International Journal of Education, Psychology and Counseling IJEPC
EISSN : 0128-164X
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

INTERNATIONAL JOURNAL OF EDUCATION, PSYCHOLOGY AND COUNSELLING (IJEPC)
www.ijepc.com

GLOBAL ACADEMIC EXCELLENCE

EXPLORING THE RELATIONSHIP BETWEEN NUMBER CONCEPT AND WORKING MEMORY IN EDUCATION: A SYSTEMATIC REVIEW

Faiqah Mohammad Fauzi[1*], Low Hui Min[2], Phoon Hooi San[3]

[1] Department of Education, University Science of Malaysia, Malaysia.
Email : faiqahfauziusm@student.usm.my
[2] Department of Education, University Science of Malaysia, Malaysia
Email: lowhm@usm.my
[3] Department of Education, University Science of Malaysia, Malaysia
Email: hsphoon@usm.my
[*] Corresponding Author

Article Info:

Article history:
Received date: 30.06.2024
Revised date: 17.07.2024
Accepted date: 25.09.2024
Published date: 30.09.2024

To cite this document:

Fauzi, F. M., Low, H. M., & Phoon, H. S. (2024). Exploring The Relationship Between Number Concept And Working Memory In Education: A Systematic Review *International Journal of Education, Psychology and Counseling, 9* (55), 947-967.

DOI: 10.35631/IJEPC.955064.

Abstract:

This study explores the intricate relationship between Working Memory (WM) and mathematical proficiency, particularly focusing on its implications for cognitive development and academic achievement. WM, responsible for the temporary storage and manipulation of information, is crucial in shaping mathematical skills and cognitive functions. However, there remains a gap in understanding how WM deficits impact students, particularly those with Learning Disabilities (LDs). The research examines three key themes: the role of WM in mathematical and cognitive skills, the influence of numeracy and number sense on mathematical achievement, and the impact of cognitive function on LDs and academic performance. To achieve this, we extensively searched scholarly articles from reputable databases such as Scopus, Web of Science, and Eric, focusing on studies published between 2022 and 2024. The flow of the study is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The database discovered (n = 20) that the final primary data was analyzed. The finding was divided into three themes: (1) WM and its roles in mathematical and cognitive skills, (2) numeracy, number sense, and mathematical achievement, and (3) cognitive functions, LDs, and academic achievement. Findings also reveal that WM plays a pivotal role in mathematical proficiency, with its components significantly influencing various cognitive and academic outcomes. Moreover, number sense is identified as a critical predictor of mathematical success, underscoring the need for early interventions. Lastly, the study highlights the challenges faced by students with LDs, where deficits in WM and related cognitive functions contribute to academic struggles. The research concludes that addressing WM deficits through targeted interventions could enhance

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

mathematical performance and overall academic achievement, particularly for students with learning difficulties. These insights emphasize the necessity for educators and policymakers to integrate cognitive skill development into educational strategies, ensuring that students receive comprehensive support tailored to their cognitive needs.

Keywords:

Number Concept, Working Number, Special Education, Mathematic Approach, Arithmetic Skill, Short-Term Memory, Visuospatial Sketchpad

Introduction

In education, understanding the cognitive processes underpinning learning is crucial for developing effective teaching strategies and interventions. Among these cognitive processes, Working Memory (WM) plays a pivotal role in various academic domains, particularly in acquiring numerical concepts. The number concept, which refers to the ability to understand, relate, and manipulate numbers, is foundational in mathematics education and has significant implications for broader cognitive development (Huwaina & Lotfi, 2022). Accordingly, this article explores the intricate relationship between the number concept and WM, shedding light on how these cognitive functions interact to influence learning outcomes in educational settings (Kok, 2012).

The number concept is a fundamental cognitive ability that underlies mathematical reasoning and problem-solving (Huwaina & Lotfi, 2022). It encompasses a range of skills, including counting, number recognition, number comparison, and arithmetic operations. Notably, these skills are essential for academic success in mathematics, which, in turn, is a critical component of the overall curriculum in primary and secondary education. In addition, mastery of numerical concepts is crucial for mathematical proficiency and a predictor of future academic achievement across various subjects. Research has consistently proven that early numeracy skills are strong indicators of later success in mathematics and general education (Shvartsman & Shaul, 2023). Given the significance of the number concept, educators and researchers have long sought to understand the factors that influence its development. Among these factors, WM has emerged as a key cognitive function that supports acquiring and applying numerical knowledge. In particular, WM, which refers to the ability to temporarily hold and manipulate information, is integral to many cognitive tasks, including those involved in mathematics.

WM is a central component of the cognitive architecture that supports learning and problem-solving. It involves the short-term storage and manipulation of information necessary for complex cognitive tasks, such as reasoning, comprehension, and decision-making (Nelwan et al., 2022). In the context of mathematics education, for tasks that require the simultaneous processing of multiple pieces of information, such as solving multi-step arithmetic problems or understanding mathematical concepts that involve abstract reasoning. Several studies have highlighted the role of WM in mathematical learning and performance (Mad Amin et al., 2020). For example, children with strong WM capacities tend to perform better in mathematics, as they are better able to hold numerical information in mind while performing calculations or solving problems (Allen et al., 2021). Conversely, deficits in WM are associated with difficulties in mathematical learning, particularly in tasks that require information integration over time.

International Journal of Education, Psychology and Counseling IJEPC
EISSN : 0128-164X
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064
The relationship between the number concept and WM is bidirectional and complex. On the one hand, WM supports developing and applying numerical concepts by enabling learners to retain and manipulate numerical information (Shvartsman & Shaul, 2023). For instance, when students learn to add or subtract, WM allows them to keep the numbers in mind while performing the necessary operations. This cognitive process is crucial for developing a deep understanding of numerical relationships and performing arithmetic tasks efficiently. On the other hand, the acquisition of numerical concepts can also influence the development of WM. Note that engaging with numerical tasks often requires the use of WM, which, over time, can lead to improvements in WM capacity (Kok, 2012). This reciprocal relationship suggests that enhancing one of these cognitive abilities can positively affect the other, creating a virtuous cycle that supports overall cognitive development and academic achievement. Therefore, understanding the relationship between the number concept and WM significantly impacts educational practice (Viesel-Nordmeyer et al., 2022). Teachers and educators can leverage this knowledge to design instructional strategies that support both the development of numerical concepts and the enhancement of WM. For example, incorporating activities that challenge students to hold and manipulate numerical information can strengthen their WM, improving their mathematical performance (Raghubar et al., 2010). Additionally, targeted interventions for students with WM deficits can help them overcome challenges in acquiring numerical concepts, leading to better educational outcomes.

In conclusion, the interplay between the number concept and WM is a critical area of study in educational research. By exploring this relationship, educators and researchers can gain insights into the cognitive processes that underpin mathematical learning, leading to more effective teaching strategies and improved educational outcomes (Silverman & Ashkenazi, 2022). This article aims to contribute to this growing body of knowledge by examining the specific ways WM and number concepts interact, with the ultimate goal of enhancing educational practices and supporting student learning.

Literature Review

The intersection of the number concept and WM has been a focal point in cognitive and educational psychology. Research consistently highlights the essential role that WM plays in developing and applying numerical concepts. A study by Yang and Yu (2021) examined the relationship between mental rotation, a cognitive skill closely tied to spatial reasoning, and arithmetic performance, considering the roles of number line estimation, WM, and the place-value concept. Their findings suggested that WM capacity directly influences the ability to understand and manipulate numerical information, which is crucial for tasks like mental rotation and arithmetic. This underscored the significance of WM as a foundational cognitive skill that supports the development of numerical abilities in children (Yang & Yu, 2021).

The relationship between the number concept and WM has been a focal point in cognitive and educational psychology (Nelwan et al., 2022). WM, which involves the temporary storage and manipulation of information, is crucial for acquiring and applying numerical concepts, as evidenced by various studies across different educational contexts. Notably, the connection between the number concept and WM is a central topic in both cognitive and educational psychology, reflecting the fundamental role WM plays in numerical cognition and mathematics learning. In particular, WM is a cognitive system that temporarily holds and manipulates information, enabling individuals to perform complex tasks such as problem-solving, reasoning, and comprehension. In the context of mathematics, WM is particularly crucial as it supports the mental processes required to understand and apply numerical concepts.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

Several studies have underscored the pivotal role of WM in numerical processing and arithmetic tasks. For instance, Yang and Yu (2021) investigated the connection between mental rotation and arithmetic, revealing that WM is critical in number line estimation and place-value concept acquisition. Their findings suggested that students with stronger WM are better equipped to handle complex arithmetic tasks, as they can hold and manipulate numerical information more effectively. Similarly, Coulanges et al. (2021) demonstrated that inhibitory control, a component of WM, is closely linked to mathematical achievement, particularly in tasks that involve comparing conflicting decimal numbers. These studies collectively highlighted the significance of WM in facilitating numerical processing and underscored the necessity of enhancing WM to improve mathematical performance.

From a developmental perspective, the relationship between the number concept and WM evolves as children progress through different educational stages. Ma et al. (2024), Ali et al. (2024), and Yoong (2023) explored the number sense-arithmetic link in early elementary grades, emphasizing the importance of WM in developing arithmetic fluency. Their research indicated that students with better-developed WM in Grades 1 and 2 tend to perform more efficiently in arithmetic tasks, which is crucial for their overall mathematical development. This developmental trajectory aligns with the findings of Gehlot (2021), who discussed the role of cognitive development, particularly within the Zone of Proximal Development (ZPD), in enhancing WM and numerical understanding. Gehlot's research suggested that targeted ZPD interventions can significantly improve WM and number concepts, providing a strong foundation for later mathematical learning.

Theoretical models and cognitive frameworks have been instrumental in understanding the interplay between the number concept and WM. Peltokorpi and Jaber (2022) proposed an interference-adjusted power learning curve model that incorporates the role of forgetting in the learning process. Their model suggested that the interaction between WM and the number concept is dynamic, with the capacity of WM influencing the retention and retrieval of numerical information over time. This model is supported by the work of Qu et al. (2024), who examined rational number representation through the Approximate Number System (ANS). Their research highlighted the role of WM in rational number processing, suggesting that students with stronger WM can better represent and manipulate rational numbers, leading to improved mathematical reasoning.

Gender differences in the relationship between WM and the number concept have also been explored, with some studies indicating that these differences can influence mathematical performance. Danan and Ashkenazi (2022) investigated the influence of sex on the relationship between spatial ability, math anxiety, and math performance. Their findings suggested that while WM is a critical factor in mathematical performance for both sexes, the interaction between math anxiety and WM may differ between males and females. This potentially leads to different educational outcomes. This research underscored the significance of considering gender when designing interventions to enhance WM and number concepts.

The insights gained from these studies have significant implications for educational practice, particularly in designing interventions to enhance WM and number concepts. Wong and Law (2023) explored the potential of non-linguistic cognitive stimulation in improving cognitive and linguistic functions in individuals with aphasia. Although their study focused on a different population, the underlying principles of cognitive stimulation can be applied to educational settings to enhance WM and number concepts in students. Similarly, the work of Hu et al.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064
(2022) on neurocognitive feedback during design brainstorming suggested that providing real-time cognitive feedback can sustain cognitive processes. Accordingly, it could be adapted to educational interventions to improve WM and numerical processing in students.

The relationship between the number concept and WM is complex and multifaceted, with significant implications for educational practice and cognitive development. The targeted interventions enhance WM and the number concept (Qu et al., 2024). Thus, future research should continue to explore these relationships, with a particular focus on developing effective educational strategies that can support students in overcoming cognitive challenges and achieving mathematical proficiency

In conclusion, the literature consistently underscores the integral role of WM in developing and applying numerical concepts. Whether through its direct influence on arithmetic fluency, its role in supporting complex numerical representations, or its interaction with other cognitive functions like inhibitory control, WM emerges as a critical component of mathematical cognition. The studies reviewed here comprehensively understand the multifaceted relationship between the number concept and WM, offering valuable insights for educational practice and cognitive intervention.

Research Question

Research Questions (RQ) are crucial in a Systematic Literature Review (SLR) since they provide the foundation and direction for the entire review process. They guide the scope and focus of the SLR, helping to determine which studies to include or exclude, ensuring that the review remains relevant and specific to the topic of interest. A well-defined RQ ensures that the literature search is exhaustive and systematic, covering all relevant studies that address key aspects of the topic. This minimizes the risk of bias and ensures a complete overview of the existing evidence. Additionally, RQs facilitate the categorization and organization of data from included studies, providing a framework for analyzing findings and synthesizing results to draw meaningful conclusions. They also enhance clarity and focus, avoiding ambiguity and keeping the review concentrated on specific issues, making the findings more actionable and relevant. Furthermore, well-formulated RQs contribute to the transparency and reproducibility of the review, allowing other researchers to follow the same process to verify findings or extend the review to related areas. Ultimately, RQs ensure that the review aligns with the overall objectives of the study, whether it is to identify gaps in the literature, evaluate the effectiveness of interventions, or explore trends in a specific field, making them the backbone of a rigorous, focused, and relevant SLR.

Specifying the RQs is the most important activity at the planning stage. However, it is also a crucial part of any SLR, as it drives the entire review methodology (Kitchenham, 2007). This is considering that the goal of our SLR is to identify and analyze the state of the art. The PICo framework is a mnemonic style used to formulate RQs, particularly in qualitative research. PICo stands for Population, Interest, and Context. Here is what each component means:

1. **Population (P):** This refers to the group or participants of interest in the study. It specifies who the research is focused on, such as a specific demographic, patient group, or community.
2. **Interest (I):** This represents the main focus or phenomenon of interest in the study. It could be a particular experience, behavior, intervention, or issue that the research aims to explore or understand.

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

3. **Context (Co):** This defines the setting, environment, or specific context in which the population and interest are situated. It might refer to geographical location, cultural or social settings, or any other relevant backdrop for the research.

Using the PICo framework helps structure RQs clearly and systematically by breaking down the key elements of the study into these three components. This approach ensures that the research is focused and the questions are well-defined, making searching for relevant literature or designing a study easier.

Based on an advanced searching strategy on the Scopus database for the title "Exploring the Relationship between Number Concept and WM in Education," we discovered and developed three themes, which are (1) WM and its role in Mathematic and cognitive skills, (2) numeracy, number sense, and Mathematic achievement, and (3) cognitive function Learning Disability (LD). Based on themes and using the mnemonics style by PICo, please develop two RQs.

1. How does WM influence the development of mathematical cognitive skills in primary school students with LDs?
2. To what extent do early number sense and numeracy skills predict mathematics achievement in early childhood educational programs?

Material and methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework is a highly regarded standard for conducting SLRs, ensuring the process is transparent, thorough, and consistent. By adhering to PRISMA guidelines, researchers are systematically directed to identify, screen, and include relevant studies in their review, which in turn enhances the precision and rigor of the analysis. This methodology also highlights the significance of randomized studies, recognizing their role in minimizing bias and providing solid evidence for the review.

For this analysis, three essential databases, Scopus, Science Direct, and ERIC, were selected due to their robustness and extensive coverage. Scopus provides a broad index of peer-reviewed literature across multiple disciplines. Science Direct specializes in life sciences research, and ERIC focuses on education. However, it is essential to acknowledge that no database is without limitations. Note that each has potential shortcomings, such as incomplete coverage or varying levels of detail, which should be considered during the review process.

The PRISMA approach is further structured into four significant sub-sections: identification, screening, eligibility, and data abstraction. Identification involves searching databases to find all relevant studies, followed by screening, where studies are assessed against predefined criteria to exclude irrelevant or low-quality research. The eligibility phase further evaluates the remaining studies to ensure they meet the criteria for inclusion. Finally, data abstraction involves extracting and synthesizing data from the included studies, which is crucial for drawing meaningful and reliable conclusions. This structured approach ensures that the systematic review is conducted with high rigor, producing reliable results that can inform further research and practice.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

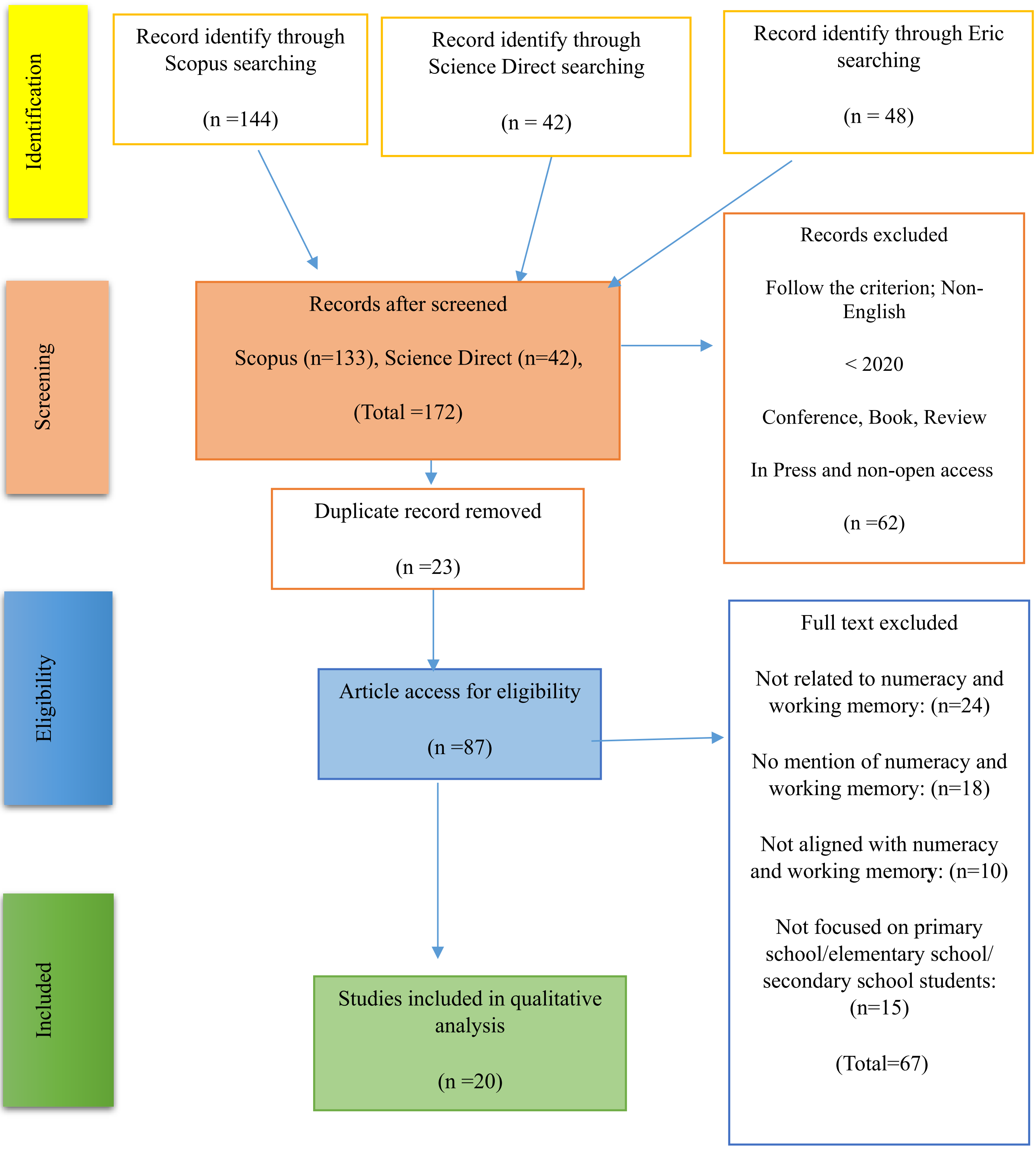

Figure 2. Flow Diagram Of The Proposed Search Study

Source: (Moher D, Liberati A, Tetzlaff J, 2009)

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

Identification

In this study, key steps of the systematic review process were utilized to gather a substantial amount of relevant literature. The process began with selecting keywords and searching for related terms using dictionaries, thesauri, encyclopedias, and prior research. All relevant terms were identified, and search strings were created for the Scopus, Eric, and Science Direct databases (refer to Table 1). This initial phase of the systematic review yielded 234 publications from the three databases pertinent to the study topic.

Table 1: The Search String

Scopus	TITLE-ABS-KEY ((implement* OR approach) AND "Flip* Classroom*" AND education AND technology) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "ENGI")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2024)) **Date of Access: August 2024**
Eric	("number concept" OR "number sense" OR "numeracy" OR "arithmetic skill" AND "working memory" OR "visual-spatial" OR "short-term memory") **Date of Access: August 2024**
ScienceDirect	("number concept" OR "number sense" OR "numeracy" OR "arithmetic skill" AND "working memory" OR "visual-spatial" OR "short-term memory") **Date of Access: August 2024**

Screening

During the screening step, potentially relevant research items are evaluated to ensure they align with the predefined RQ(s). This phase often involves selecting research items based on the number concept and WM. Duplicate papers are removed at this stage. Initially, 172 publications were excluded, leaving 62 papers for further examination based on specific inclusion and exclusion criteria (see Table 2). The first criterion was literature, as it is the main source of practical recommendations, including reviews, meta-syntheses, meta-analyses, books, book series, chapters, and conference proceedings not covered in the most recent study. The review was limited to English-language publications from 2020 to 2024. Overall, 23 publications were rejected due to duplication.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

Table 2: The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2020 – 2024	< 2022
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject	Social science, Psychology	Besides Social science and Psychology

Eligibility

In the third step, known as the eligibility phase, 87 articles were prepared for review. During this stage, the titles and key content of all articles were carefully examined to ensure they met the inclusion criteria and aligned with the current research objectives. Consequently, 67 data/papers/articles were excluded as they did not qualify due to the out-of-field, title not significantly, abstract not related to the study's objective, and no full-text access founded on empirical evidence. As a result, a total of 20 articles remain for the upcoming review.

Data Abstraction and Analysis

An integrative analysis was used as one of the assessment strategies in this study to examine and synthesize various research designs (quantitative methods). The goal of the competent study was to identify relevant topics and subtopics. Note that the data collection stage was the first step in developing the theme. Figure 2 displays how the authors meticulously analyzed a compilation of 20 publications for assertions or material relevant to the topics of the current study. Consequently, the authors evaluated the current significant studies related to the number concept. The methodology used in all studies, as well as the research results, are being investigated. Next, the author collaborated with other co-authors to develop themes based on the evidence in this study's context. In addition, a log was kept throughout the data analysis process to record any analyses, viewpoints, riddles, or other thoughts relevant to the data interpretation. Finally, the authors compared the results to observe any inconsistencies in the theme design process. It is worth noting that if there are any disagreements between the concepts, the authors discuss them amongst themselves.

The produced themes were eventually tweaked to ensure consistency. The analysis selection was performed by two experts, one in early childhood and special education and the other in mathematics, to determine the validity of the problems. The expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity**.**

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

Result and Finding

From the selected article, the results of all the articles are written below.

Table 3: Background Of Selected Study

No	Authors	Title	Year	Journal	Scopus	Science Direct	Eric
1	Hamidi F.; Soleymani S.; Dazy S.; Meshkat M.	Teaching Mathematics based on Integrating Reading Strategies and Working Memory in Elementary School	2024	Athens Journal of Education	/		
2	Gaye F.; Groves N.B.; Chan E.S.M.; Cole A.M.; Jaisle E.M.; Soto E.F.; Kofler M.J.	Working Memory and Math Skills in Children With and Without ADHD	2024	Neuropsychology	/	/	
3	Shvartsman M.; Shaul S.	The Role of Working Memory in Early Literacy and Numeracy Skills in Kindergarten and First Grade	2023	Children	/		/
4	Muñez D.; Lee K.; Bull R.; Khng K.H.; Cheam F.; Rahim R.A.	Working Memory and Numeracy Training for Children With Math Learning Difficulties: Evidence From a Large-Scale Implementation in the Classroom	2022	Journal of Educational Psychology	/		
5	Stanford E.; Delage H.	Complex syntax and working memory in children with specific learning difficulties	2020	First Language	/		/
6	Passiatore Y.; Costa S.; Grossi G.; Carrus G.; Pirchio S.	Mathematics self-concept moderates the relation between cognitive functions and mathematical skills in primary school children	2024	Social Psychology of Education	/	/	
7	Frolli A.; Cerciello F.; Esposito C.; Ricci M.C.; Laccone R.P.; Bisogni F.	Universal Design for Learning for Children with ADHD	2023	Children	/		/

International Journal of Education, Psychology and Counseling IJEPC
EISSN : 0128-164X
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

No	Authors	Title	Year	Journal	Scopus	Science Direct	Eric
8	Bonifacci P.; Trambagioli N.; Bernabini L.; Tobia V.	Home activities and cognitive skills in relation to early literacy and numeracy: testing a multifactorial model in preschoolers	2022	European Journal of Psychology of Education	/		/
9	Charitaki G.; Alevriadou A.; Soulis S.-G.	Early numeracy profiles in young children with intellectual disabilities: The role of cognitive functions	2024	Journal of Intellectual Disabilities	/	/	
10	Lunardon M.; Decarli G.; Sella F.; Lanfranchi S.; Gerola S.; Cossu G.; Zorzi M.	Low discriminative power of WISC cognitive profile in developmental dyscalculia	2023	Research in Developmental Disabilities	/		
11	Santos S.; Cordes S.	Math Abilities in Deaf and Hard of Hearing Children: The Role of Language in Developing Number Concepts	2021	Psychological Review	/		
12	Zhou H.; Tan Q.; Ye X.; Miao L.	Number sense: the mediating effect between nonverbal intelligence and children's mathematical performance	2022	Psicologia: Reflexao e Critica	/	/	
13	Kroesbergen E.H.; Huijsmans M.D.E.; Friso-van den Bos I.	A Meta-Analysis on the Differences in Mathematical and Cognitive Skills Between Individuals With and Without Mathematical Learning Disabilities	2023	Review of Educational Research	/		
14	Lira C.J.; Pando E.V.B.; García D.S.P.; Susperreguy M.I.; Gardea L.C.P.; Fernández F.M.	Early symbolic numeracy and gross, fine, and perceptual-motor skills in Mexican preschool children; [Habilidades numéricas simbólicas y motricidad gruesa, fina y perceptivo-	2024	Retos	/	/	

International Journal of Education, Psychology and Counseling IJEPC
EISSN : 0128-164X
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

		motoras en niños preescolares mexicanos]					
No	Authors	Title	Year	Journal	Scopus	Science Direct	Eric
15	Maldonado Moscoso P.A.; Castaldi E.; Arrighi R.; Primi C.; Caponi C.; Buonincontro S.; Bolognini F.; Anobile G.	Mathematics and Numerosity but Not Visuo-Spatial Working Memory Correlate with Mathematical Anxiety in Adults	2022	MDPI	/	/	
16	Yang X.; Zhang X.; Huo S.; Zhang Y.	Differential contributions of cognitive precursors to symbolic versus non-symbolic numeracy in young Chinese children	2020	Early Childhood Research Quarterly	/		/
17	Ma M.; Likhanov M.; Zhou X.	Number sense-arithmetic link in Grade 1 and Grade 2: A case of fluency	2024	British Journal of Educational Psychology	/		/
18	Cui J.; Xiao R.; Ma M.; Yuan L.; Cohen Kodash R.; Zhou X.	Children skilled in mental abacus show enhanced non-symbolic number sense	2022	Current Psychology	/	/	
19	Harrison A.G.; Beal A.L.; Armstrong I.T.; Gallagher A.	Measurement of Working Memory on the Wechsler Adult Intelligence Scale: Should We Subtract Arithmetic?	2024	Psychological Injury and Law	/	/	
20	Lopez J.; Behrman J.; Cueto S.; Favara M.; Sánchez A.	Late-childhood foundational cognitive skills predict educational outcomes through adolescence and into young adulthood: Evidence from Ethiopia and Peru	2024	Economics of Education Review	/		/

Source: Scopus, Science-direct, and Eric

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

The produced themes were eventually tweaked to ensure consistency. The analysis selection was conducted by three experts, two in special education and the other in mathematics, to determine the validity of the problems. The expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity.

The authors also compared the findings to resolve discrepancies in the theme-creation process. Note that if any inconsistencies in the themes arose, the authors addressed them with one another. Finally, the developed themes were tweaked to ensure their consistency. To ensure the validity of the problems, two experts performed the examinations, one specializing in education and the other in psychology. The expert review phase helped ensure each sub-theme's clarity, importance, and adequacy by establishing domain validity. Consequently, adjustments based on feedback and expert comments have been made at the author's discretion.

Theme 1: Working Memory and Its Role in Mathematical and Cognitive Skills

WM is a cognitive system responsible for temporarily holding and manipulating information, and it plays a crucial role in both mathematical and cognitive skills. The significance of WM in mathematical proficiency is well-documented, with various studies highlighting its impact on different aspects of learning and performance. For instance, the study by Gaye et al. (2024) emphasized the role of WM in mathematical skills among children with and without Attention Deficit–Hyperactivity Disorder (ADHD). The research discovered that WM components, including the central executive, phonological short-term memory, and visuospatial short-term memory, significantly influence math skills, explaining 56% of the variance in children's math achievement. This finding aligns with the study by Shvartsman and Shaul (2023), who examined the relationship between WM and early numeracy skills in kindergarten and first-grade students. The study highlighted the stronger contribution of complex WM in mathematical tasks. Furthermore, Hamidi et al. (2024) demonstrated that integrative teaching methods incorporating WM can enhance basic math skills, particularly in problem-solving, although arithmetic skills may remain unaffected. Together, these studies underscored the critical role of WM in various mathematical domains, with implications for typical and atypical developmental trajectories.

The relationship between WM and mathematical learning difficulties has also been extensively studied. Muñez et al. (2022) explored the effectiveness of WM and numeracy training in children with math learning difficulties, discovering that while numeracy skills improved with intervention, WM did not demonstrate significant gains, likely due to insufficient training dosage. This suggests that while WM is crucial for mathematical learning, the effectiveness of interventions may depend on the intensity and duration of the training. The study by Stanford and Delage (2020) further elaborated on the connection between WM and learning difficulties, particularly in children with Specific Learning Disorders (SLD). They discovered that WM limitations in these children affect numeracy and language development, particularly in processing complex syntactic structures. This highlights the broader cognitive implications of WM deficits, extending beyond mathematics to other academic areas, thus necessitating a holistic approach to intervention strategies.

The intricate relationship between WM and Mathematical Anxiety (MA) also provides insight into how cognitive processes interact with emotional factors. The study by Maldonado Moscoso et al. (2022) investigated the link between MA, WM, and numerosity perception, revealing that while MA negatively affects math performance and numerosity estimation, it is not directly related to visuospatial WM capacities. This finding suggested that MA primarily

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

affects mathematical skills by diminishing WM resources rather than directly resulting from WM deficits. Such insights are crucial for understanding the cognitive underpinnings of MA and for developing interventions that address both cognitive and emotional factors in mathematical learning.

In summary, the literature consistently supports the pivotal role of WM in mathematical and cognitive skills, with significant implications for educational practices and interventions. The reviewed studies highlight the ways WM contributes to math proficiency, from supporting basic numeracy and problem-solving skills to interacting with emotional factors like MA. Notably, interventions that enhance WM, particularly when integrated with numeracy training, show promise in improving mathematical outcomes. However, the success of such programs depends on factors such as training intensity and the specific components of WM targeted. As research unravels the complexities of WM's role in cognitive development, it becomes increasingly clear that addressing WM deficits is essential for supporting typical and atypical learners in achieving mathematical success.

Theme 2: Numeracy, Number Sense, and Mathematical Achievement

Numeracy, a fundamental skill in early childhood education, is closely tied to cognitive precursors such as visual-spatial skills and WM. Yang et al. (2020) examined these relationships in young Chinese children, finding that visual-spatial skills significantly predicted non-symbolic numerical skills. In contrast, phonological short-term memory predicted symbolic numerical skills. These findings suggest that different cognitive skills contribute to various aspects of numeracy, underscoring the significance of early identification and support in these areas. Moreover, the study by Bonifacci et al. (2022) added that verbal WM and inhibition are critical cross-domain predictors for early numeracy, emphasizing the interconnectedness of cognitive development and numeracy. These results align with the work of Zhou et al. (2022), who discovered that number sense acts as a mediator between nonverbal intelligence and mathematical performance, further highlighting the complex interplay between cognitive skills and numeracy.

The concept of number sense, which refers to an intuitive understanding of numbers and their relationships, has been widely recognized as a critical predictor of mathematical achievement. Zhou et al. (2022) demonstrated that number sense significantly mediates the relationship between nonverbal intelligence and children's mathematical performance, suggesting that developing number sense is crucial for mathematical success. This finding is echoed by Ma et al. (2024), who indicated that number sense contributes to arithmetic tasks even when other cognitive factors are controlled for, with the relationship between number sense and arithmetic becoming more pronounced as children gain formal mathematics education. These studies collectively indicated that number sense is foundational for early mathematical skills and evolves with educational experience, making it a key target for educational interventions.

Recent research has also explored the role of motor skills in numeracy development, with Lira et al. (2024) examining the connection between symbolic numeracy and various motor skills in Mexican preschool children. The study discovered that while numeracy precursor skills predict applied problem-solving, perceptual-motor skills are significant predictors of symbolic number comparison. This suggests that motor skills, particularly those related to perception, are integral to the development of certain aspects of numeracy. These findings complement earlier research by Cui et al. (2022), who suggested that children skilled in mental abacus, a practice requiring fine motor coordination and visual-spatial processing, exhibit enhanced non-

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

symbolic number sense. Together, these studies highlighted the significance of integrating motor skills development into early numeracy education, particularly for tasks involving symbolic number understanding.

Developmental Dyscalculia (DD) poses significant challenges in educational psychology, particularly concerning its diagnosis and differentiation from other LDs. Lunardon et al. (2023) investigated the utility of the Wechsler Intelligence Scale for Children (WISC) cognitive profiles in identifying DD. However, they discovered that these profiles have low discriminative power. The study revealed that cognitive profiles, particularly those involving verbal comprehension and perceptual reasoning, did not reliably distinguish between children with DD and those without. This suggests that domain-general cognitive abilities may not be as pivotal in DD as previously thought. This finding contrasts with the earlier work by Ma et al. (2024), who supported the "fluency hypothesis" that number sense contributes to simple arithmetic tasks, even when domain-general cognitive factors are accounted for. The disparity in these findings underscores the complexity of DD and the need for more refined diagnostic tools that can accurately capture the unique cognitive deficits associated with the disorder.

The development of numeracy and literacy skills in early childhood is also influenced by environmental factors, as evidenced by the work of Bonifacci et al. (2022). This study assessed a multifactorial model in preschoolers, finding that home numeracy activities and verbal WM significantly predict early numeracy skills. The study suggested that a stimulating home environment enriched with numeracy activities can bolster the cognitive skills necessary for early mathematical development. This aligns with the findings of Yang et al. (2020), who highlighted the importance of cognitive precursors in numeracy, indicating that both cognitive and environmental factors must be considered in early childhood education.

Theme 3: Cognitive Functions, Learning Disabilities, and Academic Achievement

This theme investigates the impact of cognitive functions and LDs on academic achievement, with a particular focus on special populations such as children with ADHD, intellectual disabilities, and DD.

The interrelation between cognitive functions, LDs, and academic achievement is a well-examined topic in educational psychology. Cognitive functions, such as WM, inhibitory control, and long-term memory, have been recognized as critical determinants of academic success. For instance, Lopez et al. (2024) discovered foundational cognitive skills measured at age 12, including WM and long-term memory, were consistently associated with subsequent domain-specific cognitive achievement tests in Ethiopia and Peru. Their study underscored the persistent influence of these cognitive abilities on educational outcomes, including numeracy, vocabulary, and literacy achievement. This evidence aligns with findings by Passiatore et al. (2024), who reported that WM and mathematics self-concept significantly predicted mathematical abilities in primary school children. Such studies collectively highlight the essential role of cognitive functions in academic performance across different contexts.

LDs, particularly Mathematical Learning Disabilities (MLDs), are closely tied to deficits in specific cognitive skills. Kroesbergen et al. (2023) conducted a meta-analysis revealing that individuals with MLDs consistently exhibit lower scores in mathematics, number sense, WM, and rapid automatized naming compared to typically developing peers. These findings are critical as they provide a comprehensive overview of the cognitive profiles associated with MLDs, emphasizing the heterogeneity of these disabilities. Similarly, Charitaki et al. (2024)

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064
identified distinct early numeracy profiles among young children with intellectual disabilities, further illustrating the variability in cognitive and numerical skills within this population. The variations in cognitive function observed in children with LDs underline the necessity for targeted interventions to support their academic achievements.

The academic challenges faced by children with ADHD further demonstrate the complex interplay between cognitive functions and learning outcomes. Frolli et al. (2023) emphasized the importance of individualized educational approaches, such as Universal Design for Learning (UDL), in addressing the learning difficulties associated with ADHD. Their study discovered that UDL interventions significantly improved basic learning skills, including reading, writing, and arithmetic. These findings suggested that tailored educational strategies that accommodate the cognitive strengths and weaknesses of children with ADHD can effectively enhance their academic performance. Furthermore, the significance of such interventions is also supported by the work of Passiatore et al. (2024), who highlighted the protective role of self-concept in mathematical learning, indicating that cognitive and affective factors must be considered in educational practices.

The relationship between cognitive functions and academic achievement is also evident in studies focusing on Deaf and Hard-of-Hearing (DHH) children. Santos and Cordes (2021) explored how limited language access, particularly in the early months of life, can delay the acquisition of number concepts in DHH children, leading to persistent difficulties in mathematics. Their research highlighted the potential impact of lower WM capacity observed in some DHH children on early numerical learning and task performance. This suggests that interventions aimed at enhancing cognitive functions, particularly WM, could mitigate the academic challenges faced by DHH students, paralleling the findings in populations with MLDs and ADHD.

In summary, the literature consistently indicates that cognitive functions are crucial in academic achievement, particularly among students with LDs. The studies reviewed demonstrate that deficits in cognitive skills such as WM, inhibitory control, and number sense are closely linked to LDs, affecting academic performance. Note that interventions tailored to these cognitive profiles, such as UDL for children with ADHD or targeted support for DHH children, have shown promise in improving educational outcomes. Accordingly, these findings underscore the significance of integrating cognitive and educational psychology to develop effective strategies for supporting students with LDs.

Discussion and Conclusion

The relationship between WM and mathematical skills is multifaceted, influencing various aspects of cognitive development and mathematical achievement. WM, a cognitive system responsible for temporarily holding and manipulating information, is integral to mathematical proficiency. Research consistently highlights that WM components, including central executive and short-term memory, significantly contribute to math skills across different developmental stages. These findings underline the significance of WM in typical and atypical developmental trajectories, particularly in children with learning difficulties, such as ADHD and SLD. Furthermore, the effectiveness of interventions aimed at improving mathematical skills through WM training appears to be contingent on the intensity and duration of the training. While WM is crucial for mathematical learning, improvements in numeracy following intervention do not always coincide with significant gains in WM, suggesting a need for more robust training methods. Additionally, WM limitations have broader cognitive implications,

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

affecting language development and other academic areas. This emphasizes the necessity for comprehensive intervention strategies that address multiple cognitive domains.

MA presents another layer of complexity in understanding the interaction between cognitive and emotional factors in mathematical learning. While MA negatively impacts math performance, it does not directly relate to visuospatial WM capacities, indicating that MA diminishes WM resources rather than being caused by WM deficits. This insight is crucial for developing interventions that address both cognitive and emotional aspects of mathematical learning. In early childhood, numeracy is closely tied to cognitive precursors such as visual-spatial skills and WM, with different cognitive skills contributing to various aspects of numeracy. Thus, early identification and support for these cognitive skills are essential for fostering mathematical development. Moreover, number sense, an intuitive understanding of numbers and their relationships, is a key predictor of mathematical achievement. At the same time, the development of number sense is crucial for mathematical success and becomes more pronounced with formal education, making it a significant focus for educational interventions.

Motor skills also play a vital role in numeracy development, particularly in symbolic number understanding tasks. Research suggests that perceptual-motor skills are significant predictors of symbolic number comparison, highlighting the importance of integrating motor skills development into early numeracy education. The diagnosis of DD remains challenging, as traditional cognitive profiles have low discriminative power in identifying DD. This suggests that domain-general cognitive abilities may not be as critical in DD as previously thought, indicating a need for more refined diagnostic tools that accurately capture the unique cognitive deficits associated with the disorder.

Lastly, environmental factors, particularly home numeracy activities, significantly influence the development of numeracy and literacy skills in early childhood. A stimulating home environment enriched with numeracy activities can enhance cognitive skills necessary for early mathematical development. This highlights the importance of considering both mental and environmental factors in early childhood education to support optimal numeracy and literacy development.

Acknowledegment
The authors would like to express our gratitude to everyone who supported us in the completion of this article. In addition, no potential conflict of interest was reported by the author(s).

References

Abouzahra, A., Sabraoui, A., & Afdel, K. (2020). Model composition in Model Driven Engineering: A systematic literature review. Information and Software Technology, 125, 106316. https://doi.org/10.1016/j.infsof.2020.106316
Ali, N. S. M., Fauzi, M. A., Saidin, N., Nor, N. R. M., Ismail, N. F. S., & Aling, N. A. (2024). Adoption of e-learning by pre-university students following the COVID-19 pandemic: An analysis based on the unified theory of acceptance and use of technology (UTAUT). International Review of Education, 70(3), 453–475. https://doi.org/10.1007/s11159-023-10046-6
Allen, K., Giofrè, D., Higgins, S., & Adams, J. (2021). Using working memory performance to predict mathematics performance 2 years on. Psychological Research, 85(5), 1986–1996. https://doi.org/10.1007/s00426-020-01382-5

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064
Bonifacci, P., Trambagioli, N., Bernabini, L., & Tobia, V. (2021). Home activities and cognitive skills in relation to early literacy and numeracy: Testing a multifactorial model in preschoolers. Early Childhood Research Quarterly, 56, 101-113. https://doi.org/10.1016/j.ecresq.2020.12.010

Charitaki, G., Alevriadou, A., & Soulis, S.-G. (2021). Early numeracy profiles in young children with intellectual disabilities: The role of cognitive functions. International Journal of Disability, Development and Education, 68(4), 482-496. https://doi.org/10.1080/1034912X.2019.1699290

Coulanges, L., Abreu-Mendoza, R. A., Varma, S., Uncapher, M. R., Gazzaley, A., Anguera, J., & Rosenberg-Lee, M. (2021). Linking inhibitory control to math achievement via comparison of conflicting decimal numbers. Cognition, 214. https://doi.org/10.1016/j.cognition.2021.104767

Cui, J., Xiao, R., Ma, M., Yuan, L., Cohen Kadosh, R., & Zhou, X. (2024). Children skilled in mental abacus show enhanced non-symbolic number sense. British Journal of Educational Psychology, 94(1), 1-19. https://doi.org/10.1111/bjep.12693

Dalmaijer, E. S., Gibbons, S. G., Bignardi, G., Anwyl-Irvine, A. L., Siugzdaite, R., Smith, T. A., Uh, S., Johnson, A., & Astle, D. E. (2021). Direct and indirect links between children's socio-economic status and education: Pathways via mental health, attitude, and cognition. Developmental Science, 24(6), e13149. https://doi.org/10.1111/desc.13149

Danan, Y., & Ashkenazi, S. (2022). The influence of sex on the relations among spatial ability, math anxiety and math performance. Trends in Neuroscience and Education, 29. https://doi.org/10.1016/j.tine.2022.100196

Eteng-Uket, S. (2021). The development, validation, and standardization of a new tool: The Dyscalculia Test. International Journal of Educational Research, 109, Article 101847. https://doi.org/10.1016/j.ijer.2021.101847

Frolli, A., Cerciello, F., Esposito, C., Ricci, M. C., Laccone, R. P., & Bisogni, F. (2021). Universal Design for Learning for children with ADHD. Journal of Education and Learning, 10(4), 23-30. https://doi.org/10.5539/jel.v10n4p23

Gaye, F., Groves, N. B., Chan, E. S. M., Cole, A. M., Jaisle, E. M., Soto, E. F., & Kofler, M. J. (2021). Working memory and math skills in children with and without ADHD. Journal of Attention Disorders, 25(9), 1226-1236. https://doi.org/10.1177/1087054719877984

Gehlot, L. (2021). Cognitive development by Zone of Proximal Development (zpd) Gettier problem & corpus linguistics in epistemology. Journal of Education Culture and Society, 12(2), 432 – 444. https://doi.org/10.15503/jecs2021.2.432.444

Harrison, A. G., Beal, A. L., Armstrong, I. T., & Gallagher, A. (2021). Measurement of working memory on the Wechsler Adult Intelligence Scale: Should we subtract arithmetic? Applied Neuropsychology: Adult, 28(5), 477-485. https://doi.org/10.1080/23279095.2019.1606635

Hu, M., Shealy, T., Milovanovic, J., & Gero, J. (2022). Neurocognitive feedback: A prospective approach to sustain idea generation during design brainstorming. International Journal of Design Creativity and Innovation, 10(4), 311-329. https://doi.org/10.1080/21650349.2021.1976678

Huwaina, N., & Lotfi, R. (2022). WORLD CONFERENCE AND INNOVATION WCIECE 2021 | A U G U S T 7 - 8. April

Kitchenham, B. (2007). Guidelines for performing systematic literature reviews in software engineering. Technical Report, Ver. 2.3 EBSE Technical Report. EBSE.

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064
Kok, M. (2012). Grammatical terminology as a tool: On the tense system and the ergonomics of its teaching practices in l2-finnish. Lahivordlusi Lahivertailuja, 22, 101–130. https://doi.org/10.5128/LV22.04

Kroesbergen, E. H., Huijsmans, M. D. E., & Friso-van den Bos, I. (2022). A meta-analysis on the differences in mathematical and cognitive skills between individuals with and without mathematical learning disabilities. Educational Research Review, 35, Article 100401. https://doi.org/10.1016/j.edurev.2021.100401

Liu, C., Chung, K. K. H., & Tang, P. M. (2022). Contributions of orthographic awareness, letter knowledge, and patterning skills to Chinese literacy skills and arithmetic competence. Journal of Educational Psychology, 114(5), 976-989. https://doi.org/10.1037/edu0000662

Lopez, J., Behrman, J., Cueto, S., Favara, M., & Sánchez, A. (2024). Late-childhood foundational cognitive skills predict educational outcomes through adolescence and into young adulthood: Evidence from Ethiopia and Peru. Developmental Psychology, 60(2), 322-335. https://doi.org/10.1037/dev0001459

Lira, C. J., Pando, E. V. B., García, D. S. P., Susperreguy, M. I., & Gardea, L. C. P. (2021). Early symbolic numeracy and gross, fine, and perceptual-motor skills in Mexican preschool children. Early Childhood Research Quarterly, 57, 215-226. https://doi.org/10.1016/j.ecresq.2021.07.002

Lunardon, M., Decarli, G., Sella, F., Lanfranchi, S., Gerola, S., Cossu, G., & Zorzi, M. (2021). Low discriminative power of WISC cognitive profile in developmental dyscalculia. Journal of Learning Disabilities, 54(3), 196-209. https://doi.org/10.1177/0022219420965955

Ma, M., Likhanov, M., & Zhou, X. (2024). Number sense-arithmetic link in Grade 1 and Grade 2: A case of fluency. British Journal of Educational Psychology, 94(1), 144-162. https://doi.org/10.1111/bjep.12693

Mad Amin, A., Tahar, M., & Zakaria, A. (2020). Mathematical Learning Approach for Special Education Pupils: The Effectiveness of Mauselis Board in Improving Adding Skills. Journal of ICSAR, 4(2), 1–6.

Maldonado Moscoso, P. A., Castaldi, E., Arrighi, R., Primi, C., Caponi, C., Buonincontro, S., & Anobile, G. (2021). Mathematics and numerosity but not visuo-spatial working memory correlate with mathematical anxiety in adults. Frontiers in Psychology, 12, Article 734546. https://doi.org/10.3389/fpsyg.2021.734546

Muñez, D., Lee, K., Bull, R., Khng, K. H., Cheam, F., & Rahim, R. A. (2021). Working memory and numeracy training for children with math learning difficulties: Evidence from a large-scale implementation in the classroom. Journal of Educational Psychology, 113(6), 1058-1070. https://doi.org/10.1037/edu0000644

Nelwan, M., Friso-van den Bos, I., Vissers, C., & Kroesbergen, E. (2022). The relation between working memory, number sense, and mathematics throughout primary education in children with and without mathematical difficulties. Child Neuropsychology, 28(2), 143–170. https://doi.org/10.1080/09297049.2021.1959905

Oppenheimer, K. E., Lee, J., Huang, Y. T., & Ratner, N. B. (2023). Decontextualized utterances contain more typical and stuttering-like disfluencies in preschoolers who do and do not stutter. Journal of Speech, Language, and Hearing Research, 66(3), 871-885. https://doi.org/10.1044/2023_JSLHR-23-00173

O'Toole, S. E., Monks, C. P., Tsermentseli, S., & Rix, K. (2022). The contribution of cool and hot executive function to academic achievement, learning-related behaviors, and classroom behavior. Journal of Educational Psychology, 114(2), 368-383. https://doi.org/10.1037/edu0000658

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064
Qu, C., Clarke, S., Luzzi, F., & Brannon, E. (2024). Rational number representation by the approximate number system. Cognition, 250. https://doi.org/10.1016/j.cognition.2024.105839

Passiatore, Y., Costa, S., Grossi, G., Carrus, G., & Pirchio, S. (2021). Mathematics self-concept moderates the relation between cognitive functions and mathematical skills in primary school children. Learning and Individual Differences, 86, Article 101958. https://doi.org/10.1016/j.lindif.2020.101958

Peltokorpi, J., & Jaber, M. Y. (2023). Impact of knowledge sharing on employee learning: A longitudinal study in primary education. Journal of Learning and Instruction, 82, Article 101749. https://doi.org/10.1016/j.learninstruc.2021.101749

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. Learning and Individual Differences, 20(2), 110–122. https://doi.org/10.1016/j.lindif.2009.10.005

Rodríguez, C., Rodríguez-Álvarez, M., & Luque, J. L. (2023). Home numeracy environment and parental involvement in homework predict mathematical achievement. Learning and Individual Differences, 102, Article 102066. https://doi.org/10.1016/j.lindif.2023.102066

Shvartsman, M., & Shaul, S. (2023). The Role of Working Memory in Early Literacy and Numeracy Skills in Kindergarten and First Grade. Children, 10(8). https://doi.org/10.3390/children10081285

Silverman, S., & Ashkenazi, S. (2022). The differential relationship between visual and spatial working memory in children's mathematics performance. Trends in Neuroscience and Education, 29(March), 100188. https://doi.org/10.1016/j.tine.2022.100188

Siugzdaite, R., Bignardi, G., Uh, S., Van Bochove, M. E., Astle, D. E., & Dalmaijer, E. S. (2022). The structure of working memory and its relationship with academic skills in children. Journal of Learning and Individual Differences, 88, Article 102020. https://doi.org/10.1016/j.lindif.2021.102020

Stelzer, F., & Vashlishan Murray, A. (2022). The role of executive function in the relationship between language skills and mathematics achievement. Journal of Cognitive Development, 23(2), 218-234. https://doi.org/10.1080/15248372.2022.1826564

Viesel-Nordmeyer, N., Röhm, A., Starke, A., & Ritterfeld, U. (2022). How language skills and working memory capacities explain mathematical learning from preschool to primary school age: Insights from a longitudinal study. PLoS ONE, 17(6 June). https://doi.org/10.1371/journal.pone.0270427

Wang, S., Ci, C., Cui, Y., & Li, J. (2022). The association of executive function and math ability in young children: The mediating role of visual working memory and patterning skills. Cognitive Development, 63, Article 101202. https://doi.org/10.1016/j.cogdev.2022.101202

Wilson, C., Wozney, L., Jibb, L. A., & Lucas, K. (2021). Systematic review of knowledge translation outcomes related to mathematical learning difficulties in elementary school students. Educational Psychology Review, 34, 1-38. https://doi.org/10.1007/s10648 -021-09630-4

Wong, W. W.-S., & Law, S. P. (2023). Can non-linguistic cognitive stimulation enhance the cognitive and linguistic functions of people with aphasia receiving conversation therapy? Preliminary findings. Aphasiology, 37(9), 1456 –1483. https://doi.org/10.1080/02687038.2022.2096873

Yang, X., & Yu, X. (2021). The relationship between mental rotation and arithmetic: do number line estimation, working memory, or place-value concept matter? British

Volume 9 Issue 55 (September 2024) PP. 947-967
DOI 10.35631/IJEPC.955064

Journal of Educational Psychology, 91(3), 793 – 810. https://doi.org/10.1111/bjep.12403

Yoong, S. M. (2023). Design and Development of Basic Arithmetic Skills (Bas) Module for Pupils With Dyscalculia Symptoms.

Zuilkowski, S. S., Bhana, P., Ssentongo, R. A., van der Westhuizen, C., & Jukes, M. C. H. (2021). Literacy and numeracy acquisition in refugee settings: Evidence from Uganda. International Journal of Educational Development, 87, Article 102473. https://doi.org/10.1016/j.ijedudev.2021.102473