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"Enhancing The Performance Of School Students With Dyscalculia And Dyslexia In Science Subjects Using Technology: A Scoping Review"

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Abstract

Students with dyslexia and dyscalculia are being encouraged to achieve high academic standards in science education to understand the natural world, acquire life skills, and experience career success. To help students with learning disabilities attain science literacy, digital technology is utilized. While relevant research has presented evidence-based practices to teach science content, the role of technology has yet to be clearly defined in teaching and learning for students with dyslexia and dyscalculia. This article presents a scoping literature review on the contribution of technology in science education for students with dyslexia and dyscalculia. A total of 17 journal articles during the 2019-2023 period were identified after an exhaustive search of five academic databases (PubMed, Sage, Eric, Science Direct, and Google Scholar). The educational context and learning outcomes of these 17 empirical studies were analyzed. The findings indicate that the primary benefit of integrating digital technology into science education is higher motivation to learn among students. The way digital technology is used, or the affordances of each unique technological implementation, is likely to determine positive learning outcomes. Other quality indicators, such as digital technology, and its affordances are suggested for evidence-based research designs in digitally supportive learning environments, particularly for students with disabilities.

Keywords *Science Education · Digital Technology · Dyslexia · Dyscalculia · Learning Disabilities*

1. Introduction

In the realm of education, science subjects play a pivotal role in fostering knowledge, curiosity, and critical thinking among students, facilitating their understanding and interaction with the external world (DeBoer, 2019). This academic phase, crucial for middle school students, signifies a [1]transition from foundational knowledge to more intricate, abstract ideas. Science education aims to instill a profound comprehension of the natural world, providing students with the tools to critically engage with complex scientific concepts. However, the intersection of learning disabilities, especially dyslexia and dyscalculia, creates challenges during this crucial transition, necessitating specialized approaches and a thorough examination of effective teaching strategies (DeBoer, 2019). For students with learning disabilities, science subjects pose difficulties due to the simultaneous demand for comprehension, cognitive, executive, linguistic, and math skills (King-Sears & Johnson, 2020).

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Unfortunately, this issue is often overlooked by educational institutions, leading to a significant obstacle for approximately one-third of students with learning disabilities who struggle to pass their high school science courses (King-Sears & Johnson, 2020). Despite the National Science Education Standards emphasizing "Science standards for all students" and advocating for equity, the reality falls short of ensuring that students with disabilities, irrespective of their race or gender, have equal access to fundamental science material (NRC, 1996).

Dyscalculia is a neurological learning disability that primarily affects around 8% of the student population by reducing their ability to understand and comprehend numerical concepts (Plessis, 2023). It goes beyond the typical math challenges that some students might experience. Students with dyscalculia frequently experience trouble with basic arithmetic operations, number sense, and mathematical reasoning (Aquil and Ariffin, 2020). This disability can make it exceptionally challenging for middle school students to grasp complex science concepts that rely heavily on mathematical understanding, such as physics and chemistry. They have challenges interpreting graphs, understanding mathematical relationships in scientific equations, and even measuring basic scientific quantities. Dyscalculia has been linked with frustration, lowered self-esteem, and a lack of interest in science (Israel and Olubunmi, 2014).

Dyslexia is another common neurological disorder that mainly affects a student's ability to read, write, and spell proficiently. Around 10% of the school's population is diagnosed with dyslexia (Elias, 2023). It is often characterized by challenges in processing phonological information, which is essential to comprehending written language. In the context of science education, dyslexic middle school students might have trouble comprehending complex scientific texts, interpreting diagrams and charts, and expressing their scientific ideas in writing. Furthermore, dyslexia can limit their ability to decode scientific terminology and use the abundance of knowledge available in textbooks and online resources (Fazmina et al., 2020). Consequently, students with dyslexia might experience frustration and a sense of exclusion from the scientific community. Understanding the particular difficulties associated with dyslexia and dyscalculia and exploring effective teaching strategies are important to ensure that these students can actively engage in and benefit from their science education, fostering a lifelong interest in the subject (Anderson, 2021).

This research investigates both dyslexia and dyscalculia in the context of school science education for three reasons. First, these learning disabilities frequently appear within the same individual, demonstrating the practicality of addressing them together, especially in a subject like science, which demands proficiency in both reading and mathematical skills. Second, students with dyslexia and dyscalculia experience similar difficulties with working memory and cognitive processing, both of which are necessary for understanding scientific ideas, performing mathematical calculations, and interpreting data (Pestun et al., 2019). This highlights the potential for developing comprehensive strategies when dealing with both conditions at once. Third, combining the study of dyslexia and dyscalculia improves resource efficiency in research and teacher preparation, allowing educational institutions to offer a more thorough support for a wider range of learners (Peters et al., 2020). Additionally, this strategy is in line with the fundamental ideas of inclusive education, sending a strong message of inclusivity within the context of science education and creating an atmosphere in which all students, regardless of their particular learning challenges, have an equal opportunity to succeed.

Despite the close link between science education and learning disabilities is crucial, there is a significant research gap that is focused on the lack of understanding of the most effective teaching strategies for middle school students with dyslexia and dyscalculia. Even though it is insightful, the literature that is currently available frequently lacks thorough synthesis that would provide educators and stakeholders with clear directions regarding best practices. The complexity of learning disabilities is what makes them challenging because every student is unique and has unique needs (Karlina et al., 2019). It is crucial to fill this research gap and investigate particular teaching methods that are tailored to the special learning needs of students with dyslexia and dyscalculia.

Additionally, with the rapid development of technology and its applications in everyday lives, there is a significant lack of practical implementations where technology can be used to enhance inclusivity and offer encouraging tools for improving the accessibility and engagement of students with dyslexia and dyscalculia (Gin et al., 2021). By addressing and analyzing the latest research (2019-2023) regarding this topic, educators and policy-makers can gain a deeper understanding of how technology can be harnessed effectively to bridge the educational divide and provide tailored learning experiences for these students.

The use of technological tools and procedures to assist learners in the twenty-first century is highly recommended by major educational organizations (Association for Educational Communications and Technology [AECT], 2012; International Society for Technology in Education (ISTE), 2017). Studies by Adam & Tatnall (2017), Lannin et al. (2023), Cakir & Korkmaz (2019), Mallidis-Malessas et al. (2021), Slemrod et al. (2021), and Polat et al. (2019) suggest that technology may also benefit students with disabilities by improving their learning outcomes and achievements. In special education, the use of technology has grown in the last few years. One of the technology courses that is most frequently supported these days is science (Kermani & Aldemir, 2015). Technology lengthens students' attention spans, makes academic skills easier to learn, and enhances critical thinking abilities in science classes. In recent years, there have been more studies that support science education for students with learning disabilities (LD) through technology (Ok et al., 2021; Turan & Atila, 2021; Yenioglu & Guner-Yildiz, 2022).

This paper aims to provide a comprehensive review of the practical approaches that can be used to enhance science learning by identifying the best technologies for instructing school students with dyslexia and dyscalculia. To do this, this paper examines existing literature, synthesizes findings, and delves into the technological and contextual aspects. This study addresses the following research questions:
1- What are the technologies used for teaching science to dyslexic and dyscalculic students at the school level throughout the literature in the last five years?
2- What are the advantages of integrating technology into science education for students with learning disabilities?
3- What are the challenges faced by teachers and students when dealing with technology in a science context?

2. Method

2.1 Design

A scoping review of empirical research articles was conducted to identify the educational technologies used in the past five years in the context of science education to enhance students with specific learning disabilities (dyslexia and dyscalculia) at the school level. Unlike other review formats, scoping reviews are intended to offer an overview or, rather than a critically evaluated and synthesized conclusion or response to a particular topic, a map of the evidence (Tricco et al., 2018). Furthermore, because they provide a clear indication of the amount of literature and studies that are available, they are a great method for figuring out how much of a particular issue is covered in a body of literature. These tools assist in examining newly acquired information, especially when it is uncertain which specific, more targeted questions a more focused systematic review could investigate (Sucharew and Macaluso, 2019). However, because study designs and outcome measures vary, a meta-analysis was not practical for this review. Consequently, rather than being statistical, the synthesis is descriptive and narrative. The Preferred Reporting Items for Scoping Literature Reviews (PRISMA) are followed in this study procedure (Tricco et al., 2018).

2.2. Search Strategy

The review was limited to English language and peer-reviewed articles published between 2019-2023. An electronic search was conducted on the following bibliographic databases: PubMed, Sage, Eric, Science Direct, and Google Scholar.

In this scoping review, students with learning disabilities, learning difficulties, dyslexia, and/or dyscalculia were included. In addition, teachers who teach science, STEM, and/or special education were also included in the population.

Dyslexia and dyscalculia are referred to in the literature using various terms. However, the core premise is the same, whether you name them reading, writing, math difficulties or disabilities, or intellectual disabilities. As a result, the following search query was created using phrases that were used as synonyms in the literature:

((educational technology [Title/Abstract]) OR (technology [Title/Abstract])) OR (assistive technology [Title/Abstract])) OR (instructional technology [Title/Abstract])) OR (multimedia [Title/Abstract])) OR (UDL[Title/Abstract])) AND (learning difficulties [Title/Abstract])) OR (learning disabilities [Title/Abstract])) OR (dyslexia [Title/Abstract])) OR (dyscalculia [Title/Abstract])) OR (reading and writing difficulties [Title/Abstract])) OR (mathematical difficulties [Title/Abstract]))AND (Science education [Title/Abstract]))) OR (physics [Title/Abstract])) OR (chemistry [Title/Abstract])) OR (biology [Title/Abstract])) (geography[Title/Abstract]))

2.3. Research Criteria

Inclusion criteria

1- The learning disabilities included were intellectual disabilities, dyslexia, and dyscalculia. And reading, writing, and mathematics difficulties. The selected studies have one or more students who were diagnosed with one or more of the mentioned disabilities.

2- The study must include an intervention using any kind of technology using a quasi-experimental or experimental research design.

3- The intervention settings must be conducted in general science classes or related science fields, e.g., chemistry, physics, geography, or biology.

4- The study must be conducted in any school setting, e.g., elementary, middle, or high school.

5- The selected studies must have been conducted during the past five years, between 2019-2023 in the English language. This is because the objective of this review is to investigate the most recent technologies used in the area of science to enhance learning for students with learning disabilities. Given the fact that educational technologies have been developing rapidly during the past few years.

Exclusion Criteria
1- Studies included other disabilities, e.g., autism and physical disabilities
2- Review papers of any kind, e.g., systematic reviews, scoping reviews
3- Studies conducted in other classes rather than science
4- Studies conducted in higher education institutions, e.g., colleges and universities
5- Studies conducted before 2019.

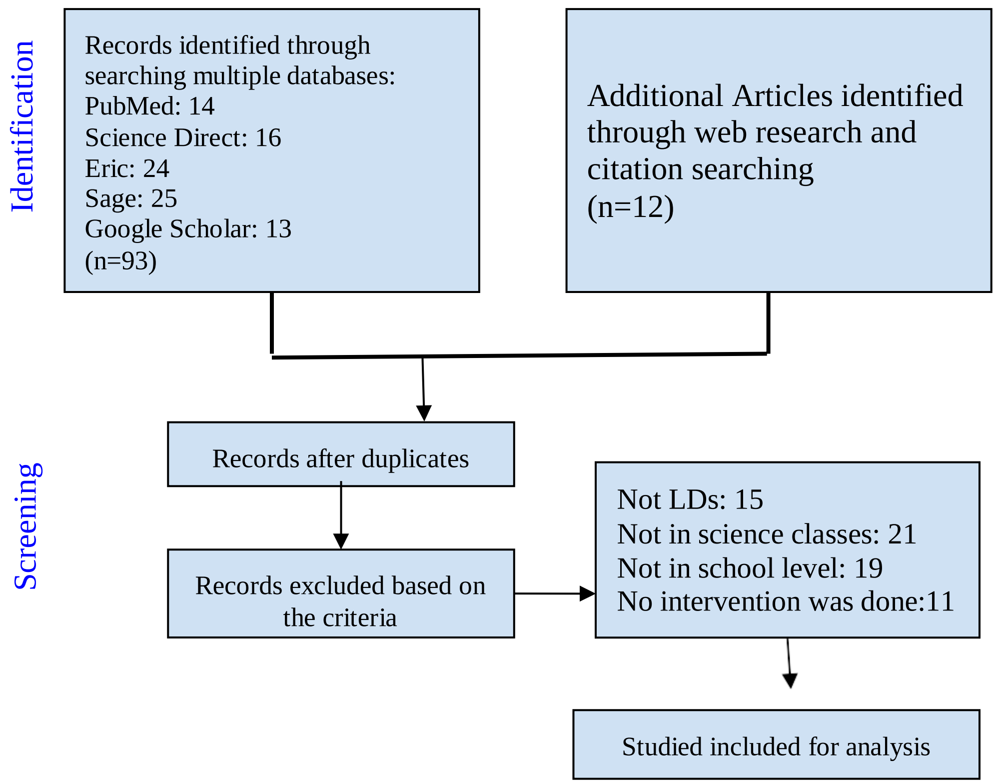

Figure 1 Screening procedure flowchart

3. Results

Table 1 shows the main characteristics of the articles; database where the article was found, location, research design, school level, LDs, and type of technology integrated. In a wide range of geographical and cultural contexts, the articles offer a nuanced investigation of the effectiveness of technology-based interventions for students with learning disabilities (LDs). The inclusion of studies from various regions, including the USA, India, Canada, Greece, Jordan, Germany, Saudi Arabia, and Turkey, is a noteworthy strength. The understanding of how cultural subtleties may affect the use and efficacy of technology in special education is enhanced by this geographical diversity. On the other hand, because cultural differences may have an impact on the results, it also presents issues with the generalizability of the findings.

Furthermore, the articles are laudable for their incorporation of diverse research designs, encompassing quantitative, qualitative, and mixed methods, thereby enriching the breadth of the exploration. However, this methodological diversity, while contributing to a holistic view of the field in terms of school levels and addressing learning disabilities, presents challenges in conducting a meta-analysis and deriving conclusive insights into the overall effectiveness of technology in supporting students with learning disabilities (LDs).

Some of the articles were conducted in general education classes, where students with LDs are included in the main classroom. In all the general education classes, a differentiated instruction strategy was used to ensure the inclusion of all students' needs (Lannin et al., 2023; Mallidis-Malessas, et al., 2021; Rizk and Hillier, 2022; Sghaier et al., 2022; Wood et al., 2019). Other articles were conducted in special education classes, where students with LDs are taught separately in general inclusive schools or special education schools (Alqarni, 2021; Baumann and Melle, 2019; Elfakki et al., 2023; Iatraki, 2020; Polat et al., 2019; RathnaKumar, 2019; Slemrod et al., 2022; VanUitert et al., 2020)

In the general education studies, the number of participants ranges from 37 to 445 students, and the studies focus on various scientific topics, such as chemistry, physics, and biology. In the special education studies, the number of participants ranges from 3 to 40 students, and the studies also focus on various scientific topics, including physics, chemistry, and biology. Special education studies often aim to improve students' academic performance, engagement, and social skills, while general education studies focus on students' engagement, confidence, and understanding of scientific concepts.

Some articles explicitly mentioned the type of LDs and learning difficulties of students who are involved in the intervention (Mallidis-Malessas et al., 2021; Slemrod et al., 2022; Yenioglu et al., 2023; Wood et al., 2019; Turan and Atila, 2021; Elfakki et. al., 2023; Iatraki et al., 2020). Other studies only mentioned the term LDs, or learning difficulties, without further specifications (Lannin et al., 2023; VanUitert et al., 2020; Saghaier et al., 2022; Polat et al., 2019; Baumann and Melle, 2019; RathnaKumar, 2019; Rizk and Hillier, 2022). Whereas in the King-Sears and Johnson (2020) and Yenioglu and Guner-Yildiz (2022) articles, they mentioned implicitly that students involved were eligible for special education due to reading, writing, and math problems. Alqarni (2021) stated in their discussion that students with dyslexia benefited the most from the intervention, but in the participant's section, they mentioned special needs, including LDs.

RQ1: Types of Technology

The educational technologies in the articles varied from easy accessibility to specially designed programs. Some tools were available and low-cost while others needed special physical equipment and were relatively high-cost to implement. In the Lannin et al. (2023) and Rizk and Hillier (2022) articles, each teacher chose their own approach to using technology; most of the technologies were computers already in the school setting, and others used Chromebooks for educational purposes, which are considered a relatively high-cost device. Other articles used only open-access software, e.g., PowerPoint, 3D images, Ed Puzzle, and computer devices (Mallidis-Malessas et al., 2021; VanUitert et al., 2020; Alqarni, 2021; King-Sears and Johnson, 2020; Iatraki et al., 2020; Baumann and Melle, 2019). Some interventions used iPads, iPods, and touchscreen computers (Slemrod et al., 2022; Yenioglu et al., 2023; Wood et al., 2019; Yenioglu and Guner-Yildiz, 2022; Turan and Atila, 2021; RathnaKumar, 2019). On the other hand, Elfakki et al. (2023), Polat et al. (2019), and Sghaier et al. (2022) used more complex settings and software, including Open-Simulators, Sloodle, and specially designed physical equipment. Next is a more in-depth overview of the technologies for each article.

Three articles used AR (Augmented Reality) as an instructional intervention (Alqarni, 2021; Yenioglu et al., 2023; Turan and Atila, 2021). Previous research showed that AR technology usage significantly affected the outcomes of students' learning, indicating that the use of such technology was an effective tool, particularly when applied to students with learning disabilities. It is worth investigating students' behavior and attitudes toward using such technology in science classrooms. Students' attitude contributes significantly to their engagement and, therefore, their academic performance. Alqarni (2021) explores attitudes and learning outcomes after implementing a 4-week intervention using AR by enabling the visualization and audio of scientific abstract concepts by combining reality with 3-D pictures and videos. Yenioglu et al. (2023) examined four students with dyslexia and dyscalculia between the ages of 10 and 11 years old. The intervention was through a mobile app on the iPad that uses visual and auditory stimuli to explain abstract concepts in solar system systems and planets, with the main goal of investigating the effectiveness of augmented reality (AR) in teaching solar systems to students with LD in writing, spelling, comprehension, and mathematics. Finally, Turan and Atila (2021) used augmented books to investigate the effects and views of students with LDs in middle school on science topics related to the state of matter and physical and chemical changes.

Elfakki et al. (2023) and Sghaier et al. (2022) used Virtual Learning Environments (VLE) as instructional technology in their articles. VLE is a digital platform or system that offers online spaces for educational interactions, content delivery, and collaboration. It acts as a centralized hub for students and teachers to engage in learning activities, access course materials, and communicate in a virtual setting. Both articles created whole virtual environments with three-dimensional objects and models, specially designed for students with LDs in mind. This is because it incorporates a range of colorful, three-dimensional objects that will catch students' attention. It was used to simulate scientific experiments and concepts in an environment that allows students to experience situations and scenes while they are in their actual physical classrooms through 3-D tools that synchronize the images with the sound effects.

Whereas four articles used videos as instructional technology using easy-access devices, e.g., computers. Yenioğlu and Güner-Yıldız (2022) used science experiments displayed on tablet computers via videos for each experiment. This article was conducted to find a solution, as many public schools in rural areas of Turkey do not have laboratories, but the importance of conducting experiments for science learning is vital. King-Sears, E., and Johnson, M. (2020) used six videos to demonstrate the process of molar mass conversion in chemistry on computers. Furthermore, Baumann and Melle (2019) used interactive videos to explain some chemical reactions. The videos included audio and graphs along with differentiated instructions. Finally, VanUitert et al. (2020) used videos to implement content acquisition podcasts (CAP), which play a vital role in comprehending and memorizing scientific terms.

Nevertheless, four articles conducted interventions using open-access free applications and websites. Iatraki et al. (2020) and Mallidis-Malessas et al. (2021) used two digital learning objectives from a website called the Greek National Learning Object Repository to simulate transverse waves and simple pendulum motion in physics on computers. In addition, Wood et al. (2019) examined the efficiency of e-texts on computers to improve students' reading comprehension skills. A free app called Go Talk Now was also used on students' iPads to generate questions and answers related to the text. Similarly, Slemrod et al. (2022), used free software for iPods to examine the difference between using flashcards on iPods and traditional teaching in students' biology vocabulary acquisition.

On the other hand, two articles designed specialized applications and programs for their interventions. Polat et al. (2019) examined the influence of using educational technology that uses physical movement in digital environments on students with learning disabilities academic achievements and attitudes toward learning science. They designed an application on the iPads, along with its physical objects, to teach students cell concepts. Also, RathnaKumar (2019) developed the Computer-Assisted Instructional Framework (CAIF) and Programme for Science Learning using iPads to provide intervention to the sample. The intervention was used as an assistive technology to help students learn science concepts, e.g., parts of plants, living and non-living things, water, natural resources, Work- (push and pull), and solids, liquids, and gases.

Finally, the two articles did not determine one type of technology; the type of technology decision was left to the teachers. Lannin et al. (2023) investigated the implementation of a scaffolding multimodal text set strategy using instructional technology to teach complex science texts to middle school students, including students with LD. Teachers included in this study used different technologies to simplify complex texts, e.g., digital simulations, virtual reality, videos, and Chromebooks. In addition, Rizk and Hillier (2022) conducted observations and interviews with teachers from 27 classrooms where technology was placed as an intervention. Some of the technologies were robotics, smartboards, and iPads.

In conclusion, the reviewed articles present a range of instructional technologies that meet various learning requirements. The selection is wide, ranging from free choices like open-access software and films to more sophisticated instruments like virtual learning environments (VLE) and augmented reality (AR). Certain interventions demonstrated adaptability to various contexts by utilizing specialized applications and programs. While some studies showed a broad range of technology choices, others concentrated on particular gadgets like iPads and touchscreen PCs. The frequency of AR in research suggests that it has a favorable effect on student engagement and learning outcomes.

RQ2: Advantages of using technology

The reviewed studies that were conducted in special education classes collectively reveal promising insights into the use of technology to enhance the educational experiences of students with learning disabilities. Elfakki et al. (2023) showed that students with particular learning disabilities had improvements in their cognitive and practical skills. Augmented reality (AR) was studied by Yenioglu et al. (2023), who highlighted the benefits of academic performance, engagement, and attention. According to Rathna Kumar (2019), iPad-based computer-aided instruction (CAI) significantly raised achievement scores for students with mild intellectual disabilities. Iatraki (2020) offered information about how Digital Learning Objects (DLOs) improve students with mild intellectual disabilities' understanding of physics. The benefits include more accessibility, better engagement, and customized interventions; however, there are certain drawbacks as well, like small sample sizes and the need for more research.

Meanwhile, Slemrod et al. (2022) focused on Quizlet for flashcard creation as a user-friendly tool benefiting students with LDs academically and behaviorally. Alqarni (2021) and Turan and Atila (2021) both investigated the beneficial effects of augmented reality technology on students who struggle with learning; Turan and Atila placed particular emphasis on individual differences. Polat et al. (2019) provided evidence of how a tangible mobile application can help students with particular learning disabilities become more knowledgeable.

According to Wood et al. (2019), students with moderate intellectual disabilities can improve their comprehension and ability to formulate questions by using iPads for systematic instruction.

On the other hand, the following are the benefits of the articles that were conducted in inclusive classes: Two studies, Lannin et al. (2023) and Yenioğlu and Güner-Yıldız (2022) highlighted the benefits of their approaches for improving students with LDs understanding of scientific concepts and facilitating knowledge retention. Lannin et al. (2023) found that multimodal STEM texts, combining text, images, and multimedia elements, significantly improved the Claim-evidence-reasoning (CER) abilities of students with LDs, comparable to students without disabilities. However, the study identified challenges in claim-making and written communication, suggesting the need for additional instructional support in these areas. Yenioğlu and Güner-Yıldız (2022) provided evidence of the efficacy of science experiments utilizing tablets in instructing students with learning disabilities about motion and force. The study highlighted the benefits of long-term, hands-on learning enabled by tablets, surpassing the drawbacks of conventional laboratories.

Sghaier et al. (2022) revealed significant achievement gains compared to traditional methods. The 3D facilitated collaboration, active participation, and inclusive access to virtual activities, overcoming physical limitations and fostering digital skill development. Rizk and Hillier (2022) took a different approach, examining the integration of digital technology in classrooms to create new rituals and cultural capital for students with LDs. Their study, based on classroom observations and interviews, found that assistive technologies empowered students with LDs and transformed traditional classroom rituals. Students with LDs demonstrated increased engagement and participation, taking on more active roles in classroom activities. This shift in dynamics highlights the potential of technology to decentralize teacher authority and promote student-led interactions.

In conclusion, the studies that have been reviewed highlight the significant advantages of using technology in the classroom for students who have learning disabilities. Technology appears to be a powerful instrument for promoting favorable results, from tailored interventions to increased accessibility and involvement. These benefits include increased achievement scores, improvements in cognitive abilities, and a positive influence on classroom dynamics. As technology continues to evolve, these studies offer valuable insights, paving the way for ongoing advancements in inclusive education.

RQ3: Challenges and Limitations

Not all the reviewed articles addressed challenges related to the implementation of technology for students with LD. Nonetheless, a number of studies have brought attention to difficulties and offered fresh perspectives on the difficulties that educators confront. Lannin et al. (2023) underscore the difficulty of implementing strategies in inclusive classrooms with severe cases of dyslexia. As noted by Mallidis-Malessas et al. (2021), who stress the need for adjustments to address a variety of learning needs, particularly in mathematical skills, the authors highlight the time-consuming nature of developing such strategies. But even with all of this work, Wood et al. (2019) cast doubt on the usefulness of technology by pointing out that knowledge cannot be generalized without the iPad, which makes integration even more difficult.

The challenges extend beyond preparation and implementation to encompass the assessment of outcomes. Both Lannin et al. (2023) and Yenioglu et al. (2023) bemoan the absence of a systematic approach to measuring academic achievement and student satisfaction, underscoring a critical void in our knowledge of the effects of these technological interventions. Yenioglu and Güner-Yıldız (2022) as well as Polat et al. (2019) add to this discussion by highlighting the limited applicability and generalization of technology in inclusive and general education classrooms. According to Polat et al. (2019), there is variation in the number of participants in different groups, which complicates the process of drawing definitive conclusions.

In their exploration of the human side of technology integration, Slemrod et al. (2022) highlight the critical importance of teacher preparation programs and technological know-how. Simultaneously, the study by Baumann and Melle (2019) highlights the technological obstacles related to the use of technology, underscoring the significance of proper teacher preparation. Slemrod et al. (2022) argue that students require a transition period that emphasizes the social dynamics involved in integrating technology, depicting smart devices not only as instructional tools but also as social mechanisms.

In conclusion, these studies collectively reveal a multifaceted landscape of challenges in implementing technology in educational settings. From pedagogical considerations to technical barriers and the social dimensions of technology use, educators must navigate a complex interplay of factors to ensure effective and inclusive technology integration in the learning environment.

Table 1 Articles Description

Ref.	Database	Location	Design	Setting	LDs	Participants	Technology	Major Findings
Alqarni, (2021)	Eric	Jordan	Quantitative	Middle school SE class	LDs, including Dyslexia	24 students	AR using Computers	Improvements in students' engagement, autonomy, and academic performance Minimizing the stigma associated to LDs
Baumann and Melle (2019)	Google Scholar	Germany	Mixed method	Middle school GI class	LDs, hearing impairments, and social behavioral disorders	89 students	Interactive software On computers	Significant improvements in students' performance and positive feedback
Elfakki et al. (2023)	Google Scholar	Saudi Arabia	Quantitative	Middle school SE class	Dyslexia, dyscalculia, ADHD, and information retrieval disabilities	40 students	3D lab simulation	Improvements in students' cognitive skills and positive attitude
Iatraki (2020)	Google Scholar	Greece	Quantitative	High school SE class	Dyslexia	3 students	Digital Learning Objects	Improvements in students' self-confidence, autonomy, and slight improvement in their academic performance
King-Sears and Johnson (2020)	Sage	USA	Quantitative	High school 1st study in GI 2nd study in	Various LDs, including dyslexia and dyscalculia	37 students	Interactive videos	Students from the first study showed higher academic performance and satisfaction

Ref.	Data base	Locat ion	Design	Setting	LDs	Particip ants	Technology	Major Findings
				SE				
Lannin et al. (2023)	Sage	USA	Mixed method	Middle school GI	LDs	11 teachers 1,046 students	Videos, simulator, Chromebooks, VR	Improvements in students' engagement, confidence, and understanding Challenging implementation in inclusive general classes
Mallidis-Malessas, et al. (2021)	Eric	Greec e	Quantit ative	High school SE	Reading comprehension, writing, spelling, and math-related disabilities	13 students	Interactive simulations	Improvements in students' engagement Noticeable challenges when working on math content
Polat et al. (2019)	Eric	Turke y	Quantit ative	Middle school SE class	LDs	3 students	Tangible mobile application	Improvements in students academic performance, concentration, satisfaction, and engagement
RathnaKu mar (2019)	Eric	India	Mixed method	Element ary school SE	LDs	20 students	Computer-assisted instructional program using iPad	Improvements in students learning Feasibility of the implementation
Rizk and Hillier (2022)	Scien ce Direc t	Canad a	Qualitat ive	Element ary and middle schools GI	Various disabilities, including LDs	362 students 11 teachers	Robotics, smartboards, and iPads	Improvements in students' engagement and interactions

Ref.	**Data base**	**Locat ion**	**Design**	**Setting**	**LDs**	**Particip ants**	**Technology**	**Major Findings**
Sghaier et al. (2022)	Pub Med	Saudi Arabi a	Quantit ative	Middle school GI	Dyslexia-dyscalculia and other learning and physical disabilities	50 students	3D virtual environment and simulation	Improvements in students academic performance, satisfaction, and social skills Minimizing the stigma associated to LDs
Slemrod et al. (2022)	Sage	USA	Quantit ative	High school SE	Reading and writing disabilities	3 students	Flashcards using Quizlet	Minor academic improvement High students' satisfaction
Turan and Atila (2021)	Eric	Turke y	Mixed method	Middle school SE	Dyslexia, dyscalculia, and ADHD	4 students	Augmented books displayed on tablet computers	Improvements in students' academic performance and satisfaction Students maintained their knowledge Many technical issues were faced
VanUitert et al. (2020)	Eric	USA	Quantit ative	Middle school SE	speech/language impairment and other LDs, including ADHD	43 students 2 teachers	Podcasts using videos	Significant improvement in academic achievements
Wood et al. (2019)	Sage	USA	Quantit ative	Element ary school SE	Dyslexia and other moderate LDs	3 students	E-texts using iPads and graphic organizers using computers	Improvements in comprehending texts, mostly while using the iPad only

Ref.	Data base	Locat ion	Design	Setting	LDs	Particip ants	Technology	Major Findings
Yenioğlu and Güner-Yıldız (2022)	Goog le schol ar	Turke y	Quantit ative	Middle school GI	Math and language related LDs	3 students	Tablet computers	Improvements in students' understanding and memorization of science concepts Students maintained knowledge
Yenioglu et al. (2023)	Sage	Turke y	Quantit ative	Element ary and middle schools SE	Dyslexia and dyscalculia	4 students	AR using iPads	Improvements in students' attention, curiosity,, and understanding Students maintained their knowledge of the abstract concepts

4. Discussion and Conclusion

Science subjects are critical in forming students' knowledge, curiosity, and critical thinking skills in the classroom, especially during the middle school transition period. Despite the importance of science education, dyslexic and dyscalculic students face obstacles that prevent them from participating fully and succeeding in science classes. These difficulties frequently lead to problems that are not addressed in educational settings, which hinders the academic advancement of a significant number of students with learning disabilities.

The goal of this paper was to address this gap by synthesizing existing literature and providing educators and stakeholders with clear guidance on best practices tailored to the unique learning needs of these students. The study also looked at the understudied area of using technology to improve inclusivity and engagement for dyslexic and dyscalculic students in an effort to close the achievement gap and offer individualized learning opportunities. The research questions guided this exploration, encompassing an analysis of technologies used, the advantages of technology integration, and the challenges faced by teachers and students in the science education context over the last five years.

A wide range of instructional technologies, from easily accessible and affordable tools to specialized and more expensive programs, are presented in the reviewed articles. In studies like Rizk and Hillier (2022) and Lannin et al. (2023), teachers were free to select whatever technology they wanted to use, including Chromebooks or already-owned computers. Some studies made use of iPads, iPods, and touchscreen computers; others used open-access software and desktop computers. Certain interventions involved the use of more sophisticated settings and software, like Sloodle and Open-Simulators (Elfakki et al., 2023; Polat et al., 2019; Sghaier et al., 2022). Augmented Reality (AR) featured prominently in Alqarni (2021), Yenioglu et al. (2023), and Turan and Atila (2021), demonstrating its effectiveness in engaging students. Virtual Learning Environments (VLE), as seen in Elfakki et al. (2023) and Sghaier et al. (2022), provided immersive digital platforms for students with learning disabilities. Videos, free applications, and specialized programs also played vital roles in diverse interventions, showcasing the flexibility and adaptability of technology choices. Overall, these studies underscore the dynamic landscape of instructional tools available to educators, offering versatile options to meet diverse learning needs.

The reviewed studies, which were carried out in inclusive and special education classrooms, offer encouraging new information about the beneficial role that technology can play in improving learning outcomes for students with learning disabilities. The benefits of augmented reality (AR) on academic performance and engagement, the advantages of iPad-based computer-aided instruction (CAI) for students with mild intellectual disabilities, the advantages of Digital Learning Objects (DLOs) in physics education, and the user-friendly advantages of Quizlet for creating flashcards are among the findings. Improvements in cognitive and practical skills are also included. Benefits in inclusive environments include the effectiveness of multimodal STEM texts, science experiments conducted on tablets, notable progress gains from 3D technology, and the revolutionary effects of digital technology on classroom dynamics. In summary, the aforementioned studies highlight the potential of technology to enhance academic performance, cognitive capacities, and classroom engagement among students with learning disabilities. These findings offer important new perspectives for the continuous progress of inclusive education.

While not all reviewed articles delved into challenges related to implementing technology for students with learning disabilities (LD), several studies shed light on the difficulties educators face. The articles underscore the complexities of implementing strategies in inclusive classrooms, particularly for severe cases of dyslexia. Difficulties include the time-consuming process of creating customized strategies to meet a range of learning needs and concerns about the generalizability of knowledge without specialized equipment like iPads. Assessment challenges are also evident, with authors lamenting the absence of a systematic approach to measuring academic achievement and student satisfaction, revealing a critical gap in understanding the effects of technological interventions. Further contributing to the conversation are worries regarding the limited generalization and application of technology in inclusive and general education classrooms, as well as the difficulties in drawing firm conclusions due to differences in participant numbers. In examining the human side of technology integration, emphasis is placed on the crucial role of teacher preparation programs and technological proficiency, while acknowledging the need for a transitional period that highlights the social dynamics involved in integrating technology.

The array of technological interventions explored in the reviewed studies, spanning Augmented Reality (AR), Virtual Reality (VR), simulations, interactive software, and podcasts, highlights the dynamic landscape of educational technology. This diversity allows for customization to address various learning needs but poses challenges in making direct cross-study comparisons due to the absence of a standardized methodology for technology integration.

Recent studies emphasize the potential of technology to enhance learning for students with LDs but simultaneously reveal critical limitations requiring further investigation. A comprehensive discussion of key constraints identified across studies is essential.

Limited Generalizability and Specificity:
Several studies, such as Elfakki et al. (2023) and Yenioglu et al. (2023), grapple with limitations related to small sample sizes and insufficient details regarding specific intervention components. This lack of specificity hampers the generalizability of findings, impeding the identification of factors contributing to observed success. RathnaKumar (2019) further restricted applicability by utilizing iPads for Computer-Assisted Instruction (CAI) without delineating content and strategies.

Methodological Considerations:
Iatraki (2020) introduced a constraint by concurrently implementing two Digital Learning Objects (DLOs) for all participants, complicating the isolation of each intervention's impact. Slemrod et al. (2022) faced challenges due to the non-traditional setting of their study, raising concerns about the applicability of results within regular curriculum contexts. Turan and Atila (2021) acknowledged the potential novelty effect of AR, suggesting that initial positive outcomes may not guarantee long-term effectiveness.

Incomplete Assessments and Lack of Follow-Up:
Elfakki et al. (2023) omitted critical information on the study's duration and follow-up, casting doubt on the sustainability of the observed improvements. Yenioglu et al. (2023) employed a non-standardized achievement test, potentially compromising the objectivity of the results. RathnaKumar (2019) lacked follow-up data, leaving the long-term impact of their intervention unclear.

Focus on Specific Disabilities and Age Groups:
Studies such as Slemrod et al. (2022) concentrated on students with learning disabilities (LD), while RathnaKumar (2019) involved students with mild intellectual disabilities. Heterogeneity in participant characteristics, exemplified by Iatraki (2020) focus on high school students, complicates the generalizability of findings across different disability types and age groups. Also, the different students' conditions required different kinds of intervention. Therefore, the technology used is good insofar as the particular type of condition that the students present in the study. It is not generalizable to other conditions. In addition, the severity of the LD may vary. Therefore, an Individualized Educational Plan (IEP) approach is needed to incorporate the use of technology to assist students with LDs in learning science subjects.

5. Limitations and Future Research

A small number of studies regarding technology-based interventions in science education for students with disabilities were identified. The main limitation of this systematic review was the inclusion of papers published in the English language and in peer-reviewed journals. Additional searches in peer-reviewed conferences could have possibly added more resources, although researchers usually present their initial results in conferences following extended studies published in journals. Another limitation was the authors' search in four databases (PubMed, Sage, Eric, Science Direct, and Google Scholar).

Empirical studies currently investigate the pedagogical added value of digital technology in science education for students with disabilities. Future research has to involve interventions that take into account the affordances of the technologies used, and a thorough assessment of the research design, and should configure one or more items regarding the proposed technology quality indicator.

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