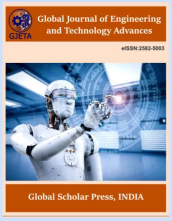
Global Journal of Engineering and Technology Advances
eISSN: 2582-5003
Cross Ref DOI: 10.30574/gjeta
Journal homepage: https://gjeta.com/



(RESEARCH ARTICLE)

Check for updates

The Use of Artificial Intelligence in the Education of Students with Learning Disabilities – A Systematic Review

Parthenopi Papalexandratou, Agathi Stathopoulou * and Constantina Skanavis

Department of Public and Community Health School of Public Health University of West Attica, Greece.

Global Journal of Engineering and Technology Advances, 2024, 21(03), 033-049

Publication history: Received on 03 November 2024; revised on 11 December 2024; accepted on 13 December 2024

Article DOI: https://doi.org/10.30574/gjeta.2024.21.3.0223

Abstract

Learning disabilities are a neurodevelopmental disorder that affects a significant percentage of students worldwide, creating academic and socioemotional challenges that can impact adulthood. Although learning disabilities cannot be fully resolved, individuals living with them can significantly enhance their abilities with the help of appropriate teaching methods and support tools. Artificial intelligence offers innovative capabilities to support students with learning disabilities by providing personalized digital tools and learning strategies tailored to their specific educational needs. The aim of this study is to examine, through a systematic literature review, the most recent applications of artificial intelligence that have been developed to support students with learning disabilities. Through the literature search in the Scopus, PubMed, and Google Scholar databases, only a limited number of studies were identified regarding the role of artificial intelligence in the education of students with learning disabilities. However, the aforementioned studies demonstrated that artificial intelligence can enhance the educational path of individuals with learning disabilities and facilitate the learning process, improving their academic performance, reducing the challenges and inequalities they face and thereby providing equal opportunities for success in the educational field.

Keywords: Artificial intelligence; Learning Disabilities; Education; Personalized Learning; Digital Tools; Learning Strategies; Personalized Interventions; School-Aged Students; University Students

1. Introduction

Learning Disabilities (LDs) is a neurological disorder that affects one or more of the basic psychological processes involved in understanding or using spoken or written language and affects a person's ability to receive, store, process, retrieve, or communicate information (Handler, Fierson and Section on Ophthalmology and Council on Children with Disabilities, American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, and American Association of Certified Orthoptists, 2011; Ouherrou, et al., 2019). LDs affect up to 10% of the world's population (Alone and Bamnote, 2023; Dhamal and Mehrotra, 2021; Rico-Olarte, et al., 2020) and occur in students regardless of their native language or medium of instruction (Vidyadharan and Tharayil, 2019). Students with LDs may suffer academically and socio-emotionally if the difficulties they face are not detected early (Ravichandran, et al., 2023). While specific learning disabilities cannot be fully resolved and are lifelong (Alshehri, et al., 2023; David and Balakrishnan, 2010; Turan and Atila, 2021; Youssef and Youssef, 2019), those living with them are still able to significantly improve their capabilities with the help of appropriate teaching methods and assistive tools (David and Balakrishnan, 2010; Turan and Atila, 2021; Youssef and Youssef, 2019). Early detection of LDs and provision of appropriate intervention are paramount not only to support students with LDs in addressing their academic needs but also to enhance their social and emotional well-being (Bhatti, et al, 2024; Fortes, et al., 2016; Zhai and Panjwani-Charania, 2023), their proper development and their quality of life (Fortes, et al., 2016; Turan and Atila, 2021).

* Corresponding author: Agathi Stathopoulou

The rapid development of artificial intelligence (AI) in education has the potential to increase learning opportunities, enrich personalized learning experiences, provide limitless possibilities and exciting opportunities to address educational issues, achieve desired learning outcomes by improving learning (Zheng, et al., 2023), and assist and empower educators to make the learning process an enjoyable experience for students (Fitria, 2021).

The aim of this study is to provide a comprehensive documentation of recent research on the role of AI in the education of students with LDs. To achieve this, a systematic literature review (SLR) of articles in the international literature on this topic was conducted.

After reviewing the international literature, the following research questions were formulated:

- What applications of artificial intelligence have been developed in recent years (2021-2024) to support students with learning disabilities?
- What is the impact of the use of these applications on the learning performance of students with LDs?
- How do teachers perceive the use of AI as a tool to support students with LDs?

1.1. Definition of learning disabilities

LDs is the most common neurodevelopmental disorder found in a typical classroom setting, reflecting a wide range of difficulties in reading, mathematics and written expression (Iaia, et al., 2024; Johnson, 2017; Kulkarni, et al., 2001; Layes, Lazar and Mecheri, 2024; Papadopoulou, et al., 2022). In the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), the prevalence of LDs, which includes educational domains of reading, writing and mathematics, was reported as 5%-15% among school-aged children from different cultures and speaking different languages (Altay and Görker, 2018; Anthony, Reupert and McLean, 2024). The most common learning disability is dyslexia (Benmarrakchi, et al., 2018; Handler, Fierson and Section on Ophthalmology and Council on Children with Disabilities, American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, and American Association of Certified Orthoptists, 2011; Morciano, et al, 2024; Papadopoulou, et al, 2022; Shaywitz and Shaywitz, 2003; Shaywitz and Shaywitz, 2005; Yeguas-Bolívar, et al., 2022).

LDs are officially defined in various ways in many countries (David and Balakrishnan, 2010). According to the Individuals with Disabilities Education Improvement Act (IDEIA), an LD is a disorder in one or more of the basic psychological processes involved in understanding or using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. This term includes conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia and developmental aphasia. The term does not include students who have learning disabilities that are primarily the result of visual, auditory or motor impairments, intellectual disabilities, or adverse environmental, cultural or economic conditions (Alone and Bamnote, 2023; Hong and Chick, 2013; Rai, Saluja and Pimplapure, 2023; Rao, et al., 2024).

However, experts in this field have not yet reached full agreement on the definition of an LD and its precise meaning (Nanni and Lumini, 2009; Wu, Huang and Meng, 2006; Wu, et al., 2011). Most of the scientific community currently adopts the approach of the fifth edition of the American Psychological Association's Diagnostic and Statistical Manual of Mental Disorders (known as DSM-5). DSM-5 led to significant changes in the diagnostic criteria for learning disabilities. More specifically, criterion A requires the presence of at least one symptom of difficulty in reading, writing or mathematics that persists despite the provision of interventions aimed at that difficulty. Criterion B requires that academic skills be "substantially and quantitatively" lower than expected based on chronological age and cause significant impediments to academic or professional performance or everyday activities. Criterion C indicates that learning disabilities begin during the school years, but may not fully manifest until the demands on the affected academic skills exceed the individuals' limited abilities. Finally, criterion D remains similar to previous versions of the DSM and stipulates that learning disabilities do not include intellectual disabilities, uncorrected visual or auditory acuity, other mental or neurological disorders, psychosocial adversity, lack of proficiency in the language of academic instruction, or inadequate educational instruction. These four criteria must be met based on a clinical synthesis of the individual's history (including developmental, medical, family, and educational history), school reports, and psychoeducational evaluation. (Goldstein and DeVries, 2017; Papadopoulou, et al., 2022).

1.2. Need for early identification of LDs and provision of appropriate interventions

LDs such as dysgraphia, dyslexia, dyspraxia, and others hinder academic progress and also have long-term educational, social, and economic impacts that extend beyond the school years (Handler, Fierson and Section on Ophthalmology and Council on Children with Disabilities, American Academy of Ophthalmology, American Association for Pediatric

Ophthalmology and Strabismus, and American Association of Certified Orthoptists, 2011; Poornappriya and Gopinath, 2020; Vidyadharan and Tharayil, 2019).

Students with LDs fail to meet their academic goals due to low academic performance (Ahuja, 2022; Arumugam, Govindaraju and Tamilarasan, 2022; Hu, 2024; Johnson, 2017; Khan, Cheng and Bee, 2018; Koutromanos, et al., 2020; Kulkarni, et al, 2001; Turan and Atila, 2021) and may not be treated fairly (Trewin, et al., 2019). These students with LDs tend to exhibit lower levels of motivation and encounter significant obstacles to pursuing further education. (Arumugam, Govindaraju and Tamilarasan, 2022; Arumugam, Govindaraju and Tamilarasan, 2022; Hu, 2024; Khan, Cheng and Bee, 2018; Turan and Atila, 2021).

LDs not only affect a wide range of students' academic skills, but can also affect their emotions and social skills (Zhai and Panjwani-Charania, 2023). Students who are identified late may experience prolonged difficulties, reduced self-esteem and disinterest in their studies (Ravichandran, et al., 2023; Zhai and Panjwani-Charania, 2023). Reduced self-esteem as well as social and behavioral problems at school can become persistent, creating a significant emotional burden (Arumugam, Govindaraju and Tamilarasan, 2022; Khan, Cheng and Bee, 2018; Zhai and Panjwani-Charania, 2023). These effects can impact adulthood, leading to significant difficulties in social adjustment (Fortes, et al., 2016) and professional employment (Arumugam, Govindaraju and Tamilarasan, 2022; Fortes, et al., 2016; Hu, 2024; Khan, Cheng and Bee, 2018).

AI-based learning interventions are among the educational innovations that can address the challenges faced by these students (Mohammad Abedrabbu Alkhawaldeh, 2023; Sukiman and Abdl Aziz, 2021).

Artificial intelligence offers promising avenues for identifying students' unique needs and devising personalized strategies and digital tools to effectively address learning difficulties (Bhatti, et al., 2024). Thus, AI can help not only in the early diagnosis of students with LDs, but also in creating personalized techniques for their support (Bhatti, et al., 2024; Rai, Saluja and Pimplapure, 2023; Yenduri, et al., 2023; Zhai and Panjwani-Charania, 2023).

1.3. The role and benefits of AI and Digital Technologies in the education of students with LDs

Modern technology has become an integral part of our era. It has not only changed the way people live, but it has also changed the way we work, learn and interact. A more recent technological development is the emergence of the term artificial intelligence (AI), which is currently beginning to gain attention as a tool that acts like a human (Fitria, 2021). AI refers to the simulation of human intelligence in machines that are programmed to replicate human thinking and behavior (Yenduri, et al., 2023).

As AI has developed, it has also entered the field of education. The modern educational reality makes it necessary for the educational sector to adapt to technological advancements to improve the quality of education, especially through the integration of Information and Communication Technologies (ICT) (Fitria, 2021).

AI, as a machine-based technique with algorithmic power to make predictions, diagnoses, recommendations and decisions, has established its position in the educational community for its ability to support learning in various contexts in recent years (Chen, et al., 2022).

AI technologies contribute to the achievement of the United Nations' 4th Sustainable Development Goal (Hopcan, et al., 2023; Pedro, et al., 2019; Sukiman and Abdl Aziz, 2021), which aims to ensure equitable and inclusive quality education and promote lifelong learning opportunities for all (Pedro, et al., 2019; United Nations, 2020).

In addition, AI is reshaping the educational content. Nowadays, a growing number of educational methodologies and programs are incorporating AI and digital culture into the curriculum (Gkeka, Agorastou and Drigas, 2019). AI systems help students learn at their own pace, guide teachers on how to support students (Hopcan, et al., 2023) and improve the quality and standards of learning to be more effective and practical (Fitria, 2021). AI can also automate basic activities, ensuring ample time for teachers (Gkeka, Agorastou and Drigas, 2019). It has the potential to automatically grade essays, identify reading and writing challenges among students with LDs, develop psychological profiles for these students, assess their spelling problems (Bhatti, et al, 2024; Rai, Saluja and Pimplapure, 2023; Zhai and Panjwani-Charania, 2023) and provide them with assessment (Ahmad, et al., 2021; Chen, Chen and Lin, 2020; Chen, et al., 2022; Dutt, Ahuja and Kumar, 2022; Fitria, 2021; Haryanto, Ditta and Ditasari, 2023; Hernández, Mousalli and Rivas, 2009; Hopcan, et al., 2023), feedback (Ahmad, et al., 2021 ; Bhatti, et al., 2024; Chen, Chen and Lin, 2020 ; Chen, et al., 2022; Dutt, Ahuja and Kumar, 2022; Fitria, 2021; Hopcan, et al, 2023; Hu, 2024; Kharbat, Alshawabkeh and Woolsey, 2021; Luckin and Holmes, 2016; Mohammad Abedrabbu Alkhawaldeh, 2023; Rai, Saluja and Pimplapure, 2023; Ravichandran,

et al., 202; Zhai, et al., 2021; Zhai and Panjwani-Charania, 2023; Zheng, et al., 2023) and progress monitoring (Ahmad, et al., 2021; Chen, et al., 2022; Fitria, 2021). AI techniques can help students with LDs by replicating human decision making, minimizing uncertainties, and enhancing learning contexts, emphasizing their importance for intelligent and adaptive e-learning environments (Bressane, et al., 2024).

A vital aspect of education is to help students identify their learning challenges so that appropriate interventions and support systems can be implemented to improve their academic performance and overall well-being (Tiwari and Bawa, 2023). It has been shown that early identification and diagnosis methods, when combined with specific teaching strategies, can reduce the impact of learning disabilities and improve the long-term academic performance of students with LDs (Pannu, 2015; Tiwari and Bawa, 2023; Yenduri, et al., 2023). Early diagnosis and intervention can also significantly mitigate the negative impact of an LD on mental health by helping to prevent frustration and reduced well-being caused by an undiagnosed LD (Mor and Dardeck, 2021) AI can detect LDs early and provide personalized learning, enabling teachers to address the unique needs of each student in a rapidly changing educational environment (Ravichandran, et al., 2023; Yenduri, et al., 2023).

AI-based learning interventions are among the most frequently used practices to encourage personalized learning among students with LDs (Sukiman and Abdl Aziz, 2021). AI can analyze a specific type of LD that a student has and then suggest personalized learning strategies (Bhatti, et al., 2024). By providing creative solutions to improve learning outcomes, address issues in the educational sector and enhance learning experiences, AI is revolutionizing education (Ravichandran, et al., 2023).

Finally, emphasis is placed on the significance of all digital technologies in the field of education and in Learning Disabilities training, which is highly effective and productive and facilitates and improves assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere (Politi-Georgousi and Drigas, 2020; Stathopoulou, et al., 2019), various ICTs applications that are the main supporters of education (Alexopoulou, Batsou and Drigas, 2019; Bravou and Drigas, 2019; Chaidi, Drigas and Karagiannis, 2021; Drakatos, et al., 2023a; Drakatos, et al., 2023b; Drigas and Petrova, 2014; Drigas and Theodoropoulou, 2016; Galitskaya and Drigas, 2020; Loukeri, Stathopoulou and Driga, 2023; Stathopoulou, et al., 2022; Stathopoulou, Spinou and Driga, 2023a; Stathopoulou, Spinou and Driga, 2023b; Vouglanis and Driga. 2023a; Vouglanis and Driga, 2023b), and AI, STEM, Games and ROBOTICS (Chaidi, et al., 2021; Chaidi and Drigas, 2022a; Lytra and Drigas, 2021; Pergantis and Drigas, 2024) that raise educational procedures to new performance levers. Additionally, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the cultivation of emotional intelligence (Bamicha and Drigas, 2022; Chaidi and Drigas, 2022b; Drigas, Mitsea and Skianis, 2021a; Drigas, Mitsea and Skianis, 2021b; Drigas, Mitsea and Skianis, 2022a; Drigas, Mitsea and Skianis, 2022b; Drigas and Sideraki, 2021; Galitskaya and Drigas, 2021; Karyotaki, et al., 2022; Kontostavlou and Drigas, 2021; Mitsea, Drigas and Skiannis, 2022a; Mitsea, Drigas and Skiannis, 2022b), accelerates and improves the educational practices and results, especially in children with LDs.

2. Methodology

This study was based on the systematic review method. A 4-step process was followed to conduct it:

- International literature identification based titles and abstracts
- Selection and exclusion of studies according to inclusion and exclusion criteria
- In- depth review of selected literature
- Extraction of Results

Regarding the search strategy, an online search of studies in three databases - Scopus, Google Scholar and PubMed - was conducted to identify relevant literature. The search was completed in October 2024. The search terms used in the study employing Boolean logic were:

("Artificial Intelligence" OR "AI") AND ("learning difficult*" OR "learning disabilit*" OR "learning disorder*")

2.1. Inclusion and exclusion criteria

To effectively address the research questions, ensure the generalizability of the findings and avoid bias in the selection of articles, a number of specific inclusion and exclusion criteria were established in this study to refine the focus and identification of relevant research, as shown in Table 1.

The preliminary study conducted indicates that the use of AI in supporting students with LDs, despite its initial surge in the 1990s, has increased significantly over the past 10-15 years. Figures 1, 2 and 3 illustrate the year-on-year growth in the number of published articles on the topics of "Artificial Intelligence" and "Learning disabilities" as documented in Scopus, Google Scholar and PubMed covering the period from 2010 to 2024. In the last three years, 2022 - 2024, there has been a rapid increase in the number of published articles. It is noteworthy that these years account for a significant proportion of the total results, representing 58.06%, 39.80% and 54.09% of all the 15-year results in Scopus, Google Scholar and PubMed respectively. Consequently, the search was narrowed to these years and extended by one additional year to encompass 2021, as 2021 may have marked the beginning of this upward trend in subsequent years. This approach ensured that all studies relevant to the new data were included in the review.

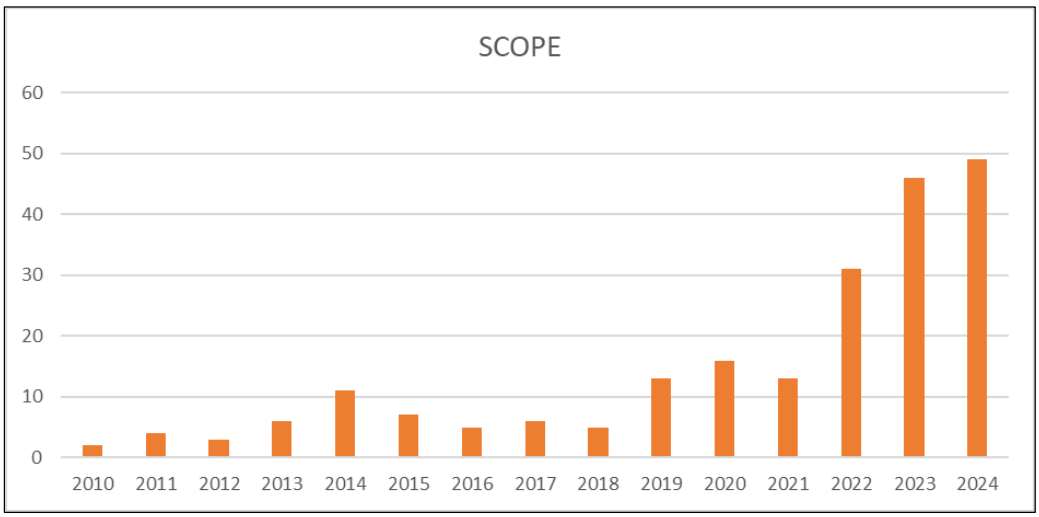


Figure 1 Articles published in Scopus in the last 15 years

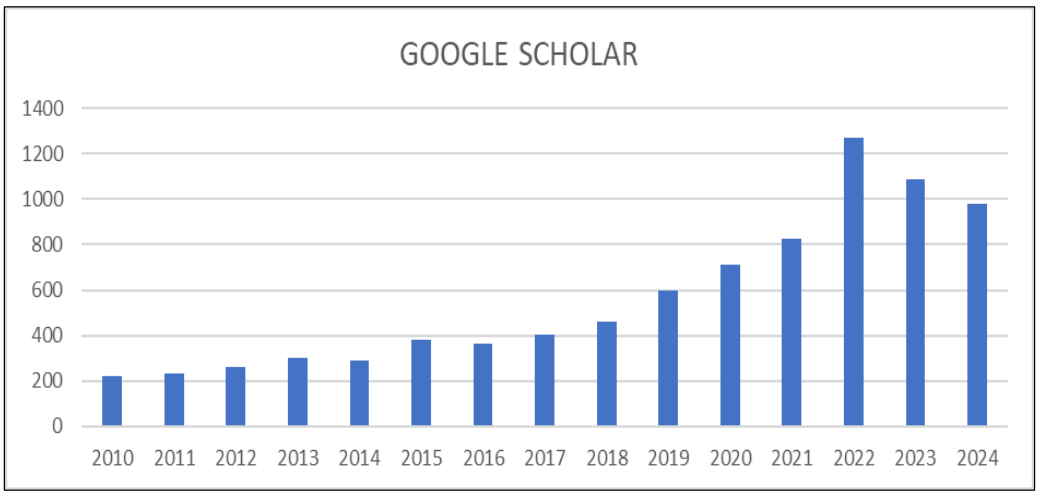


Figure 2 Articles published in Google Scholar in the last 15 years

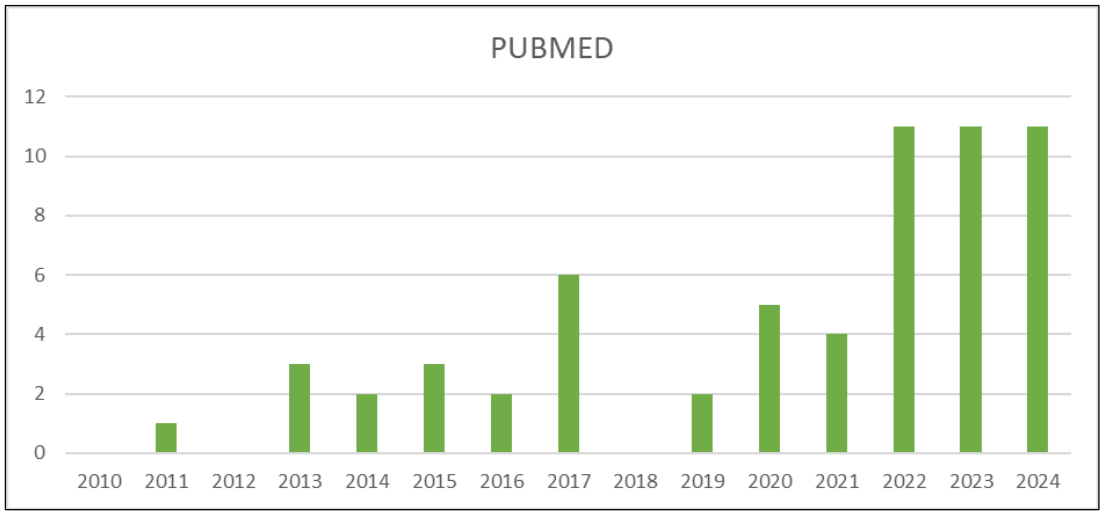


Figure 3 Articles published in PubMed in the last 15 years

Regarding the sample, this study focuses on school-aged and university students. As the education system may differ across countries, studies involving primary to high school students (aged 6-18 years old) and university students were selected. In particular, the study includes only students diagnosed with LDs as this focus ensures more accurate and targeted data, avoiding generalizations from undiagnosed students with similar symptoms. In addition, articles published in English in reputable journals were selected. Reputable journals are defined as those indexed in databases such as Google Scholar, Scopus and PubMed. More specifically, only Field Studies, Meta-analyses and Systematic Reviews were selected to ensure the validity of the results and conclusions, as these provide the most reliable and evidence-based data on the effectiveness of AI applications in supporting students with LDs. The field of study was limited to the educational sector, excluding studies conducted in medical or clinical settings. Finally, the content of the included studies focuses on supporting students with LDs, excluding studies focused on diagnosis. This distinction aligns with the purpose of this study- to support the teaching and learning of students already diagnosed with LDs.

Table 1 Inclusion and exclusion criteria

	INCLUSION CRITERIA	**EXCLUSION CRITERIA**
YEAR RANGE	2021-2024	Years before 2021
SAMPLE	School-aged students and university students	Pre-school students or adults who are not university students
TARGET POPULATION	Students diagnosed with LDs	Students not diagnosed with LDs or students without LDs or students with other special educational needs
TYPES OF STUDIES	Articles	Other types other than articles
TYPES OF ARTICLES	Field Studies, Meta-analyses, Systematic Reviews	Reviews
PUBLICATION LANGUAGE	English	Languages other than English
FIELD OF STUDY	Education	Clinical environments
CONTENT FOCUS	The content focuses on supporting students with LDs and/or creating appropriate educational interventions	The content focuses on the diagnosis or on general psychosocial interventions for people with LDs not related to the educational process

2.2. Study selection process

In order to select the most relevant studies, filters based on the defined inclusion and exclusion criteria were applied. These filters limited the search to articles published between 2021-2024, available in English and as full-text open access documents. In the case of PubMed, additional filters were used for meta-analyses and systematic reviews to ensure the selection of high-quality studies. Duplicates were removed using the Zotero tool and results were extracted using the PRISMA Flow Diagram (PRISMA Flow Diagram, 2020).

For the study selection process, an online search in the three databases - Scopus, Google Scholar and PubMed - as mentioned earlier, was initially conducted employing Boolean logic and more specifically the terms:

("Artificial Intelligence" OR "AI") AND ("learning difficult*" OR "learning disabilit*" OR "learning disorder*")

The search yielded 111 results in Scopus, 8,070 in Google Scholar and 71 in PubMed. Therefore, 8,252 articles were included in the initial eligibility screening stage. Subsequently, the aforementioned filters were applied thus reducing the results to 316. Specifically, in Scopus the filters "Year Range: 2021-2024", "Document type: Article", "Language: English" and "Open Access: All open access" were applied, reducing the results to 15. In Google Scholar, the filters "Custom Range: 2021-2024" and "Review Articles" were applied, yielding 300 results. In PubMed, the filters "RESULTS BY YEAR: 2021-2024", "TEXT AVALABILITY: Free Full Text", "ARTICLE TYPE: Meta-Analysis, Systematic Review" and "ARTICLE LANGUAGE: English" were applied, reducing the results to 1. Then, the results were further reduced to 313 after duplicate removal using the Zotero tool.

Following the title and abstract screening process, 245 studies that were not relevant to the study and 19 that were conducted in Italian, Portuguese, Swedish, Spanish, Indonesian, Russian and Chinese were excluded. Consequently, the results were limited to 49. An attempt was then made to retrieve these studies, in which the results were reduced to 44 since 5 articles were not accessible.

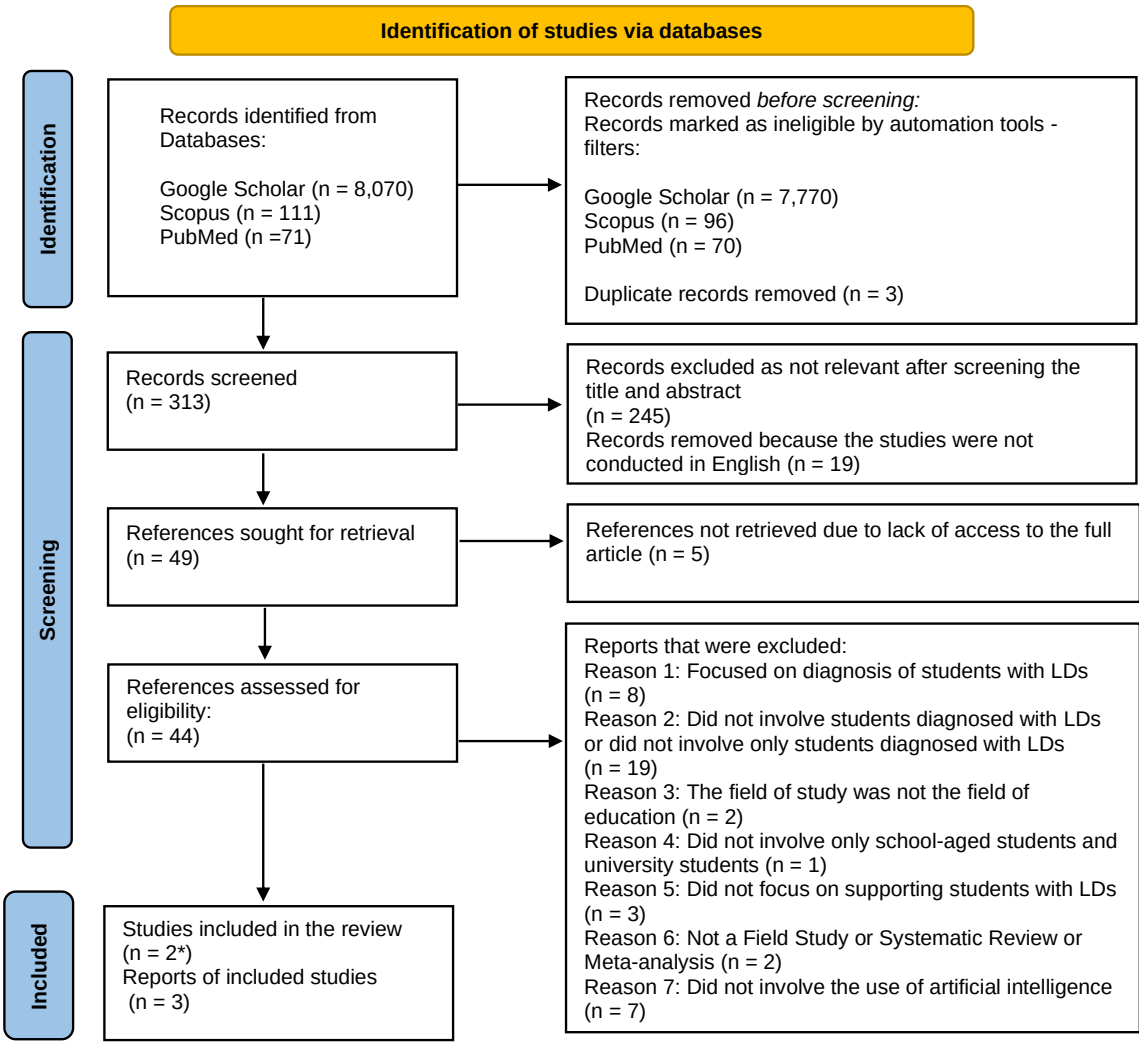
Finally, following a comprehensive review of the 44 articles, the results were narrowed down to 2, as shown in Figure 4. Of these two articles, one Field Study was fully utilized, along with one study report, while from the second article (a systematic review), only two study reports meeting the inclusion criteria were used. Consequently, 4 articles were included in the study. The reasons for excluding the remaining 42 articles were as follows:

- They focused on diagnosing students with LDs rather than supporting them
- They did not involve students diagnosed with LDs or did not involve only students diagnosed with LDs
- The field of study was not the field of education
- They did not involve exclusively school-aged and university students
- They did not focus on supporting students with LDs
- It was not a Field Study or Systematic Review or Meta- analysis
- They did not involve the use of artificial intelligence

2.3. Flow diagram

The Prisma (Preferred Reporting Items for Systematic reviews and Meta-Analyses), first published in 2009 and revised in 2020, was developed to enhance the clarity, transparency, quality and value of systematic reviews and meta-analyses (Sohrabi, et al., 2021). In this systematic review, the results were extracted using the following PRISMA 2020 flow diagram (PRISMA Flow Diagram, 2020), which makes the study selection process more transparent and reliable and enhances the validity of the methodological process. This diagram outlines the process of searching, identifying, screening for appropriateness and final selection of articles meeting the inclusion criteria for the systematic review, as detailed in Figure 4. Specifically, the diagram illustrates:

- The number of initial results identified from the 3 databases (Google Scholar, Scopus and PubMed)
- The number of articles removed through automation tools – filters, as well as the number of duplicates removed.
- The number of studies excluded during the title and abstract screening process.
- The number of articles excluded after the full text screening along with the reasons for their exclusion.
- The number of studies and their reports included in the systematic review.



* One of the two studies, which was a systematic review, was not used as a study but two of its study reports were used which met the inclusion criteria for the study.

Figure 4 PRISMA Flow Diagram (PRISMA Flow Diagram, 2020)

3. Results

In this systematic review, studies that met the predefined inclusion criteria and utilized AI in the education of students diagnosed with LDs were analyzed. These 4 studies that were included applied different AI methods and technologies to support students with LDs and enhance their learning experience. The results show that there is a wide range of AI capabilities, from recommendation systems and tailored learning platforms that suggest personalized content and learning strategies, to applications and digital tools that facilitate reading and communication for individuals with LDs. The key findings from the studies are as follows:

The study by Zingoni, et al. (2021), conducted in Italy and Spain, explored the development and initial effectiveness assessments of the "BESPECIAL" platform, which was designed within the VRAIlexia project to provide personalized support to university students with dyslexia. The platform combines artificial intelligence and virtual reality (VR), thus offering an innovative learning environment that responds to students' specific needs and difficulties. Students with dyslexia faced significant difficulties in their university course, especially in reading, memory and understanding complex concepts. This platform was developed to provide personalized support to students, by addressing these difficulties and offering appropriate tools and learning strategies. The aim was to enhance the skills of students with

dyslexia, improve their academic performance and reduce the risk of dropping out of their studies. The research sample consisted of 700 university students diagnosed with dyslexia, mainly from schools of humanities. The tools used to collect data in the survey were: 1) The "BESPECIAL" platform, which uses AI to assess students' individual needs and VR to monitor progress 2) Psychometric tests that measure self-confidence, anxiety and self-esteem 3) OCR (Optical Character Recognition) to collect data from clinical reports and 4) questionnaires that analyzed students' individual needs while the adaptation of learning strategies was based on this data. Preliminary results showed that the platform demonstrated significant improvement in both students' academic performance and self-confidence, as participants reported that they improved in understanding and recalling the concepts taught and that their self-confidence was enhanced. They also reported the usefulness of interactive virtual reality experiences which - through visualization - enabled them to actively participate in learning and better understand difficult concepts, as well as the usefulness of artificial intelligence which offered learning strategies that responded to the individual challenges they faced. In conclusion, the research showed that the "BESPECIAL" platform can provide support to students with dyslexia and demonstrates how personalization, combined with technologies such as AI and VR, can improve the academic performance of these students. The study suggests integrating modern technologies into learning strategies, rather than limiting them to mere supportive tools, in order to continuously improve the skills of students with dyslexia and provide equal opportunities for their success in academia.

The study by Wang, Muthu and Sivaparthipan (2022) investigated the use of an Augmentative Alternative Communication (AAC) model that leverages artificial intelligence to support students with dyslexia. The survey was conducted in China and India and aimed to improve the reading and learning skills of students through a flexible system tailored to their individual needs. Regarding the sample, the survey included 20 dyslexic students from schools and universities. The tools used for data collection were: 1) assessment questionnaires to collect data on students' needs and difficulties with reading and comprehension 2) specially designed pictograms to support students in the learning process through the visualization of information 3) an AI-AAC hybrid model that integrated the pictograms and 4) machine learning (ML) algorithms to classify data and present appropriate recommendations. More specifically, the algorithms applied were as follows: Maximum Entropy (ME), Support Vector Machine (SVM), Complement Naive Bayes (CNB) and Naive Bayes (NB). These algorithms were compared in terms of their effectiveness in both classifying data and providing appropriate recommendations tailored to the specific needs of students. The results showed that the AI - AAC model was highly effective in supporting students with dyslexia and improving the learning process. In particular, the research found that the AI - AAC increased the accuracy of personalized recommendations by 40.88%, with an overall accuracy of 94.98%. At the same time, efficiency increased by 39.71%, achieving an overall performance rate of 96.95%. In addition, there was a 36.56% reduction in the effort required by a student to understand and complete educational tasks, while response time decreased by 66.34%, improving the overall learning experience by providing faster access to information and support tools. In conclusion, the AI - AAC model proved to be highly effective in improving the learning skills of students with dyslexia by providing them with tailored and personalized support. The high accuracy and effectiveness rates of the AI - AAC suggest that such personalized tools can meet the specific learning needs of students with dyslexia by providing better access to appropriate support and increasing their reading and comprehension abilities.

The study by Morciano, et al. (2024), which took place in Italy and Spain, focused on the use of an AI recommendation system to provide personalized support to students with dyslexia during their learning journey at university. The aim of the research was to compare three collaborative-filtering recommendation models, an item-based model, a user-based model and a weighted-hybrid model, in order to identify the model that offers the best support tools and learning strategies for students with dyslexia to improve their academic performance. The research sample consisted of 1,237 Italian students with dyslexia who completed self-assessment questionnaires about the most used digital tools (17) and learning strategies (22). In addition, the system was tested on 50 students (20 with dyslexia and 30 without) to evaluate the effectiveness of the recommendations. The tools used in the study were: 1) the three collaborative-filtering recommendation models (item-based model, user-based model and weighted hybrid model) 2) three similarity metrics (Pearson correlation, Euclidean distance and Cosine similarity) 3) the K-Nearest Neighbors (k-NN) machine learning algorithm 4) questionnaires that included the 39 digital tools and learning strategies. Each model was compared with all three similarity metrics. The results show that the hybrid recommendation model demonstrated the highest performance with 85% accuracy, 83% recall and low error rate of 11.93%. The system proved to be helpful to students with dyslexia by identifying the most appropriate learning tools and strategies based on their needs. Students with dyslexia who used this system increased their scores by approximately one point (on a scale of 1-10) compared to those who did not receive recommendations from the system. In conclusion, the positive results of the study demonstrated that the recommendation system can be effectively used in education to support students with LDs during their educational journey by suggesting the optimal tools and learning strategies and providing them with personalized assistance that improves their performance and reduces the challenges they face.

In the study by Zingoni, Taborri and Calabrò (2024), which was conducted in Italy, a classification model of the most useful methodologies for providing personalized support for university students with dyslexia was created. The prediction algorithm was based on supervised machine learning (ML) techniques to suggest tailored digital support tools and learning strategies to students based on their individual learning difficulties. The aim was to improve their educational journey and enhance their skills. The algorithm was trained and tested using data obtained through a self-assessment questionnaire, which was designed and then completed by 1,217 Italian students diagnosed with dyslexia, who constituted the main sample of the study. In addition, to evaluate the effectiveness of the classification system in a real case, a trial was conducted with 43 students. The questionnaires included questions regarding the students' learning difficulties, as well as the supportive tools and learning strategies which they found useful, allowing the identification of 17 useful tools and 22 useful strategies. The questionnaire responses were given in a Likert scale format, enabling the researchers to quantify the usefulness of the suggested supportive learning tools and strategies. The tools used in the study were as follows: 1) four of the best performing supervised machine learning algorithms for classification, namely random forest (RF), linear/logistic regression (LR), k-nearest neighbors (kNN) and support-vector machines (SVM) 2) performance metrics: accuracy, recall and F1-score 3) self-assessment questionnaires. The results show that the average prediction accuracy was 88.7% for the tools and 91.6% for the learning strategies. Globally, the achieved average accuracy is 90.4%. A recalculation of the average prediction accuracy was performed after excluding the four tools and four strategies for which a rate of less than 85% had been achieved, resulting in an increase in average accuracy to 92.7% for the tools, 94.8% for the strategies and 94.0% globally. Furthermore, the proposed algorithm was tested in a real case, achieving prediction accuracy higher than 90% by suggesting useful and useless support methodologies to a sample of 43 students with dyslexia. In conclusion, the developed classification system is effective in providing individualized support to students with dyslexia, helping them to identify the most appropriate learning tools and strategies based on their individual needs. The algorithm implemented can achieve the intended goal by reducing the gap between students with and without dyslexia. This success opens up new perspectives for approaching the dyslexia issue in universities, focusing on adapting teaching activities to students' needs, rather than limiting itself to decreasing their study load or obligations.

4. Discussion

The aim of this research was to record and analyze new research data on the role of AI in the education of individuals with LDs. The goal was to explore, through a systematic review of the literature, the tools and applications of AI that have been developed in recent years (2021-2024) to support students with LDs and their effectiveness in improving the academic performance of this population.

The advancements in AI over the past four years have enhanced the ability to provide personalized support to students with LDs based on their specific educational needs, improving their educational experience and offering them learning opportunities equivalent to those of people without learning disabilities. The rapid increase in the number of relevant publications in recent years indicates the growing recognition of AI as a supportive tool in education. Despite this progress, the findings from this systematic review revealed that there has not been a significant number of studies focusing on the student population with LDs. Specifically, of the four studies that met the inclusion criteria of the systematic review, three focused on university students and only one included a small proportion of school-aged students. Furthermore, this limited number of studies was exclusively related to dyslexia and not LDs in general.

In response to the first research question, the AI applications developed between 2021-2024 to support students with LDs are the "BESPECIAL" platform, which uses artificial intelligence and virtual reality, the Augmentative Alternative Communication (AAC) model which uses machine learning algorithms, a Hybrid Recommendation System which uses collaborative filtering and similarity metrics and a classification system which uses machine learning algorithms.

Regarding the second research question, these applications demonstrated positive results in enhancing the learning performance of students with LDs, who showed improvement in reading and communication, improvement in comprehension and recall of concepts taught, overall improvement in the learning process, an increase in their scores by approximately one point, as well as an increase in their confidence and self-esteem. Through these applications, which provide personalized support by suggesting the most appropriate learning strategies and digital tools, the learning process was facilitated and the barriers faced by students with and without LDs were reduced. Furthermore, the disparities between students with and without LDs were reduced, providing equal opportunities for success in the educational field. Therefore, these findings demonstrate the potential of AI to support the education of students with LDs more effectively.

5. Conclusions

For the further development of AI in education, it is essential that applications focusing on the learning needs of school-aged students with LDs and not only university students with LDs be developed. Additionally, the studies included in the systematic review focused exclusively on dyslexia rather than learning disabilities in general, which underscores the necessity for further research addressing other LDs in order to meet the diverse educational needs of students. Furthermore, the third research question remained unanswered, despite an extensive search, as no studies were identified that examined teachers' perceptions regarding the use of AI to support students with LDs. This lack suggests a potential gap in the literature and highlights the need for further investigation into teachers' perceptions, as their perspectives may prove pivotal in the integration of AI into the learning process. Finally, it is recommended that further research be conducted on existing applications with a view to improving personalization algorithms and ensuring optimal performance in the education of students with LDs.

Compliance with ethical standards

Acknowledgments

The Authors would like to thank the SPECIALIZATION IN ICTs AND SPECIAL EDUCATION: PSYCHOPEDAGOGY OF INCLUSION Postgraduate studies Team, for their support.

Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

References

[1] Ahmad, S. F., Rahmat, M. K., Mubarik, M. S., Alam, M. M., & Hyder, S. I.,2021. Artificial intelligence and its role in education. Sustainability, 13(22), 12902. https://doi.org/10.3390/su132212902

[2] Ahuja, N. J., Dutt, S., Choudhary, S. L., & Kumar, M., 2022. Intelligent tutoring system in education for disabled learners using human–computer interaction and augmented reality. International Journal of Human–Computer Interaction, pp. 1-13. https://doi.org/10.1080/10447318.2022.2124359

[3] Alexopoulou, A., Batsou, A., & Drigas, A. S., 2019. Effectiveness of Assessment, Diagnostic and Intervention ICT Tools for Children and Adolescents with ADHD. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 7(3), pp. 51–63. https://doi.org/10.3991/ijes.v7i3.11178

[4] Alone, Y., & Bamnote, G. R., 2023. Machine Learning Based Application For Improving Learning Disabilities In Children. Webology, 20(3). Available at: https://www.webology.org/data-cms/articles/20230805122812pmWEBOLOGY%2018%20(2)%20-%20132.pdf [Accessed 13 November 2024].

[5] Alshehri, M., Sharma, S., Gupta, P., & Shah, S. R., 2023. Detection and Diagnosis of Learning Disabilities in Children of Saudi Arabia with Artificial Intelligence. https://doi.org/10.21203/rs.3.rs-3301949/v1

[6] Altay, M. A., & Görker, I., 2018. Assessment of psychiatric comorbidity and WISC-R profiles in cases diagnosed with specific learning disorder according to DSM-5 criteria. Archives of Neuropsychiatry, 55(2), pp. 127- 134. https://doi.org/10.5152/npa.2017.18123

[7] Anthony, H., Reupert, A., & McLean, L., 2024. Parent experiences of specific learning disorder diagnosis: A scoping review. Dyslexia, 30(1), e1757. https://doi.org/10.1002/dys.1757

[8] Arumugam, D., Govindaraju, K., & Tamilarasan, A. K., 2022. AIIoT-based smart framework for screening specific learning disabilities. In Machine Learning for Critical Internet of Medical Things: Applications and Use Cases, pp. 103-124. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-80928-7_5

[9] Bamicha, V., Drigas, A., 2022. The Evolutionary Course of Theory of Mind - Factors that facilitate or inhibit its operation & the role of ICTs , Technium Social Sciences Journal 30, pp. 138-158. https://doi.org/10.47577/tssj.v30i1.6220

[10] Benmarrakchi, F., Ouherrou, N., Elhammoumi, O., & El Kafi, J., 2018, July. An innovative approach to involve students with learning disabilities in intelligent learning systems. In International Conference on Advanced Intelligent Systems for Sustainable Development, pp. 39-50. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-11884-6_4

[11] Bhatti, I., Mohi-U-din, S. F., Hayat, Y., & Tariq, M., 2024. Artificial Intelligence Applications for Students with Learning Disabilities: A Systematic Review. European Journal of Science, Innovation and Technology, 4(2), pp. 40-56. Available at: https://ejsit-journal.com/index.php/ejsit/article/view/397 [Accessed 7/11/2024].

[12] Bravou, V., Drigas, A., 2019. A contemporary view on online and web tools for students with sensory & learning disabilities , iJOE 15(12) 97. https://doi.org/10.3991/ijoe.v15i12.10833

[13] Bressane, A., Zwirn, D., Essiptchouk, A., Saraiva, A. C. V., de Campos Carvalho, F. L., Formiga, J. K. S., ... & Negri, R. G., 2024. Understanding the role of study strategies and learning disabilities on student academic performance to enhance educational approaches: A proposal using artificial intelligence. Computers and Education: Artificial Intelligence, 6, 100196. https://doi.org/10.1016/j.caeai.2023.100196

[14] Chaidi, E., Kefalis, C., Papagerasimou, Y., Drigas, A., 2021. Educational robotics in Primary Education. A case in Greece, Research, Society and Development journal 10(9), e17110916371-e17110916371. https://doi.org/10.33448/rsd-v10i9.16371

[15] Chaidi, I., & Drigas, A., 2022a. Social and Emotional Skills of children with ASD: Assessment with Emotional Comprehension Test (TEC) in a Greek context and the role of ICTs. , Technium Social Sciences Journal, 33(1), pp. 146–163. https://doi.org/10.47577/tssj.v33i1.6857

[16] Chaidi, I., Drigas, A., 2022b. Digital games & special education , Technium Social Sciences Journal 34, pp. 214-236. https://doi.org/10.47577/tssj.v34i1.7054

[17] Chaidi, I., Drigas, A., Karagiannidis, C., 2021. ICT in special education , Technium Soc. Sci. J. 23, p. 187. https://doi.org/10.47577/tssj.v23i1.4277

[18] Chen, L., Chen, P., & Lin, Z., 2020. Artificial intelligence in education: A review. Ieee Access, 8, pp. 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510

[19] Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C., 2022. Two decades of artificial intelligence in education. Educational Technology & Society, 25(1), pp. 28-47.

[20] David, J. M., & Balakrishnan, K., 2010. Machine learning approach for prediction of learning disabilities in school-age children. International Journal of Computer Applications, 9(11), pp. 7-14. https://doi.org/10.5120/1432-1931

[21] Dhamal, P., & Mehrotra, S., 2021, May. Finding learning disorder based on machine learning. In Proceedings of the International Conference on Smart Data Intelligence (ICSMDI 2021). https://dx.doi.org/10.2139/ssrn.3852544

[22] Drakatos, N., Tsompou, E., Karabatzaki, Z., Driga, A.M., 2023a. Virtual reality environments as a tool for teaching Engineering. Educational and Psychological issues, TechHub Journal 4, pp. 59-76. Available at: https://www.techhubresearch.com/index.php/journal/article/view/87 [Accessed 13 November 2024].

[23] Drakatos, N., Tsompou, E., Karabatzaki, Z., Driga, A.M., 2023b. The contribution of online gaming in Engineering education, Eximia 8, pp. 14-30. Available at: https://eximiajournal.com/index.php/eximia/article/view/239 [Accessed 13 November 2024].

[24] Drigas, A,. Sideraki, A,. 2021. Emotional Intelligence in Autism, Technium Social Sciences Journal 26, 80. https://doi.org/10.47577/tssj.v26i1.5178

[25] Drigas, A., Mitsea, E., Skianis, C., 2021a. The Role of Clinical Hypnosis & VR in Special Education , International Journal of Recent Contributions from Engineering Science & IT (IJES) 9(4), pp. 4-18. https://doi.org/10.3991/ijes.v9i4.26147

[26] Drigas, A., Mitsea, E., Skianis, C., 2021b. The Role of Clinical Hypnosis and VR in Special Education , International Journal of Recent Contributions from Engineering Science & IT (IJES) 9(4), pp. 4-17. https://doi.org/10.3991/ijes.v9i4.26147

[27] Drigas, A., Mitsea, E., Skianis C,. 2022a. Virtual Reality and Metacognition Training Techniques for Learning Disabilities , SUSTAINABILITY 14(16), 10170. https://doi.org/10.3390/su141610170

[28] Drigas, A., Mitsea, E., Skianis, C., 2022b. Intermittent Oxygen Fasting and Digital Technologies: from Antistress and Hormones Regulation to Wellbeing, Bliss and Higher Mental States , Technium BioChemMed journal 3(2), pp. 55-73. https://doi.org/10.47577/biochemmed.v3i2.6628

[29] Drigas, A., Petrova, A., 2014. ICTs in speech and language therapy , International Journal of Engineering Pedagogy (iJEP) 4(1), pp. 49-54. https://doi.org/10.3991/ijep.v4i1.3280

[30] Drigas, A., Theodorou, P., 2016. ICTs and music in special learning disabilities , International Journal of Recent Contributions from Engineering, Science & IT. (iJES), 4(3), pp. 12-16. https://doi.org/10.3991/ijes.v4i3.6066

[31] Dutt, S., Ahuja, N. J., & Kumar, M., 2022. An intelligent tutoring system architecture based on fuzzy neural network (FNN) for special education of learning disabled learners. Education and Information Technologies, 27(2), pp. 2613-2633. https://doi.org/10.1007/s10639-021-10713-x

[32] Fitria, T. N., 2021, December. Artificial intelligence (AI) in education: Using AI tools for teaching and learning process. In Prosiding Seminar Nasional & Call for Paper STIE AAS, 4(1), pp. 134-147. Available at: https://prosiding.stie-aas.ac.id/index.php/prosenas/article/view/106 [Accessed 13 November 2024].

[33] Fortes, I. S., Paula, C. S., Oliveira, M. C., Bordin, I. A., de Jesus Mari, J., & Rohde, L. A., 2016. A cross-sectional study to assess the prevalence of DSM-5 specific learning disorders in representative school samples from the second to sixth grade in Brazil. European child & adolescent psychiatry, 25, pp. 195-207. https://doi.org/10.1007/s00787-015-0708-2

[34] Galitskaya, V., & Drigas, A., 2020. Special Education: Teaching Geometry with ICTs. International Journal of Emerging Technologies in Learning (iJET), 15(06), pp. 173–182. https://doi.org/10.3991/ijet.v15i06.11242

[35] Galitskaya, V., Drigas, A., 2021. The importance of working memory in children with Dyscalculia and Ageometria, Scientific Electronic Archives journal 14 (10). https://doi. org/10.36560/141020211449

[36] Gkeka, E., Agorastou, E., & Drigas, A., 2019. Artificial Techniques for Language Disorders. Int. J. Recent Contributions Eng. Sci. IT, 7(4), pp. 68-76. https://doi.org/10.3991/ijes.v7i4.11845

[37] Goldstein, S., & DeVries, M. (Eds.)., 2017. Handbook of DSM-5 disorders in children and adolescents. Cham, Switzerland: Springer International Publishing. Available at: https://link.springer.com/content/pdf/10.1007/978-3-319-57196-6.pdf [Accessed 13 November 2024].

[38] Handler, S. M., Fierson, W. M., & Section on Ophthalmology and Council on Children with Disabilities, American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, and American Association of Certified Orthoptists, 2011. Learning disabilities, dyslexia, and vision. Pediatrics, 127(3), pp. 818-856. https://doi.org/10.1542/peds.2010-3670

[39] Haryanto, S. D., Ditta, A. S. A., & Ditasari, R. A., 2023, July. EDUPEDIA: Intelligent Tutoring System on Learning Difficulties. In 3rd International Conference on Education and Technology (ICETECH 2022), pp. 835-848. Atlantis Press. https://doi.org/10.2991/978-2-38476-056-5_77

[40] Hernández, J., Mousalli, G., & Rivas, F., 2009. Learning difficulties diagnosis for children's basic education using expert systems. WSEAS Transactions on Information Science and Applications, 7(6), 1206-1215. Available at: https://www.researchgate.net/profile/Francklin-Rivas/publication/262364091_Learning_difficulties_diagnosis_for_children's_basic_education_using_expert_systems/links/55c1154408ae9289a09cffef/Learning-difficulties-diagnosis-for-childrens-basic-education-using-expert-systems.pdf [Accessed 8 November 2024].

[41] Hong, B. S., & Chick, K. A., 2013. Understanding Students with Learning Difficulties: How Do They Learn? Kappa Delta Pi Record, 49(1), pp. 30-36. https://doi.org/10.1080/00228958.2013.759829

[42] Hopcan, S., Polat, E., Ozturk, M. E., & Ozturk, L., 2023. Artificial intelligence in special education: a systematic review. Interactive Learning Environments, 31(10), pp. 7335-7353. https://doi.org/10.1080/10494820.2022.2067186

[43] Hu, A., 2024. Developing an AI-Based Psychometric System for Assessing Learning Difficulties and Adaptive System to Overcome: A Qualitative and Conceptual Framework. arXiv preprint arXiv:2403.06284. https://doi.org/10.48550/arXiv.2403.06284

[44] Iaia, M., Vizzi, F., Carlino, M. D., Turi, M., Marinelli, C. V., & Angelelli, P., 2024. Specific learning disabilities and associated emotional-motivational profiles: a study in Italian university students. Frontiers in Psychology, 15, 1365980. https://doi.org/10.3389/fpsyg.2024.1365980

[45] Johnson, B., 2017. Learning disabilities in children: Epidemiology, risk factors and importance of early intervention. Bmh medical journal-issn 2348–392x, 4(1), pp. 31-37. Available at: https://www.babymhospital.org/BMH_MJ/index.php/BMHMJ/article/view/120 [Accessed 8 November 2024].

[46] Karyotaki, M., Bakola, L., Drigas, A., Skianis, C., 2022. Women's Leadership via Digital Technology and Entrepreneurship in business and society, Technium Social Sciences Journal. 28(1), pp. 246–252. https://doi.org/10.47577/tssj.v28i1.5907

[47] Khan, R. U., Cheng, J. L. A., & Bee, O. Y., 2018. Machine learning and Dyslexia: Diagnostic and classification system (DCS) for kids with learning disabilities. International Journal of Engineering & Technology, 7(3.18), pp. 97-100. Available at: https://d1wqtxts1xzle7.cloudfront.net/59232703/2.1_MachineLearningandDyslexia-DiagnosticandClassificationSystemDCSforKidswithLearningDisabilities20190513-3123-13dhfvq.pdf?1557739883=&response-content-disposition=inline%3B+filename%3DMachine_Learning_and_Dyslexia_Diagnostic.pdf&Expires=1731491301&Signature=MypkKrziFHJiuwSRdGTs2HUy6oJFPC0vWlg9SVUsFh3SxrBLgvcocS0ikEwlQEeurSvwLTFxhRJs3wQk-ZOEqCgFGKtAYbHoCz1oMsi7LUT4M5UfofloZhvFPo6Tr85CrHfCMPRgdSFmo8RYGSDywwoIa8HmLyovCGX~7PcDq8Z1ybnyle7-ok1pTFNJ~VPQcciWAeo-Uh5q~2kfSX6CEs9WsCayvft04mJMpi9LXBeHU4GCMDBUmeZ5q9tEgnn2maYRz8EftBz~3BDsGOyab8LicbUg5dhKG4ikDGPTL0ujqNeeEMjLmclFWcWsZvrw3xeVzbYoNkhJ2xV926kMLA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA [Accessed 13 November 2024].

[48] Kharbat, F. F., Alshawabkeh, A., & Woolsey, M. L., 2021. Identifying gaps in using artificial intelligence to support students with intellectual disabilities from education and health perspectives. Aslib Journal of Information Management, 73(1), pp. 101-128. https://doi.org/10.1108/AJIM-02-2020-0054

[49] Kontostavlou, E. Z., & Drigas, A., 2021. How Metacognition Supports Giftedness in Leadership: A Review of Contemporary Literature. , International Journal of Advanced Corporate Learning (iJAC), 14(2), pp. 4–16. https://doi.org/10.3991/ijac.v14i2.23237

[50] Koutromanos, G., Mavromatidou, E., Tripoulas, C., & Georgiadis, G., 2020, December. Exploring the educational affordances of augmented reality for pupils with moderate learning difficulties. In Proceedings of the 9th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, pp. 203-207. https://doi.org/10.1145/3439231.3439250

[51] Kulkarni, M., Kalantre, S., Upadhye, S., Karande, S., & Ahuja, S., 2001. Approach to learning disability. The Indian Journal of Pediatrics, 68, pp. 539-546. https://doi.org/10.1007/BF02723250

[52] Layes, S., Lazar, K., & Mecheri, S., 2024. Do learning disabilities in reading, spelling and numeracy have common underlying factors? Evidence from Arabic-speaking children sample. Applied Neuropsychology: Child, 13(2), pp. 113-125. https://doi.org/10.1080/21622965.2022.2137024

[53] Loukeri, P.I., Stathopoulou, A., Driga, A.M, 2023. Special Education Teachers' Gifted Guidance and the role of Digital Technologies, TECH HUB 6(1), pp. 16-27. Available at: https://techhubresearch.com/index.php/journal/article/view/95 [Accessed 13 November 2024].

[54] Luckin, R., & Holmes, W., 2016. Intelligence unleashed: An argument for AI in education. Available at: https://discovery.ucl.ac.uk/id/eprint/1475756/ [Accessed 13 November 2024].

[55] Lytra, N., Drigas, A., 2021. STEAM education-metacognition–Specific Learning Disabilities , Scientific Electronic Archives journal 14(10). https://doi.org/10.36560/141020211442

[56] Mitsea E., Drigas, A., Skianis, C., 2022b. Metacognition in Autism Spectrum Disorder: Digital Technologies in Metacognitive Skills Training , Technium Social Sciences Journal, pp. 153-173. Available at: https://heinonline.org/HOL/Page?handle=hein.journals/techssj31&div=11&g_sent=1&casa_token=&collection=journals [Accessed 13 November 2024].

[57] Mitsea, E., Drigas, A., Skianis, C., 2022a. Breathing, Attention & Consciousness in Sync: The role of Breathing Training, Metacognition & Virtual Reality , Technium Social Sciences Journal 29, pp. 79-97. https://doi.org/10.47577/tssj.v29i1.6145

[58] Mohammad Abedrabbu Alkhawaldeh, M. A. S. K., 2023. Harnessing The Power of Artificial Intelligence for Personalized Assistive Technology in Learning Disabilities. Journal of Southwest Jiaotong University, 58(4). https://doi.org/10.35741/issn.0258-2724.58.4.60

[59] Mor, N. S., & Dardeck, K., 2021. Applying a Convolutional Neural Network to Screen for Specific Learning Disorder. Learning Disabilities: A Contemporary Journal, 19(2), pp. 161-169. Available at: https://files.eric.ed.gov/fulltext/EJ1314763.pdf [Accessed 13 November 2014].

[60] Morciano, G., Llergo, J. M. A., Zingoni, A., Bolívar, E. Y., Taborri, J., & Calabrò, G., 2024. Use of recommendation models to provide support to dyslexic students. Expert Systems with Applications, 249, 123738. https://doi.org/10.1016/j.eswa.2024.123738

[61] Nanni, L., & Lumini, A., 2009. Ensemble generation and feature selection for the identification of students with learning disabilities. Expert Systems with Applications, 36(2), pp. 3896-3900. https://doi.org/10.1016/j.eswa.2008.02.065

[62] Ouherrou, N., Elhammoumi, O., Benmarrakchi, F., & El Kafi, J., 2019. Comparative study on emotions analysis from facial expressions in children with and without learning disabilities in virtual learning environment. Education and Information Technologies, 24(2), pp. 1777-1792. https://doi.org/10.1007/s10639-018-09852-5

[63] Pannu, A., 2015. Artificial intelligence and its application in different areas. Artificial Intelligence, 4(10), pp. 79-84. Available at: https://d1wqtxts1xzle7.cloudfront.net/47569713/IJEIT1412201504_15-libre.pdf?1469644203=&response-content-disposition=inline%3B+filename%3DArtificial_Intelligence_and_its_Applicat.pdf&Expires=1731495035&Signature=Mzw7OBzSaj~QgKZH1V88r8d9XfyqFP43hxehArDZqrubmMp8s1wmeHQAtMx8dpUW3rSU6nQL8eyNiLmzpsxpj2aQCS-2sXWoMO93E2LHw~UqMs8QV-f0pE07CzoA9gskvmOJkaW6MM5Fev1w20WmlblH4CyjEMz~i~NwH58nHJGNw6goYdssmNOQd~gRWGSO-xpcYbQmONinRrmpi5PLSsrDgBBDxPnOsrGkIFwgwqrKSGEYznX6b8jG7sFwN-CuGuFdCB4GiVywwj18oUMqUtDNKx~EdkXw23kOPfhRKIXZpEui789FnJCJRYS-PB9pTCYUz5fgOhaqwTDIMigFfg__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA [Accessed 13 November 2024].

[64] Papadopoulou, M. T., Karageorgiou, E., Kechayas, P., Geronikola, N., Lytridis, C., Bazinas, C., ... & Evangeliou, A. E., 2022. Efficacy of a robot-assisted intervention in improving learning performance of elementary school children with specific learning disorders. Children, 9(8), 1155. https://doi.org/10.3390/children9081155

[65] Pedro, F., Subosa, M., Rivas, A., & Valverde, P., 2019. Artificial intelligence in education: Challenges and opportunities for sustainable development. Available at: https://hdl.handle.net/20.500.12799/6533 [Accessed 13 November 2024].

[66] Pergantis, P., & Drigas, A., 2024. The effect of drones in the educational Process: A systematic review. Education Sciences, 14(6), 665. https://doi.org/10.3390/educsci14060665

[67] Politi-Georgousi, S., Drigas, A., 2020. Mobile Applications, an Emerging Powerful Tool for Dyslexia Screening and Intervention: A Systematic Literature Review , International Association of Online Engineering. Available at: https://www.learntechlib.org/p/218339 [Accesed 13 November 2024].

[68] Poornappriya, T. S., & Gopinath, R., 2020. Application of machine learning techniques for improving learning disabilities. International Journal of Electrical Engineering and Technology (IJEET), 11(10), pp. 392-402. http://dx.doi.org/10.34218/IJEET.11.10.2020.051

[69] Rai, H. L., Saluja, N., & Pimplapure, A., 2023. AI and Learning Disabilities: Ethical and Social Considerations in Educational Technology. Educational Administration: Theory and Practice, 29(4), pp. 726-733. https://doi.org/10.53555/kuey.v29i4.5693

[70] Rao, P. S., Pandey, M. K., Mishra, P., Deshmukh, S., Jahan, M., & Manohar J, S., 2024. Is training working memory in children with learning disabilities a viable solution? A systematic review. Annals of Neurosciences, 31(2), pp. 124-131. https://doi.org/10.1177/09727531231198639

[71] Ravichandran, K., Virgin, B. A., Tiwari, A., Javheri, S. B., Fatma, G., & Lourens, M., 2023, December. Predictive Analysis in Education: Using Artificial Intelligence Models to Identify Learning Difficulties Early. In 2023 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), 10, pp. 1754-1758. IEEE. https://doi.org/10.1109/UPCON59197.2023.10434783

[72] Rico-Olarte, C., López, D. M., Becker, L., & Eskofier, B., 2020. Towards classifying cognitive performance by sensing electrodermal activity in children with specific learning disorders. IEEE Access, 8, pp. 196187-196196. https://doi.org/10.1109/ACCESS.2020.3033769

[73] Shaywitz, S. E., & Shaywitz, B. A., 2003. Dyslexia (specific reading disability). Pediatrics in review, 24(5), pp. 147-153. https://doi.org/10.1542/pir.24-5-147

[74] Shaywitz, S. E., & Shaywitz, B. A., 2005. Dyslexia (specific reading disability). Biological psychiatry, 57(11), pp. 1301-1309. https://doi.org/10.1016/j.biopsych.2005.01.043

[75] Sohrabi, C., Franchi, T., Mathew, G., Kerwan, A., Nicola, M., Griffin, M., ... & Agha, R., 2021. PRISMA 2020 statement: what's new and the importance of reporting guidelines. International Journal of Surgery, 88, 105918. https://doi.org/10.1016/j.ijsu.2021.105918

[76] Stathopoulou, A., Karabatzaki, Z., Tsiros, D., Katsantoni, S., Drigas A., 2019. Mobile apps the educational solution for autistic students in secondary education , Journal of Interactive Mobile Technologies (IJIM) 13(2), pp. 89-101. https://doi.org/10.3991/ijim.v13i02.9896

[77] Stathopoulou. A., Spinou, D., Driga, A.M., 2023a. Burnout Prevalence in Special Education Teachers, and the Positive Role of ICTs, iJOE 19(08), pp. 19-37.

[78] Stathopoulou, A., Spinou, D., Driga, A.M., 2023b. Working with Students with Special Educational Needs and Predictors of Burnout. The Role of ICTs. iJOE 19(7), pp. 39-51.

[79] Stathopoulou, A., Temekinidou, M., Driga, A.M., Dimitriou, E., 2022. Linguistic performance of Students with Autism Spectrum Disorders, and the role of Digital Technologies , Eximia 5(1), pp. 688-701. Available at: https://www.eximiajournal.com/index.php/eximia/article/view/199 [Accessed 13 November 2024].

[80] Sukiman, S., & Abdl Aziz, N., 2021. ARTIFICIAL INTELLIGENCE AS THE KEY PLAYER IN LEARNING INTERVENTIONS: A MINI REVIEW AMONG STUDENTS WITH LEARNING DIFFICULTIES. International Journal Of Technology Management And Information System, 3(2), pp. 1-14. Available at: https://myjms.mohe.gov.my/index.php/ijtmis/article/view/16450 [Accessed 8 November 2024].

[81] Tiwari, T., & Bawa, D. S., 2023, December. Predictive Analysis in Education: Using Machine Learning Models to Identify Learning Difficulties. In 2023 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), 10, pp. 1678-1682. IEEE. https://doi.org/10.1109/UPCON59197.2023.10434522

[82] Trewin, S., Basson, S., Muller, M., Branham, S., Treviranus, J., Gruen, D., ... & Manser, E., 2019. Considerations for AI fairness for people with disabilities. AI Matters, 5(3), pp. 40-63. https://doi.org/10.1145/3362077.3362086

[83] Turan, Z., & Atila, G., 2021. Augmented reality technology in science education for students with specific learning difficulties: Its effect on students' learning and views. Research in Science & Technological Education, 39(4), pp. 506-524. https://doi.org/10.1080/02635143.2021.1901682

[84] United Nations, Department of Economic and Social Affairs, 2020. Sustainable Development Goal 4: Quality Education. Available at: https://sdgs.un.org/goals/goal4 [Accessed 7 November 2024].

[85] Vidyadharan, V., & Tharayil, H. M., 2019. Learning disorder or learning disability: Time to rethink. Indian Journal of Psychological Medicine, 41(3), pp. 276-278. https://doi.org/10.4103/IJPSYM.IJPSYM_371_18

[86] Vouglanis, T., Driga, A.M., 2023a. Factors affecting the education of gifted children and the role of digital technologies. TechHub Journal 6, pp. 28-39. Available at: https://www.techhubresearch.com/index.php/journal/article/view/96 [Accessed 13 November 2024].

[87] Vouglanis, T., Driga, A.M., 2023b. The use of ICT for the early detection of dyslexia in education, TechHub Journal 5, pp. 54-67. Available at: https://www.techhubresearch.com/index.php/journal/article/view/91 [Accessed 13 November 2024].

[88] Wang, M., Muthu, B., & Sivaparthipan, C. B., 2022. Smart assistance to dyslexia students using artificial intelligence based augmentative alternative communication. International Journal of Speech Technology, 25(2), pp. 343-353. https://doi.org/10.1007/s10772-021-09921-0

[89] Wu, T. K., Huang, S. C., Meng, Y. R., Liang, W. Y., & Lin, Y. C., 2011. Rough sets as a knowledge discovery and classification tool for the diagnosis of students with learning disabilities. International Journal of Computational Intelligence Systems, 4(1), pp. 29-43. https://doi.org/10.1080/18756891.2011.9727761

[90] Wu, TK., Huang, SC., Meng, YR., 2006b. Effects of Feature Selection on the Identification of Students with Learning Disabilities Using ANN. In: Jiao, L., Wang, L., Gao, Xb., Liu, J., Wu, F. (eds) Advances in Natural Computation. ICNC 2006. Lecture Notes in Computer Science, 4221. Springer, Berlin, Heidelberg. https://doi.org/10.1007/11881070_77

[91] Yeguas-Bolívar, E., Alcalde-Llergo, J. M., Aparicio-Martínez, P., Taborri, J., Zingoni, A., & Pinzi, S., 2022, October. Determining the difficulties of students with dyslexia via virtual reality and artificial intelligence: An exploratory analysis. In 2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE), pp. 585-590. IEEE. https://doi.org/10.1109/MetroXRAINE54828.2022.9967589

[92] Yenduri, G., Kaluri, R., Rajput, D. S., Lakshmanna, K., Gadekallu, T. R., Mahmud, M., & Brown, D. J., 2023. From Assistive Technologies to Metaverse–Technologies in Inclusive Higher Education for Students with Specific

Learning Difficulties: A Review. IEEE Access, 11, pp. 64907-64927. Available at: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10163808 [Accessed 13 November 2024].

[93] Youssef, B. E., & Youssef, A. E., 2019, October. Mathematical modeling combined with machine learning for social networks to match children with learning disabilities and specialists. In 2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), pp. 0001-0004. IEEE. https://doi.org/10.1109/IEMCON.2019.8936233

[94] Zhai, X., & Panjwani-Charania, S., 2023. AI for Students with Learning Disabilities: A Systematic Review. Available at: https://ssrn.com/abstract=4617715 [Accessed 13 November 2024].

[95] Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., ... & Li, Y., 2021. A Review of Artificial Intelligence (AI) in Education from 2010 to 2020. Complexity, 2021(1), 8812542. https://doi.org/10.1155/2021/8812542

[96] Zheng, L., Niu, J., Zhong, L., & Gyasi, J. F., 2023. The effectiveness of artificial intelligence on learning achievement and learning perception: A meta-analysis. Interactive Learning Environments, 31(9), pp. 5650-5664. https://doi.org/10.1080/10494820.2021.2015693

[97] Zingoni, A., Taborri, J., & Calabrò, G., 2024. A machine learning-based classification model to support university students with dyslexia with personalized tools and strategies. Scientific Reports, 14(1), 273. https://doi.org/10.1038/s41598-023-50879-7

[98] Zingoni, A., Taborri, J., Panetti, V., Bonechi, S., Aparicio-Martínez, P., Pinzi, S., & Calabrò, G., 2021. Investigating issues and needs of dyslexic students at university: Proof of concept of an artificial intelligence and virtual reality-based supporting platform and preliminary results. Applied Sciences, 11(10), 4624. https://doi.org/10.3390/app11104624