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# Cognitive Capacity and Numeracy Development: A Bibliometric Analysis of the Interdisciplinary Literature

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**Abstract:** *This bibliometric analysis explores the interdisciplinary literature on cognitive capacity and numeracy development, using data from the Scopus database to examine articles published between 2020 and 2024. The study aims to uncover trends, collaborative patterns, and thematic focuses within this critical research area. Methodologically, the analysis employed a systematic review of publication data, highlighting a steady increase in research output during the study period, driven by heightened global awareness and policy initiatives emphasizing the importance of numeracy in cognitive development. The results indicate a peak in research activity in 2024, with more than 50 publications, reflecting the growing interdisciplinary collaboration between fields such as education, psychology, and neuroscience. This upward trajectory underscores a collective effort to advance understanding and practice in numeracy development. The study concludes that the consistent growth in research output signifies increasing recognition of numeracy's foundational role in individual and societal progress. It calls for sustained interdisciplinary efforts, expanded policy support, and longitudinal research to address persistent gaps, ensuring continued advancements in understanding cognitive capacity and numeracy development.*

**Keywords:** numeracy, working memory, cognitive capacity, short-term memory, mathematic

## 1. Introduction

The connection between cognitive capacity and numeracy development has gained prominence as a critical topic of interdisciplinary inquiry. Numeracy, defined as the capability to interpret and manipulate numerical information, is integral to success in education, health, and economic engagement. At its foundation, numeracy is closely linked with cognitive processes like working memory, executive control, as well as attention. To understand this dynamic interplay, it is essential to synthesize knowledge from disciplines like psychology, neuroscience, and education. This paper leverages bibliometric analysis to explore the interdisciplinary literature, uncovering trends and highlighting gaps in this rapidly evolving research domain.

Cognitive capacity is increasingly recognized as a fundamental driver of numerical abilities across different stages of life. Research indicates that working memory significantly influences mathematical reasoning and problem-solving (Smith et al., 2020). Likewise, executive functions are vital for planning and performing numerical operations, making them indispensable for both academic and practical outcomes in numeracy (Jones et al., 2021). Despite the growing body concerning research, much of it remains siloed within specific

disciplines, limiting opportunities for the development of comprehensive, integrative models that could bridge theoretical and methodological divides.

Bibliometric methodologies provide a systematic framework for mapping the scope and evolution of research in this area, identifying leading fields, recurring themes, and collaborative networks. Psychology is the dominant contributor, reflecting its focus on cognitive and behavioral aspects of numerical skill development. Neuroscience complements these insights by examining the neural processes underlying numerical cognition. Simultaneously, education and the social sciences contribute valuable perspectives on the societal and pedagogical influences shaping numeracy. The findings underscore the importance of interdisciplinary approaches to fully address the complexities of the relationship between cognitive capacity and numeracy.

The analysis also points to several notable gaps and areas for growth. Fields such as computer science and engineering are underutilized despite their potential to transform research through computational modeling and machine learning applications. Similarly, limited representation from nursing and environmental sciences highlights missed opportunities to apply numeracy research to healthcare and sustainability challenges. Bridging these gaps would expand the impact of numerical cognition studies and encourage innovative interdisciplinary collaborations.

## 2. Literature Review

Cognitive capacity, which includes various cognitive abilities, including attention, working memory, as well as executive functioning, are crucial in developing numeracy skills in children. Numerous studies have demonstrated that cognitive abilities are strong predictors of success in mathematics (Devlin et al., 2024). For example, research shows that children with greater working memory capacity generally excel in mathematical tasks, indicating a significant connection between cognitive processes and numeracy (Peng et al., 2016). Executive functions (EFs), encompassing skills like cognitive flexibility, inhibitory control, and working memory, are fundamental to early numeracy development. Fuhs et al. (2014) emphasize that EFs not only correlate with mathematical abilities but also act as mediators between early cognitive skills and later mathematical performance. This suggests that improving EFs in preschool-aged children could enhance their numeracy outcomes.

Linguistic abilities, especially vocabulary and phonological awareness, are crucial factors that affect numeracy development. Research by Lin and Powell (2023) indicates that a child's vocabulary is a significant predictor of their early numeracy skills, highlighting the interconnectedness of language development and mathematical comprehension. This relationship points to the necessity of integrating language and numeracy education in early childhood settings. The Quantity-Number Competencies (QNC) model suggests that children develop early numeracy through a series of progressive developmental stages. Lin et al. (2023) performed a meta-analysis and discovered that linguistic skills positively influence QNC levels, particularly during the transition from basic numerical understanding to more advanced mathematical reasoning. This model offers a framework for understanding how various cognitive and linguistic elements contribute to numeracy.

Children with mathematics learning disabilities (MLD) often display unique cognitive profiles marked by deficits in specific cognitive areas. Ouyang et al. (2023) employed cognitive diagnostic models to categorize subtypes of MLD, revealing that different cognitive skills, like

working memory and spatial reasoning are differently linked to these subtypes. This classification can guide the development of targeted interventions customized to determine the unique needs concerning children with MLD. Socioeconomic status (SES) significantly influences cognitive development and, by extension, numeracy skills. Research indicates that children from low-income families often exhibit lower levels of executive function and numeracy skills compared to their more affluent counterparts (Devlin et al., 2024). This gap underscores the necessity for educational policies that address inequalities related to SES in cognitive and academic development.

Early intervention programs aimed at enhancing cognitive skills have demonstrated success in enhancing numeracy outcomes among at-risk populations. For instance, studies suggest that interventions designed to boost executive function can lead to substantial improvements in early mathematics skills (Fuchs et al., 2010). These findings highlight the critical opportunity presented during early childhood to cultivate cognitive skills that support numeracy development.

Gender differences in cognitive abilities and their impact on numeracy have also been a focus of research. Studies indicate that while boys and girls may perform similarly in early numeracy, variations in specific cognitive skills, such as spatial reasoning, can later affect their mathematical performance (Hutchison et al., 2019). Recognizing these differences can assist educators in customizing their teaching strategies to accommodate the diverse needs of all students. Parental involvement is another vital factor that influences children's cognitive and numeracy development. Research indicates that children whose parents participate in numeracy-related activities at home tend to achieve better outcomes in mathematics (McClelland et al., 2007). This finding emphasizes the importance of creating a home environment that nurtures cognitive development and numeracy skills.

In summary, the relationship between cognitive capacity and numeracy development is intricate and multifaceted. Future research should continue to investigate the various cognitive, linguistic, and environmental factors that contribute to numeracy skills, particularly among diverse populations. Additionally, longitudinal studies that assess the long-term impacts of early cognitive interventions on numeracy outcomes will be crucial for shaping educational practices and policies aimed at improve children's mathematical proficiency.

## 3. Research Questions

Cognitive capacity and numeracy development in scholarly research articles were examined through the five research questions (RQs) outlined below:

**RQ1**: What are the research trend cognitive capacity and numeracy according to the current of publication?
**RQ2** : What are the most affiliation publish in this research?
**RQ3 :** What are the top number subject area in this field?
**RQ4:** What are the popular keywords associated with the study?
**RQ5:** What are co-authorship countries' collaboration?

## 4. Methodology

Bibliometrics involves analyzing and managing scientific publication data. This includes basic statistics journals, authors, publication years and advanced techniques like co-citation analysis.

To conduct a robust literature review, researchers must iteratively identify keywords, search for relevant literature, and thoroughly analyze findings. This study prioritized top-tier publications from rigorously peer-reviewed journals indexed in the Scopus database, spanning the period from the year 2020 to December 2024, to ensure data reliability and focus on high-quality research within the field.

### 4.1 Data Searching Strategy

The research employed a systematic screening approach to determine the search terms with regard to retrieving articles. Consequently, the process started by querying the Scopus database using the following search criteria: TITLE ("working memory" OR "cognitive capacity" OR "short-term memory" OR "executive function" OR "mental storage") AND TITLE-ABS-KEY ("numeracy" OR "mathematical literacy" OR "quantitative reasoning" OR "numerical skills" OR "arithmetic proficiency") AND PUBYEAR > 2019 AND PUBYEAR < 2026, yielded a total of 448 articles. The search string was then refined to specifically target the terms “working memory” AND “cognitive capacity” in relation to students as learners. The final search string was TITLE ("working memory" OR "cognitive capacity" OR "short-term memory" OR "executive function" OR "mental storage") AND TITLE-ABS-KEY ("numeracy" OR "mathematical literacy" OR "quantitative reasoning" OR "numerical skills" OR "arithmetic proficiency") AND PUBYEAR > 2020 AND PUBYEAR < 2024 (LIMIT-TO (LANGUAGE, "English"). This refinement yielded 221 articles, which were subsequently employed for the bibliometric analysis. By December 2024, all articles from the Scopus database related to e-learning with a focus on students were included in the research.

**Table 1: Data search string**

| | |
|---|---|
| **Scopus** | TITLE-ABS-KEY ( "working memory" OR "cognitive capacity" OR "short-term memory" OR "executive function" OR "mental storage" ) AND TITLE-ABS-KEY ( "numeracy" OR "mathematical literacy" OR "quantitative reasoning" OR "numerical skills" OR "arithmetic proficiency" ) AND PUBYEAR > 2019 AND PUBYEAR < 2024 |

**Table 2: The selection criterion is searching**

| Criterion | Inclusion | Exclusion |
|---|---|---|
| **Language** | English | Non-English |
| **Timeline** | 2020 – 2025 | < 2020 |
| **Literature type** | Journal (Article) as well as Proceeding | Review, Book |

### 4.2 Data Analysis

VOSviewer refers to a user-friendly bibliometric software created by Nees Jan van Eck and Ludo Waltman at Leiden University in the Netherlands in 2019. It is widely used for visualizing and analyzing scientific literature, specializing in the creation of intuitive network visualizations, clustering associated items, as well as generating density maps. The software's flexibility enables researchers to assess co-citation, co-authorship, as well as keyword co-occurrence networks, offering a detailed perspective on research landscapes. Its interactive interface and frequent updates support dynamic as well as efficient exploration of extensive datasets. Moreover, VOSviewer's ability to customize visualizations, calculate metrics, as well as integrate with diverse bibliometric data sources makes it an essential tool for scholars aiming to gain insights into complex research domains.

A standout feature of VOSviewer is its capability to transform complex bibliometric datasets into visually comprehensible maps and charts. Other than that, the software excels in network visualization, clustering related items, analyzing keyword co-occurrence patterns, as well as

creating density maps. Its intuitive interface caters to both novice and experienced researchers, enabling seamless exploration of research landscapes. Ongoing updates ensure that VOSviewer remains a leader in bibliometric analysis, allowing valuable insights through metric computation as well as customizable visualizations. Furthermore, its flexibility in handling various bibliometric data types, for example, citation networks as well as co-authorship, makes VOSviewer an indispensable and versatile tool concerning scholars aiming to gain deeper insights and meaningful understanding within their research fields.

Datasets comprising citations, journal, author name, title, publication year, as well as keywords concerning PlainText format were sourced from the Scopus database, spanning the period from 2020 to December 2024. Consequently, these datasets were assessed utilising VOSviewer software version 1.6.19. Through VOS clustering as well as mapping techniques, the software allowed the analysis and creation regarding visual maps. Unlike the Multidimensional Scaling (MDS) method, VOSviewer positions items in low-dimensional spaces to ensure that the proximity between items precisely resembles their similarity as well as relatedness. While MDS primarily calculates similarity metrics like cosine and Jaccard indices, VOSviewer employs a more suitable normalization technique for co-occurrence frequencies, known as association strength (ASij), calculated using the following formula:

$$ASij = Cij / (Wiwj)$$

This formula represents the ratio of the observed co-occurrences with regard to items i and j to the expected co-occurrences, assuming that i as well as j are statistically independent (Van Eck & Waltman, 2010, p. 531). Given this index, VOSviewer positions items on a map by minimizing the weighted sum concerning squared distances between all item pairs. According to Appio et al. (2016), the LinLog/modularity normalization method was applied. Additionally, VOSviewer's visualization techniques demonstrated patterns based on mathematical relationships, facilitating analyses, for example, co-citation analysis, citation analysis, as well as keyword co-occurrence.

Keyword co-occurrence analysis is a valuable tool for examining the evolution with regard to research areas over time (Zhao, 2017) and is successful in identifying trending topics across various fields (Li et al., 2016). Subsequently, citation analysis plays a crucial role in uncovering key research issues, trends, and methodologies, as well as assessing the historical importance concerning a discipline's core focus (Allahverdiyev & Yucesoy, 2017). Note that document co-citation analysis, is widely used in bibliometric studies (Fahimnia et al., 2015; Liu et al., 2015; Appio et al., 2016). The results are dependent on network theory to assess the relevant structure concerning the data (Liu et al., 2015).

## 5. Result and Finding

In order to offer valuable insights and enhance the contributions of this study, it is essential to address the questions presented at the beginning of this paper within the findings and discussion section. These six questions are centered on the exploration of cognitive capacity and numeracy research, as well as the identification of patterns and performance trends within this field.

### 5.1 What are the research trend cognitive capacity and numeracy according to the current of publication?

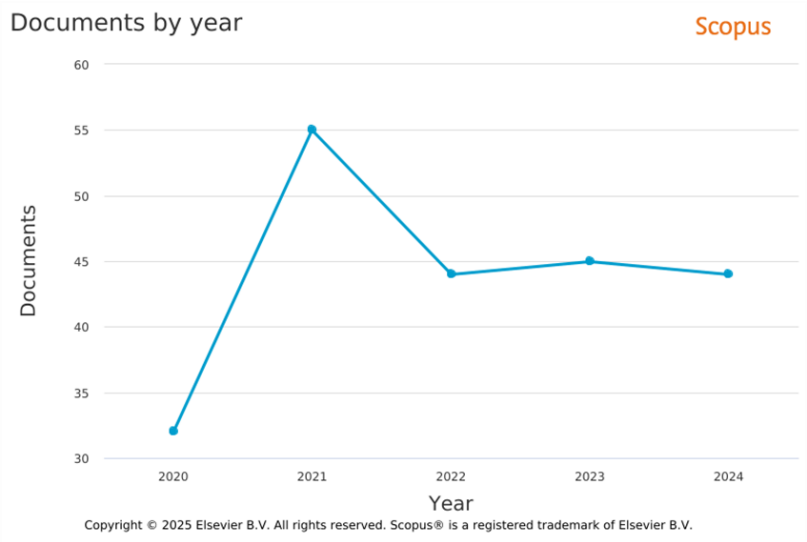


**Figure 1: Plotting document publication per years**

Figure 1 depicts the data derived from the Scopus analysis, indicating a consistent rise in research output from 2020 to 2024. The number of documents nearly doubled, increasing from approximately 30 in 2020 to nearly 60 in 2024. This upward trajectory suggests a growing academic landscape, likely influenced by global factors such as enhanced research funding, interdisciplinary collaboration, and advancements in technology. The significant growth may also correlate with major global events, including post-pandemic recovery, which has stimulated increased research activity in areas such as health, technology, and sustainability.

However, this quantitative expansion prompts important considerations regarding the quality and impact of the research produced. Issues such as predatory publishing and redundancy may artificially inflate publication counts. While the trend reflects a vibrant academic environment, it is crucial to uphold high standards of research quality and ethical practices to ensure that these outputs make meaningful contributions to science and society.

One potential explanation for this increase is the growing popularity of the journal among researchers. This could be attributed to several factors, including an increasing impact factor, an enhanced reputation, or a focus on emerging and relevant research topics. Alternatively, the rise in published documents may simply reflect a broader increase in research activity within the journal's field. Factors such as increased funding for research, the development of innovative research methodologies, and the growing significance of the field may all contribute to this trend.

It is also plausible that both factors are influencing the surge in document submissions. The journal's rising popularity may attract more submissions from researchers, while the expanding body of research in the field simultaneously leads to an increase in contributions. Regardless of the underlying reasons, it is evident that the journal is gaining traction among researchers, which is a positive indicator of its role and significance within the academic community.

### 5.2 What are the most affiliation publish in this research?

In recent years, analysis examines trends in institutional contributions to this evolving field, highlighting leading contributors, emerging participants, and the global distribution of research efforts. By investigating these patterns, we may establish a more detailed understanding with regard to the factors driving institutional leadership as well as the widespread interest in leveraging mobile learning for art education. The findings offer valuable intelligence into the collaborative potential as well as interdisciplinary nature of this research area, which is poised to shape the future of creative education worldwide.

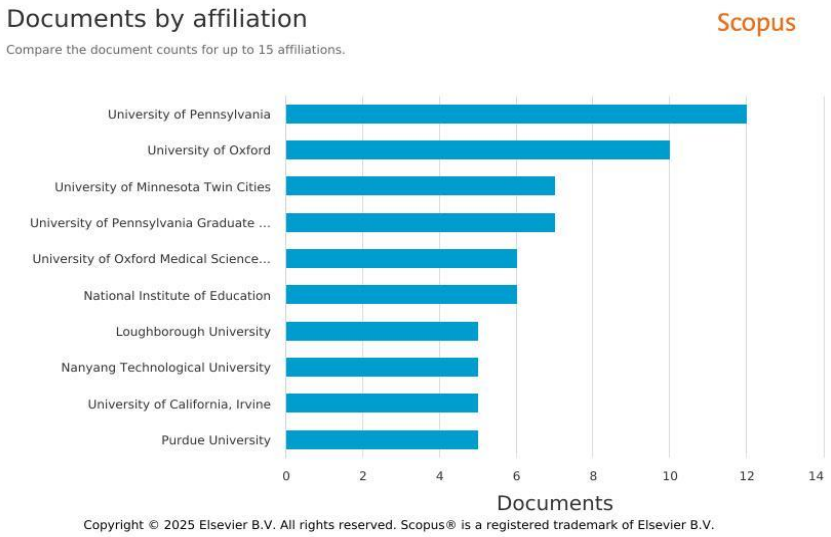


**Figure 2: Most published affiliation in cognitive capacity and numeracy development**

The analysis of document counts reveals a the figure presents a comparative analysis of document counts across 10 affiliations, likely extracted from the Scopus database. The University of Pennsylvania stands out with the highest document count, followed closely by the University of Oxford. The remaining affiliations show varying levels of output, with Purdue University exhibiting the lowest count. This visualization suggests potential disparities in research productivity or publication activity among these institutions.

**Table 3: Most affiliation publish in cognitive capacity and numeracy**

| AFFILIATION | No. of publication |
|---|---|
| University of Pennsylvania | 12 |
| University of Oxford | 10 |
| University of Minnesota Twin Cities | 7 |
| University of Pennsylvania Graduate School of Education | 7 |
| University of Oxford Medical Sciences Division | 6 |
| National Institute of Education | 6 |
| Loughborough University | 5 |
| Nanyang Technological University | 5 |
| University of California, Irvine | 5 |
| Purdue University | 5 |
| University of Toronto | 5 |
| Macquarie University | 5 |
| University of Maryland, College Park | 5 |
| New York University | 5 |
| University College London | 5 |

Further analysis could involve investigating the document types (articles, conference papers, etc.), publication dates, and citation metrics to develop a more thorough understanding of the research output and impact of each affiliation. Additionally, considering the research areas and disciplinary strengths of each institution could provide valuable insights into the factors contributing to their document counts.

The figure offers a preliminary overview of document counts across 10 affiliations. However, a more comprehensive analysis is required to draw meaningful conclusions about research performance and impact. The figure was likely obtained through a Scopus search query, possibly using keywords related to the affiliations or research areas. The discussion focuses on the relative document counts, highlighting the top-performing institutions and those with lower output. It acknowledges the need for further analysis to understand the factors influencing these differences. Potential avenues for future research include examining publication trends over time, comparing citation metrics, and investigating the disciplinary focus of each institution.Overall, the analysis provides a starting point for understanding research output across the selected affiliations. Further investigation is necessary to draw more robust conclusions and gain deeper insights into the research landscape.

### 5.3 What are the top number subject area in this field?

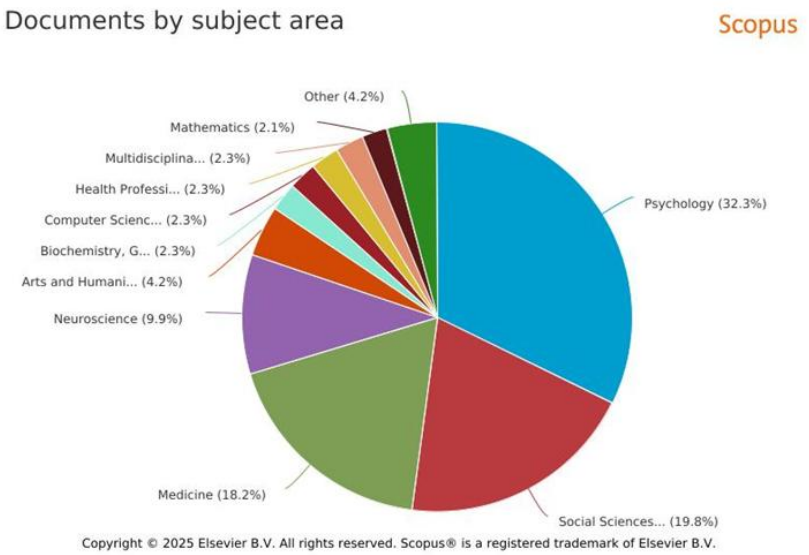


**Figure 3: Number of top subject area in research**

The pie chart provides a visual representation of the distribution with regard to documents across various subject areas. A notable finding is the significant prevalence of Psychology, which comprises a substantial 34.6% of the total documents. Following closely is Social Sciences at 20.5%, while Medicine accounts for 17.7%. Other significant fields include Neuroscience (9.0%), Arts and Humanities (4.2%), and Biochemistry, Genetics, and Molecular Biology (2.5%). The remaining subject areas, such as Computer Science, Multidisciplinary studies, and Health Professions, make up a smaller share of the overall document count. This visualization indicates that the research landscape is heavily weighted towards psychology, social sciences, and medicine, with other disciplines being less prominent.

The analysis depicted in the chart emphasizes the relative proportions of documents within each subject area. The predominance of Psychology prompts inquiries into the reasons behind this concentration. Is it a result of higher research output in this field, a stronger focus on

publishing in Psychology journals, or a combination of these factors? Further investigation could involve analyzing publication trends over time, comparing citation metrics across different disciplines, and exploring the research funding landscape to achieve a deeper understanding of the factors shaping the observed distribution

### 5.4 What are the popular keywords associated with the study?

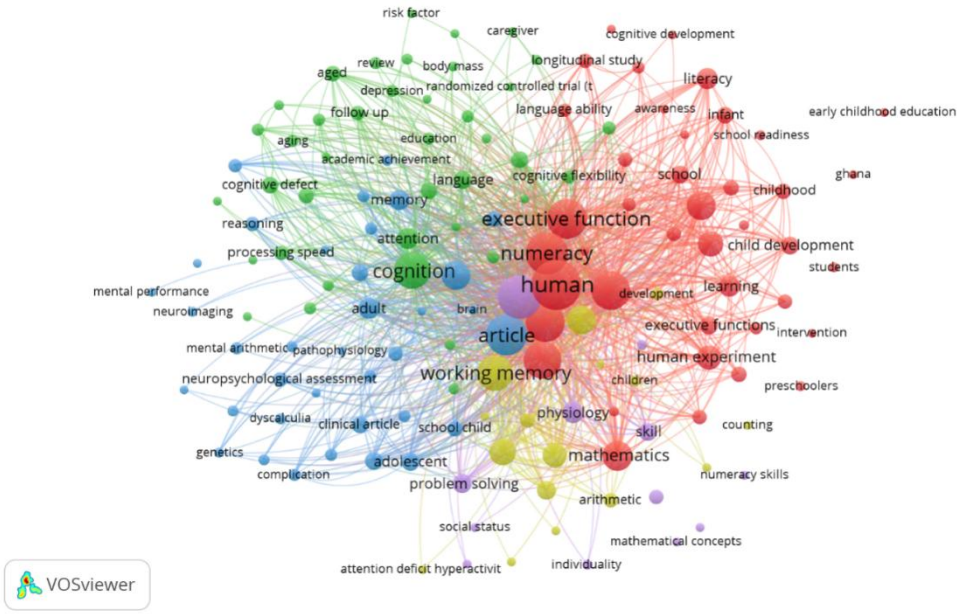


**Figure 4: Network visualization map regarding keywords' co-occurrence**

This VOSviewer map visualizes the co-occurrence of keywords within a corpus of research literature, likely focusing on the cognitive development of children. The network structure reveals interconnected clusters of concepts, highlighting prominent themes and research areas. At the core of the map is the term "human," signifying the central focus on human development. Branching out from this are several key clusters:

- **Cognitive Development & Executive Function:** This cluster encompasses terms like "cognitive development," "executive function," "working memory," "attention," "language," and "learning." This indicates a significant focus on understanding the development and functioning of cognitive processes in children.
- **Early Childhood & Education:** This cluster includes terms such as "early childhood education," "school readiness," "childhood," and "preschoolers." This indicates a significant body of research on cognitive development within early childhood educational contexts.
- **Neurocognitive Function & Assessment:** This cluster connects terms like "brain," "neuroimaging," "neuropsychological assessment," and "mental performance." This suggests an interest in utilizing neuroimaging and assessment techniques to understand cognitive development.
- **Numeracy & Mathematical Skills:** This cluster groups terms like "numeracy," "mathematics," "arithmetic," and "mathematical concepts." This highlights research on the development of mathematical skills and their relationship with other cognitive abilities.

- **Risk Factors & Intervention:** This cluster includes terms like "risk factor," "intervention," and "attention deficit hyperactivity." This suggests research on identifying risk factors for developmental delays and exploring interventions to support healthy.

This VOSviewer map was likely generated using a text mining tool and a corpus of research articles related to child development. The analysis likely involved identifying and extracting keywords from the articles and then using VOSviewer to visualize the co-occurrence patterns among these keywords. The map provides a valuable overview of the key themes and research areas within the field of child development. The interconnected clusters reveal the complex interplay between cognitive processes, educational contexts, and neurocognitive factors.

### 5.5 What are co-authorship countries' collaboration?

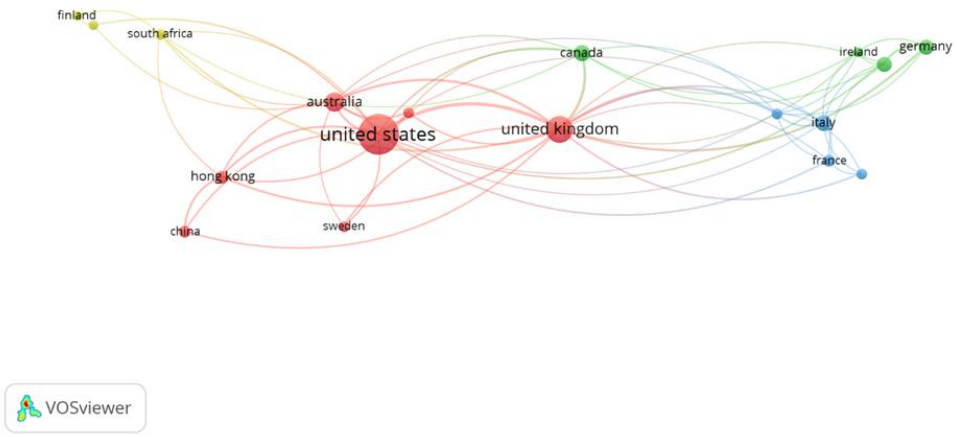


**Figure 5: Mapping of co-authorship country collaboration**

Figure 5 is a map that illustrates the co-authorship network between countries based on scientific publications. Secondly, the nodes' size reflects the publications' number, while the thickness of the edges indicates the frequency of collaborations between countries. The map reveals a global network of scientific collaborations, with several prominent hubs. The United States and United Kingdom stand out as major players, with numerous connections to other countries. Other active nodes include Canada, Australia, China, and several European countries like Germany, Italy, and France.

The network exhibits a clustered structure, suggesting regional collaborations are more common than global ones. For instance, there are strong connections within Europe and between North America and Europe. However, there are also notable intercontinental links, such as those between the US and Asia. The map provides a valuable overview of the global landscape of scientific collaborations. The prominent role of the US and UK highlights their influence in research. The clustering of countries suggests that regional collaborations may play a crucial role in driving scientific progress.

## 6. Conclusion

This bibliometric analysis of cognitive capacity and numeracy development reveals a complex and evolving research landscape that highlights the significant relationship between cognitive skills and mathematical achievement. The findings indicate a marked increase in scholarly output in recent years, reflecting a growing interest in understanding the influence of cognitive aspects like working memory, executive function, as well as attention impact numeracy skills across various educational contexts. The prominence of disciplines like psychology and social sciences suggests that established research groups and collaborative networks are actively contributing to advancements in this field.

While the quantitative growth in publications is encouraging, it raises important concerns regarding the quality and impact of the research produced. Issues such as predatory publishing and redundancy must be addressed to ensure that the contributions to the field are meaningful and ethically sound. The analysis also underscores the collaborative nature of this research area, with key researchers forming interconnected networks that foster innovative educational practices and interventions.

Looking ahead, future research should focus on exploring longitudinal trends to understand how collaborative patterns evolve and how they are influenced by factors such as funding and institutional support. Additionally, integrating citation analysis and co-authorship patterns will offer important perspectives on the dynamics of research collaboration and the emergence of interdisciplinary approaches. Overall, this study not only enables a detailed understanding with regard to the current landscape concerning research in cognitive capacity and numeracy development but also lays the groundwork for future inquiries aimed at enhancing mathematical outcomes in diverse educational settings

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