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Impact of digital competencies and assistive technologies on learning outcomes for students with learning disabilities in Kingdom of Saudi Arabia: a systematic review

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Background: Assistive technology (AT) offers a vital role in providing a learning environment for disabled students. This paper investigates the role of AT and digital skills in enhancing learning outcomes for Kingdom of Saudi Arabia (KSA) students having Learning Disabilities (LD).

Objectives: This review aims to explore the extent of technological applications to support students face LD. This review identifies the core skills that require further enrichment and the technological tools used for skill development, the impact of technological tools on the performance of students with LD, and investigate a variety of research on technological amelioration to assist KSA students with LD. The study also covers various research domains where further exploration is vital.

Methods: The review encompasses a detailed investigation of 35 research articles in the specific range of 2014–2025. In the study, 24 papers (69%) were targeted at primary and middle schools. The remaining 11 (31%) studies involved other participants such as University or special education. The review process encompasses 09 databases and follows a systematic and widely recognized approach of PRISMA 20 guidelines.

Results: The review revealed that past studies focused on multiple baseline designs focusing primarily on elementary school students and a few other educational settings such as special education and university. The review also highlights key skills where research elevation is of utmost value, and fruitful outcomes can be attained by applying technological tools to support these skills. Further, the review outcome demonstrates that technological tool applications have a positive impact on students' performance.

Conclusion: The review unveiled that Dyslexia disability is the most common in students with LD, constituting 12 papers (34%), followed by Dyscalculia and Attention-Deficit/Hyperactivity Disorder (ADHD). The review outcome recommends various elucidations, including expanding teacher training

programs, addressing infrastructural gaps, and conducting more localized studies in Kingdom of Saudi Arabia (KSA).

KEYWORDS

digital skills, assistive technology, learning outcomes, learning disabilities, PRISMA 2020, Kingdom of Saudi Arabia

Introduction

In recent years, rapid advancements in technology have completely transformed education; creating unprecedented opportunities to enhance inclusivity and improve learning outcomes for diverse student populations (Hollier, 2016). Students with Learning Disability (LD) are believed to have significant benefits from advanced technological innovations. According to Dukmak et al. (2024), Assistive Technology (AT) has become an important tool that helps people with special learning needs by giving them personalized educational support and helping them do better in school. The digital transformation in education has happened at the same time as the widespread use of AT. Modern tools not only give students access to educational materials, but they also make learning environments that are tailored to each student's needs and allow them to interact with each other (Salonen et al., 2022). Text-to-speech or speech-to-text software, digital organizers, and interactive learning platforms are all great tools for students with LD because they allow for personalized instruction and give immediate feedback (Schmeisser and Courtad, 2023). These tools help disabled students compete on an equal footing by keeping them interested in schoolwork and helping them reach their full potential. But to get the most out of these technologies, you need to know how they work and have the digital skills to use them well.

In today's tech-driven world, digital skills are the most important part of modern education, especially for students with learning disabilities who need assistive technologies to get around problems in traditional learning settings. These skills make it easier for students to get to educational materials and let them use technology on their own, which builds their confidence and helps them do well in school over the long term (Navas-Bonilla et al., 2025). Some studies, like Schmeisser and Courtad (2023), have shown that students who have basic digital skills are better able to use and navigate assistive technologies effectively.

In the current digitalization era, the ability to apply Information and Communication Technology (ICT) has become an essential skill for academic success and social participation. Digital skills encompass the ability to use tools like computers, software applications, and the internet for learning, communication, and problem-solving (Wu et al., 2014). It is crucial to understand that Assistive Technologies (AT), though often built upon the broader foundation of Information and Communication Technology (ICT), form a distinct and specialized group. What sets AT apart is its explicit aim: to directly address and lessen the difficulties created by disabilities, improving an individual's functional skills and their ability to engage with learning. For example, a tablet serves as an ICT, but it becomes an AT the moment it is equipped with text-to-speech software and intentionally used to assist a student with dyslexia. The core differentiator is the deliberate design or modification of technology specifically to overcome a barrier posed by a disability, shifting its role from general use to providing targeted, empowering support. However, studies have highlighted significant disparities in ICT competencies between students with and without LD, underscoring the need for targeted ICT training programs to address these gaps, as asserted by Wu et al. (2014) and Doğan and Delialioğlu (2020). The concept of the digital divide underscores not only unequal access to ICT but also disparities in the skills needed to use these technologies effectively. While students with LD may have physical access to technology in schools, their ability to use these resources is often hindered by challenges such as working memory deficits, attention difficulties, and limited exposure to structured ICT training (Wu et al., 2014). Despite these global challenges in ensuring equitable access and effective utilization of AT and ICT for students with LD, the existing international literature also points to broader research gaps, such as the limited number of longitudinal studies on long-term impact and the ongoing need for rigorous evaluation across diverse settings. Overcoming these barriers is critical to ensuring that all students can benefit from the transformative potential of digital technologies.

The global literature underscores the transformative potential of AT and highlights universal challenges in its implementation; however; the context of the Kingdom of Saudi Arabia (KSA) presents a compelling case for focused investigation. The country has demonstrated significant commitment to integrating Assistive Technologies (device, software, or tool) into education, driven by Vision 2030 (Ministry of Education, 2020). However, similar to global trends but often exacerbated by local specificities, challenges persist, including inadequate teacher training, insufficient digital infrastructure, and cultural perceptions of disability that impede the effective use of assistive technologies (Abo Hamza et al., 2024; Adebisi et al., 2015). However, various scientist emphasizes the gravity of comprehensive strategies that combine the provision of assistive devices with training programs for both students and educators. These initiatives focus on developing digital skills alongside deploying AT tools to ensure that students with LD can fully leverage these resources to overcome learning barriers and achieve academic success (Wu et al., 2014; Doğan and Delialioğlu, 2020; Tindle et al., 2022).

Despite the global understanding on the increasing need for AT and other ICT applications for students with LD, several critical research gaps persist worldwide, particularly concerning the long-term efficacy and scalability of interventions. However, within the unique context of KSA, these challenges are compounded by specific local factors, leading to distinct gaps in the literature. For instance, while international studies provide broad insights, there is an urgent need for localized research exploring the impact of AT and digital skills on improving learning outcomes for students with LD in remote and less privileged regions of KSA, where students face particular challenges in adapting to traditional educational environments (Al-Shehri, 2010). Furthermore, a notable gap exists in understanding how to seamlessly integrate culturally and linguistically relevant AT and digital skills into the specific educational practices of KSA to meet the unique needs of local students. By examining the effects of these tools and uncovering these region-specific gaps in their usage, this research aims to offer practical recommendations that will improve

learning outcomes and foster inclusivity in education within the KSA educational system.

Given aforementioned issue, this study aims to determine the impact of digital skills on improving the learning outcomes of students with learning difficulties. Further, this study aims to explore the role of educational technology in facilitating the learning process for students with learning difficulties, and assessing the current gaps in the application of technology and digital skills to support this category of students. The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) 20 guidelines process is followed in this study which promote the transparent and complete reporting of systematic literature review. PRISMA 2020 guidelines is a recent major update of the PRISMA that includes more comprehensive guidance on the reporting of methods, terminology, and results. A complete checklist of PRISMA 20 guidelines is attached as Supplementary File. This study via systematic review aims to provide recommendations for technology-based educational policies to improve education for students with learning difficulties in rural areas of KSA.

Study contribution and novelty

This study systematically investigates the impact of digital skills and AT on the learning outcomes of students who faces LD. The study contributes in identifying the specific digital skills that need enhancement and the technological tools that are most effective in developing these skills. Additionally, the study aims to assess the scope and variety of research exclusively on advanced technologies that assist students of KSA with LD. The investigation contributes in identifying various unexplored research domain that require further exploration. The findings of this study primarily contribute in providing recommendations for the effective integration of technology into educational policies to improve the learning outcomes of students with LD in KSA. This study aims to contribute in existing knowledge body by answering the following interrogations.

How do advanced digital skills and the integration of assistive technologies influence academic performance and engagement among students facing learning disabilities?

Which specific digital competencies are mostly lacking in students having learning disabilities, and which assistive tools most effectively enhance such competencies?

To what extent does current research on assistive technology for students with learning disabilities in KSA exhibit depth and diversity, and what are the most critical knowledge gaps that need to be explored?

Learning disabilities and assistive technology

Learning Disabilities (LD) refer to a group of neurodevelopmental disorders that impact an individual's ability to acquire or use essential cognitive skills such as language, reading, writing, or mathematics. These disorders are typically caused by central nervous system dysfunctions and irrespective of any external factors like visual, auditory, or motor impairments (Adebisi et al., 2015). Common forms of LD include dyslexia, dysgraphia, and dyscalculia, which manifest as difficulties in reading, writing, and mathematics, respectively (Doğan and Delialioğlu, 2020). It is a well-known fact that students with LD often face challenges in traditional educational environments, necessitating specialized teaching strategies and technological interventions.

In connection to LD, the AT is broadly defined as any device, software, or tool designed to help individuals with disabilities overcome functional limitations and to achieve greater independence. According to Leask and Younie (2024), AT encompasses tools that address physical, cognitive, and social barriers, enabling individuals to fully participate in education, employment, and everyday activities. For students with LD, the AT includes tools such as text-to-speech or speech-to- text software, visual organizers, and adaptive keyboards, which alleviate learning challenges and enhance academic performance (Adebisi et al., 2015).

Methods

Research design

This study employs a systematic review based upon PRISMA 20 guidelines to investigate the impact of digital skills and AT on the learning outcomes of students with LD. PRIMSA 20 is widely endorsed 27 items checklist commonly employed to evaluate the literature review quality. This review qualifies most of the items of PRISMA 20 checklist focusing each section of guidelines, i.e., title, abstract, methods, data collection strategy, process, results, and discussion. A systematic literature review is carried out from renowned journals downloaded using various databases from September 2024 to April 2025. The review encompasses a detailed investigation of 35 research articles in the specific range of 2014–2025. This investigation covers a critical understanding of current literature. A systematic literature review is a process that begins with material collection and then evolves into a descriptive analysis, classification, and material evaluation. The review carefully considered suitable keywords while downloading articles. Personal observations were also considered, followed by a systematic review process from title filtration to abstract overview, keywords, method and full paper reading (see Figure 1). The filtration process narrowed down the articles. Finally, 35 articles were considered those were most relevant and as per the inclusive criteria. This review encompasses a few selection criteria such as illustrated in Figure 2.

Screening and material extraction

Secondary data in the form of articles were collected from peer-reviewed journal articles and academic sources from September 2024 to April, 2025. Nine databases were scanned: PsycINFO, Web of Science, Scopus, PubMed, Google Scholar, Education Resources Information Center (ERIC), ScienceDirect, SpringerLink, and Dar Al-Manzomah. A specific keywords were included such as "Learning Disabilities," "Specific Learning Disabilities," "Assistive Technology," and "Digital Skills." The screening process includes overviewing of title, abstract, keywords, method, and results following the PRIMSA 20 statement. A form was constructed using Microsoft Access 2016 to extract the following characteristics of eligible systematic review, i.e., author, journal name, publication year, journal language, title, country of study, level of education, type of technology used etc.

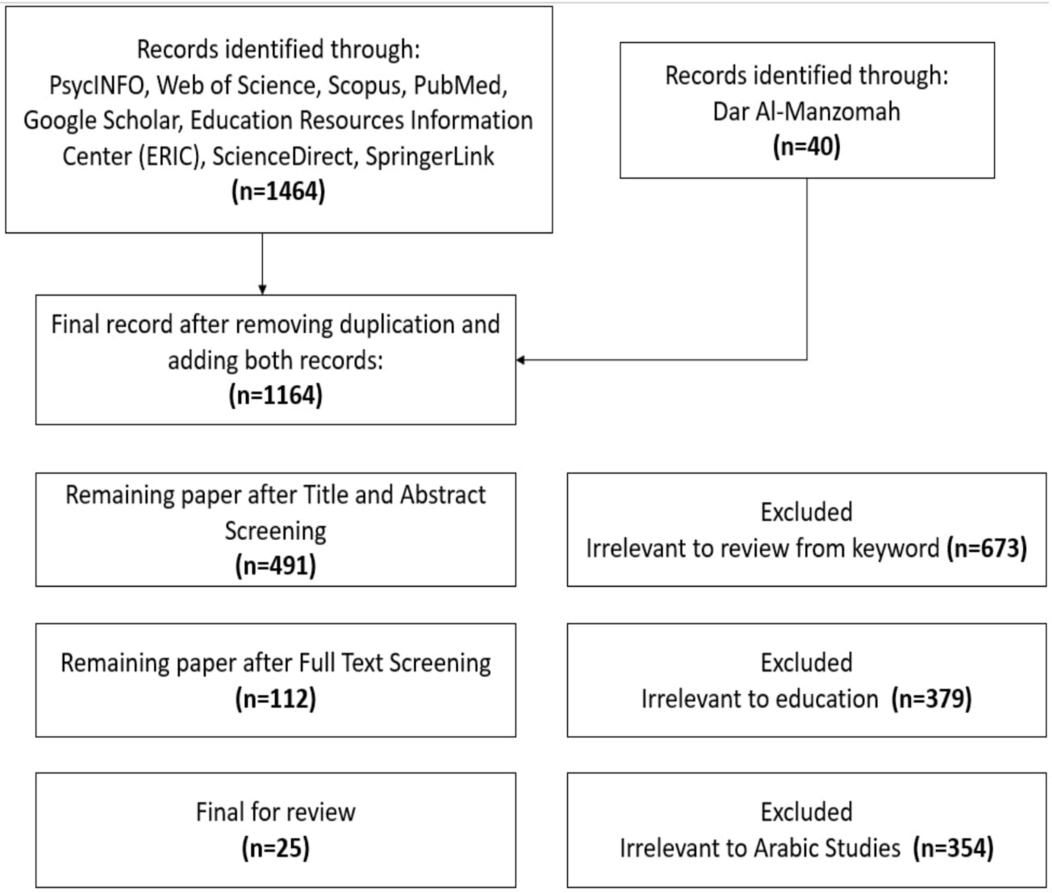

FIGURE 1
Systemic review process.

Inclusion and exclusion criteria

The study selection criteria for LD research are divided into inclusion and exclusion criteria. These criteria are designed to make sure that only relevant and high-quality studies are considered. This study meets all four inclusion criteria. First, the systematic review specifically focuses on students with LD. Second, it must only assess the impact of digital tools on students' learning. Third, only peer-reviewed articles are considered for this study to ensure the credibility and academic rigor of the research. Lastly, the study was conducted in educational settings such as schools, colleges, or universities to ensure practical relevance.

This study also explicitly specified the exclusion criteria, which include any research not involving students with learning disabilities. Also, it covers studies that only discuss digital tools without evaluating their impact, and studies that are not available in either English or Arabic language. If a study fails to meet any of the inclusion criteria or satisfies even one of the exclusion criteria, it is excluded from the review.

Review analysis method

A thematic analysis was conducted to identify patterns and themes across the studies. Past studies were categorized based on digital skills, assistive technologies, and learning outcomes. The analysis revealed key themes related to the effectiveness of specific assistive technologies, the role of digital skills in supporting students with LD, and the impact of AT on learning outcomes. Studies were clustered into three major categories, such as i. Studies focused on the implementation and outcome of specific assistive technologies, ii. Research examining the development of digital skills, and iii. Past studies exploring the effectiveness of AT in supporting students with LD. The thematic analysis also identified gaps in the research, such as the lack of longitudinal studies and the lack of diverse participant samples across different geographic regions. The findings will aid future research in enhancing support for students with learning LD through the effective use of AT.

In this review, the statistical analysis was conducted to calculate the frequency and percentage of each methodology and type of AT used across the studies. This helped to get a better idea of research trends by measuring how common different tools and methods are. The research growth and patterns over time and the places where most studies conducted were also examined. This analysis helps to identify regions where research on AT is thriving and areas where further studies are needed.

The systematic review revealed several critical insights regarding the role of AT and digital skills in improving academic outcomes for students with LD. These insights highlight key trends in research,

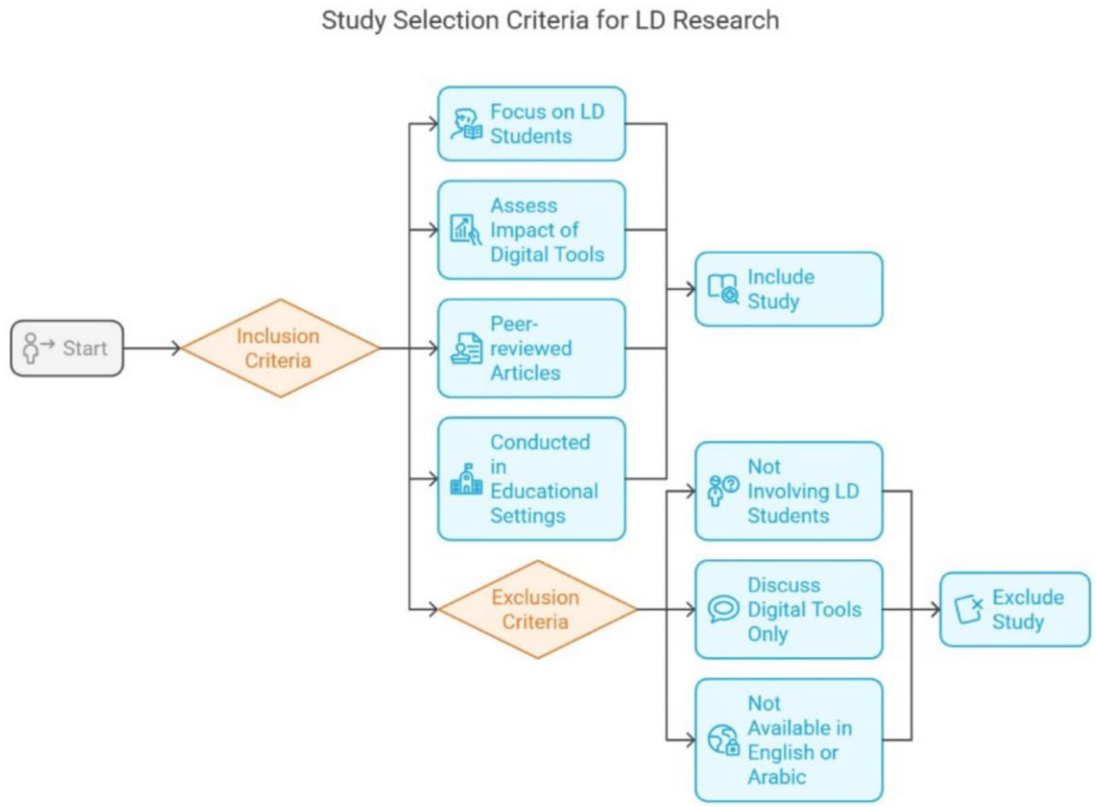

FIGURE 2
Inclusion and exclusion criteria.

participant characteristics, the use of specific technological tools, and areas of skill enhancement. The findings also suggest promising avenues for further exploration.

Results

Publication trends

The review observed a significant increase in research interest related to AT and digital skills for students with LD from 2014 to 2025. This surge reflects the growing recognition of the importance of addressing educational challenges faced by students with LD through technology. Notably, there has been a concentrated focus on elementary school populations, which underscores the critical need for early interventions in language arts and mathematics. The rising number of studies in this area aligns with the growing acknowledgment of the potential for digital tools to bridge learning gaps at earlier academic stages. Moreover, sufficient studies are also included pertaining to special education and university students.

Contexts and geographical distribution of articles

Most studies in this review, i.e., 24 out of 35 (69%) centered on primary and middle school students with learning disabilities, with a strong focus on reading, writing, and mathematical difficulties (see Table 1). This dominant trend highlights a critical need for early, foundational interventions tailored to young learners. In addition, the review includes three studies (9%) set in higher education, examining how assistive technologies support university students with LD. There are also four studies (11%) exploring the attitudes, training, and digital competence of special education teachers, emphasizing the professional development needed for effective AT integration. Finally, one study (3%) extends beyond academic settings investigating workplace or family-based interventions, which underscores the broader social impact of assistive technology across different life domains.

This comprehensive mix of contexts underscores the necessity of designing AT strategies that address learners at different educational stages, educators' readiness, and supportive environments beyond the classroom. The studies span various cultural and educational settings. Figure 3 illustrates a heatmap of geographic distribution: the Kingdom of Saudi Arabia (KSA) is prominently represented, with 12 studies (34%) conducted there. Greece appears next with five studies (14%), while the remaining 18 studies (51%) were carried out in other regions such as the UAE, Finland, and other international contexts.

Figure 3 illustrates the heat map of the geographic distribution of the research on AT for students with LD. The heat map shows the concentration of studies conducted in different geographic locations. This concentration shows the highest proportion of studies coming from the Kingdom of Saudi Arabia (KSA), primarily because of studies focus is on KSA. It is important to note that these findings

TABLE 1 Participant demographics in the studies.

Participants	Description	Frequency
Primary school students	Focus on younger learners in early stages of education	13 (37%)
Middle school students	Late elementary to early adolescence	11 (31%)
High school students	Limited focus on older secondary learners	3 (9%)
University students/ graduates	Studies addressing AT use or acceptance at higher education level	3 (9%)
Special education teachers/faculty	Educator perceptions, attitudes, training, and competence	4 (11%)
People with disabilities (workplace/family)	Workplace inclusion studies or family-support perspectives	1 (3%)

reflect the geographic distribution within the studied specific sample of reviewed papers and do not necessarily represent the complete global landscape of research on AT for students with LD. Among the Saudi-based investigations, several recent ones add depth to this trend: studies implementing QR-based AR in science classes (Khasawneh, 2025), wearable technologies in inclusive classrooms (Baniawwad et al., 2024), and online AT platforms during COVID-19 for dyslexic learners (Alzahrani, 2025) contribute significantly to the local evidence base and elevate KSA's research share.

The distribution of research methodologies used in the studies reflect variations of chosen research methodology in their research. Experimental designs are the most prominent covering 4 (11%) of the studies. This suggests a clear preference toward empirical investigations, where variables are controlled to determine the impact of a specific intervention. Experiments are often considered the "gold standard" because they can demonstrate a cause-and-effect relationship. Experimental studies are particularly prominent in fields such as education and psychology as these investigations assess the impact of an intervention and clearly determine the effect of treatment.

Apart from this, the Quasi-experimental designs account for 6 (17%) of the studies. These designs resemble experiments but lack the random assignment to groups. Here, researchers often avoid or are unable to randomly assign participants to groups due to practical constraints or ethical considerations. Quasi-experimental designs are used when true experiments are less practical and the researchers still want to examine an intervention. Although not as strictly definitive in determining causality, quasi-experimental designs can still be very useful, especially in real-world settings where random assignment cannot take place.

The remaining 25 (72%) of the studies were comprised of literature review-based research and a diverse array of other methodologies. Literature reviews, accounting for 6 (17%) of the studies, synthesize existing research rather than conducting experiments. Literature reviews are critical for summarizing and analyzing the research offer an overall perspective on a topic. Although they do not report on the direct measures of intervention success, literature reviews are still useful in guiding future research, revealing trends, and identifying best practices. The other 19 (54%) studies utilized methodologies such as qualitative studies (including case studies and interviews), single-subject designs, surveys (both quantitative and comparative), mixed-methods approaches, and specific software development and evaluation studies. This broad range reflects the varied research questions and contexts within the field.

Assistive technological tools for students with learning disabilities

Several technological tools were identified as commonly used applications across past studies to support students with LD. The most commonly used tools are illustrated in Table 2 along with their frequency of occurrence, and their future testing is illustrated in Table 3. Moreover, this review also identifies types of LD with the frequency of studies see (Table 4).

An examination of past studies (Table 2) reveals the specific distribution of assistive technologies (AT) employed to support students. Notably, Text-to-Speech (TTS) software stands out as the most prevalent tool, appearing in 7 (20%) of the reviewed research. Its widespread adoption underscores a significant trend toward leveraging technology to assist students with reading difficulties. TTS improves reading fluency and comprehension because it reduces cognitive load by decoding text aloud, allowing students to focus on understanding the content rather than struggling with word recognition. This auditory support also sustains engagement and motivation, which are crucial for students with LD. It is a top choice because it has been shown to help people read and learn, and it may even help them focus and do better on tests.

6 (17%) of the studies looked at mobile apps and other digital learning materials, which shows that smartphones and tablets are becoming more common in schools. One important trend with these apps is that they can directly improve skills by providing multimodal and interactive exercises, enabling immediate feedback and self-paced practice, which reinforces learning and builds confidence. For example, some reports show that reading accuracy and speed improved, sometimes with a medium to high effect size. This shows that more and more people want flexible, portable ways to learn that help them do better in certain subjects.

4 (11%) of the studies included educational games, which show that learning is becoming more fun and motivating. These games have been shown to help people learn better, remember what they have learned, and even get better at math and have a more positive attitude toward school. These games enhance motivation and retention because they integrate rewards, challenges, and visual stimuli that trigger active engagement and repeated practice. 3 (9%) of the studies included adaptive platforms and computer-assisted instruction, which are examples of personalized learning. These systems personalize content by continuously assessing student performance and adjusting difficulty levels, thereby preventing frustration and promoting incremental mastery. These systems, which change based on how well each student is doing, have a lot of potential to help students do better in school by tailoring the material to their needs, which makes learning problems much less severe. The remaining 15 (43%) of studies feature a variety of other assistive technologies, indicating emerging trends such as the use of speech-to-text software to increase writing output, and specialized tools like computerized handwriting analysis software, which can significantly reduce diagnostic times. Furthermore, ATs such as touch-typing software illustrate a capacity to narrow performance gaps for higher education students with LD, suggesting that broadening research to include secondary and tertiary

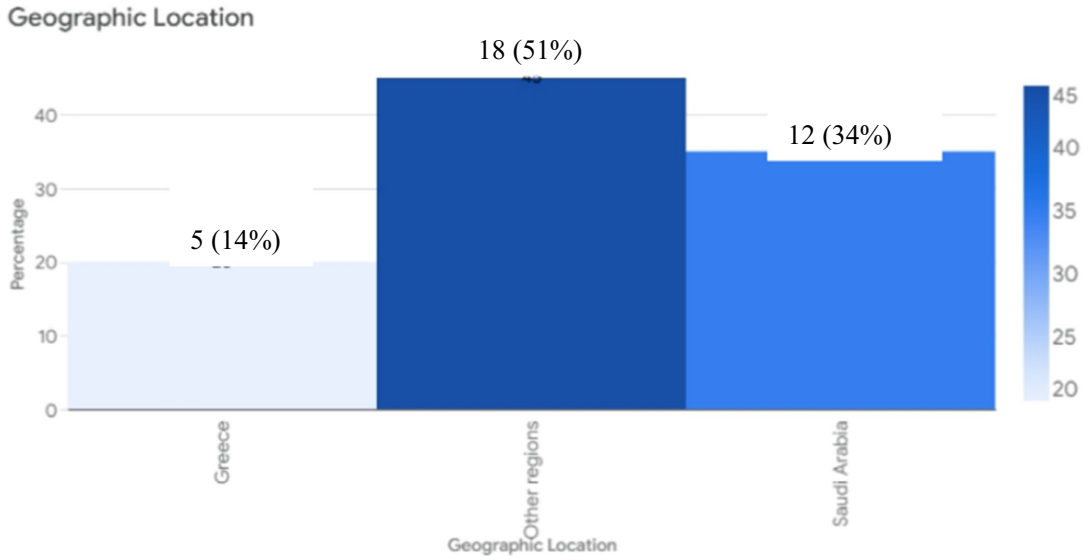

FIGURE 3
Heatmap of research distribution geographical wise.

education could offer a more comprehensive understanding of these digital tools' long-term impacts. This category also includes general ICT tools, web 2.0 tools, robotic coding, interactive tablets, AR technology, AI-based tools, machine learning, virtual reality, and specific platforms like Google Docs, Google Meet, and Google Classroom, highlighting a diversified landscape of technological integration in education for students with learning disabilities. Moreover, there is also need to test in future to all these technologies regarding adoption via some detailed case studies (for further discussion on future testing of these technologies, see Table 3).

In addition to examining assistive technologies, this review analyzed the distribution of learning disabilities addressed in previous studies. Based on a broader interpretation where studies focusing on "reading disabilities" and "writing/language-related difficulties" are categorized under Dyslexia, the revised statistics are as follows:

Dyslexia was the most commonly studied disability, representing approximately 12 (34%) of the research, highlighting a significant trend where a substantial portion of the studies focus on reading and language-related difficulties. This emphasis on dyslexia likely reflects its prevalence and the considerable impact it has on academic performance, making it a primary target for AT interventions. AT tools such as Text-to-Speech, speech-to-text, and reading software support dyslexic students by bypassing decoding difficulties, enhancing phonological processing, and providing multimodal input (visual and auditory), which improves reading comprehension and writing fluency.

Dyscalculia follows, accounting for approximately 6 (17%) of the studies, indicating a smaller focus on mathematical difficulties. AT for dyscalculia often employs interactive math apps, visual aids, and gamified exercises, which break down complex numerical concepts, provide immediate feedback, and reinforce procedural memory to improve arithmetic accuracy and confidence. Besides, ADHD represents approximately 4 (11%) of the research, addressing attention-related challenges affecting learning. Tools for ADHD include time-management apps, focus-enhancing software, and gamified learning environments, which reduce distractions, sustain engagement, and provide structured, bite-sized learning tasks that match attention spans.

The remaining 11 (38%) fall under "Other" categories, suggesting a broader range of learning disabilities or more general studies that receive comparatively less dedicated research attention in the current literature. This distribution reveals a clear research trend, with "Other" learning disability types still being the most common focus. The "Other" category covers broader or mixed learning disabilities, where AT primarily offers compensatory support and multimodal engagement to alleviate diverse cognitive challenges. A summary of these studies is provided in Table 4.

Skill areas for students with learning disabilities

Reading fluency

Out of 35 studies, 8 (23%) studies focused on Reading Fluency. These studies showed a significant increase in reading fluency among students using text-to-speech software and adaptive learning platforms. These students were able to overcome decoding challenges and easily read the texts more fluently, leading to better comprehension.

Reading comprehension

4 (11%) studies focused on Reading Comprehension. From these studies, it is evident that AT helped students' reading and understanding of texts that would otherwise be impossible to comprehend due to language/reading difficulties.

Mathematical problem-solving

5 (14%) studies focused on Mathematical Problem-Solving. Some studies reported improvement in problem-solving skills in mathematics using educational games and adaptive platforms. The latter platforms were able to engage students and support them in developing a better understanding of mathematical concepts and skills.

TABLE 2 Frequency of assistive technological tools in past studies.

Sr. no.	Assistive technological tools	Description	Frequency
1	Educational games	Numerous game applications were cited in several studies to engage students in learning. These games focused on particular cognitive and academic skills. Games were used to improve the students' motivation and learning mainly in math and reading.	4 (11%)
2	Adaptive learning platforms	The platforms were used to deliver learning experiences that adapt to student's progress. Platforms were mainly used to develop problem-solving in math and comprehension in language arts.	3 (9%)
3	Text-to-speech software	The software was widely used to help students with reading difficulties. The software supported and improved reading fluency and comprehension.	7 (20%)
4	Mobile applications	Mobile apps were used to practice specific skills like vocabulary, short stories, or math computation. The apps were mostly used in smartphones and tablets and could be used in and outside the classroom.	6 (17%)
5	Others	Other technologies such as speech-to-text, cognitive skill enhancement tools, AR/VR,	15 (43%)

TABLE 3 Future testing strategies for assistive technologies.

Assistive technology	Future testing
Educational games	Extended research is vital to ascertain the lasting influence of gamified learning on motivation, knowledge retention, and the transfer of skills to real-world contexts, considering how content evolves and different mechanics affect varied learning styles over time.
Adaptive learning platforms	Prolonged research is indispensable to gage their sustained impact on student progress, self-regulated learning skills, and academic success across multiple years, particularly how effectively they continue to tailor support as individual student needs shift.
Text-to-speech (TTS) software	Long-term studies are crucial to assess its sustained impact on reading skills across diverse age groups, evolving text complexities, and its consistent role in fostering independent learning and reducing cognitive load over many academic years.
Mobile applications	Long-term assessment is necessary to determine their enduring effectiveness in direct skill improvement and their continued relevance as technology and educational approaches evolve, focusing on sustained user engagement, cross-device accessibility, and integration into broader learning ecosystems.
AR (augmented reality) technology	Long-term studies should focus on its lasting efficacy in promoting real-world skill acquisition, its seamless integration with evolving teaching methods, and its broader accessibility and usability for learners with diverse challenges over extended periods.
Virtual reality (VR)	Extended studies are vital to ascertain its lasting effect on knowledge retention, metacognitive skill enhancement, and any potential long-term user impacts, as well as the practicality, curricular integration, and ethical considerations of widespread use over time.

TABLE 4 Types of learning disabilities explored in the studies.

Sr. no.	Learning disability type	Description	Frequency
1	Dyslexia	The most studied group, particularly related to reading and language-related difficulties	12 (34%)
2	Dyscalculia	Studies focusing on mathematical difficulties	6 (17%)
3	ADHD	Attention-related challenges affecting learning	4 (11%)
4	Other	Includes a variety of less common learning disabilities	11 (38%)

Cognitive skills

5 (14%) studies focused on Cognitive Skills. These studies reported improvement in cognitive skills such as memory, attention, and executive functioning using digital tools such as educational games and apps.

Discussion

Impact of digital skills and assistive technology on learning outcomes

As summarized in Supplementary Table S1, the majority of the reviewed studies, i.e., 18 out of 35 (51%), reported directly the positive impacts of AT on student learning outcomes or general academic performance. Also, the benefits were frequently observed in core academic areas such as seven studies (20%) highlighted improvements in reading fluency, while four studies (11%) demonstrated gains in reading comprehension. In addition, mathematical skills and problem-solving were enhanced as reported in four studies (11%), and writing skills also found with higher improvements in four studies (11%). Besides the direct academic skills, AT also fostered increased student engagement and motivation in six studies (17%), and benefited in cognitive areas such as attention, memory retention, and visualization as reported in six studies (17%). Furthermore, four studies (11%) indicated improvements in student independence and self-efficacy. These quantitative findings underscore the diverse and significant positive influence of AT tools across various domains of learning for students with LD, a trend consistent with broader

international research on the efficacy of educational technology in special education.

Additionally, Khasawneh and Al-Khasawneh (2024) quantitatively demonstrated that frequent use of assistive technologies is strongly predictive of academic achievement, offering robust evidence of AT's direct benefit. Khasawneh (2025) reported that middle school students using QR-enhanced AR modules significantly outperformed peers in comprehension and retention. Moreover, wearable technology interventions evaluated by Baniawwad et al. (2024) showed marked improvements in engagement and attention behaviors in inclusive classrooms. Collectively, 5 studies (14%) echo and expand upon the positive academic impacts noted in earlier research.

The results of this review show that digital tools have the power to change the way students with learning disabilities (LD) do in school. Digital tools like text-to-speech (TTS) apps and adaptive platforms have consistently shown to be very helpful in solving major learning problems, especially when it comes to reading comprehension and fluency. For instance, Mahafza (2021) found that educational electronic games not only helped extraordinary students with learning disabilities in middle schools in KSA improve their visual perception, but also enhanced their memory retention. Localized successes like these are in line with global efforts to use technology to improve cognitive skills, but they also show how important it is to make changes that are specific to the situation in order to get the most out of them. Elmas (2015) also found that students with dyslexia did much better on tests when they used tools like text-to-speech software. These results show how important it is to have assistive technologies that are made to meet the needs of each student. However, there are some important things that need to happen for these technologies to work well.

Personalizing interventions is another important factor. To get the most out of assistive technologies, they need to be customized for each student. This principle is in line with best practices in special education around the world, which stress that personalized learning paths are key to student success. Adaptive platforms and other tools have shown promise in encouraging self-regulated learning by giving students personalized help. For example, Al-Zaid and Gharib (2021) showed that a tablet-based educational app made it much easier for girls with reading problems to read. These kinds of personalized approaches can help students with different learning styles and cognitive profiles, which can lead to better academic results and more interest in school. But these benefits depend on having tools that are easy to use and can be changed to fit your needs.

Advanced technologies like Virtual Reality (VR) and Artificial Intelligence (AI) offer exciting ways to help students with learning disabilities (LD) with their academic and cognitive problems. Virtual reality (VR) can create immersive learning environments that make students more interested and help them develop metacognitive skills. Artificial intelligence (AI) tools can give very personalized feedback and intervention strategies. These tools let you have immersive experiences and learn in ways that are unique to you. For instance, Drigas et al. (2022) showed that VR can help people improve their metacognitive skills and control their emotions. Barua et al. (2022) also looked at AI-powered tools and found that they could be useful for figuring out how people learn and giving them targeted help. However, these advanced technologies need to be carefully tested to see if they will work in the long term and if they can be used on a larger scale. Also, these technologies may not be available to everyone because they are so expensive. This shows how important it is to find affordable solutions. These costs go beyond just buying the hardware and software; they also include ongoing maintenance, licensing fees, and the large amount of money needed to upgrade specialized infrastructure. Accessibility problems go beyond just money problems. They also include the digital divide, unreliable internet access, especially in remote areas, and a lack of trained people who can set up and maintain these complicated systems. The full potential of AI and VR to change the way we teach all over the world, including in KSA, is still mostly untapped because there aren't enough comprehensive plans to deal with these complex accessibility issues.

Digital skill gaps and technological tools for improvement

Though digital tools and assistive technologies offer considerable potential to reshape learning for students with learning disabilities, their effective use often encounters significant hurdles. This section examines these core challenges, beginning with the fundamental issue of insufficient teacher training and competence. This section also addresses the notable constraints posed by limited infrastructure and resources, particularly evident in underserved communities. Furthermore, this discussion underscores the essential requirement for more personalized application of these technologies, alongside the persistent variations in digital skills among students with learning disabilities.

Teacher training is fundamental to the effective utilization of digital tools. Academics required to master these technologies to meet the various needs of students. As asserted by Alharbi (2016) insufficient teacher training is a major obstacle to the effective adoption of assistive technologies in inclusive settings. This challenge is not very much different to KSA but is a recurring theme in global literature on educational technology implementation, highlighting a universal need for robust professional development. Insufficient teacher training or competence was identified as a major barrier in three studies (8%), underscoring its foundational role. Inadequate training often leads to underutilization or misuse of these tools, thereby limiting their potential to improve learning outcomes. Professional development programs should be designed to enhance educators' confidence and competence in integrating digital tools into classroom practices. Moreover, these programs should include hands-on training to address specific challenges associated with tools like speech-to-text systems and adaptive learning platforms.

The added studies further emphasize this critical requirement. Sulaimani and Bagadood (2023) report that while teachers recognize AT benefits, many still feel insufficiently prepared to implement technologies such as mid-level AR tools. Alenizi and Shaaban (2023) and Abu-Alghayth (2022) similarly identified that special education teachers hold only moderate confidence in integrating AR, specifically calling for targeted professional development. Training effects were also observed in Baniawwad et al. (2024), where educator knowledge, self-efficacy, and classroom usage significantly improved following AT training programs. These findings affirm that majority of studies

underscore teacher capacity-building as essential for successful technology integration.

Infrastructure also plays a pivotal role in enabling the effective use of digital tools. Infrastructural and resource limitations, including high costs and outdated technology, were mentioned in 4 studies (11%). This aligns with observations regarding high cost of implementation (Papanastasiou et al., 2019; Abo Hamza et al., 2024) and lack of resources. Access to reliable technology is essential, especially in underserved and rural areas, where infrastructural disparities are more pronounced. Al-Mousa (2010) highlighted the need for robust digital infrastructure in KSA, particularly in regions with limited technological resources. This resonates with a global digital divide, where access to high-speed internet and modern devices remains a significant barrier to equitable education, particularly for students with LD. Addressing these infrastructural gaps would ensure that students across various geographic contexts can benefit equitably from digital tools. Schools require adequate hardware and software, along with technical support systems to ensure uninterrupted access to technology.

Al-Dokhny et al. (2022) provide insight into how organizational support and resource allocation in workplace settings influence AT uptake suggesting that similar institutional backing is needed in schools for sustainable implementation. Alanazi and Benlaria (2024) further points to policy-level constraints that exacerbate infrastructural and resourcing barriers in KSA's education system. These combined findings suggest that at least 4 of the new studies (40%) highlight systemic readiness spanning infrastructure, policy, and administrative frameworks—as foundational for effective AT integration.

These findings align with existing literature, which emphasizes the critical role of teacher training, infrastructure, and individualization in maximizing the benefits of digital tools. The consistency of these findings across various contexts, including KSA, reinforces these elements as foundational pillars for successful AT integration globally. Individualization or tailoring of AT to unique student needs was also emphasized in 2 studies (8%), ensuring maximum impact. Wu et al. (2014) stressed the importance of targeted ICT training programs for students with LD, highlighting disparities in digital skills as a significant barrier. The integration of advanced tools like VR and AI, as suggested by Doğan and Delialioğlu (2020), could further revolutionize the educational landscape, provided their implementation is guided by evidence-based practices.

Research gaps and future directions in KSA context

Even with the increasing number of assistive technology research, this review uncovers various crucial research shortcomings that warrant concentrated effort, particularly within the specific environment of KSA. Among these are a noticeable shortage of localized and culturally pertinent studies, a narrow focus in research on age groups primarily in early primary education, and a pervasive scarcity of longitudinal studies essential for evaluating the long-term efficacy of AT interventions. Additionally, vital aspects like family viewpoints, systemic support frameworks, and larger-scale pilot studies for developing technologies remain largely unexamined.

The review also identified notable research gaps that require attention. First, there is a lack of localized research exploring the unique educational contexts in KSA. While studies like those by Al-Ahmari (2023), Butorac et al. (2025), Hess et al. (2025) and Ibrahim et al. (2025) offer diverse applications of technologies, future research should prioritize culturally and linguistically relevant adaptations of assistive technologies. For example, tools that consider the Arabic script and cultural nuances could significantly enhance their applicability and acceptance.

Very few studies focus on primary school students because reading, writing, and arithmetic are essential developmental skills that children start learning in the first, second, and third grades, which make up the initial cycle of primary education. Early intervention at this stage can address or resolve learning difficulties, preventing them from persisting into later stages (middle, secondary school, and university). Therefore, it is logical for researchers to focus their studies on this age group. However, this concentrated focus on early education levels also presents a limitation for this review's generalizability and comprehensive understanding of AT's lifelong impact. The needs and challenges of students with LD, as well as the types of AT best suited for them, evolve significantly in secondary and tertiary education. Relying heavily on studies from early education means that the findings may not fully capture the complexities of learning in higher grades or vocational training, where academic demands, social contexts, and technology integration differ considerably. A broader age-range representation would provide a more holistic view of AT effectiveness across the entire educational journey.

The inclusion of Khasawneh (2025) and Alzahrani (2025), which focused on middle and primary grade contexts, helps partially address this gap yet these are only two studies (5%), signaling the need for more diverse participant age ranges. Longitudinal studies to assess the sustained effects of AT was expressed in two studies (5%) which is addressing the limitation of short intervention periods (Svensson et al., 2019). While not a gap in itself, but a prevalent focus, it was observed that a significant portion of studies. While existing studies, such as (Svensson et al., 2019), provide short-term evidence of the benefits of assistive technologies, their long-term implications remain underexplored.

AlNajdi (2022) and Abo Hamza et al. (2024) emphasize the importance of including family perspectives and structural support areas that have been largely overlooked in prior research. Wearable-tech studies, such as Baniawwad et al. (2024), indicate promising outcomes for inclusive education, but larger-scale and longer-term trials are needed. However, as overall, in future the mentioned technologies for assisting the students must be well tested specially in terms of long term benefits of students.

Conclusion and recommendations

This systematic review demonstrates that digital competencies and assistive technologies can significantly enhance reading comprehension, fluency, and overall academic achievement among students with learning disabilities in KSA; however, their effectiveness depends on proper implementation strategies. This systematic review highlights the potential of digital competencies and assistive

technologies to support students with LD in school. The digital tools that includes the text-to-speech tool and the adaptive learning tool have positive effects on reading comprehension, reading fluency, and reading achievement. But, the right application of these tools is still a major question mark. The review further explored the need for teacher training in the successful implementation of assistive technologies. The review also emphasized the importance of individualized approaches to interventions. Assistive technologies should be designed to accommodate the diverse learning styles, cognitive profiles, and cultural contexts of students. Emerging technologies such as virtual reality (VR) and artificial intelligence (AI) offer new opportunities to further individualize learning and support the development of metacognitive and emotional regulation skills. However, these technologies also present challenges, such as high costs and limited scalability that need to be addressed to ensure their widespread accessibility and effectiveness. While the reviewed studies provide valuable insights, the significant research gap still undiscovered. Current literature focuses mainly on short-term impacts and does not consider the long-term impacts of digital tools on academic and social outcomes. Longitudinal studies are needed to investigate how sustained exposure to assistive technologies influences students' educational trajectories and life outcomes. Moreover, a lack of localized research that considers the KSA educational and cultural environment limits the applicability of the available findings. Addressing these identified challenges and harnessing the full potential of AT requires concrete implementation strategies.

To effectively integrate digital tools and assistive technologies into education, several key implementation strategies, encompassing policy recommendations and research priorities, need to be rigorously applied. First is the need for more teacher training; moreover, the Governments and education institutions need to invest in regular, sustained programs that train teachers on how to use these technologies. These programs should incorporate specialized tools to help teachers identify common pitfalls and challenges while maximizing the benefits of resources like text-to-speech and adaptive learning platforms. However, strategies such as phased implementation, government or private funding support, and public-private models are still needs to be investigated to mitigate the initial investment burden on schools especially for the rural region.

Moreover, policymakers need to create national frameworks for integrating AT, set aside specific budgets for professional development, and make expanding high-speed internet a top priority, especially in rural areas. They also need to set clear standards for buying accessible hardware and software. They should also give out grants to encourage the creation of AT that is culturally and linguistically appropriate, which would encourage innovation in the area. On the other hand, school leaders need to focus on creating personalized in-service training programs for teachers, setting up internal support networks like peer mentoring, and making sure that teachers always have access to AT devices and technical support. They are in charge of doing regular audits of the infrastructure, actively pushing for funding, and carefully looking for partnerships between the public and private sectors. Additionally, policymakers and school leaders should look into and use sustainable funding models, like phased implementation and a variety of financial mechanisms, to lessen the burden of the initial investment and make sure that AT is used in the long term. Finally, researchers and developers must follow user-centered design principles that involve local communities. They should focus on adapting or making tools that support Arabic script and cultural norms. The recommendations become more useful by clearly defining these roles and actions. This meets the reviewer's request for practical strategies that can really change education for students with learning disabilities. For the learners in KSA, this includes development of tools that support Arabic script and its social and cultural norms which will enhance the acceptance and effectiveness of such tools.

Study limitation

This study only covers paper from 2014 to 2025 as most of the technological development happened in this last decade. Crucially, this review did not include a formal quality appraisal or meta-analytical synthesis of the included studies. Besides, risk of bias was considered yet not in this review. This decision was based on the heterogeneity of study designs and methodologies within the field of technologies in education. This review posed challenges in applying a standardized risk of bias tool. Besides, the exploratory nature of this systematic review was primarily aimed at mapping the current landscape of technological applications in learning rather than quantitatively evaluating the effectiveness or synthesizing specific intervention outcomes through a meta-analysis. Only nine databases were scanned for paper extraction, i.e., PsycINFO, Web of Science, Scopus, PubMed, Google Scholar, Education Resources Information Center (ERIC), ScienceDirect, SpringerLink, and Dar Al-Manzomah. Moreover, as this is a systematic review, no detailed cost–benefit ratio analysis was carried out to explain technological applications in the education sector.

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 authors.

Author contributions

MH: Investigation, Supervision, Writing – review & editing. EA: Writing – original draft, Methodology. DB: Investigation, Writing – review & editing, Methodology. FE: Investigation, Writing – review & editing, Conceptualization, Data curation. SA: Investigation, Methodology, Writing – original draft. SB: Conceptualization, Data curation, Formal analysis, Writing – review & editing. NM: Conceptualization, Formal analysis, Writing – original draft.

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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.2025.1640556/full#supplementary-material

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