 32 studies, supports active student participation, which is essential for promoting better knowledge retention.

Ease of use, mentioned in 9 studies, emphasizes that technologies should be intuitive and accessible for both teachers and students, which is crucial for their adoption in the classroom. Also mentioned in 8 studies, multisensory materials refer to the incorporation of visual, auditory, and tactile stimuli, enriching the learning experience by engaging different senses.

Other relevant characteristics, though mentioned in fewer studies, include adaptability, which appears in 6 studies, referring to the ability of technologies to adjust to the individual needs of students, offering personalized experiences that enhance their learning. Additionally, portability, cited in 6 studies, highlights the importance of using technological tools anywhere, especially through mobile devices, thus expanding access to education.

Other less frequently mentioned, but equally important characteristics, include security and reliability (2 studies), which highlight the need for technologies to be dependable and not disrupt the educational process due to technical failures. Gamification (2 studies) incorporates game elements into learning, contributing to increased student motivation.

Finally, with only one mention in the literature, flexible approaches are highlighted, allowing teaching methods to be adapted to student needs; compatibility, ensuring the smooth integration of technologies with other educational tools; and currency, referring to the ability of technologies to stay up-to-date with advances in the educational field, ensuring the relevance of the resources used. Although mentioned less frequently, these characteristics are key to creating an inclusive and efficient learning environment.

3.4 RQ4. How are the diverse inclusion needs of students addressed through the use of technological tools?

Table 4 presents the technologies mentioned or used in the reviewed studies, classified according to the type of educational inclusion, with a particular focus on disabilities, which is the most widely addressed type of inclusion in the literature. These technological tools allow the adaptation of the educational environment to the specific needs of students with disabilities, facilitating their active and equitable participation in the learning process.

Technological tools in inclusive education enable the adaptation of content and teaching methods to the individual needs of students, providing accessibility, autonomy, and a more personalized educational experience. The general use of these technologies includes converting content into accessible formats, such as audiobooks, Braille files, or adapted digital formats, which facilitates universal access to education. Moreover, they allow students to progress at their own pace, promoting a more engaging and motivating learning experience through interaction with dynamic digital environments, such as virtual and augmented reality.

For students with visual impairments, technologies include screen readers, digital magnifiers, and voice synthesizers that convert text into audio, enabling more direct access to information. Tools like touchscreens and Braille displays, as well as the conversion of content into accessible formats (MP3, ePub, tagged PDFs), allow students to interact with educational materials tailored to their needs. Applications with audio-tactile graphics and navigation systems also help improve their independence and understanding of the environment. Additionally, augmented reality offers a new way to explore visual concepts, such as shapes and graphs, in a sensory manner.

In the case of hearing impairments, technologies focus on voice-to-text conversion and sign language translation, facilitating real-time communication through videophones and interpreters, both human and animated. This allows deaf students or those with hearing difficulties to interact more effectively with their peers and teachers. Additionally, there are specific tools for parents and educators to learn sign language, easing communication and support at home and in the classroom.

For students with physical motor disabilities, tools like adapted keyboards, joysticks, and alternative mice enable physical interaction with devices, adapting to their motor abilities. Head or foot control systems, along with digital pens and touchscreens, provide alternative means for writing and completing practical activities. These assistive technologies increase the functionality and autonomy of students, creating interactive environments where they can engage in learning through multiple means of interaction, such as voice, touch, or gestures.

Finally, intellectual and cognitive disabilities are addressed through personalized and adaptive learning systems designed to meet the specific needs of each student. Computer games help improve cognitive skills, while multisensory environments enrich the learning experience. Tools like vibrating alarms or digital pens help improve attention and behavior, and technology is also used to diagnose dyslexia and other learning difficulties. These resources enable the inclusion of students in STEM projects and other educational environments, ensuring that they can fully participate in the learning process.

3.5 Main benefits of technology in inclusive education

As identified in the literature, the use of technology in inclusive education offers multiple benefits that can significantly transform the teaching and learning process. It facilitates student participation by enabling broader interaction and collaboration, which in turn fosters an inclusive and dynamic learning environment. The availability of a variety of digital resources enriches educational content and allows students to access diverse and up-to-date information, thereby stimulating the development of critical and analytical skills.

Furthermore, technology enables educators to reflect on and improve their pedagogical practices through the use of analytical tools that provide real-time feedback on the effectiveness of their teaching methods. Students can explore and debate topics related to social justice and diversity, adapting to various needs and learning styles, which contributes to a more equitable education tailored to individual needs.

The study conducted by Lusigi (2019) highlights how in South Africa, the use of ICT has improved educational quality not only by increasing enrollment and access to distance education but also by enhancing "learning productivity." This is achieved by optimizing costs and customizing teaching to meet specific labor market and community needs, enabling students to acquire skills that are immediately applicable in professional environments. On the other hand, Kim and Higgs (2023) observe that technology allows future teachers to build more meaningful relationships with their students

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TABLE 4 Technologies used by type of educational inclusion.

General use of technologies in inclusive education (Gender, Social, Age Inclusion, etc.)	Conversion of content into different formats to facilitate universal access to education.
	Tools that allow students to study at their own pace.
	Creating more engaging, social, and motivating learning environments.
	Assistive technology for effective interaction with educational content.
	Use of virtual and augmented reality for exploration and learning in various formats.
	Access to educational content for students in remote locations
	Computer-assisted language learning, for linguistic diversity
	Creation of collaborative digital mind maps, for the development of creativity and imagination.
	Creative writing, automatic translation and summarization of texts. Automatic creation and editing of images
Visual disability	Screen readers, screen magnifiers, audiobooks.
	Touch screens, Braille displays, voice synthesizers.
	Convert digital content to multiple formats: MP3, tagged PDF, HTML, ePub.
	Conversion of digital content into various formats: MP3, tagged PDF, HTML, ePub.
	Audio-tactile graphics, audio descriptions, applications for learning mathematics.
	Augmented reality for exploring and recognizing shapes.
	Technologies for parents and teachers of blind children, such as learning Braille.
	Conversion of Braille to text.
	Navigation systems for determining movement routes.
	Creation of virtual learning environments to develop visual skills.
Hearing disability	Videophone, sign language interpreters, animated sign language interpreters.
	Voice-to-text and text-to-voice conversion.
	Conversion of sign language to text and text to sign language.
	Technologies for parents and teachers of deaf children to learn sign language.
	Manipulators for people with hearing and speech disabilities.
Physical motor disability	Adapted keyboards, joysticks, trackballs, head control systems, foot mouse.
	Keyboard modifications and manipulators for people with musculoskeletal disorders.
	Digital pen, instructional screens, pointing devices.
	Aids for writing, practical activities, and improving functional skills.
	Evaluation of muscle strength and endurance using technology.
	Assistive technology to enhance functional capabilities.
	Creation of interactive support environments that allow the use of multiple interaction methods (voice, text, video, touch, gestures).

(Continued)

TABLE 4 (Continued)

Intellectual and cognitive disability	Personalized and adaptive learning systems.
	Devices programmed with specific vocabulary.
	Computer games to enhance skills and correct speech disorders.
	Multisensory learning environments.
	Psychological support and individual tutoring.
	Creation of artificial learning companions.
	Use of vibrating alarms and digital pens to improve attention and behavior.
	Facilitate personalized learning by adapting resources to specific needs.
	Use of technologies to diagnose dyslexia and other reading difficulties.
	STEM projects and technologies that enable participation in inclusive educational environments.

through digitally mediated interactions. This approach contributes to a deeper and more critical understanding of literacy in the current digital context and underscores the potential of technology to address racial and cultural gaps in education.

Similarly, Coker and Mercieca (2023) emphasize how, by addressing the digital divide, especially in rural areas, technology promotes greater equity in educational participation. Access to digital tools and resources facilitates real-time connections to global resources, enriching learning and fostering international collaboration among students. This enables all students, regardless of their geographical location, to access quality educational opportunities, thus overcoming the traditional limitations imposed by distance and physical resources. Together, these benefits highlight how technology can be a powerful facilitator of more inclusive, equitable, and high-quality education, preparing students to be effective global citizens in an increasingly interconnected society.

3.6 Main challenges of technology in inclusive education

Unequal access to technologies represents one of the major challenges in inclusive education, especially noticeable in rural areas and among students from different socioeconomic levels. Kormos and Julio (2020) highlight how the lack of adequate technological infrastructure, including limitations in hardware and software, amplifies the digital divide and complicates the effective integration of technologies into the educational process. This disparity in access underscores the need not only to provide technological tools but also to ensure that they are adequate and functional for all students.

Another significant challenge is the lack of skills or competencies in teachers related to the use of technology. Insufficient training of teachers in handling new technologies limits their ability to integrate these tools effectively into their teaching methodologies. This is exacerbated by the general lack of teacher training, which prevents educators from adopting pedagogical practices that maximize the benefits of technology in inclusive educational settings.

Furthermore, accessibility issues in applications and virtual platforms, such as difficulties in generating image descriptions, proper semantic structuring, keyboard navigation, and content synchronization, present additional barriers. Acosta-Vargas et al. (2024) emphasize that accessibility evaluation should be thorough and multifaceted, using both automatic and manual assessments to better understand the barriers faced by users with disabilities. It is also crucial to integrate accessibility principles from the early stages of technology development, as well as to consider the ethical implications associated with their use.

Additionally, an excessive dependence on technology, particularly artificial intelligence, can undermine the development of critical thinking and research skills. Lin et al. (2024) point out how technology can demotivate students by reducing their effort in learning, and how web search engines and AI often provide incorrect or irrelevant answers. These authors also highlight the ethical challenges associated with academic integrity and the impact of false accusations of plagiarism on student well-being, underscoring the need for careful and ethical implementation of technology in education.

Wen and Castek (2020) mention that it is fundamental to focus on fostering critical understanding and meaningful use of technology, rather than merely providing access to tools. This involves integrating exploration and fabrication skills, promoting collaboration and knowledge sharing, and maintaining a critical perspective on the impact of technology on communities. Moreover, it is essential to combine technological literacy with content knowledge and pedagogy.

3.7 Successful case examples

In the realm of inclusive education, the integration of technology has proven to be a transformative approach, enabling broader and more effective participation of students from diverse backgrounds and abilities. Among the successful implementations of technology, the study by Kross and Guo (2019) stands out, which presents an innovative approach aimed at adults from historically marginalized and underrepresented communities, proposing an educational program accessible through MOOCs to teach them basic data science skills. This program was specifically designed to equip these adults with the competencies necessary to access entry-level jobs in the technology field, directly addressing the lack of educational and employment opportunities in their communities.

Moreover, Smeins et al. (2022) explored how digital tools can be used to enhance linguistic inclusion in primary education. Through the implementation of digital games that employ augmented reality, such as BabelAR, they sought to inspire future teachers to actively integrate multilingualism into their pedagogical practices. This tool facilitates the teaching of different languages, thus promoting a more inclusive and enriching learning environment for all students, regardless of their mother tongue.

Simultaneously, Singh-Pillay (2023) in South Africa investigated the use of mobile technologies to overcome language barriers and enhance student participation in diverse educational contexts. Using applications like Google Classroom, which incorporates voice dictation functions and dictionaries, teachers were able to adapt their lesson plans and assessments to include the students' native languages, utilizing these as valuable resources in the learning process. Moreover, virtual platforms have facilitated the conduct of practical work, allowing students to engage in active learning experiences even in resource-limited settings, such as the lack of equipped laboratories in rural environments.

Parallelly, Shmeleva and Litovchenko (2022) propose the use of technical devices such as touch screens for people with visual impairments, modified keyboards for those with musculoskeletal disorders, and special manipulators for students with auditory and speech disabilities. Additionally, programs like "Screen Reader," which read aloud the content on the screen, and audio materials, such as lectures and audio simulators, enable students with visual impairments to access information effectively. These tools facilitate individualized learning and promote the active participation of students in the educational process, thus enhancing their experience and academic outcomes.

Additionally, Rocha et al. (2023) employed 3D animated avatars as sign language interpreters to teach the alphabet in Portuguese and Brazilian Sign Language (Libras) to children. This approach allows both deaf and hearing children to interact with the content effectively, improving communication and learning in an inclusive environment.

Likewise, Horna-Saldaña and Canaleta (2024) utilized 3D printing technologies to develop a Braille instrument that teaches the chemical elements to students with visual disabilities. This method facilitated playful and accessible learning of chemistry and fostered an inclusive educational environment where students with and without disabilities could share and enjoy learning together.

Equally, Diolaiuti et al. (2021) created immersive learning experiences using 360° video technology, allowing individuals, including those with physical limitations or disabilities, to explore and learn about remote places in an accessible manner. Through devices like smartphones and tablets, users can navigate virtual environments without needing to be physically present in those locations, eliminating physical barriers and facilitating participation for all.

Fang et al. (2024) implemented the Mindomo platform, powered by artificial intelligence, for the creation of collaborative mind maps, improving the inclusion and education of students with intellectual and learning disabilities. This was applied to students with neurodevelopmental disorders, specifically students with Asperger's Syndrome, ADHD, and dyslexia. The results showed a positive impact on the development of creative thinking, and the use of this tool allowed each student to contribute equitably to the learning process, which improves their engagement and self-esteem. Moreover, by facilitating the organization of ideas and the visualization of concepts, it helps students develop critical and creative thinking skills.

Finally, the study by Materazzini et al. (2024) applied the OLOS® technology, an innovative audio-visual interface, to enhance inclusive education in museums, focusing on individuals with learning disorders (ADHD, dyslexia, among others). This tool allows interaction with life-size holographic figures that converse with visitors, facilitating a more accessible and engaging educational experience. The results of the study, which included responses from over 1,300 individuals certified with learning disorders, suggest that the implementation of visual effects, gamification methods, and user-friendly informational materials can significantly improve accessibility and participation of this population in museum environments.

Each of these studies represents an important step toward achieving truly inclusive education, demonstrating how technology can be effectively used to confront and overcome educational barriers, and how it can be adapted to the specific needs of different groups of students.

3.8 Practical limitations

It is important to note that, in the context of inclusive education, multiple practical challenges are faced when attempting to effectively integrate technologies into learning environments. One of the main obstacles is the digital divide and the lack of adequate infrastructure, especially in remote or low-income regions. It is crucial to focus technological expansion not only on the availability of tools but also on improving the learning environment and digital literacy. An approach that enhances education through the development and implementation of ICT systems that leverage existing infrastructure, supported by both public and private investments, is needed.

Additionally, there is a significant lack of skills and digital literacy among teachers and students, a problem particularly evident in some educational institutions where many teachers lack the access and skills necessary to use ICT effectively. This situation underscores the urgent need for training and continuing education programs that can close this skills gap.

Moreover, the absence of an institutional framework and coherent national policies that foster the use of technology for innovation and ensure quality education represents another considerable obstacle. A holistic and collaborative approach among different sectors and levels of government is required to establish policies that effectively promote the integration of technology in inclusive education.

Despite governmental efforts to promote the use of ICT, many teachers still fail to modify their teaching methods to integrate these technologies. Some educators continue to resort to traditional pedagogical approaches, rather than adopting more student-centered methods that incorporate ICT. This highlights the need to focus attention not only on physical and digital infrastructure but also on the continuous training and updating of educators, enabling them to effectively implement technology in their teaching practices.

This complex landscape of practical limitations for the effective use of technologies in inclusive education illustrates the importance of multidimensional approaches that include improvements in infrastructure, teacher training, coherent policies, and digital literacy programs, framed within a comprehensive strategy that addresses both technological and human and structural needs.

4 Discussion

The analysis of the literature on inclusion reveals a clear trend toward prioritizing sensory and physical disabilities, with less focus on mental or intellectual disabilities and learning difficulties. As Şahin et al. (2023) mention, students with disabilities are a crucial part of the implementation of inclusive education. This distribution suggests that educational and social environments still face the challenge of fully adapting to the needs of all individuals with disabilities. However, inclusive education should not be limited solely to the integration of students with disabilities, as it is often understood. In reality, inclusive education encompasses a wide range of aspects beyond physical or cognitive disabilities. Factors such as age, gender, health status, race, customs, nationality, and other elements that differentiate individuals also play a crucial role in processes of exclusion or unequal treatment within the educational domain. Similarly, Bulathwela et al. (2024) and Uygur et al. (2020) highlight the powerful influence of circumstances such as wealth, gender, ethnicity, and location as important factors in shaping educational and life opportunities.

True inclusive education means ensuring that people of all ages can access opportunities for lifelong learning without restrictions based on their stage of life. It also advocates for students of different nationalities or with diverse customs to enjoy the same rights and benefits as local residents (Rodrigo-Martín et al., 2020). Likewise, those who suffer from conditions that may limit their active participation in education should be treated equally to those who do not face such barriers, such as individuals with HIV, asthma, obesity, or diabetes (Houston-Wilson and Lieberman, 2020). Inclusion, therefore, should be seen as a broad and comprehensive concept that seeks to remove any type of barrier that prevents equitable access to education for all individuals, regardless of their differences. As Uygur et al. (2020) note, factors such as gender, disability, ethnicity, poverty, or migration reflect the versatility that inclusive education must have. Each of these aspects presents specific challenges that require differentiated and adaptive approaches to ensure that all students have equitable access to quality education.

In the context of inclusive education, various technological tools have proven key to promoting the participation and learning of students with diverse needs. Among the most commonly used are mobile devices and tablets, such as PCs, smartphones, and tablets (Chambers, 2020; Sarsenbayeva et al., 2022; Karagianni and Drigas, 2023a). These devices offer flexibility and portability, facilitating their integration into various educational settings and allowing students to access content tailored to their needs at any time and place. Additionally, their intuitive interface makes them easy to use for students with different abilities.

Another highlighted resource is interactive games and applications, which, being dynamic and participatory, provide a stimulating learning environment (Kuvshinova et al., 2019; Collazo, 2022; Rocha et al., 2023). These tools encourage direct interaction between students and content, which not only improves understanding but also fosters motivation and active participation in the educational process, aspects essential for skill development in inclusive environments.

Furthermore, educational platforms and specialized software designed for students to learn in various ways, regardless of their differences, have had a significant impact. These systems allow for personalized learning, offering multiple ways to access content, whether visually, auditorily, or tactilely, facilitating the inclusion of students with different disabilities (Desideri et al., 2023; Karagianni and Drigas, 2023a).

Regarding physical and sensory accessibility tools, such as electronic Braille displays or adapted devices (keyboards, mice), they are essential for removing barriers to accessing information. As Srivastava et al. (2021) mention, these technologies enable students with visual or physical disabilities to interact effectively with devices, ensuring their participation in the educational environment.

Similarly, emerging technologies like augmented and virtual reality, along with educational robotics, are gaining relevance. Augmented and virtual reality devices allow students to interact with simulated environments that can be tailored to their specific needs, providing immersive and personalized learning experiences. Additionally, educational robotics, using tutor robots, offers personalized assistance and guidance, making learning easier for students who struggle with traditional teaching methods (Kuvshinova et al., 2019).

Key features, such as multimedia content, interactivity, accessibility, and adaptability, are essential for inclusive education as they provide diverse ways of presenting information and adjusting to the individual needs of students. As Chambers (2020) mentions, technological devices and programs must be accessible and easy to use for both teachers and students. The portability and ease of use of educational technologies make these tools accessible in any environment (Karagianni and Drigas, 2023b), enhancing participation. Moreover, multisensory material stimulates different senses, which is crucial for students with sensory or cognitive disabilities (Raja and Giannoumis, 2019). The security, reliability, and compatibility of technology ensure that resources are accessible to all students, while gamification and flexible approaches promote a more dynamic and motivating learning (Karagianni and Drigas, 2023b). Finally, the constant updating of these resources ensures that students can benefit from the latest advances in inclusive education.

4.1 Limitations of the study

This study presents some limitations that should be considered. First, the analysis focused on studies available in specific databases, which may have limited access to relevant research published in other sources or in languages other than English and Spanish. This could have influenced the scope of the literature review. Another limitation is that the study mainly focuses on technologies applied to inclusive education, leaving room for deeper exploration of other non-technological factors that also contribute to inclusion, such as traditional pedagogical practices or emotional support in the classroom.

Finally, although various forms of disability are addressed, the review did not delve into each one individually, as the objective was to provide a comprehensive view of inclusion. This may be considered a limitation for those seeking a detailed analysis of a specific type of disability.

4.2 Future work

For future research, it is recommended to expand the focus toward mental and intellectual disabilities, as well as learning difficulties, to obtain a more balanced view of the challenges and opportunities in inclusive education. Additionally, it would be beneficial to conduct studies that explore, in a comparative manner, how different educational institutions address the challenges of inclusion, considering variations in socioeconomic contexts and available resources.

Another area of interest is evaluating the long-term effectiveness of emerging technologies, such as augmented reality and educational robotics, in the development of specific skills in students with different needs. Future research could explore how the integration of these technologies influences students' motivation and academic performance, and whether these effects vary depending on the type of disability or educational need. Additionally, it would be relevant to consider studies that explore non-technological approaches, such as inclusive pedagogical strategies or adaptive teaching models, which could be applicable in contexts with limited access to advanced technologies.

Finally, it is suggested to investigate the intersection of inclusive education with social factors such as gender, ethnicity, and economic situation, to better understand how these elements influence students' educational experiences. This approach would allow for the design of more comprehensive and effective interventions that consider the diversity of barriers that can affect equitable access to education.

5 Conclusion

Together, these technologies transform the educational environment into a more inclusive, equitable, and accessible space by adapting to the diverse abilities and needs of students. They provide personalized support that fosters academic development and strengthens critical skills such as autonomy, creativity, and problem-solving. The use of mobile devices, interactive applications, and specialized tools enables students with physical, sensory, or cognitive disabilities to access educational content equitably, removing barriers that have traditionally limited their participation.

Through these technologies, learning environments become more flexible and dynamic, facilitating the personalization of teaching methods. This allows each student to progress at their own pace, with materials tailored to their learning styles and abilities. Additionally, the use of interactive games and applications stimulates participation and engagement, resulting in greater knowledge retention and a more engaging and meaningful learning experience.

Moreover, tools such as Braille devices, adapted keyboards, and inclusive touch screens offer students with sensory disabilities the ability to interact effectively with the digital environment, leveling the playing field compared to their peers. Similarly, augmented and virtual reality, along with educational robotics, open new opportunities for creating immersive learning experiences that can be tailored to the specific needs of each student, promoting a multisensory approach to learning.

These technologies also facilitate the creation of inclusive learning communities, where all students, regardless of their abilities, can collaborate, share ideas, and develop greater empathy and mutual understanding. This not only enriches their academic education but also contributes to their social and emotional development, which are fundamental aspects for their full integration into society.

In conclusion, the integration of these technological tools in the educational field goes beyond simply adapting to individual needs. It represents a decisive step toward building an educational system that recognizes diversity as a central value, offering each student the opportunity to reach their full potential. By promoting equitable and accessible learning, these technologies transform the educational environment and open new possibilities for the future of inclusive education.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CN-B: Conceptualization, Formal analysis, Funding acquisition, Investigation, Resources, Supervision, Writing – review & editing. JG-A: Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Validation, Writing – original draft. DO-G: Funding acquisition, Investigation, Methodology, Software, Validation, Writing – original draft. DM-N: Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Gen AI was used in the creation of this manuscript. All content has been generated by the authors without the use of Generative AI; however, ChatGPT was used for correction and translation.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1527851/full#supplementary-material

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