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Technology-based Interventions for Dyslexic Children: A Systematic Literature Review (SLR)

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Abstract

In modern society today, reading skills are increasingly important. Thus, any failure in mastering reading skills can limit an individual's potential to grow to an optimal level. The main importance of reading as a basic skill in modern life has prompted many studies to be carried out to implement more effective interventions in tandem with education that has changed dramatically in recent decades under the influence of the development of digital technology and the fourth industrial revolution (IR4.0). In this article, a review of the systematic literature (SLR) was conducted to identify current research on the use of technology in the implementation of reading skills teaching interventions to dyslexic pupils. The main objective of the study was to identify the use and effectiveness of the technologies used in meeting the learning needs of children with dyslexia. Three databases are used, namely Scopus, Web of Science and Google Scholar. Of the 318 articles that were screened, 46 relevant articles were accepted for analysis based on the appropriateness of the title and only 21 were included in the study after further screening. The results showed the use of different forms of technology such as audiobooks, text-to-speech (TTS), speech-to-text (STT); digital technologies such as computer software programs, gaming applications; haptic technologies such as virtual reality (VR) and augmented reality (AR); new technologies such as mulsemedia; robotic technologies in addition to the use of non-digital technologies. Studies have also found that the use of technology has a positive impact on the learning of dyslexic children, especially the mastery of reading skills. Studies have found that technology intergration in education provides a more enjoyable learning experience and increases children's motivation through a learning while playing approach. Therefore, the practice of Technological Pedagogical Content Knowledge (TPACK) should be enhanced among teachers. In addition, more studies are needed to identify the use of technology in the aspect of the diagnosis and management of dyslexic children in the future. This is because most individuals with disabilities such as dyslexia benefit from additional support that allows them to learn and function on their own.

Keywords: Dyslexia, Intervention, Reading Skills, Technology

Introduction

Dyslexia is one of the categories of children with Specific Learning Disability (SLD) and is also categorized as Developmental Language Delay (DLD) which is associated with neurobiology. Dyslexia is often associated with a weakness in reading words despite having a good level of intelligence and education and an acceptable socioeconomic background (Soriano-Ferrer et al., 2021). Dyslexia is one of the most common learning problems and affects the academic performance of 5%-10% of pupils worldwide (Money & Bi, 2022).

The International Dyslexia Association (IDA) (2020) states that children diagnosed with dyslexia have difficulties in language in particular reading. This is because they have problems in visually discriminating against letters and auditory causing difficulties in the process of denunciating, decoding, spelling in turn reading words (Smirni et al., 2020). Many studies have confirmed that two mental functions are involved in the process of written word recognition, namely phonological function and visual recognition (Cheng et al., 2021; Dobson, 2019). This explains that the children that has dyslexia is not caused by a pathological disease but is due to the difficulty of the brain processing information that connects sounds and visual symbols. The areas of the brain that process language are greatly affected due to dyslexia. Due to the differences found in the brains of people with dyslexia, experts believe that dyslexia is related to dysfunction in the left hemisphere and the area of the brain responsible for connecting speech (the Wernicke motor speech area) and sound and speech production (Broca's) (Démonet et al., 2004; Habib, 2000). On the other hand, right hemisphere dysfunction can cause difficulties in word recognition, and genetic factors are also the main reason for the grouping of dyslexic family members. This is because, between 40% and 80% of dyslexia is genetically related (Schumacher et al., 2007).

Clearly, the most significant problem of language proficiency in the aspect of dyslexic pupil reading is the ability to recognize letters and connect letters with sounds (Amirin, 2020). This means that a person's language proficiency depends on their understanding of the phonemic, phonetic and phonological aspects of the language. If this problem is not addressed, the dyslexic pupil will not be able to correctly adjust the shape of the letter to the sound of the letter. Not only that, but these obstacles also make their vocabulary mastery less satisfying. The effect is that the language level of dyslexic children is not aligned with normal children's language levels. As a result, pupils who have trouble mastering reading and writing skills feel weak and disinterested in the subject. It is very clearly found that the learning difficulties faced by dyslexic pupils have a significant impact in various aspects of pupils' lives. Meany-Walen et al (2016) states that interventions are very important in early childhood because without intervention, children's behavior will become habits and habits as adults. Therefore, it is very important to implement an intervention plan on problematic and weak pupils. An interventionist approach that suits the needs and cognitive capabilities of pupils can generate interest and motivation of pupils to achieve the objectives that teachers want. It can also enhance the student's achievement and success, not only academically but also in terms of moral building and personality.

Numerous past studies have shown that technology has a significant role to play in helping pupils master learning. Jing & Chen (2017) states that children with dyslexia can improve their reading habits by using various technologies such as games, virtual learning environments, TTS, technology-based reading aids such as interactive e-books or specialized program

software. Interventions with this tool may improve reading comprehension, reading fluency and reduce errors. In addition to Read-Aid, Sprint is a program that helps reading provide computer speech so that programs can read the text displayed on the screen. Since such programs can read texts written by children, such software is very helpful in identifying errors.

Based on the strengths and important role of technology integration in teaching and learning, this review of the systematic literature was conducted to identify technology-based interventions and the effectiveness of interventions used to assist children with dyslexia through research on past studies.

Methodology

This study used a systematic literature review (SLR) to collect past studies related to technology-based interventions for dyslexic children. SLR is an organized, comprehensive and planned research method (Fink, 2019). In conducting SLR studies, researchers must systematically and explicitly identify, evaluate, analyze and synthesize past studies by other researchers (Moher et al., 2009).

In selecting articles related to the question of the study presented, the study also used the flowchart Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al., 2015; Page et al., 2021). The PRISMA flowchart was chosen because the process is rigorous, in-depth and can study many studies. Additionally, Randour et al (2020) states that this method allows literature-related writing to be clearly formulated. Several other studies that prove PRISMA's ability as a guide for SLR studies such as (Tong et al., 2020; Dipper et al., 2020; Muller et al., 2020; Oxley and De Cat, 2021). Based on the PRISMA flowchart, there are four stages of article selection, namely identification, screening, qualification, and inclusion of articles in the SLR study conducted (Page et al., 2021). Therefore, the SLR studies conducted include search strategies, selection criteria, selection processes, data collection and data analysis for the articles obtained.

Article Search Strategy

Article searches are conducted using the Scopus, Web of Science (WOS) and Google Scholar databases. The Scopus database was chosen as the main database in conducting this study because it is one of the fourteen main databases in article search and provides high-impact articles (Gusenbaur and Haddaway, 2020). Moreover, according to Zhu and Liu (2020), Scopus is the most comprehensive source of metadata and impact indicators. The Google Scholar database is used because it contains large data in empirical and scientific research across various fields such as economics, medicine, social sciences, environment, engineering, accounting and development, marketing, business, and law (Shafrill et al., 2018). Google Scolar was also selected as a database to supplement the search results of past studies, especially studies conducted in Malaysia.

To get the appropriate articles from the data source, proper keyword building is required. This is because according to Joklitschke et al (2018), the search terms or keywords used are the main components of the article search process. In addition, the proper use of the term affects the effectiveness of the search through the identification process used (Rowley and Slack, 2004).

Search through the Scopus and WoS databases uses three main English terms keywords, namely "dyslexia", "intervention", "technology". Searching through the Google Scholar database uses the main keywords of the Malay terms "disleksia", "intervensi", and "teknologi". These key keywords are further diversified so that article search can be done more widely. Key keywords and other relevant keyword variations have been applied using other words that carry the same synonymous or meaning as the main keyword as well as combined with Boolean search (AND, OR). The results of the identification process in the search string format can be referenced in Table 1.

Table 1
Keyword builds from the identification process.

Database	Search strings and keywords	Number of articles
Scopus	TITLE-ABS-KEY (("dyslexi*" AND "intervention" OR "reading intervention" AND "technolog*" OR "assistive technology" OR "assistive tools" OR "games" OR "application"))	251
Web of Science (WoS)	Topic (("dyslexi*" OR "reading disability" OR "reading disorder") AND "intervention" OR "reading intervention" AND "technolog*" OR "assistive technology" OR "assistive tools" OR "games" OR "application")	1430
Google Scholar	(("disleksia" AND "intervensi" AND "teknologi" OR "teknologi asistif" OR "ICT" OR "TMK" OR "permainan" OR "applikasi" OR "komputer")	915

Through the Scopus database, a total (n=251) of articles are found based on search strings that use relevant keywords while (n=1430) are found in the WoS database using keywords as in table 1. Searches on the Google Scholar database use keywords in Malay so that searches tend towards article findings in Malay, but the search results also show the findings of articles from English as well. This search on the Google Scholar database sums up the results of (n =915) articles. Although Google Scholar has the disadvantages of the lack of quality control of articles such as views Halevi et al (2017), the diversity of article findings helps in achieving the objectives of this systematic review.

Article Selection Criteria

At the identification stage, search results in three databases namely Scopus (n=251), WoS (n=1430) and Google Scholar (n=915) provided a list of 2,596 related articles based on the built keyword string. A total of 2,596 of these searches went through the second stage of screening. At the screening stage, several entry criteria for Linares-Espinos et al (2018); Johnson and Hennessy (2019) were used to determine which articles corresponded to the SLR study. In order to get rid of articles that are not relevant or do not match the objectives of the study, it is important to set criteria for the acceptance and rejection of the article (Shaffril et al., 2021). The acceptance and rejection of the article is based on the selection criteria set i.e. year of publication, type of publication, language and focus of the study as shown in Table 2.

Table 2
Criteria for acceptance and rejection of articles

Criteria	Receipt	Rejection
Year of publication	Publication in the latest five years (2019-2023)	Publications before 2019
Types of publications	Articles, proceedings, conference papers	theses, book chapters, books, reviews
Language	English and Malay	In addition to English and Malay
Focus of the study	Interventions involving dyslexic children	Interventions included children with comorbidities such as dyscalculia, attention deficit hyperactivity disorder (ADHD) and autisme

The first criterion is the year of publication, where only articles published within the most recent five years are accepted from 2019 to 2023 to collect the latest studies only. The criterion for the acceptance and rejection of the second article is the type of publication, which is only in the form of journal articles, proceedings and conference papers. In terms of language, only English-language and Malay-language articles are accepted. Finally, the criteria of articles related to interventions involving dyslexic children alone are accepted. An irrelevant and rejected article is an article that talks about the learning problems of dyslexic children involving comorbidities such as dyscalculia, attention deficit hyperactivity disorder (ADHD) and autism.

Article Selection Process

Then, the selected article from the screening process goes through the qualification screening phase (Eligibility). According to Shaffril et al (2021), credential filtering is done manually to reduce the lack of screening from the database. The reading process at this stage will focus on the title and abstract parts of the journal article. The reading process will also be carried out on the methodological part to ensure that the information provided is in accordance with the writing of the SLR. A total (n=46) full article that is eligible to be screened requires two reviewers to evaluate the quality of the article. This is in line with the proposal put forward by Petticrew and Roberts (2006) in Shaffril et al (2021), which suggests that at least two reviewers must review the article based on a verified theme. Each abstract of the article is reviewed and an assessment is made based on the question of the study that was fixed at the beginning of the study. Both assessors are from this group of researchers themselves in order to gain a better understanding of the objectives of this SLR. The article selection process for SLR was carried out in December 2023. Figure 1 shows the flowchart of the article selection process adapted from the PRISMA flowchart (Tawfik et al., 2019).

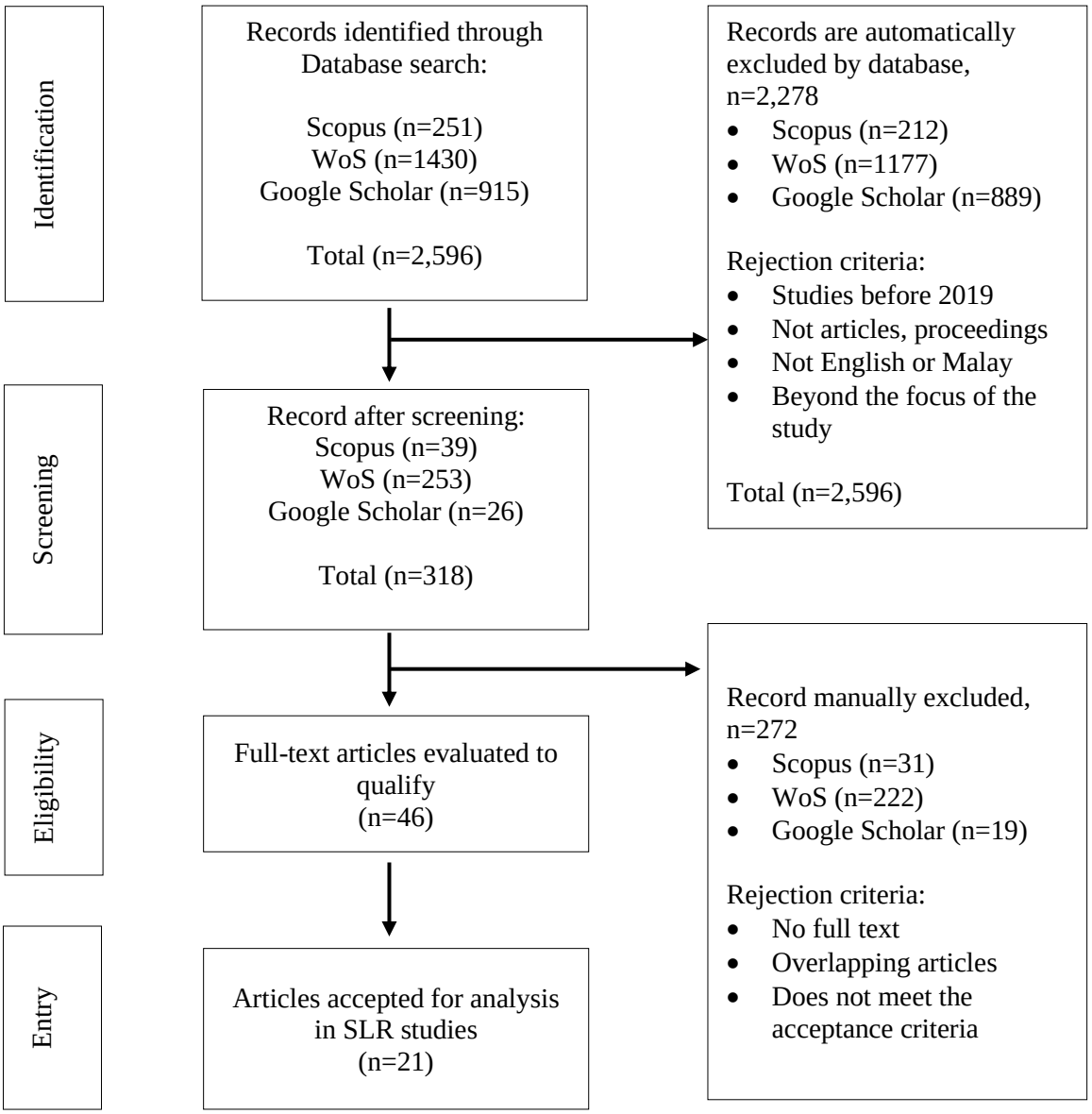

Figure 1: Flowchart of article selection process based on PRISMA.

Based on Figure 1, this SLR study consists of four stages of the article selection process. At the identification stage, a total of 2,596 articles were identified using three databases. Next the article is screened using the acceptance and rejection criteria listed in Table 2 before the article is entered into the qualification stage for a more thorough and rigorous screening process. Of the 318 study articles screened through research on the title and abstract of the study, 46 articles were assessed for eligibility by two reviewers, while 272 articles were eliminated for not meeting the focus of the study, lacking full text and overlapping. At the entry phase, a total of 21 study articles were selected and used as samples for this SLR study. This selected study article is closely related to the focus of the study and focuses more on interventions in children with dyslexia without involving cases of comorbidity.

Data Collection and Data Analysis

The search results found 318 potential study articles but only 21 articles met the criteria. Articles that have gone through a systematic vetting process are subsequently extracted. The

analysis of the article is focused on the appropriate part of the SLR focus which is on the type of technology used and the findings of past studies related to the technology used as an intervention tool in the learning of dyslexic children as shown in table 3.

Table 3
List of extracted articles

No.	Author/ Country	Paper Title	Technology Involved	Intervention Purposes	Finding
1	Almgren Bäck et al. (2023) Sweden	Dyslexic Students Experiences in Using Assistive Technology to Support Written Language Skills: A Five-Year Follow-up	Audiobook text-to-speech (TTS) speech-to-text (STT)	To explore user experiences with AT on different devices in reading and writing activities.	Listening to texts might improve text comprehension, pace and independence, and required less effort in text-based activities. Drawbacks was the technical issues.
2	Romero et al. (2023) Spain	**Efficacy of Berni: A software for preschoolers at risk of dyslexia**	Computer game software (Berni)	To design an educational software to improve phonological awareness, verbal memory, alphabetic awareness, receptive language and print awareness.	Multimedia training with the Berni programme helped to overcome difficulties in phonological awareness, rapid automatised naming and verbal memory.

3	Darrot et al. (2023) France	**Effects of a developmental dyslexia remediation protocol based on the training of audio-phonological cognitive processes in dyslexic children with high intellectual potential: study protocol for a multiple-baseline single-case experimental design.**	Audio software (Rapdys©) for intensive audio-phonological training program	To improve phonological and reading skills involved perception, rapid automatized naming and phonemic analysis.	Some limitations were found when preparing this protocol such as cognitive overload and participant dropout.
4	Vialatte et al. (2023) France	**Enhancing reading accuracy through visual search training using symbols**	Mobile serious game (VisioCogLetters)	To stimulate SPL lesion using visual symbol search skill to increase reading accuracy.	Reading accuracy increased and improved visual search skills on symbols can enhanced reading performance.
5	Hussain et al. (2023) Pakistan	ARLexic game: an augmented reality-based serious game for training of dyslexic and dysgraphic children.	Augmented Reality (AR) mobile Serious game (ARLexic)	To design and develop AR serious game.	Eengagement level increases with time. Children learn quickly without being bored and enjoying it.
6	Lazo-Amado & Andrade-Arenas (2023) Peru	Designing a Mobile Application for Children with Dyslexia in Primary Education Using Augmented Reality	Augmented Reality (AR) mobile game (Educadyslexia)	To improve reading comprehension and spelling.	Validated by 5 experts showing a level of acceptance of 91%.

7	Jun et al. (2023) Malaysia	DysPReX: A Game-based Reading Tool for Children with Dyslexia.	Mobile video game (DysPReX) uses Malay as medium	To help the dyslexics learn spelling and reading in fun way at their own pace using mobile game.	Evaluated by 30 respondents given score above 4.0 for user interface, functionality, learnability, and satisfaction aspect. The criteria used agreed as appropriate for the dyslexics.
8	Mohana et al. (2023) India	Technology Enhanced Mulsemedia Learning (TEML) for Learners with Dyslexia	Technology Enhanced Mulsemedia Learning (TEML)	To stimulate various sensory channels to reinforce the learning process by designing Mulsemedia devices using IoT technology.	Help to analyze the learner's emotional responses while experiencing Mulsemedia content and can be use as comprehensive e-learning platform for individuals with dyslexia.
9	Maresca et al. (2022) Italy	**Use of Virtual Reality in Children with Dyslexia**	Virtual Reality Rehabilitation System (VRRS)	To explore how virtual reality can affect improving cognitive domains and cross-cutting pedagogical skills.	Significant difference in word-reading test scores and homophonic writing and encourages active exploration, improves engagement, and provides motivation and enjoyment, allowing longer training sessions and improving treatment adherence.

10	Hurwitz & Vanacore (2022) U.S.	**Educational Technology in Support of Elementary Students with Reading or Language-Based Disabilities: A Cluster Randomized Control Trial**	Lexia Core5 Reading Program (Core5) as online instructional program	To improve phonological awareness, phonics, structural analysis, fluency/automaticity, vocabulary and comprehension.	Effective supplement reading instruction.
11	Al-Dokhny et al. (2022) Saudi Arabia	**Infuence of assistive technology applications on dyslexic students: The case of Saudi Arabia during the COVID-19 pandemic**	Graphical design of online application (Quizlet)	Improving the visual perception (VP) and phonological processing (PhP) abilities of students with dyslexia.	Significant and positive relationship between FA and the VP and PhP abilities of students.
12	Papadopoulou et al. (2022) Greece	**Efficacy of a Robot-Assisted Intervention in Improving Learning Performance of Elementary School Children with Specific Learning Disorders**	Social robot NAO	Potential role of social robots (SRs) in special education.	Improvements in both groups in cognition skills (decoding, phonological awareness and reading comprehension).
13	Forne et al. (2022) Spain	Improving Reading Skills Using a Computerized Phonological Training Program in Early Readers with Reading Difficulties	Computerized phonological training program (Software)	To improve reading skills via phonemic awareness, decoding and reading fluency.	Increased reading performance after the intervention and phonics training is effective strategy to remediate reading difficulties.

14	Brennan et al. (2022) Ireland	Cosmic Sounds: A Game to Support Phonological Awareness Skills for Children with Dyslexia.	Mobile adventure games (Cosmic Sounds)	To support the teaching of phonological awareness skills.	Increased engagement, positive impact on the children's phonological awareness skills especially areas of consonant digraphs, vowel digraphs, syllabication, CVCe words.
15	Bhola (2022) India	Effect of Text-to-speech Software on Academic Achievement of Students with Dyslexia.	Text-to-speech (TTS) Software	To study the effect TTS software on the academic achievement of dyslexic students.	Experimental group performed significantly better than the control group based on scores on posttest.
16	Jaramillo-Alcázar et al. (2021) Spain	**An approach to accessible serious games for people with dyslexia.**	Mobile serious video game (Puzzle Pieces)	Developing serious games to improve the treatment of dyslexia with 2 puzzles to train certain cognitive.	Serious video games are an alternative for learning and treating dyslexia, being a fun and entertaining tool for the target audience.
17	Vanden Bempt et al. (2021) Germany	**Digital Game-Based Phonics Instruction Promotes Print Knowledge in Pre-Readers at Cognitive Risk for Dyslexia**	Mobile serious game (GraphoGame)	To improve phonological and reading skill.	Larger improvements in letter knowledge and word decoding.
18	Rodríguez-Cano et al. (2021) Spain	**Design of a Virtual Reality Software to Promote the Learning of Students with Dyslexia**	Mobile Virtual Reality (VR) video game (Wibu)	To design a VR application to support learning of students with dyslexia based on user-centered design.	VR technology is an interesting as it offers a ludic, safe, controlled, and motivating environment for students with dyslexia.

19	Malliakas et al. (2021) Spain	**Educational Intervention through a Board Game for the Teaching of Mathematics to Dyslexic Greek Students**	Board game as teaching aids	To investigate the effectiveness of an intervention strategy in teaching mathematics.	Improved dyslexic students' performance in Maths. Integrating a board game adapted to mathematics into the secondary school curriculum could have positive effects on dyslexic students.
20	Peters et al. (2021) Australia	**Action video game training improves text reading accuracy, rate and comprehension in children with dyslexia: a randomized controlled trial**	Computer action video game (AVGs) (Fruit Ninja)	To improved text reading accuracy, rate and comprehension through dynamic visual attention training using AVGs.	Playing 'Fruit Ninja' for only 5 hour significantly improved reading accuracy, rate, comprehension and rapid naming.
21	Bigueras et al. (2020) Philippines	Mobile Game-Based Learning to Enhance the Reading Performance of Dyslexic Children.	Mobile game (LaroLexia)	To identify the specific game elements to be integrated to increase reading performance	Improved reading performance in area of familiarization and sounds of an individual letter and also reading word.

Finding

This SLR study detailed the analysis of 21 articles identified into two main themes, namely the type of technology used, and the effectiveness of technology-based interventions used in the learning of dyslexic pupils. The effectiveness of the interventions is based on several important factors, namely the emphasis on phonological skills and an important element in the construction of applications to attract dyslexic children.

The use of technology in the learning of dyslexic children

Based on the analysis of the 21 articles analyzed, there are various technologies used to support the learning of children with dyslexia based on their needs. Some forms and types of technology as a learning medium that help improve the learning process of dyslexic children have been harnessed. Among them are the use of digital technology such as audiobooks, TTS, STT, computer software, applications and games. There is also the use of newer technologies such as robotic technology, virtual reality technology, augmented reality technology and mulsemedia. In addition, the implementation of interventions also involved the use of non-digital technologies such as modifications to the teaching curriculum and innovation of teaching aids. The list of articles based on the use of technology is as shown in Table 4.

Table 4
List of articles based on the type of technology used.

Author	Type of Technology	Study /Intervention Purposes
Almgren Bäck et al. (2023)	Audiobook TTS STT	To describe dyslexic students' experiences of AT on different devices (tablet, computer, mobile phone) for written language skills.
Bhola (2022)	TTS software	To study the effect of text-to-speech software on the academic achievement of students with dyslexia.
Al-Dokhny et al. (2022)	Graphical design of online application (Quizlet)	To enhance the students' visual perception (VP) and phonological processing (PhP) by combining the visual information in the graphical user interface design in the online applications.
Hurwitz & Vanacore (2022)	Lexia Core5 Reading Program (Core5), online instructional program	To investigate the effectiveness of edtech in supporting elementary school students with reading literacy skills involve phonological awareness, phonics, structural analysis, fluency/ automaticity, vocabulary, and comprehension.
Darrot et al. (2023)	Audio software (Rapdys©) for intensive audio-phonological training program	To present a remediation protocol for developmental dyslexia in HIP-DD children and comparing the effect on phonological abilities of an intensive intervention combining training in categorical perception (CP), rapid automatized naming (RAN), and phonemic analysis (PA).
Forne et al. (2022)	Computerized phonological training program using Binding Method software	To investigate the effectiveness of an intensive computerized phonological training program to improve reading performance involving phonemic awareness, decoding, and reading fluency.
Romero et al. (2023)	Computer Game (Berni)	To design and assess an educational software for early intervention to overcome difficulties in phonological awareness, verbal memory,

		alphabetic awareness, receptive language and print awareness.
Peters et al. (2021)	Computer Action Games (Fruit Ninja)	Dynamic visual attention training using Action Video Games (AVGs) to improved text reading accuracy & comprehension.
Vialatte et al. (2023)	Mobile Serious Game (VisioCogLetters)	To stimulate SPL lesion using visual symbol search skill to increase reading accuracy.
Jaramillo-Alcázar et al. (2021)	Mobile Serious Games (Puzzle Pieces)	Developing serious games to improve the treatment of dyslexia using two puzzles designed to train certain cognitive domain to solve the follow-up of therapies for children with dyslexia.
Vanden Bempt et al. (2021)	Mobile Serious Games (GraphoGame)	To improve receptive letter knowledge and phonological awareness.
Hussain et al. (2023)	Mobile AR Serious Game (ARLexic Game)	Design and develop AR serious game to check the engagement level of the ARLexic Game.
Lazo-Amado & Andrade-Arenas (2023)	Mobile AR Game (Educadyslexia)	To improve reading comprehension and spelling.
Rodríguez-Cano et al. (2021)	Mobile VR Game (Wibu)	To design a VR application to support learning of students with dyslexia based on usercentered design.
Jun et al. (2023)	Mobile Game (DysPReX)	To help the dyslexics to learn spelling and reading in a more fun and exciting way at their own pace.
Brennan et al. (2022)	Mobile Adventure Game (Cosmic Sounds)	To support the teaching of phonological awareness skills.
Bigueras et al. (2020)	Mobile Game (LaroLexia)	To identify the specific game elements that shall be integrated into the mobile game-based learning system to increase reading performance.
Malliakas et al. (2021)	Board Game (Teaching aids)	To investigate the effectiveness of an intervention strategy in teaching mathematics.
Maresca et al. (2022)	Virtual Reality Rehabilitation System (VRRS)	To improve cognitive domains, involve memory, attention, language, spatial–temporal orientation, executive functions, calculation, and practice.
Papadopoulou et al. (2022)	Social Robot NAO	To investigate the efficacy of a social robot as the tutor with the assistance of a special educator for the delivery of an intervention.
Mohana et al. (2023)	Technology Enhanced Mulsemedia Learning (TEML)	To stimulate various sensory channels to reinforce the learning process using Mulsemedia devices and IoT technology.

There were 12 of the 21 articles (f=12; 57%) analyzed leveraging technology in game-based

learning. Of the 12 studies, 11 studies used digital video games, while one study was a non-digital game, a traditional board game (Malliakas et al., 2021). In terms of platform, there are 9 games in the form of mobile games namely VisioCogLetters, Puzzle Pieces, GraphoGame, ARLexic Game, Educadyslexia, DysPReX, Wibu, Cosmic Sounds and LaroLexia, while Berni and Fruit Ninja are computer games. The games use a variety of genres and designs namely serious games Vialatte et al (2023); Hussain et al (2023); Jaramillo-Alcázar et al (2021) Vanden Bempt et al (2021), action video games (Peters et al., 2021), adventure video games Brennan et al (2022) and six studies were educational games.

In terms of the use of graphics, there are three studies that interpreted haptic technology namely AR video game *(*Hussain et al., 2023), VR video game (Rodríguez-Cano et al., 2021; Lazo-Amado & Andrade-Arenas, 2023). Haptic technology is a technology that applies tactile sensations when interacting with a physical or virtual environment through the user's movement, vibration, or force. Haptic devices allow users to touch, feel, manipulate, create or alter the dimensions of simulated objects in a virtual environment such as those found in the use of VR adan AR (Biswas & Visell, 2019; Sreelakshmi & Subash, 2017). The effectiveness of interventions in the therapeutic treatment of dyslexic children using VR haptic devices was also tested in the Maresca et al (2022) study through Virtual Reality Rehabilitation System (VRRS) that used multisensory and interactive simulations with computer assistance in 50 rehabilitation activities.

In addition, three studies used asistive technology as a learning medium in dyslexic child intervention programmes. Bäck et al (2023) in his study of nine dyslexic pupils using audiobooks, TTS and STT. TTS technology is used to decode text to help dyslexic children who have difficulty decoding letters that affect spelling skills. The use of TTS in audiobooks can also improve text comprehension, smooth reading and self-learning, as well as saving time and facilitating text-based reading activities for children. Audiobooks and TTS allow dyslexic children to access and interact with text by listening, while STT allows them to dictate what is spoken as the tool is able to convert speech into text in writing. An experimental study in India by Bhola (2022) of 20 dyslexic children used TTS software for four months in teaching and learning to test the effectiveness of TTS. In text-to-voice software, teaching content can be delivered at a slower rate of speed, words can be highlighted and limited text can be produced at a time. All of those things help pupils in strengthening the relationship between words and sounds that lead to a better understanding of phonology. Al-Dokhny et al (2022) in his study used graphic and visual learning materials in the delivery of teaching content to improve visual perception and phonological awareness of dyslexic pupils.

In addition to the use of mobile devices, there were three experimental studies using computers and specific software programs. The Hurwitz & Vanacore Study (2022) uses the Lexia Core5 Reading Program in an online reading intervention program to improve literacy skills involving phonological awareness, phonics, reading fluency, vocabulary and comprehension. Rapdys©, an audio software in the Darrot et al (2023) study, is an intervention tool used in audio-phonology training-intensive programs. Forné et al.(2022) through an intervention program to increase phonological awareness, decoding and reading fluency using Binding Method software in a computer-assisted phonology training program.

Robotic technology using social robots in an experimental study of Papadopoulou et al (2022)

was conducted in Greece on 134 pupils with specific learning problems such as dyslexia and dysgraphia. The study examined the effectiveness of the use of NAO social robots as tutors that assist Special Education teachers in implementing interventions. The NAO social robot is a small-sized humanoid robot with a height of 57 cm with a head, legs, hands and torso and has extensive interacting capabilities capable of traction for children.

Other than that, mulsemedia which is one of the latest advances in technology is also developed as a 21st century learning medium for dyslexic students. Mohana et al (2023) submitted a web portal-based Technology Enhanced Mulsemedia Learning (TEML) to provide a comprehensive online learning platform for dyslexic children. The web portal was developed for inclusive learning of dyslexic students to improve literacy skills and integrate with STEM skills namely Biology and Physics. Mulsemedia stands for multiple sensorial media, aiming to create a deeper experience by combining various senses such as sight, hearing, smell, taste, and touch (Bordegoni et al., 2022). In short, mulsemedia combines multimedia content (audio, video, images, text) and various human senses (Gheorghita et al., 2014).

Effectiveness of technology-based interventions for dyslexic children

Hussain et al (2023) conducted a study on the effectiveness of AR Lexic Game in increasing the involvement of dyslexic and dyslexic students in providing focus and interest in completing the assigned tasks. The study involved five dyslexic and dysgraphia pupils aged between seven and 14 years old who were selected from the Syeda Khatoon-e-Jannat Trust Hospital and Special Education. This study found that there was a significant association between the use of technology in teaching and learning sessions and the involvement of pupils with dyslexia and dysgraphia. Pupils who regularly use AR Lexic Game can increase concentration to quickly complete tasks. Based on the observation, it was found that 4 out of 5 dyslexic students were able to focus and engage in completing tasks using AR Lexic Game within 45 minutes equivalent to 0.8, the game usage rate.

The study of Jun et al (2023) also built an AR-based game called DysPReX as an intervention for dyslexic children by emphasising reading skills through a learning and play approach. A total of 30 respondents were selected to provide feedback on the DysPReX game in several aspects that have been built. The results of the survey found that respondents gave positive feedback as users and were satisfied with the aspects built with a score of 4.0. In this study, dyslexic children showed great interest by showing active involvement in the assigned tasks. This constructed AR game also has a variety of elements applied to increase pupils' involvement in reading skills such as the use of colours, meaningful pictures, creativity, and letter size. The study also found that the constructive AR game DysPReX can help improve the quality of learning of dyslexic pupils.

The Almgren Back et al (2022) study found that the use of AT such as audiobooks, TTS and STT had a positive effect in improving the reading skills of dyslexic pupils. However, the development of reading dyslexic pupils with the use of AT needs to receive support from various parties as dyslexic pupils have problems understanding texts containing long sentences. This is also stated in Bigueras et al (2020) which uses several strategies, namely game-based learning and applying positive reinforcement from teachers to increase the motivation of students to engage in completing tasks. In this study, a game called LaroLexia integrated various elements such as interesting stories, clear instructions and easily accessible

test scores using smartphones only. The study used a qualitative approach in analyzing data. The researchers selected 78 children aged 7 who could speak English. The findings found that computer-using interventions were effective and could be a medium for pupils to screen for dyslexic pupils in reading skills. This is due to some elements that are applied in the computer game and have scores that increase the motivation of students to read. Therefore, the teacher gives a reward such as a stationery-shaped gift after the pupil has successfully completed the game.

Numerous past studies have proven that the effectiveness of game-based learning has led to the widespread use of mobile gaming applications in the implementation of dyslexic children's reading interventions. Therefore, Jaramillo-Alcázar et al (2021) in his study put forward guidelines for building effective games for dyslexic pupils and can be used as an intervention by family members, therapists and teachers of Special Education. The study used a qualitative approach and was conducted on several dyslexic pupils as a sample of the study. In this study, the serious game design was used as an intervention to identify the ability of dyslexic pupils to read. The results of the study found that dyslexic pupils can read and pay better attention when using serious games built. For example, the construction of puzzle games that can be accessed online using a smartphone. This is clear in this study that games that have features that allow dyslexic pupils to access easily can help improve the ability to read.

In a development study by Mohana et al (2023), researchers presented a web portal-based Technology Enhanced Mulsemedia Learning (TEML) that can provide a comprehensive online learning platform. The web portal was developed for inclusive learning of dyslexic pupils to improve reading skills and integrated with STEM concepts to promote scientific literacy and critical thinking skills. By combining various technologies such as Arduino micro-control, exhaust fan, humidifier with smell sensor, and even haptic feedback device, as a result TEML provides a truly multisensory learning experience to dyslexic children. A unique feature of the TEML web portal is that it has a synchronous Arduino code-specific device. By triggering the Arduino code with XML in a web portal, the platform emits the smell of rosemary used to improve cognitive function and memory span while studying.

Discussion

Today, technology is seen as a high-potential instructional aid to be integrated into the teaching and learning process to help pupils acquire new skills, improve their performance, ability and academic achievement. In addition, technology also allows the integration of teaching content with entertainment making learning more enjoyable, increasing motivation, stimulating and strengthening students' learning, in addition to encouraging curiosity and information acquisition. Special Education is also no exception to benefiting from the use of technology, with growing support for the participation of children with learning difficulties including dyslexia to actively study in the classroom (Bakar, 2023; Bhola, 2022; Hurwitz & Vanacore, 2022; Brennan et al., 2022).

The findings prove that the important role of technology in education, which is that studies focusing on dyslexia and the use of technology are increasing year by year. There are over 300 articles that talk about the use of technology in helping children with dyslexia, especially in the aspect of reading skills. This is because the use of technology can increase interest,

provide a fun learning experience and extend the duration of a pupil's focus through the use of interesting multimedia and graphics (Hussain et al., 2023; Maresca et al., 2022; Jaramillo-Alcázar et al., 2021). There are studies agreeing that the use of technology reduces tactile sensory i.e. pupils are unable to touch words in a way but can increase the attention span of a pupil (Bakar, 2023; Contreras, 2023). Studies prove that by increasing the attention span, more input to dyslexic pupils can be given. This shows that the use of technology in teaching reading skills has a positive impact, thus helping dyslexic pupils overcome their reading problems more effectively.

Based on the findings of the studies, most studies carried out game-based interventions. The widespread use of game-based technology in the learning of dyslexic children has a positive effect on the factors of the use of the technology itself that is common to children (Mahazir et al., 2019). In developing games, studies are more focused on mobile applications or also better known as apps. Only 3 of the 21 (f=3; 14%) studies produced software programs to develop reading software programs. This is because, in order to produce comprehensive software, studies require expertise in the field of technology, in addition to high cost and taking a long time (Mohana et al., 2023). Such limitations are among the factors in the selection of mobile applications over programming software. The selection of mobile apps is due to the easy-to-carry features of the game anywhere, cheap, and easy to download (Dawson et al., 2016; Reid et al., 2013). In addition, the user-friendly mobile app features that suit dyslexic children who have problems in gross motor skills cause those who are more comfortable using the touch screen than the mouse (Kılıç et al., 2019).

In conclusion, this study provides a brief overview of the different types and forms of technology used today and the effectiveness of technology as an intervention tool and learning medium of dyslexic children. Along with the boom of the digital technology era and the fourth industrial revolution, the practice of Technological Pedagogical Content Knowledge (TPACK) among teachers needs to be improved. TPACK practices require teachers to teach effectively with a technological framework to ensure the effectiveness of teaching and learning and the interventions implemented.

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