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Abstract

Dyscalculia, a specific learning disability affecting numerical cognition and mathematical reasoning, presents substantial challenges for primary school students. This qualitative synthesis critically examines contemporary research on its causes, impacts, and interventions while providing a novel, interdisciplinary perspective. The study uniquely integrates cognitive, neurological, socio-emotional, and educational dimensions, offering a comprehensive framework for understanding dyscalculia. It highlights cognitive and neurological deficits, including impaired number sense, working memory limitations, and atypical brain activation patterns. Genetic predispositions and environmental factors, such as ineffective teaching methods and socio-economic disparities, further exacerbate these difficulties. Beyond academic struggles, dyscalculia significantly impacts emotional well-being, contributing to math anxiety, low self-esteem, and social difficulties, which can persist into adulthood. The study also advances the field by synthesizing evidence-based interventions, including structured teaching approaches, multisensory learning, digital tools, gamification, and cognitive training. It underscores the critical roles of teacher training, parental involvement, and inclusive educational policies, such as individualized education plans (IEP) and special accommodations, in ensuring equitable access to support. Additionally, this research identifies key gaps, including the need for standardized diagnostic criteria, cross-cultural perspectives, and integration of emerging technologies. A distinctive contribution of this study is its emphasis on interdisciplinary collaboration among educators, psychologists, and policymakers to develop holistic, evidence-based strategies. Future research directions include longitudinal studies assessing intervention efficacy and the exploration of artificial intelligence and neuroplasticity-based training for dyscalculia support. The findings provide actionable insights to enhance early identification, intervention, and policy implementation.

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Review Article

Reasons and Remedies of Dyscalculia in Primary School: A Qualitative Synthesis of Contemporary Research Literature *

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Abstract

Dyscalculia, a specific learning disability affecting numerical cognition and mathematical reasoning, presents substantial challenges for primary school students. This qualitative synthesis critically examines contemporary research on its causes, impacts, and interventions while providing a novel, interdisciplinary perspective. The study uniquely integrates cognitive, neurological, socio-emotional, and educational dimensions, offering a comprehensive framework for understanding dyscalculia. It highlights cognitive and neurological deficits, including impaired number sense, working memory limitations, and atypical brain activation patterns. Genetic predispositions and environmental factors, such as ineffective teaching methods and socio-economic disparities, further exacerbate these difficulties. Beyond academic struggles, dyscalculia significantly impacts emotional well-being, contributing to math anxiety, low self-esteem, and social difficulties, which can persist into adulthood. The study also advances the field by synthesizing evidence-based interventions, including structured teaching approaches, multisensory learning, digital tools, gamification, and cognitive training. It underscores the critical roles of teacher training, parental involvement, and inclusive educational policies, such as individualized education plans (IEP) and special accommodations, in ensuring equitable access to support. Additionally, this research identifies key gaps, including the need for standardized diagnostic criteria, cross-cultural perspectives, and integration of emerging technologies. A distinctive contribution of this study is its emphasis on interdisciplinary collaboration among educators, psychologists, and policymakers to develop holistic, evidence-based strategies. Future research directions include longitudinal studies assessing intervention efficacy and the exploration of artificial intelligence and neuroplasticity-based training for dyscalculia support. The findings provide actionable insights to enhance early identification, intervention, and policy implementation.

Keywords: Dyscalculia, primary education, learning disabilities, mathematical difficulties, cognitive deficits, ınterventions, educational policies, numerical cognition

1. INTRODUCTION

1.1. Definition and Significance of Dyscalculia in Primary Education

Dyscalculia is defined as a specific learning disability that affects an individual's ability to understand numbers and perform mathematical tasks. It is characterized by persistent difficulties in learning arithmetic, number sense, and mathematical reasoning, which can significantly hinder academic performance and self-esteem in primary school students (Mahmud et al., 2020; Salisa & Meiliasari, 2023). The significance of dyscalculia in primary education lies in its prevalence, affecting

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approximately 5-7% of school-aged children, and its potential to impact not only academic achievement but also emotional and social development (Yoong et al., 2022). Early identification and intervention are crucial, as children with dyscalculia often face challenges that can lead to long-term academic difficulties and reduced opportunities in higher education and employment (Kahenya et al., 2022; May et al., 2021).

1.2. The Importance of Early Diagnosis and Intervention

Early diagnosis of dyscalculia is vital for effective intervention. Research indicates that children who receive timely support are more likely to develop essential mathematical skills and achieve better academic outcomes compared to those diagnosed later (Butterworth et al., 2011). Early intervention strategies can include tailored educational approaches, specialized teaching methods, and the use of assistive technologies, which can help mitigate the effects of dyscalculia (Price & Ansari, 2013). Furthermore, early identification allows educators and parents to implement supportive measures that address not only academic challenges but also emotional and psychological aspects, such as anxiety and low self-esteem, which are commonly associated with learning disabilities (Mokotjo, 2024).

1.3. Purpose and Scope of the Qualitative Literature Review

The purpose of this qualitative literature review is to synthesize contemporary research on dyscalculia, focusing on its causes, impacts, and effective interventions in primary education. By examining various studies, this review aims to provide a comprehensive understanding of dyscalculia, its implications for students, and the effectiveness of different intervention strategies (Pettigrew et al., 2015). The scope includes an analysis of cognitive, neurological, and environmental factors contributing to dyscalculia, as well as the emotional and psychological effects on affected students. Additionally, the review will explore educational practices and policies that can enhance support for students with dyscalculia (Yoong et al., 2024).

1.4. Research Questions Guiding the Review

The review is guided by several key research questions aimed at exploring the multifaceted nature of dyscalculia in primary education. These questions include:

1. What are the primary cognitive and neurological factors contributing to dyscalculia in primary school students?
2. How does dyscalculia impact the emotional and psychological well-being of affected students?
3. What evidence-based interventions and support strategies are most effective in addressing the needs of students with dyscalculia?
4. How can educational policies and practices be improved to better support students with dyscalculia in primary education settings?

1.5. THEORETICAL FRAMEWORK

1.5.1. Cognitive and neurological perspectives on dyscalculia

Cognitive and neurological perspectives on dyscalculia emphasize the underlying cognitive processes and brain mechanisms that contribute to mathematical learning difficulties. Dyscalculia is often associated with deficits in numerical processing, which can manifest as difficulties in understanding numerical magnitudes, performing arithmetic operations, and recalling mathematical facts (Dowker, 2020; Vintere, 2021). Research indicates that children with dyscalculia may exhibit atypical brain activation patterns, particularly in regions associated with numerical cognition, such as the intraparietal sulcus (Bağlama et al., 2020; Decarli et al., 2023). These neurological differences can hinder the development of essential mathematical skills, leading to significant academic challenges.

Additionally, cognitive theories suggest that dyscalculia may be linked to broader cognitive deficits, including difficulties in working memory, attention, and executive functioning (Yoong & Hoe, 2022). For instance, children with dyscalculia often struggle with tasks that require the manipulation of numerical information in working memory, which is critical for solving mathematical problems (Maurer et al., 2021). This cognitive perspective highlights the importance of understanding the interplay between cognitive processes and mathematical learning, as interventions targeting these cognitive deficits may improve mathematical outcomes for students with dyscalculia (Vintere, 2021).

1.5.2. Developmental theories related to mathematical learning difficulties

Developmental theories provide insight into how children acquire mathematical skills and the factors that contribute to learning difficulties such as dyscalculia. These theories emphasize the role of early mathematical experiences and the gradual progression of mathematical understanding from concrete to abstract concepts (Ennemoser et al., 2024; Pedemonte et al., 2022). For example, the developmental model of quantity-to-number word linkage posits that children must first develop an understanding of quantities before they can effectively associate these quantities with numerical symbols (Ennemoser et al., 2024). This progression is crucial for building a solid foundation in mathematics.

Moreover, developmental theories highlight the significance of environmental influences, such as parental involvement and educational practices, in shaping children's mathematical abilities (Käser et al., 2013; Rukli & Ma'rup, 2022). Research has shown that children who receive supportive mathematical experiences at home and in school are more likely to develop strong mathematical skills, while those who encounter barriers may be at risk for developing dyscalculia (Käser et al., 2013). Understanding these developmental trajectories is essential for designing effective interventions that can support children at various stages of mathematical learning.

1.5.3. Sociocultural influences on numerical cognition

Sociocultural influences play a critical role in shaping children's numerical cognition and their experiences with mathematics. Cultural attitudes towards mathematics, societal expectations, and educational practices can significantly impact how children perceive and engage with mathematical concepts (Filiz & Güneş, 2022; Pappas et al., 2018). For instance, in cultures that emphasize the importance of mathematics, children may be more motivated to learn and succeed in this subject, while those in cultures with less emphasis on mathematics may struggle to develop the same level of proficiency (Decarli et al., 2023).

Additionally, the sociocultural context can affect the resources available to children, including access to quality educational materials and support systems (Chan et al., 2013; Zerafa, 2015). Children from lower socioeconomic backgrounds may face additional challenges in developing mathematical skills due to limited access to educational resources and support (Chan et al., 2013). Understanding these sociocultural factors is essential for creating inclusive educational environments that promote mathematical learning for all students, particularly those at risk for dyscalculia.

1.5.4. Comparison with other learning disabilities (e.g., dyslexia, ADHD)

Dyscalculia often co-occurs with other learning disabilities, such as dyslexia and Attention Deficit Hyperactivity Disorder (ADHD), complicating diagnosis and intervention strategies (Mammarella et al., 2021). While dyslexia primarily affects reading and language processing, dyscalculia specifically impacts mathematical abilities. However, both conditions share common cognitive deficits, such as difficulties in working memory and processing speed, which can exacerbate learning challenges (Moscardini, 2015).

Furthermore, ADHD can influence a child's ability to focus and sustain attention during mathematical tasks, leading to difficulties in learning and performance (Lo, 2023). Research indicates that students with co-occurring dyscalculia and ADHD may experience more significant academic challenges compared to those with dyscalculia alone, highlighting the need for comprehensive assessment and tailored interventions (Brankaer et al., 2014). Understanding the interplay between these learning disabilities is crucial for developing effective support strategies that address the unique needs of each student.

2. METHODOLOGY

This study adopts a systematic and rigorous methodological approach to reviewing contemporary research on dyscalculia in primary school students. By synthesizing findings from multiple disciplines, this methodology ensures a comprehensive understanding of the disorder's causes, impacts, and effective interventions, contributing to evidence-based educational practices and policy recommendations.

2.1. Research Design

This study employs a qualitative research design, specifically a systematic literature review, to analyze contemporary research on dyscalculia in primary school students. A systematic literature review is appropriate for synthesizing findings across multiple studies, providing a comprehensive understanding of the causes, consequences, and interventions related to dyscalculia (Findley et al., 2023). The study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a rigorous and transparent selection and synthesis of relevant literature.

2.2. Data Collection

The data for this study were collected from peer-reviewed journal articles, books, and authoritative reports published between 2010 and 2024. The sources were identified through searches in major academic databases, including Google Scholar, PubMed, ERIC, PsycINFO, and Scopus. The following keywords and Boolean operators were used to refine the search: "dyscalculia AND primary school", "mathematical learning disability AND intervention", "dyscalculia AND neuroscience", "math anxiety AND dyscalculia", and "educational strategies AND dyscalculia." Additionally, reference lists of relevant articles were reviewed to identify further studies for inclusion.

2.3. Inclusion and Exclusion Criteria

To ensure the relevance and quality of the selected literature, the following inclusion and exclusion criteria were applied:

2.3.1. Inclusion criteria:

- Peer-reviewed empirical and theoretical studies published between 2010 and 2024
- Studies focusing on primary school students (ages 6-12) diagnosed with dyscalculia
- Research discussing neurological, cognitive, educational, and socio-emotional aspects of dyscalculia
- Studies proposing intervention strategies, including instructional techniques, technological tools, and policy recommendations

2.3.2. Exclusion criteria:

- Studies focusing exclusively on dyscalculia in adolescents or adults
- Research lacking empirical data or systematic theoretical analysis
- Studies published in non-English languages without accessible translations
- Studies on general mathematics difficulties that do not specifically address dyscalculia

2.4. Data Selection Process

A total of 889 records were identified through database searches and other sources. After removing 77 duplicates, 812 records were screened based on titles and abstracts. Of these, 691 were excluded for reasons such as lack of focus on dyscalculia (n = 243), inappropriate population (e.g., adolescents or adults; n = 168), absence of empirical or theoretical grounding (n = 112), language barriers (n = 64), poor methodological quality (n = 58), and topic irrelevance despite keyword matches (n = 46). The remaining 121 full-text articles were assessed for eligibility, resulting in the exclusion of 48 studies due to misalignment with inclusion criteria (n = 21), inappropriate target group (n = 12), insufficient focus on dyscalculia (n = 9), methodological shortcomings (n = 4), or inaccessibility (n = 2). Ultimately, 73 studies were included in the final qualitative synthesis, selected for their empirical rigor, relevance to dyscalculia in primary education, and contributions to understanding its causes, impacts, and interventions. This process is summarized in the PRISMA Flow Diagram in Figure

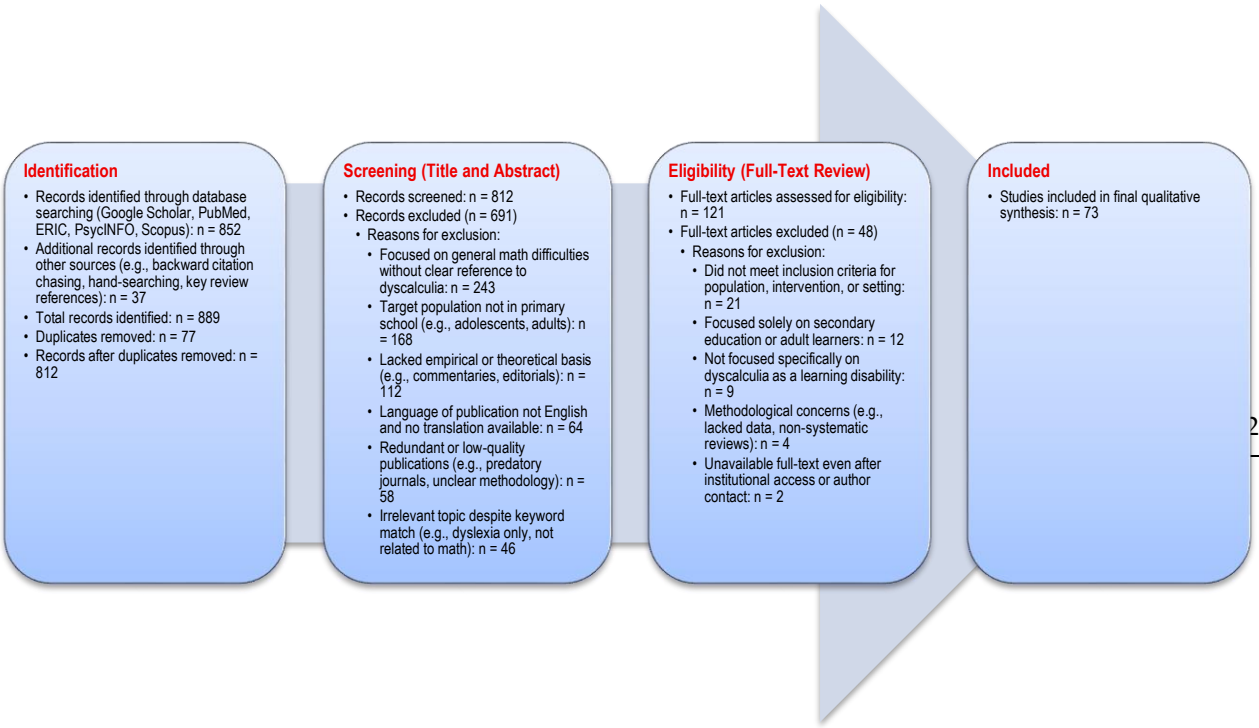

Figure 1. PRISMA flow diagram detailing the data selection process.

2.5. Data Analysis and Synthesis

The collected data were analyzed using thematic synthesis, which involves coding and categorizing findings into overarching themes. This process included:

1. *Familiarization with the Data:* Repeated reading of the selected studies to identify key insights related to dyscalculia.
2. *Coding:* Assigning descriptive codes to relevant information related to causes, interventions, emotional and psychological impact, and policy implications.
3. *Theme Identification:* Grouping similar codes into broader themes, such as neurological factors, instructional strategies, technological interventions, and cross-cultural perspectives.
4. *Synthesis and Interpretation:* Integrating the themes into a coherent narrative that addresses the study's research questions.

2.6. Ethical Considerations

Since this study is a literature review and does not involve human participants, ethical approval was not required. However, ethical research practices were maintained by accurately citing all sources and ensuring the integrity of the synthesized findings.

3. FINDINGS

Table 1 and Figure 2 summarize the research on dyscalculia into key themes, subthemes, and specific codes, providing a structured analysis of the causes, broader perspectives, co-occurrence with other learning disabilities, and intervention strategies. Each code is supported by multiple citations, with the total number of citations serving as a measure of research attention given to specific aspects of dyscalculia.

3.1. Derivation of the Themes

The themes were derived through a systematic thematic synthesis procedure following Thomas and Harden's (2008) framework. Initially, each included study was read in full and subjected to line-by-line coding to identify recurring patterns and salient concepts related to dyscalculia. These codes were then grouped into descriptive categories, which reflected the core aspects of the literature, including causes, broader impacts, and intervention strategies. An iterative process was employed to refine these categories into higher-order analytical themes through constant comparison and cross-validation across studies. To ensure conceptual clarity and theoretical saturation, the emerging themes were repeatedly tested against the dataset and reviewed by multiple coders for consistency. This process led to the formation of three overarching themes—"Causes of Dyscalculia," "Broader Perspectives on Dyscalculia," and "Evidence-Based Interventions and Support Strategies"—each supported by subthemes and codes anchored in the original studies. The 73 included articles thus formed the empirical foundation for constructing a comprehensive thematic framework that addresses the multifaceted nature of dyscalculia in primary education.

3.2. Detailed Summary and Interpretation of the Table on Dyscalculia

3.2.1. Causes of dyscalculia

The table outlines four major contributors to dyscalculia: prevalence and identification, neurological factors, genetic and biological influences, cognitive deficits and processing, and environmental/educational factors.

- *Prevalence and Identification (Total Citations: 9):* Research has addressed key aspects such as statistical insights (2 citations), common signs (2 citations), diagnostic criteria (3 citations), and challenges in diagnosing (2 citations). The number of citations indicates significant attention to identifying dyscalculia, particularly in defining diagnostic criteria.
- *Neurological Factors (Total Citations: 4):* Studies have explored how brain structure (2 citations) and working memory & attention (2 citations) affect dyscalculia. Despite being a crucial area, neurological factors receive less citation volume compared to other causes.
- *Genetic and Biological Influences (Total Citations: 4):* Research into hereditary aspects (2 citations) and neurodevelopmental disorders (2 citations) suggests that dyscalculia has biological underpinnings, though the citation count is relatively low compared to cognitive or educational factors.
- *Cognitive Deficits and Processing (Total Citations: 4):* Two major areas are number sense (2 citations) and visual-spatial deficits (2 citations), indicating that mathematical cognition and spatial reasoning are central to dyscalculia.

- *Environmental and Educational Factors (Total Citations: 4):* Teaching methods (2 citations) and socioeconomic/cultural aspects (2 citations) are discussed as external contributors. The equal number of citations in both suggests a balanced emphasis on pedagogical and socioeconomic perspectives.
- *Neuroscientific Advances (Total Citations: 6):* Neuroimaging insights (2 citations), neuroplasticity (2 citations), and brain-based interventions (2 citations) highlight a growing focus on neuroscience-driven solutions.

The most studied aspect in this category is the identification of dyscalculia (9 citations), followed by neuroscientific advances (6 citations), suggesting that more research focuses on recognizing dyscalculia than exploring its biological and cognitive roots.

3.2.2. Broader perspectives on dyscalculia

This section examines the psychosocial impact, longitudinal perspective, cross-cultural perspectives, and co-occurrence with other learning disabilities.

- *Emotional and Psychological Impact (Total Citations: 12):* Math anxiety (3 citations), self-esteem/motivation (3 citations), social challenges (3 citations), and confidence/anxiety reduction (3 citations) all receive equal research attention. The high number of citations indicates that emotional and psychological consequences are as significant as cognitive deficits.
- *Longitudinal Perspective (Total Citations: 6):* Studies address academic progress beyond primary school (2 citations), career choices (2 citations), and early vs. late diagnosis (2 citations). The equal focus across all three aspects suggests a balanced approach to understanding dyscalculia across a student's life trajectory.
- *Cross-Cultural Perspectives (Total Citations: 8):* Recognition in different countries (2 citations) and comparative interventions (2 citations) receive relatively low focus. Cultural attitudes (4 citations) have the highest citation count, indicating that societal perceptions significantly influence dyscalculia research and interventions.
- *Co-Occurrence with Other Learning Disabilities (Total Citations: 10):* Overlap with dyslexia & ADHD (4 citations) and case studies (4 citations) are the most cited topics, showing high research interest in comorbidity. Complications in diagnosis (2 citations) receive comparatively less focus.

Research on psychosocial impact (12 citations) surpasses cognitive or neurological research, suggesting that the lived experiences of individuals with dyscalculia are a major concern. The co-occurrence with dyslexia and ADHD (10 citations) is another dominant theme, underscoring the interconnectedness of learning disabilities.

3.2.3. Evidence-based interventions and support strategies

This section focuses on solutions through educational, technological, cognitive, teacher/parental involvement, and policy-level interventions.

- *Educational Strategies (Total Citations: 8):* Effective teaching methods (3 citations), multisensory learning (3 citations), and differentiated instruction (2 citations) show that adaptive teaching strategies are widely studied.
- *Technological Interventions (Total Citations: 4):* Digital tools/adaptive learning (2 citations) and gamification & AI (2 citations) highlight a growing but still limited focus on tech-based solutions.

- *Cognitive and Behavioral Interventions (Total Citations: 4):* Cognitive training (2 citations) and metacognitive strategies (2 citations) show that behavioral approaches are explored but not as extensively as other interventions.
- *Teacher and Parental Involvement (Total Citations: 5):* Teacher training (3 citations) has more focus than parental engagement (2 citations), reflecting an emphasis on professional development over home-based interventions.
- *Educational Policy and Legislative Support (Total Citations: 6):* Inclusive education policies (2 citations), special education laws (2 citations), and school-level support programs (2 citations) receive equal attention.

Among intervention strategies, educational methods (8 citations) and policy/laws (6 citations) receive the most research, while technology-based interventions (4 citations) remain relatively underexplored despite their potential for scalable solutions.

3.3. Overall Analysis

3.3.1. Key trends in research focus:

- Dyscalculia's identification (9 citations) and emotional impact (12 citations) receive the highest research attention. This suggests a strong focus on understanding the disorder's prevalence and psychological effects.
- Neuroscientific studies (6 citations) and technological interventions (4 citations) receive less attention, despite their potential for innovative solutions.
- The role of cultural attitudes (4 citations) in dyscalculia is a prominent theme, indicating a growing interest in how societal beliefs shape learning difficulties.
- Co-occurrence with dyslexia/ADHD (10 citations) is a heavily studied area, reinforcing the idea that dyscalculia is rarely an isolated condition.
- Intervention research is strongest in teaching strategies (8 citations) and policy support (6 citations), suggesting that practical classroom applications are prioritized over cutting-edge technological solutions.

3.3.2. Numerical highlights:

- *Most cited category:* Psychosocial impact (12 citations)
- *Least cited categories:* Genetic influences (4 citations) and cognitive/behavioral training (4 citations)
- *Balanced areas (6-8 citations):* Neuroscientific advances, co-occurrence with other disabilities, educational policies, and teaching strategies.

The table reveals that research on dyscalculia is comprehensive but unevenly distributed. While diagnostic criteria, psychosocial impacts, and co-occurring conditions receive extensive attention, genetic factors, cognitive training, and technological solutions remain underexplored. Future research could benefit from deeper investigations into AI-driven interventions, neuroplasticity-based therapies, and individualized cognitive training methods.

Table 1. The summary table that shows the themes, sub-themes, codes and the 73 citations supporting these.

Theme	Subtheme	Code	Citations	Number of Citations
Causes of Dyscalculia	Prevalence and Identification	Statistical Insights	Elhakeem et al. (2023); Drigas and Pappas (2015)	2
		Common Signs	Morsanyi et al. (2018); Elhakeem et al. (2023)	2

		Diagnostic Criteria	Haberstroh and Schulte-Körne (2019); Delgado et al. (2019); Gliksman et al. (2022)	3
		Challenges in Diagnosing	Williams (2013); Bergen et al. (2023)	2
	Neurological Factors	Brain Structure	Peters et al. (2018); Dresler et al. (2018)	2
		Working Memory & Attention	Dowker (2020); Morsanyi et al. (2018)	2
	Genetic and Biological Influences	Hereditary Aspects	Pettigrew et al. (2015); Malanchini and Gidziela (2022)	2
		Neurodevelopmental Disorders	Bergen et al. (2023); Morsanyi et al. (2018)	2
	Cognitive Deficits and Processing	Number Sense	Morsanyi et al. (2018); Murciano et al. (2021)	2
		Visual-Spatial Deficits	Dowker (2020); Morsanyi et al. (2018)	2
	Environmental and Educational Factors	Teaching Methods	Delgado et al. (2019); Vouglanis and Raftopoulos (2023)	2
		Socioeconomic & Cultural Aspects	Morsanyi et al. (2018); Murciano et al. (2021)	2
	Neuroscientific Advances	Neuroimaging Insights	Peters et al. (2018); Dresler et al. (2018)	2
		Neuroplasticity	Dresler et al. (2018); Gkintoni et al. (2023)	2
		Brain-Based Interventions	Dresler et al. (2018); Gkintoni et al. (2023)	2
Broader Perspectives on Dyscalculia	Emotional and Psychological Impact	Math Anxiety	Alyoubi et al. (2021); Ulfarsson et al. (2017); Khan and Lal (2023)	3
		Self-Esteem & Motivation	Ozernov-Palchik et al. (2022); Tūbele (2015); Orraca-Castillo et al. (2014)	3
		Social Challenges	Layes (2022); McCarthy et al. (2012); Ciulkinyte et al. (2025)	3
		Confidence & Anxiety Reduction	Khan and Lal (2023); Ulfarsson et al. (2017); Hussein et al. (2023)	3
	Longitudinal Perspective	Academic Progress Beyond Primary	Orraca-Castillo et al. (2014); Cheng et al. (2022)	2
		Career Choices	Khan et al. (2023); Peters et al. (2018)	2
		Early vs. Late Diagnosis	López-Resa and Moraleda-Sepúlveda (2023); Grant et al. (2020)	2
	Cross-Cultural Perspectives	Recognition in Different Countries	Pestun et al. (2019); Lopes-Silva et al. (2014)	2
		Cultural Attitudes	Pan et al. (2015); Franz et al. (2023); Singh et al. (2017); Couvignou et al. (2019)	4
		Comparative Interventions	Fajariyanti et al. (2022); Khandaker et al. (2014)	2
	Co-Occurrence with Other Learning Disabilities	Overlap with Dyslexia & ADHD	Anggrawan et al. (2023); Kunwar (2024); Ashburn et al. (2024); Unger et al. (2021)	4
		Complications in Diagnosis	Andrade-Arenas and Yactayo-Arias (2024); Ngor Achiek and Selugo (2024)	2
		Case Studies	Van Herwegen et al. (2024); Achiek (2023); Omoniyi Israel and Peter Olubunmi (2014); Calì et al. (2023)	4
Evidence-Based Interventions and Support Strategies	Educational Strategies	Effective Teaching Methods	Monei and Pedro (2017); Butterworth and Laurillard (2010); Zygouris et al. (2017)	3
		Multisensory Learning	Chodura et al. (2015); Elhakeem et al. (2023); Eghbali Ghazijahani et al. (2019)	3
		Differentiated Instruction	Ezegbe et al. (2019); López-Resa and Moraleda-Sepúlveda (2023)	2

Technological Interventions	Digital Tools & Adaptive Learning	Aquil and Ariffin (2020); Butterworth et al. (2011)	2
	Gamification & AI	Bazzaz Monsef et al. (2017); Levy et al. (2014)	2
Cognitive and Behavioral Interventions	Cognitive Training	Yoong and Hoe (2022); Tibane et al. (2024)	2
	Metacognitive Strategies	Habibi et al. (2015); Baulina and Kosonogov (2023)	2
Teacher and Parental Involvement	Teacher Training	Chin and Fu (2021); Wang'ang'a, 2023; Zerafa, 2015	3
	Parental Engagement	Miundy et al. (2019); Loenneker et al. (2021)	2
Educational Policy and Legislative Support	Inclusive Education Policies	Szücs et al. (2013); Yoong et al. (2022)	2
	Special Education Laws	Pappas et al. (2018); Li et al. (2023)	2
	School-Level Support Programs	Vasudeva et al. (2024); Pedemonte et al. (2022)	2

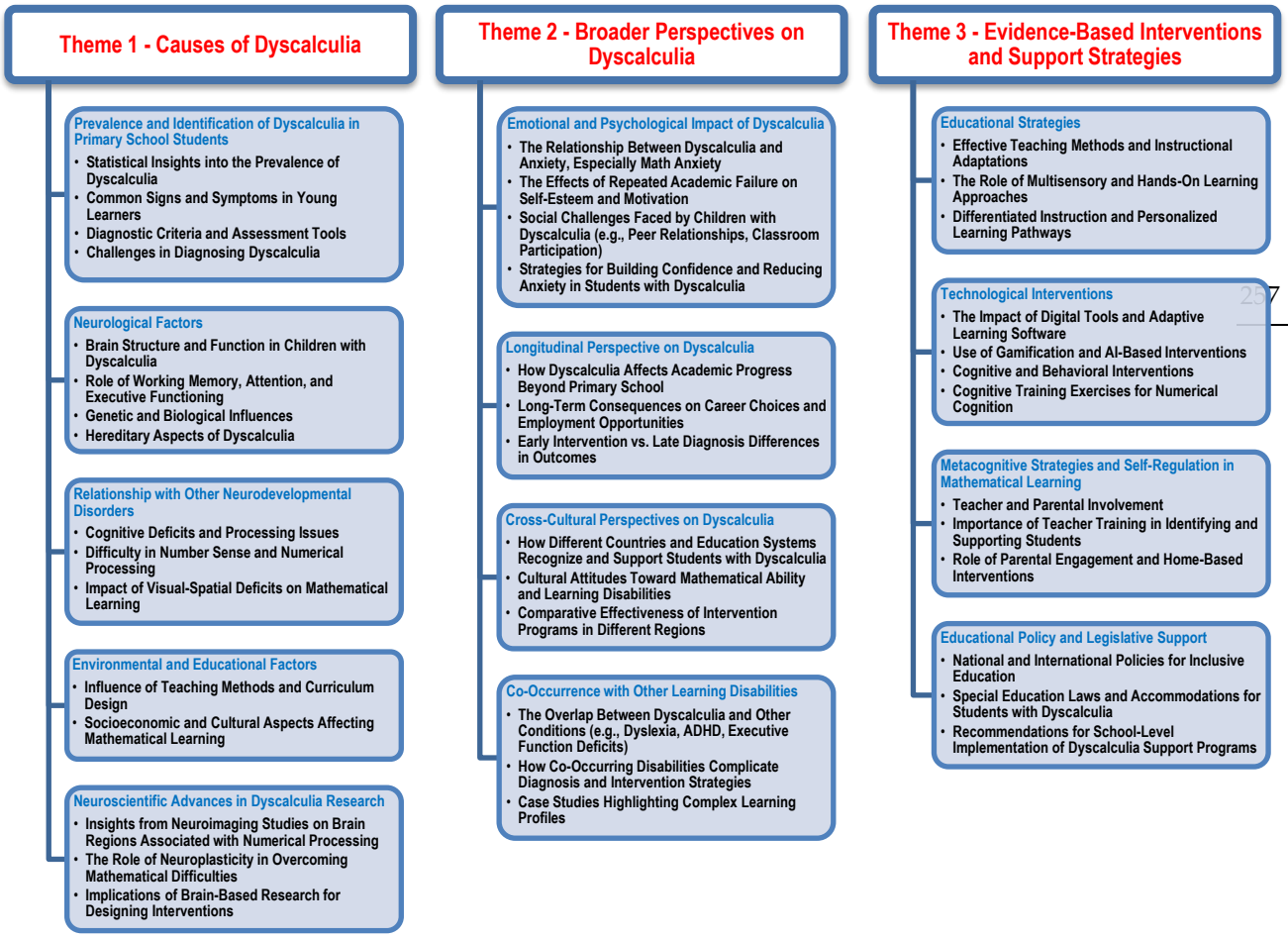

Figure 2. The pictorial representation of the themes, sub-themes and codes emerging from the qualitative synthesis.

4. RESULTS

4.1. Theme 1 - Causes of Dyscalculia

Dyscalculia is a specific learning disability that affects mathematical skills, leading to difficulties in number sense, arithmetic operations, and mathematical reasoning. It often stems from neurological differences in brain regions responsible for numerical processing and may have a genetic component. Common signs in primary school students include challenges with counting, recognizing numbers, and recalling math facts. Environmental factors, such as traditional teaching methods and limited educational support, can exacerbate these difficulties. Early diagnosis and targeted interventions that address cognitive deficits and leverage neuroplasticity are crucial for helping students overcome mathematical challenges and achieve academic success.

4.1.1. Prevalence and ıdentification of dyscalculia in primary school students

- *Statistical Insights into the Prevalence of Dyscalculia:* Dyscalculia is estimated to affect approximately 3% to 8% of the global population, with variations in prevalence reported across different studies and populations (Drigas & Pappas, 2015; Elhakeem et al., 2023). In educational settings, the prevalence may be even higher, with some estimates suggesting that up to 11% of students in higher education experience significant mathematics anxiety related to dyscalculia (Elhakeem et al., 2023). This indicates a pressing need for awareness and intervention strategies tailored to address the unique challenges faced by these students.
- *Common Signs and Symptoms in Young Learners:* Common signs of dyscalculia in young learners include difficulties with number sense, such as understanding quantities and relationships between numbers, as well as challenges in performing basic arithmetic operations (Morsanyi et al., 2018). Students may struggle with tasks that require counting, recognizing numerical symbols, and recalling math facts. Additionally, they often exhibit anxiety related to mathematics, which can further hinder their performance and willingness to engage with mathematical tasks (Elhakeem et al., 2023; Morsanyi et al., 2018).
- *Diagnostic Criteria and Assessment Tools:* The diagnostic criteria for dyscalculia typically align with those outlined in the DSM-5, which defines it as a specific learning disorder characterized by persistent difficulties in mathematical skills that are not attributable to other cognitive impairments or inadequate educational opportunities (Haberstroh & Schulte-Körne, 2019). Assessment tools used to diagnose dyscalculia include standardized tests that evaluate numerical processing, arithmetic skills, and overall mathematical reasoning (Delgado et al., 2019; Haberstroh & Schulte-Körne, 2019). Tools such as the BGU-MF (Ben-Gurion University Math Fluency test) have been developed to assess specific competencies in mathematics (Gliksman et al., 2022).
- *Challenges in Diagnosing Dyscalculia:* Despite the availability of diagnostic criteria and assessment tools, challenges remain in accurately diagnosing dyscalculia. Many educators and practitioners lack the training necessary to identify dyscalculia effectively, leading to underdiagnosis or misdiagnosis (Williams, 2013). Furthermore, the overlap of symptoms with other learning disabilities, such as dyslexia and ADHD, complicates the diagnostic process (Bergen et al., 2023). This highlights the need for improved training and resources for educators to recognize and support students with dyscalculia.

4.1.2. Neurological factors

- *Brain Structure and Function in Children with Dyscalculia:* Research has identified specific neurological differences in children with dyscalculia, particularly in brain regions associated with numerical processing, such as the intraparietal sulcus (Dresler et al., 2018; Peters et al., 2018). Neuroimaging studies have shown that children with dyscalculia exhibit atypical activation patterns in

these areas when performing mathematical tasks, suggesting a core deficit in the neural mechanisms underlying numerical cognition (Dresler et al., 2018; Peters et al., 2018).

- *Role of Working Memory, Attention, and Executive Functioning:* Working memory, attention, and executive functioning are critical cognitive processes that significantly impact mathematical learning. Children with dyscalculia often demonstrate deficits in these areas, which can hinder their ability to manipulate numerical information and solve mathematical problems (Dowker, 2020; Morsanyi et al., 2018). For instance, difficulties in working memory can lead to challenges in retaining and processing numerical information, while attention deficits may result in difficulties focusing on mathematical tasks (Dowker, 2020; Morsanyi et al., 2018).

4.1.3. Genetic and biological influences

- *Hereditary Aspects of Dyscalculia:* Genetic studies suggest that dyscalculia has a hereditary component, with familial patterns indicating a potential genetic predisposition to mathematical learning difficulties (Malanchini & Gidziela, 2022; Pettigrew et al., 2015). Twin studies have shown that dyscalculia often runs in families, supporting the notion that genetic factors contribute to the development of this learning disability (Malanchini & Gidziela, 2022; Pettigrew et al., 2015).
- *Relationship with Other Neurodevelopmental Disorders:* Dyscalculia frequently co-occurs with other neurodevelopmental disorders, such as dyslexia and ADHD, indicating shared genetic and environmental risk factors (Bergen et al., 2023; Morsanyi et al., 2018). For example, research has identified common genetic variants associated with both dyscalculia and dyslexia, suggesting that these conditions may arise from overlapping neurobiological mechanisms (Peters et al., 2018; Pettigrew et al., 2015). Understanding these relationships is crucial for developing comprehensive intervention strategies that address the needs of students with co-occurring disabilities.

4.1.4. Cognitive deficits and processing issues

- *Difficulty in Number Sense and Numerical Processing:* A hallmark feature of dyscalculia is difficulty in developing number sense, which encompasses the ability to understand and manipulate numerical quantities (Morsanyi et al., 2018; Murciano et al., 2021). Children with dyscalculia often struggle with basic numerical processing tasks, such as estimating quantities, comparing numbers, and performing arithmetic operations (Morsanyi et al., 2018; Murciano et al., 2021). These cognitive deficits can significantly impede their mathematical learning and overall academic performance.
- *Impact of Visual-Spatial Deficits on Mathematical Learning:* Visual-spatial deficits are another common issue faced by children with dyscalculia. These deficits can affect a child's ability to visualize numerical relationships and understand spatial concepts, which are essential for solving mathematical problems (Dowker, 2020; Morsanyi et al., 2018). For instance, difficulties in visualizing number lines or geometric shapes can hinder a child's ability to grasp fundamental mathematical concepts, further exacerbating their learning challenges (Morsanyi et al., 2018; Murciano et al., 2021).

4.1.5. Environmental and educational factors

- *Influence of Teaching Methods and Curriculum Design:* Teaching methods and curriculum design play a critical role in shaping mathematical learning experiences for students with dyscalculia. Research indicates that traditional teaching approaches may not adequately address the needs of these students, leading to frustration and disengagement (Delgado et al., 2019; Vouglanis & Raftopoulos, 2023). Implementing evidence-based instructional strategies, such as multisensory learning and differentiated instruction, can significantly improve outcomes for students with dyscalculia (Delgado et al., 2019; Vouglanis & Raftopoulos, 2023).
- *Socioeconomic and Cultural Aspects Affecting Mathematical Learning:* Socioeconomic factors can also influence the development of mathematical skills in children with dyscalculia.

Children from lower socioeconomic backgrounds may have limited access to educational resources and support, which can hinder their mathematical learning (Morsanyi et al., 2018; Murciano et al., 2021). Additionally, cultural attitudes towards mathematics and learning disabilities can impact how dyscalculia is perceived and addressed in educational settings (Morsanyi et al., 2018; Murciano et al., 2021).

4.1.6. Neuroscientific advances in dyscalculia research

- *Insights from Neuroimaging Studies on Brain Regions Associated with Numerical Processing:* Recent advances in neuroimaging techniques have provided valuable insights into the brain regions involved in numerical processing and dyscalculia. Studies have shown that children with dyscalculia exhibit altered activation patterns in key brain areas responsible for numerical cognition, such as the parietal cortex (Dresler et al., 2018; Peters et al., 2018). These findings underscore the importance of understanding the neurobiological underpinnings of dyscalculia to inform intervention strategies.
- *The Role of Neuroplasticity in Overcoming Mathematical Difficulties:* Neuroplasticity, the brain's ability to reorganize and form new neural connections, offers hope for children with dyscalculia. Research suggests that targeted interventions can promote neuroplastic changes in the brain, potentially improving mathematical skills and cognitive functioning (Dresler et al., 2018; Gkintoni et al., 2023). This highlights the importance of early and effective interventions that leverage the brain's capacity for change.
- *Implications of Brain-Based Research for Designing Interventions:* The insights gained from neuroscientific research have significant implications for designing interventions for students with dyscalculia. By understanding the specific cognitive and neurological deficits associated with dyscalculia, educators can develop targeted strategies that address these challenges (Dresler et al., 2018; Gkintoni et al., 2023). For example, interventions that focus on enhancing working memory and numerical processing skills may lead to improved mathematical outcomes for students with dyscalculia (Dresler et al., 2018; Gkintoni et al., 2023).

4.2. Theme 2 - Broader Perspectives on Dyscalculia

Dyscalculia, a specific learning disability affecting numerical and mathematical skills, has significant emotional, psychological, and academic consequences. Children with dyscalculia often experience math anxiety, low self-esteem, and reduced motivation due to repeated academic struggles. These challenges can extend into social interactions, career choices, and long-term employment opportunities. Cultural attitudes and educational policies influence how dyscalculia is recognized and supported worldwide, while its frequent co-occurrence with other learning disabilities complicates diagnosis and intervention. Understanding the neurological, genetic, and environmental factors underlying dyscalculia is crucial for developing effective early interventions and tailored support strategies that improve outcomes for affected individuals.

4.2.1. Emotional and psychological impact of dyscalculia

The Relationship between Dyscalculia and Anxiety, Especially Math Anxiety: Dyscalculia is closely linked to heightened levels of anxiety, particularly math anxiety, which can significantly affect a child's emotional well-being and academic performance. Research indicates that children with dyscalculia often experience intense fear and apprehension when faced with mathematical tasks, leading to avoidance behaviors and increased stress levels (Alyoubi et al., 2021; Ulfarsson et al.,2017). Math anxiety can exacerbate the difficulties associated with dyscalculia, creating a vicious cycle where anxiety impedes learning, which in turn increases anxiety (Khan & Lal, 2023). This relationship highlights the importance of addressing emotional factors in educational interventions for students with dyscalculia.

- *The Effects of Repeated Academic Failure on Self-Esteem and Motivation:* Repeated academic failures in mathematics can have detrimental effects on self-esteem and motivation among children with dyscalculia. These students often internalize their struggles, leading to feelings of inadequacy and low self-worth (Ozernov-Palchik et al., 2022; Tūbele, 2015). As they face continuous challenges in a subject that is critical for academic success, their motivation to engage with mathematics can diminish, further perpetuating their difficulties (Orraca-Castillo et al., 2014). It is essential for educators and parents to recognize these emotional impacts and provide supportive environments that foster resilience and a growth mindset.
- *Social Challenges Faced by Children with Dyscalculia (e.g., Peer Relationships, Classroom Participation):* Children with dyscalculia may encounter significant social challenges, including difficulties in peer relationships and classroom participation. Their struggles with mathematics can lead to feelings of isolation and exclusion from group activities that involve math, such as games or collaborative projects (Layes, 2022; McCarthy et al., 2012). Additionally, the stigma associated with learning disabilities can result in bullying or negative peer interactions, further exacerbating their emotional distress (Ciulkinyte et al., 2025). Creating inclusive classroom environments that promote understanding and empathy among peers is crucial for supporting the social development of students with dyscalculia.
- *Strategies for Building Confidence and Reducing Anxiety in Students with Dyscalculia:* To mitigate the emotional and psychological impacts of dyscalculia, educators can implement several strategies aimed at building confidence and reducing anxiety. These strategies may include providing a supportive and understanding classroom environment, using positive reinforcement to celebrate small successes, and incorporating engaging, hands-on learning activities that make mathematics more accessible (Khan & Lal, 2023; Ulfarsson et al., 2017). Additionally, teaching coping strategies for managing anxiety, such as mindfulness techniques and relaxation exercises, can empower students to approach mathematical tasks with greater confidence (Hussein et al., 2023).

4.2.2. Longitudinal perspective on dyscalculia

- *How Dyscalculia Affects Academic Progress Beyond Primary School:* The impact of dyscalculia extends beyond primary education, influencing academic progress in secondary school and beyond. Research has shown that students with dyscalculia often continue to struggle with mathematics throughout their educational careers, leading to lower overall academic achievement and limited opportunities for advanced study in STEM fields (Cheng et al., 2022; Orraca-Castillo et al., 2014). This persistence of difficulties underscores the need for early and ongoing support to help students navigate their academic journeys effectively.
- *Long-Term Consequences on Career Choices and Employment Opportunities:* Dyscalculia can have long-term consequences on career choices and employment opportunities. Many professions require a certain level of mathematical proficiency, and individuals with dyscalculia may find themselves at a disadvantage when pursuing careers in fields such as engineering, finance, or technology (Khan et al., 2023; Peters et al., 2018). This limitation can lead to reduced job prospects and lower earning potential, highlighting the importance of addressing dyscalculia early to improve long-term outcomes for affected individuals.
- *Early Intervention vs. Late Diagnosis: Differences in Outcomes:* The timing of intervention plays a critical role in determining the outcomes for students with dyscalculia. Research suggests that early diagnosis and intervention can significantly improve mathematical skills and overall academic performance, while late diagnosis often results in persistent difficulties and a greater likelihood of negative emotional outcomes (Grant et al., 2020; López-Resa & Moraleda-Sepúlveda, 2023). Implementing effective screening and support systems in primary education is essential for ensuring that students with dyscalculia receive the help they need to succeed.

4.2.3. Cross-cultural perspectives on dyscalculia

- *How Different Countries and Education Systems Recognize and Support Students with Dyscalculia:* Recognition and support for students with dyscalculia vary widely across countries and education systems. Some nations have established comprehensive frameworks for identifying and supporting students with learning disabilities, while others may lack the necessary resources and training (Lopes-Silva et al., 2014; Pestun et al., 2019). For instance, countries with strong special education policies often provide tailored interventions and accommodations for students with dyscalculia, leading to more positive educational outcomes (Bulthé et al., 2019; Filippo & Zoccolotti, 2018). Understanding these differences can inform the development of best practices for supporting students with dyscalculia globally.
- *Cultural Attitudes toward Mathematical Ability and Learning Disabilities:* Cultural attitudes toward mathematical ability and learning disabilities can significantly influence how dyscalculia is perceived and addressed. In cultures that place a high value on academic achievement, students with dyscalculia may face greater stigma and pressure, which can exacerbate their emotional challenges (Franz et al., 2023; Pan et al., 2015). Conversely, cultures that promote inclusivity and understanding of learning differences may foster more supportive environments for students with dyscalculia, facilitating their academic and social development (Couvignou et al., 2019; Singh et al., 2017).
- *Comparative Effectiveness of Intervention Programs in Different Regions:* The effectiveness of intervention programs for dyscalculia can vary across regions due to differences in educational practices, resources, and cultural attitudes. Comparative studies have shown that certain approaches, such as multisensory learning and individualized instruction, may be more effective in specific cultural contexts (Fajariyanti et al., 2022; Khandaker et al., 2014). Evaluating and adapting intervention programs to meet the unique needs of students in different regions is crucial for improving outcomes for those with dyscalculia.

4.2.4. Co-occurrence with other learning disabilities

- *The Overlap Between Dyscalculia and Other Conditions (e.g., Dyslexia, ADHD, Executive Function Deficits):* Dyscalculia frequently co-occurs with other learning disabilities, such as dyslexia and ADHD. Research indicates that approximately 40% of children with dyscalculia also exhibit symptoms of dyslexia, while a significant proportion may have attention-related difficulties (Anggrawan et al., 2023; Kunwar, 2024). This overlap complicates diagnosis and intervention strategies, as educators must address multiple learning challenges simultaneously (Ashburn et al., 2024; Unger et al., 2021). Understanding the co-occurrence of these conditions is essential for developing comprehensive support plans for affected students.
- *How Co-Occurring Disabilities Complicate Diagnosis and Intervention Strategies:* The presence of co-occurring disabilities can complicate the diagnostic process and the implementation of effective interventions. For instance, symptoms of dyslexia may mask or overshadow the signs of dyscalculia, leading to misdiagnosis or delayed intervention (Andrade-Arenas & Yactayo-Arias, 2024; Ngor Achiek & Selugo, 2024). Additionally, intervention strategies that are effective for one condition may not be suitable for another, necessitating a tailored approach that considers the unique needs of each student (Ali et al., 2020; Løhre et al., 2021). Collaborative efforts among educators, psychologists, and parents are essential for ensuring that students receive appropriate support.
- *Case Studies Highlighting Complex Learning Profiles:* Case studies of students with dyscalculia and co-occurring learning disabilities provide valuable insights into the complexities of their learning profiles. For example, a student with both dyscalculia and ADHD may struggle with attention and focus during math lessons, leading to difficulties in retaining and processing numerical information (Achiek, 2023; Van Herwegen et al., 2024). These case studies underscore the importance

of individualized assessment and intervention strategies that address the multifaceted nature of learning disabilities (Calì et al., 2023; Omoniyi Israel & Peter Olubunmi, 2014). By examining the experiences of students with complex learning profiles, educators can develop more effective support systems that cater to the diverse needs of learners.

4.3. Theme 3 - Evidence-Based Interventions and Support Strategies

Educational strategies for supporting students with dyscalculia emphasize tailored teaching methods, technological interventions, cognitive training, and inclusive policies. Effective instruction incorporates structured, multisensory, and differentiated approaches to enhance mathematical understanding. Digital tools, gamification, and AI-driven platforms provide personalized support, while cognitive training and metacognitive strategies improve problem-solving skills. Teacher training and parental involvement are crucial for early identification and intervention, reinforcing learning both in and out of the classroom. Policy initiatives and special education laws ensure access to necessary accommodations, promoting equitable learning opportunities. A comprehensive, multi-faceted approach is essential for improving educational outcomes for students with dyscalculia.

4.3.1. Educational strategies

Effective Teaching Methods and Instructional Adaptations: Effective teaching methods for students with dyscalculia often involve tailored instructional adaptations that address their unique learning needs. Research indicates that explicit instruction in mathematical concepts, combined with frequent practice and feedback, can significantly enhance learning outcomes for students with dyscalculia (Butterworth & Laurillard, 2010; Monei & Pedro, 2017). Teachers are encouraged to use clear, structured approaches that break down complex mathematical concepts into manageable steps, allowing students to build their understanding gradually (Zygouris et al., 2017). Additionally, incorporating visual aids and manipulatives can help students grasp abstract mathematical ideas by providing concrete representations of numerical concepts (Butterworth & Laurillard, 2010; Yoong et al., 2023).

The Role of Multisensory and Hands-On Learning Approaches: Multisensory and hands-on learning approaches have been shown to be particularly effective for students with dyscalculia. These methods engage multiple senses, facilitating deeper learning and retention of mathematical concepts (Butterworth & Laurillard, 2010; Chodura et al., 2015). For example, using physical objects to represent numbers and operations can help students visualize mathematical relationships, making it easier for them to understand and apply these concepts in problem-solving situations (Elhakeem et al., 2023). Research supports the effectiveness of such approaches, indicating that students who engage in multisensory learning demonstrate improved mathematical performance compared to those who receive traditional instruction (Eghbali Ghazijahani et al., 2019; López et al., 2020).

Differentiated Instruction and Personalized Learning Pathways: Differentiated instruction is crucial for meeting the diverse needs of students with dyscalculia. This approach involves tailoring teaching methods, materials, and assessments to accommodate individual learning styles and abilities (Ezegbe et al., 2019). Personalized learning pathways, which allow students to progress at their own pace and focus on areas where they need the most support, can also enhance engagement and motivation (López-Resa & Moraleda-Sepúlveda, 2023). Studies have shown that when students receive instruction that is responsive to their specific learning profiles, they are more likely to experience academic success and develop a positive attitude toward mathematics (Franz et al., 2023).

4.3.2. Technological interventions

The Impact of Digital Tools and Adaptive Learning Software: Digital tools and adaptive learning software have emerged as valuable resources for supporting students with dyscalculia. These technologies often provide interactive and engaging platforms for practicing mathematical skills, allowing students to work at their own pace and receive immediate feedback (Aquil & Ariffin, 2020; Butterworth et al., 2011). Research indicates that the use of adaptive learning technologies can lead to significant improvements in mathematical performance, as they can adjust the difficulty of tasks based on individual student progress (Bahrani et al., 2017). Furthermore, these tools can help to reduce math anxiety by providing a safe and supportive environment for practice (Snorrason et al., 2015).

Use of Gamification and AI-Based Interventions: Gamification, which incorporates game elements into educational contexts, has been shown to enhance motivation and engagement among students with dyscalculia (Bazzaz Monsef et al., 2017). By making learning more enjoyable and interactive, gamified interventions can help students overcome barriers to mathematical learning. Additionally, artificial intelligence (AI)-based interventions can provide personalized learning experiences by analyzing student performance and adapting content to meet their specific needs (Levy et al., 2014). Studies have demonstrated that gamified and AI-driven approaches can lead to improved learning outcomes and increased student confidence in mathematics (Van Luit & Toll, 2018).

4.3.3. Cognitive and behavioral ınterventions

Cognitive Training Exercises for Numerical Cognition: Cognitive training exercises targeting numerical cognition can be effective in improving mathematical skills among students with dyscalculia. These exercises often focus on enhancing specific cognitive processes, such as working memory, attention, and numerical processing (Tibane et al., 2024; Yoong & Hoe, 2022). Research has shown that engaging in targeted cognitive training can lead to significant gains in mathematical performance, particularly when combined with traditional instructional methods (Delgado et al., 2019). Such interventions can help students develop the foundational skills necessary for success in mathematics.

Metacognitive Strategies and Self-Regulation in Mathematical Learning: Teaching metacognitive strategies can empower students with dyscalculia to take control of their learning processes. By encouraging students to reflect on their thinking, set goals, and monitor their progress, educators can help them develop self-regulation skills that are essential for effective mathematical learning (Baulina & Kosonogov, 2023; Habibi et al., 2015). Research indicates that when students are taught to apply metacognitive strategies, they are more likely to improve their problem-solving abilities and overall mathematical performance (Laurillard, 2016). Implementing these strategies in the classroom can foster greater independence and confidence in students with dyscalculia.

4.3.4. Teacher and Parental Involvement

Importance of Teacher Training in Identifying and Supporting Students: Teacher training is critical for effectively identifying and supporting students with dyscalculia. Educators must be equipped with the knowledge and skills necessary to recognize the signs of dyscalculia and implement appropriate interventions (Chin & Fu, 2021; Wang'ang'a, 2023). Research has shown that when teachers receive specialized training in dyscalculia, they are better able to provide targeted support and create inclusive classroom environments that foster learning for all students (Zerafa, 2015). Ongoing professional development opportunities can further enhance teachers' abilities to address the needs of students with dyscalculia.

Role of Parental Engagement and Home-Based Interventions: Parental engagement plays a vital role in supporting students with dyscalculia. Research indicates that when parents are actively involved in their children's education, it can lead to improved academic outcomes and increased motivation (Loenneker et al., 2021; Miundy et al., 2019). Home-based interventions, such as providing additional practice opportunities and fostering a positive attitude toward mathematics, can complement school-based efforts and reinforce learning (Haberstroh & Schulte-Körne, 2019). Educators should encourage parental involvement by providing resources and strategies that parents can use to support their children's mathematical development at home.

4.3.5. Educational policy and legislative support

National and International Policies for Inclusive Education: National and international policies play a significant role in promoting inclusive education for students with dyscalculia. Policies that advocate for early identification, intervention, and support services are essential for ensuring that students with dyscalculia receive the assistance they need to succeed academically (Szücs et al., 2013; Yoong et al., 2022). Research highlights the importance of implementing inclusive education policies that recognize the diverse needs of students with learning disabilities and provide appropriate resources and support (Chao et al., 2022; Potter, 2024).

Special Education Laws and Accommodations for Students with Dyscalculia: Special education laws, such as the Individuals with Disabilities Education Act (IDEA) in the United States, mandate that students with dyscalculia receive appropriate accommodations and services to support their learning (Li et al., 2023; Pappas et al., 2018). These accommodations may include individualized education plans (IEPs), access to specialized instruction, and modifications to assessments (Kißler et al., 2021; Mutlu et al., 2022). Ensuring that schools comply with these laws is crucial for providing equitable educational opportunities for students with dyscalculia.

Recommendations for School-Level Implementation of Dyscalculia Support Programs: To effectively support students with dyscalculia, schools should implement comprehensive support programs that encompass early identification, targeted interventions, and ongoing monitoring of progress (Pedemonte et al., 2022; Vasudeva et al., 2024). Recommendations for school-level implementation include establishing dedicated resources for dyscalculia support, providing professional development for educators, and fostering collaboration among teachers, parents, and specialists (Agostini et al., 2022; Garcia-Planas, 2020). By creating a supportive and inclusive educational environment, schools can help students with dyscalculia achieve their full potential.

5. DISCUSSION

5.1. Discussion of Themes

5.1.1. Theme 1 - Causes of dyscalculia

Dyscalculia is a specific learning disability that significantly impairs mathematical skills, making it difficult for individuals to develop number sense, perform arithmetic operations, and engage in mathematical reasoning. It affects approximately 3% to 8% of the global population, with some estimates suggesting an even higher prevalence in educational settings, particularly among students experiencing math-related anxiety (Drigas & Pappas, 2015; Elhakeem et al., 2023). Young learners with dyscalculia often struggle with counting, recognizing numbers, and recalling math facts, which further impacts their confidence and engagement in mathematics (Morsanyi et al., 2018). Diagnosis remains challenging despite established criteria, as symptoms overlap with other learning disabilities such as dyslexia and ADHD, leading to frequent misdiagnosis or underdiagnosis (Bergen et al., 2023; Haberstroh & Schulte-Körne, 2019). Standardized tools like the Ben-Gurion University Math Fluency

test (BGU-MF) have been developed to assess mathematical competency, but the lack of educator training in identifying dyscalculia remains a significant barrier (Gliksman et al., 2022; Williams, 2013).

Neurological research has linked dyscalculia to structural and functional differences in brain regions responsible for numerical cognition, particularly the intraparietal sulcus, where atypical activation patterns have been observed in affected individuals (Dresler et al., 2018; Peters et al., 2018). Additionally, deficits in working memory, attention, and executive functioning contribute to difficulties in retaining and processing numerical information, further impairing mathematical performance (Dowker, 2020; Morsanyi et al., 2018). Genetic studies indicate that dyscalculia has a hereditary component, as twin studies show familial patterns of mathematical difficulties, and shared genetic variants with dyslexia suggest overlapping neurobiological mechanisms (Malanchini & Gidziela, 2022; Pettigrew et al., 2015). The frequent co-occurrence of dyscalculia with other neurodevelopmental disorders highlights the need for comprehensive intervention strategies that address multiple learning difficulties simultaneously (Bergen et al., 2023).

Cognitive deficits in number sense and numerical processing form the core challenges associated with dyscalculia. Affected students struggle with estimating quantities, comparing numbers, and performing basic arithmetic operations, which severely impacts their overall mathematical learning (Morsanyi et al., 2018; Murciano et al., 2021). Visual-spatial difficulties further hinder their ability to understand numerical relationships and spatial concepts, essential for problem-solving in mathematics (Dowker, 2020; Morsanyi et al., 2018). Traditional teaching methods often fail to address these deficits, leading to frustration and disengagement in students with dyscalculia (Delgado et al., 2019; Vouglanis & Raftopoulos, 2023). Additionally, socioeconomic disparities affect access to educational resources, and cultural attitudes toward mathematics can influence how dyscalculia is perceived and supported within different educational systems (Morsanyi et al., 2018; Murciano et al., 2021).

Advancements in neuroscience provide promising insights into the potential for targeted interventions based on neuroplasticity. Studies have shown that structured cognitive training can help rewire neural pathways involved in numerical processing, improving mathematical skills in children with dyscalculia (Dresler et al., 2018; Gkintoni et al., 2023). These findings emphasize the importance of early diagnosis and personalized interventions that focus on strengthening working memory and numerical cognition. By leveraging brain-based research, educators can develop more effective instructional strategies, ensuring that students with dyscalculia receive the support necessary to enhance their mathematical abilities and academic success (Dresler et al., 2018; Gkintoni et al., 2023).

5.1.2. Theme 2 - Broader perspectives on dyscalculia

Dyscalculia has far-reaching consequences that extend beyond mathematical difficulties, affecting emotional well-being, self-esteem, and long-term academic and career prospects. Math anxiety is a major concern, as students with dyscalculia often develop heightened stress and avoidance behaviors when faced with mathematical tasks (Alyoubi et al., 2021; Ulfarsson et al., 2017). Repeated academic failure can lower self-confidence and motivation, creating a cycle of disengagement that further exacerbates difficulties in learning mathematics (Ozernov-Palchik et al., 2022; Tūbele, 2015). Beyond the classroom, dyscalculia can impact social interactions, with children experiencing exclusion from group activities requiring numerical skills and, in some cases, facing bullying due to their learning difficulties (Ciulkinyte et al., 2025; Layes, 2022). Creating supportive environments that foster resilience and self-confidence is essential in mitigating these effects and encouraging students to engage with mathematics more positively (Hussein et al., 2023; Khan & Lal, 2023).

The challenges associated with dyscalculia persist beyond primary school, influencing academic progress and limiting career opportunities in fields requiring mathematical proficiency (Cheng et al., 2022; Orraca-Castillo et al., 2014). Individuals with dyscalculia may struggle in secondary education and higher education, reducing their chances of pursuing STEM careers, which often necessitate strong numerical skills (Khan et al., 2023; Peters et al., 2018). Early intervention significantly improves long-term outcomes, whereas late diagnosis often leads to persistent academic and emotional challenges (Grant et al., 2020; López-Resa & Moraleda-Sepúlveda, 2023). Given these implications, early identification through school-based screening programs is essential in providing students with timely support that can improve their mathematical abilities and academic confidence.

Recognition and support for dyscalculia vary across different countries and educational systems, reflecting disparities in policy implementation and cultural attitudes toward learning disabilities (Lopes-Silva et al., 2014; Pestun et al., 2019). Countries with strong special education frameworks tend to provide more effective interventions, while in others, limited awareness and resources hinder adequate support for affected students (Bulthé et al., 2019; Filippo & Zoccolotti, 2018). Cultural perceptions of mathematical ability also shape how dyscalculia is addressed, with societies that place high academic expectations on students often stigmatizing learning disabilities, further increasing the pressure on affected individuals (Franz et al., 2023; Pan et al., 2015). Adapting intervention programs to different cultural and educational contexts is crucial for ensuring that all students receive the necessary support to succeed in mathematics (Fajariyanti et al., 2022; Khandaker et al., 2014).

Dyscalculia frequently co-occurs with other learning disabilities, such as dyslexia and ADHD, complicating diagnosis and intervention strategies (Anggrawan et al., 2023; Kunwar, 2024). Research suggests that around 40% of children with dyscalculia also exhibit signs of dyslexia, and many struggle with attention-related difficulties, which further impede their ability to process numerical information effectively (Ashburn et al., 2024; Unger et al., 2021). Misdiagnosis or delayed recognition of co-occurring conditions can hinder effective intervention, emphasizing the need for comprehensive assessment strategies that consider multiple learning profiles (Andrade-Arenas & Yactayo-Arias, 2024; Ngor Achiek & Selugo, 2024). Case studies highlight the complexity of these overlapping learning disabilities, demonstrating the importance of individualized educational plans that accommodate students' diverse needs (Omoniyi Israel & Peter Olubunmi, 2014; Van Herwegen et al., 2024). Addressing dyscalculia in a holistic manner requires collaboration among educators, parents, and specialists to develop tailored interventions that improve both academic outcomes and overall well-being.

5.1.3. Theme 3 - Evidence-based ınterventions and support strategies

Effective interventions for dyscalculia involve a multi-faceted approach that integrates instructional strategies, technological innovations, cognitive training, and inclusive policies. Research highlights the importance of explicit instruction that simplifies complex mathematical concepts, providing structured, step-by-step guidance (Butterworth & Laurillard, 2010; Monei & Pedro, 2017). Multisensory learning, which engages students through visual, auditory, and kinesthetic methods, has shown significant benefits in helping students develop numerical understanding and problem-solving skills (Chodura et al., 2015; Eghbali Ghazijahani et al., 2019). Differentiated instruction further ensures that students receive personalized learning pathways, allowing them to progress at their own pace and focus on areas requiring additional support (Ezegbe et al., 2019; López-Resa & Moraleda-Sepúlveda, 2023).

The integration of technology into dyscalculia interventions has proven highly effective. Digital tools and adaptive learning software provide interactive learning environments that adjust to individual student progress, reducing frustration and improving engagement (Aquil & Ariffin, 2020; Butterworth

et al., 2011). Gamification strategies enhance motivation by making learning more interactive, while AI-based interventions analyze student performance and tailor instruction accordingly (Bazzaz Monsef et al., 2017; Levy et al., 2014). These digital approaches not only strengthen mathematical abilities but also help alleviate math anxiety by creating a low-pressure learning environment (Bahrani et al., 2017; Snorrason et al., 2015).

Cognitive and behavioral interventions also play a crucial role in addressing the underlying deficits associated with dyscalculia. Cognitive training exercises targeting numerical cognition and working memory have been shown to improve mathematical performance when combined with traditional teaching methods (Delgado et al., 2019; Yoong & Hoe, 2022). Additionally, metacognitive strategies, such as goal-setting and self-monitoring, empower students to regulate their learning and develop problem-solving skills (Baulina & Kosonogov, 2023; Habibi et al., 2015). Encouraging self-reflection and structured practice enhances students' ability to navigate mathematical tasks with greater independence and confidence (Laurillard, 2016).

Teacher training and parental involvement are essential components of a comprehensive intervention strategy. Educators need specialized training to recognize and support students with dyscalculia, ensuring that effective instructional adaptations are implemented in the classroom (Chin & Fu, 2021; Wang'ang'a, 2023). Research shows that when teachers receive professional development in dyscalculia support strategies, student outcomes improve significantly (Zerafa, 2015). Similarly, parental engagement reinforces learning at home, with home-based interventions complementing school-based efforts to enhance mathematical understanding and motivation (Loenneker et al., 2021; Miundy et al., 2019).

At a policy level, national and international education frameworks play a critical role in promoting inclusive learning environments for students with dyscalculia. Laws such as the Individuals with Disabilities Education Act (IDEA) mandate that students receive necessary accommodations, including individualized education plans and modified assessments (Li et al., 2023; Pappas et al., 2018). Schools must ensure compliance with these policies by implementing structured dyscalculia support programs, fostering collaboration between educators, parents, and specialists to provide targeted intervention and continuous progress monitoring (Pedemonte et al., 2022; Vasudeva et al., 2024). By integrating these strategies, educational institutions can create a more inclusive and effective learning environment, ensuring that students with dyscalculia reach their full potential.

5.2. Gaps in Existing Research

Despite significant advancements in dyscalculia research, several critical gaps remain, limiting the development of effective interventions and policies.

Methodological Limitations and Inconsistencies: Existing studies on dyscalculia often suffer from methodological shortcomings that impact the reliability and generalizability of findings. Many studies rely on small sample sizes, which may not accurately represent the broader population of students with dyscalculia. Additionally, there is a lack of longitudinal research tracking the progression of dyscalculia over time and evaluating the long-term effectiveness of interventions. Without such studies, it remains unclear whether early interventions produce sustained improvements in mathematical skills and cognitive development. Furthermore, inconsistencies in research design—such as the absence of control groups—limit the ability to establish causal relationships between interventions and student outcomes.

Variability in Assessment and Diagnosis: A major challenge in dyscalculia research is the lack of standardized diagnostic criteria and assessment tools. Different studies employ varying definitions and measurement instruments, leading to inconsistencies in identifying dyscalculia across different populations. These discrepancies contribute to underdiagnosis and misdiagnosis, preventing many students from receiving appropriate support. Without a universally accepted diagnostic framework,

educational institutions and practitioners struggle to implement effective screening and intervention strategies.

Underrepresentation of Diverse Populations: Dyscalculia research has been predominantly conducted in high-income, Western countries, leading to potential cultural and socioeconomic biases. Studies often neglect the experiences of students from linguistically and culturally diverse backgrounds, limiting the applicability of findings to global populations. The lack of research on low-income students and non-Western educational contexts hinders the development of culturally responsive interventions. Without inclusive research, educational policies and instructional approaches may fail to address the unique needs of students from underrepresented communities.

Limited Understanding of Comorbid Conditions: Dyscalculia frequently coexists with other learning disabilities, such as dyslexia and ADHD. However, research on the interplay between these conditions remains limited. Many intervention programs focus exclusively on dyscalculia, without considering the additional challenges faced by students with multiple learning disabilities. Understanding how dyscalculia interacts with other neurodevelopmental disorders is crucial for designing comprehensive support strategies that address students' diverse needs.

Limited Integration of Emerging Technologies: While technological advancements, such as adaptive learning software and AI-driven interventions, show promise in supporting students with dyscalculia, research on their efficacy remains in its early stages. Many studies fail to assess the long-term impact of these tools or explore their scalability in different educational settings. Additionally, the role of neuroplasticity-based training in dyscalculia intervention remains underexplored. Without rigorous research, the full potential of technology in supporting students with dyscalculia remains unrealized.

5.3. Future Research Directions

To address these gaps, future research should focus on developing more effective, inclusive, and evidence-based strategies for identifying and supporting students with dyscalculia.

Standardizing Diagnostic Criteria and Assessment Tools: A critical step toward improving dyscalculia research is the standardization of diagnostic criteria and assessment methods. Researchers should collaborate across disciplines to establish clear guidelines for identifying dyscalculia in primary school students. Developing universally accepted screening tools will enable early detection and ensure that interventions are appropriately targeted. Moreover, future studies should validate these tools across diverse populations to enhance their applicability in different educational contexts.

Expanding Longitudinal and Intervention Studies: Longitudinal research is essential for understanding the developmental trajectory of dyscalculia and evaluating the long-term impact of interventions. Future studies should track students with dyscalculia over time, assessing how early support influences academic achievement, cognitive development, and career outcomes. Additionally, research should examine whether intervention strategies remain effective as students progress through different educational stages.

Enhancing Cultural Responsiveness in Dyscalculia Interventions: Future research should explore how dyscalculia manifests across different cultural and socioeconomic backgrounds to ensure that all students receive equitable support. Investigating the role of cultural attitudes toward mathematics and learning disabilities will help design interventions that align with diverse educational contexts. Moreover, researchers should assess how socio-economic factors influence access to dyscalculia support services and propose solutions for addressing disparities in educational resources.

Investigating Comorbid Conditions and Multidimensional Interventions: Future research should prioritize studies that examine the interactions between dyscalculia and other learning disabilities. Developing integrated intervention programs that address multiple cognitive challenges will be crucial for supporting students with complex learning profiles. Additionally, research should explore how

personalized learning approaches can be adapted to meet the unique needs of students with co-occurring disabilities.

Leveraging Emerging Technologies for Dyscalculia Support: The potential of artificial intelligence, gamification, and neuroplasticity-based interventions in dyscalculia education requires further exploration. Future studies should focus on the effectiveness of these technologies in improving numerical cognition and reducing math anxiety. Additionally, researchers should investigate the scalability of digital interventions, ensuring that they are accessible to students across different educational settings and socio-economic backgrounds.

Strengthening Teacher Training and Curriculum Adaptation: Future research should explore the most effective ways to integrate dyscalculia support into teacher education programs. Professional development initiatives should equip educators with the knowledge and skills necessary to identify dyscalculia and implement evidence-based instructional strategies. Furthermore, curriculum adaptation research should focus on developing flexible teaching approaches that accommodate students with diverse learning needs.

Policy Recommendations for Inclusive Education: Educational policymakers should use research findings to develop comprehensive frameworks that support students with dyscalculia. Future studies should evaluate the impact of existing policies and propose strategies for enhancing inclusive education. Research should also investigate how national and international education systems can collaborate to improve access to specialized resources and interventions for dyscalculia.

By addressing these research priorities, future studies can contribute to a deeper understanding of dyscalculia and lead to the development of more effective support systems. Early identification, interdisciplinary collaboration, and the integration of emerging technologies will be key in ensuring that students with dyscalculia receive the assistance they need to succeed academically and beyond.

6. CONCLUSION

6.1 Summary of Key Findings

This study synthesized contemporary research on dyscalculia in primary school students, identifying its causes, broader perspectives, and effective intervention strategies. The findings provide a comprehensive understanding of dyscalculia's impact on cognitive, neurological, emotional, and educational aspects, along with evidence-based solutions to support affected students.

6.1.1. Causes of dyscalculia

The research highlights that dyscalculia is a complex learning disability primarily linked to neurological and cognitive deficits. Key factors contributing to dyscalculia include:

- *Neurological and Cognitive Factors:* Dyscalculia is associated with atypical brain activation patterns, particularly in the intraparietal sulcus, which is critical for numerical cognition. Deficits in working memory, number sense, and visual-spatial reasoning further exacerbate mathematical learning difficulties.
- *Genetic and Biological Influences:* Studies suggest a hereditary component, with dyscalculia often co-occurring with other neurodevelopmental disorders such as dyslexia and ADHD.
- *Environmental and Educational Factors:* Teaching methods, curriculum design, and socio-economic factors significantly impact the severity and identification of dyscalculia. Limited access to early intervention resources can hinder academic progress.
- *Challenges in Diagnosis:* Despite the availability of assessment tools, underdiagnosis and misdiagnosis are common due to the overlap of dyscalculia symptoms with other learning disabilities.

6.1.2. Broader perspectives on dyscalculia

Dyscalculia extends beyond mathematical difficulties, affecting students' emotional, social, and academic development:

- *Psychosocial Impact:* Math anxiety, low self-esteem, and social difficulties are prevalent among students with dyscalculia. Negative experiences with mathematics can lead to avoidance behaviors and reduced motivation.
- *Long-Term Consequences:* The learning disability persists into adolescence and adulthood, affecting career opportunities, particularly in STEM-related fields.
- *Cross-Cultural Recognition and Support:* Educational policies and societal attitudes toward dyscalculia vary across regions. Some countries have structured interventions, while others lack awareness and resources.
- *Co-Occurrence with Other Learning Disabilities:* Dyscalculia frequently overlaps with dyslexia and ADHD, complicating both diagnosis and intervention strategies.

6.1.3. Evidence-based ınterventions and support strategies

The study identifies multiple intervention approaches that have been effective in addressing dyscalculia:

- *Educational Strategies:* Structured teaching methods, differentiated instruction, and multisensory learning approaches improve mathematical understanding.
- *Technological Interventions:* Digital tools, gamification, and AI-based learning platforms provide personalized support and enhance engagement.
- *Cognitive and Behavioral Interventions:* Cognitive training, metacognitive strategies, and self-regulation techniques help students develop problem-solving skills.
- *Teacher Training and Parental Involvement:* Equipping teachers with specialized training and increasing parental engagement significantly improve student outcomes.
- *Policy and Legislative Support:* Inclusive education policies and accommodations, such as Individualized Education Plans (IEPs), ensure students receive necessary support.

6.2. Answers to the Research Questions

1. What are the primary cognitive and neurological factors contributing to dyscalculia in primary school students?

Dyscalculia is primarily linked to deficits in numerical cognition, which originate from neurological and cognitive impairments. Research highlights the role of the intraparietal sulcus in numerical processing, with children diagnosed with dyscalculia often showing atypical activation in this brain region (Dresler et al., 2018; Peters et al., 2018). Additionally, working memory and executive functioning deficits contribute to difficulties in numerical comprehension and problem-solving (Dowker, 2020; Morsanyi et al., 2018). Genetic studies suggest that dyscalculia has a hereditary component, with familial patterns indicating potential genetic predisposition (Malanchini & Gidziela, 2022; Pettigrew et al., 2015). These findings underscore the importance of early screening for cognitive deficits to provide timely interventions.

2. How does dyscalculia impact the emotional and psychological well-being of affected students?

Dyscalculia significantly affects students' emotional and psychological well-being, particularly in relation to math anxiety, self-esteem, and motivation. Children with dyscalculia often experience heightened anxiety when engaging in mathematical tasks, leading to avoidance behaviors and stress (Alyoubi et al., 2021; Ulfarsson et al., 2017). Repeated academic failure contributes to reduced self-confidence, social isolation, and lower academic motivation (Ozernov-Palchik et al., 2022; Tūbele,

2015). These challenges extend beyond academics, influencing peer relationships and classroom participation (Layes, 2022; McCarthy et al., 2012). Addressing these emotional factors through confidence-building strategies and supportive classroom environments is crucial for student success.

3. What evidence-based interventions and support strategies are most effective in addressing the needs of students with dyscalculia?

Research supports a multi-faceted approach to intervention, combining educational strategies, technological tools, and cognitive training. Explicit, structured teaching methods, multisensory learning, and differentiated instruction have been found to enhance mathematical understanding (Butterworth & Laurillard, 2010; Chodura et al., 2015; Ezegbe et al., 2019). Technological interventions, such as adaptive learning software and AI-driven gamification, provide personalized support and improve engagement (Aquil & Ariffin, 2020; Butterworth et al., 2011; Bazzaz Monsef et al., 2017). Additionally, cognitive training exercises targeting numerical cognition and working memory have been shown to improve mathematical performance (Tibane et al., 2024; Yoong & Hoe, 2022). Teacher training and parental involvement are also critical in ensuring effective intervention implementation (Chin & Fu, 2021; Wang'ang'a, 2023).

4. How can educational policies and practices be improved to better support students with dyscalculia in primary education settings?

Educational policies play a fundamental role in supporting students with dyscalculia by ensuring early identification, intervention, and accommodations. National and international policies should advocate for standardized diagnostic criteria and screening tools to facilitate early detection (Szücs et al., 2013; Yoong et al., 2022). Schools should implement specialized support programs, including individualized education plans (IEPs) and teacher training initiatives, to accommodate diverse learning needs (Pappas et al., 2018; Li et al., 2023). Additionally, integrating technological tools and neuroplasticity-based interventions into the curriculum can enhance learning outcomes. Policymakers should also focus on reducing socio-economic barriers by ensuring equitable access to dyscalculia support resources across diverse educational settings (Pedemonte et al., 2022; Vasudeva et al., 2024).

6.3. Limitations of this Study

While this study provides a comprehensive synthesis of contemporary research on dyscalculia in primary school students, several limitations must be acknowledged. These limitations relate to the scope of the literature review, methodological constraints, and gaps in existing research that may impact the generalizability and applicability of the findings.

- *Dependence on Existing Literature:* As a qualitative literature review, this study relies exclusively on previously published research, which may introduce biases inherent in the existing body of knowledge. The review does not incorporate primary data collection, experimental studies, or direct observations, limiting the ability to validate findings through independent empirical investigation. Additionally, the exclusion of unpublished studies or grey literature may result in a restricted representation of the full spectrum of research on dyscalculia.
- *Variability in Diagnostic Criteria and Assessment Tools:* One of the major challenges in studying dyscalculia is the inconsistency in diagnostic criteria and assessment methods across different studies. Researchers employ varied definitions and measurement tools, making it difficult to compare findings systematically. This lack of standardization affects the reliability of reported prevalence rates and intervention outcomes, limiting the ability to draw definitive conclusions regarding best practices for identification and support.

- *Limited Longitudinal and Intervention Studies:* Many studies included in this review focus on short-term effects of interventions, with limited longitudinal research tracking the long-term impact of dyscalculia on academic and professional outcomes. The effectiveness of interventions beyond primary education remains uncertain, as few studies follow students through adolescence and adulthood. Future research should aim to explore the sustained effects of various teaching strategies and technological interventions over extended periods.
- *Underrepresentation of Diverse Populations:* Most research on dyscalculia has been conducted in high-income, Western countries, leading to potential cultural and socio-economic biases. There is a lack of studies focusing on low-income and culturally diverse populations, which may have different educational systems, attitudes toward learning disabilities, and access to support resources. This underrepresentation limits the generalizability of findings and underscores the need for more inclusive research that examines dyscalculia across different socio-cultural contexts.
- *Insufficient Focus on Comorbid Conditions:* Although dyscalculia often coexists with other learning disabilities such as dyslexia and ADHD, relatively few studies explore the interplay between these conditions in depth. Many interventions are designed for isolated learning difficulties, failing to account for the complexities of multiple overlapping disabilities. Research addressing how combined interventions can target co-occurring learning challenges remains insufficient and warrants further investigation.
- *Limited Integration of Emerging Technologies:* While technological interventions such as adaptive learning platforms and gamification show promise in supporting students with dyscalculia, research on these methods remains in its early stages. Studies often lack rigorous experimental designs to assess the effectiveness of AI-based interventions and digital tools comprehensively. Future research should explore how advancements in artificial intelligence, neuroplasticity-based training, and virtual reality can be leveraged to enhance mathematical learning for students with dyscalculia.
- *Methodological Constraints in the Literature:* The studies analyzed in this review employ a variety of research methodologies, including qualitative case studies, experimental designs, and theoretical analyses. However, inconsistencies in sample sizes, research settings, and data analysis methods introduce limitations in synthesizing findings across different studies. Additionally, publication bias may favor studies with positive results, leading to an incomplete picture of the challenges and limitations of existing interventions.

By addressing these limitations, future research can contribute to a more comprehensive understanding of dyscalculia and lead to the development of more effective, evidence-based interventions for students affected by this learning disability.

6.4. Unique Contributions of this Study

This study makes several unique contributions to the field of dyscalculia research:

- *Comprehensive Thematic Synthesis:* Unlike previous reviews, this study systematically synthesizes contemporary research literature to provide an integrated understanding of cognitive, neurological, emotional, and educational aspects of dyscalculia.
- *Emphasis on Technological Interventions:* The study highlights emerging AI-driven interventions, gamification strategies, and adaptive learning tools, which are often underrepresented in traditional dyscalculia research.

- *Cross-Cultural Analysis:* The study examines how dyscalculia is recognized and addressed in different educational settings globally, identifying disparities and best practices across countries.
- *Focus on Policy Implications:* The study goes beyond identifying challenges and interventions by providing actionable policy recommendations to improve dyscalculia support frameworks in primary education.
- *Interdisciplinary Approach:* By integrating insights from neuroscience, psychology, and education, the study offers a holistic perspective that enhances the understanding and treatment of dyscalculia.

6.5. Concluding Remarks

Addressing dyscalculia requires a comprehensive understanding of its cognitive and neurological foundations, as well as its emotional and psychological impact. Evidence-based interventions, including structured teaching strategies, technology-enhanced learning, and cognitive training, have proven effective in mitigating the challenges associated with dyscalculia. Additionally, improving educational policies and ensuring equitable access to support services are crucial steps in creating inclusive learning environments for affected students. Future research should focus on standardizing diagnostic criteria, exploring emerging technological interventions, and enhancing teacher training programs to further improve outcomes for students with dyscalculia.

Ethics Committee Decision

Due to the scope and method of the study, ethics committee permission was not required.

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