International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 1, February 2024, pp. 69~79
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i1.25992

Research trend on dyscalculia by bibliometric analysis during 2017-2022

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Article Info

Article history:

Received Nov 17, 2022
Revised Apr 18, 2023
Accepted May 14, 2023

Keywords:

Bibliometric analysis
Dyscalculia
Grade
Patient
Research trend
Task

ABSTRACT

Dyscalculia is the inability to perform simple numerical calculations in everyday life. However, no one has researched this topic worldwide in about two years. This study aimed to investigate the research trends on dyscalculia through bibliometric studies and research issues related to dyscalculia in the Scopus database starting 2017 to October 2022. The sample consisted of 536 total documents. The results showed that scientific publications on dyscalculia fluctuated. In the next five years, its movements cannot be predicted. The highest number of document types is articles, which is 369. The number of cross-border documents from 2017 to 2022 is in the United States, as many as 75 papers, and in Italy, 74 copies. These two countries are more dominant on the topic of dyscalculia. Furthermore, 536 documents comprising 94.4% of articles were used in English. In general, in research on dyscalculia, researchers produce four out of five significant clusters: patient, approach, task, and grade. However, topics related to dyscalculia and mathematics often studied are deficit students, deficit addition and subtraction, mathematics difficulty, instruction, and primary school. The results can be used to shed light on developing tendencies in dyscalculia investigations and suggest directions for future studies.

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1. INTRODUCTION

Mathematical literacy ability is an ability everyone must own because it determines the success of life [1]. Numerical skills and basic arithmetic are part of the mathematical literacy needed to make decisions in everyday life. However, dyscalculia disorders hurt school, daily life, and work [2], [3]. Dyscalculia is students' difficulty learning mathematics due to not understanding the four basic operations of integers since elementary school: addition, subtraction, multiplication, and division.

When traced back, there is a possibility of misunderstanding and incorrect number recognition. Furthermore, it is due to the need for more attention and assistance from parents to children as early as possible. Dyscalculia is the inability of students to operate simple integers, sorting the values of integers, fractions, decimals, and percentages [4]–[6]. Dyscalculia is often referred to as dyscalculia disorder; Students with dyscalculia have memory problems because they struggle to understand math [7]. One of the factors causing dyscalculia disorders is right hemisphere dysfunction which causes difficulties in understanding the nature of quantities, spatial learning problems, and using arithmetic knowledge to solve daily life problems.

In contrast, left hemisphere dysfunction causes difficulty in understanding the abstract meaning of numbers and sequences of numerical and mathematical operations [8]. Other contributing factors for dyscalculia are poor cognitive development, poor language development, neuropsychiatric problems, impaired cerebellar development, attention deficit hyperactivity disorder (ADHD), Asperger and Tourette syndrome, dyslexic difficulties in reading, and inappropriate teaching methods [9]. Students with dyscalculia disorders are considered students who cannot work on initial numerical problems [4]. As a result, this dyscalculia disorder is low arithmetic performance of students, and their achievement also decreases [10]. For this reason, dyscalculia disorders must be paid special attention to by many parties. These impacts with dyscalculia disorders, not easily understand and solve math problems [11]. Students with dyscalculia will find difficulties in doing tasks that involve numbers or mathematical symbols. Students with dyscalculia are unable to digest questions and carry out mathematical processes. Furthermore, the student with dyscalculia can impact education and employment. For example, students will experience financial difficulties and even find it difficult to get a job in the future.

Although dyscalculia disorders harm students in school, daily life, and work, there is very little scientific data on dyscalculia disorders from around the world. One of the literature study methods used by researchers is bibliometric analysis. Bibliometric analysis is an appropriate method to assess a paper's influence on the progression of science [12], [13]. Bibliometric barometers, including research area, paper source, publication output, language source, Country and institutional distribution, the first place of authors, the sum of citations, and keywords, have been frequently used to analyze trends [12].

This study analyzed trends in dyscalculia in 2017-2022 to help health, education, and psychology researchers understand the dyscalculia landscape globally. Through this study, researchers explored several parameters or interrelationships between variables in dyscalculia, such as dyscalculia related to gender, children, adolescents, dyslexia, learning, and mathematics, the most influential dyscalculia researchers. Thus, this study emphasizes research trends on dyscalculia during 2017-2022 with six investigation questions: i) What is the output of publications, documents, and language sources of dyscalculia in 2017-2022?; ii) To what extent is the distribution of dyscalculia publications across countries and institutions worldwide?; iii) Who was the first place of the author of dyscalculia worldwide?; iv) What is the publication pattern of dyscalculia based on the source's title?; v) How to visualize the results of dyscalculia research trends?; and vi) How to visualize the results of research trends in mathematics related to dyscalculia topics worldwide?

2. RESEARCH METHOD

This study uses the paper's literature and bibliometric analysis, providing a valuable reference experience on time ahead research [14]. The style bibliometrics was first coined by Pritchard [15], "hoping that it will be used explicitly in all studies seeking to measure the communication writing process and will rapidly gain acceptance in the information science field" [16]. Scopus Elsevier, the most crucial academic bibliography database in the world, was optimized by researchers. A fresh, more all-encompassing view of previously researched, timely material is vital in academic work. Bibliometric analysis [13], [17], [18] profiles will provide direction and movement of research activities worldwide.

"Dyscalculia" looks for titles, abstracts, and keywords from 2017 to 2022. The search strategy titles: TITLE-ABS-KEY ("dyscalculia") AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017)). The data was collected in October 2022. A total of 6,564 documents were searched all the time. However, only 1,409 copies met the search criteria from 2017 to October 25, 2022. After filtering by limiting the search time from 2017 to 2022 put operator and to keywords "dyscalculia and mathematics", 536 articles were obtained, which were further analyzed. In addition, descriptive analysis is employed to make sense of the data. The information was analyzed using Microsoft Excel. Physical characteristics of research output, paper source, language literature, distribution of countries and organizations, distribution of production in subject categories, the origin of authors, most-cited works, and research trends from 2017 to 2022 were all explored. The VoSViewer program was used to look for patterns in dyscalculia studies [19].

3. RESULTS AND DISCUSSION

3.1. Publication outputs, sources of the document, and sources of the language of dyscalculia

Figure 1 shows the number of studies related to dyscalculia six years later (2017-2022). The number of dyscalculia research documents in 2017-2018 was similar to 2021-2022. However, the number of dyscalculia research documents in 2019 has increased. There are 1,409 search documents related to dyscalculia throughout the year on Scopus Elsevier. The number of documents about dyscalculia in five years (2017-2022)

fluctuated. In 2017, there were 87 documents. In 2018, it became 91 documents; in 2019, it became 113 documents. In the period 2017-2019, there has been an increase. However, in 2020, the number of documents related to dyscalculia experienced a drastic decrease, namely 67 papers.

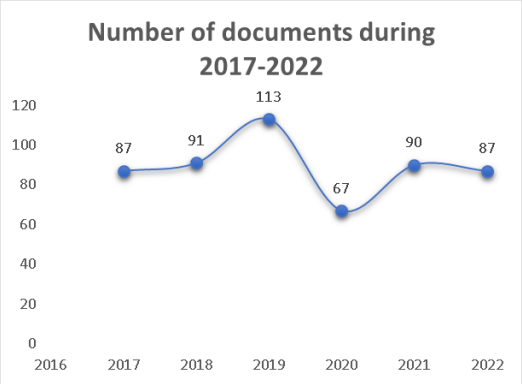

Figure 1. Number of documents during 2017-2022

Furthermore, in 2021 it will be 90 documents, and in 2022 it will be 87. Based on Figure 1, we cannot predict the number of dyscalculia documents in the next five years. Table 1 shows the number of papers based on their type. While the number of documents by type shows that the most types of articles in journals are 369 documents, this was followed by books, conference proceedings (48 papers), and a literature review (46 documents). Letter series 20 documents and book chapter 17 documents. Note 12 copies, nine editorial documents, six books and conferences each, and data paper only one document.

Table 1. Document type

No.	Document type	Number of documents
1	Article	369
2	Conference paper	48
3	Review	46
4	Letter	20
5	Book chapter	17
6	Note	12
7	Editorial	9
8	Book	6
9	Conference	6
10	Data paper	1

3.2. Distribution of dyscalculia publications across countries and institutions in the world

Table 2 shows the number of documents of dyscalculia a crosswise affiliation. The number of documents from 10 institutions or colleges is more than or equal to 9. The period for examining dyscalculia research documents is six years (2017-2022). The number of dyscalculia documents (2017-2022) across agencies is seen in Table 2. Italy seats three of its Affiliation in the world's top 10 that contribute the most to research on dyscalculia. They are Università Degli Studi di Padova in the first position with 16 documents, Università Degli Studi di Firenze in the fifth position with 12 documents, and Università di Trento in the eighth position with nine papers. France ranks second and sixth, namely Inserm, with 15 documents, and the Universite Paris-Saclay, with 11 articles. KU Leuven, Belgium, is in third place with 14 papers. Switzerland also places three representative institutions in the world's top 10, namely Kinderspital Zürich with 12 articles, Universität Zürich and ETH Zürich, with nine documents each. The Universidade Federal de Minas Gerais occupies Brazil's last position in the world's top 10 with nine papers.

Furthermore, from a total of 536 documents consisting of 506 (94.4%) articles, English was used as the language of the articles. Other documents are in German (1.5%), and 1.1% are in French. Other languages used in the paper and account for less than 1% are Spanish, Portuguese, Russian, Turkish, Chinese, Italian, and Japanese. So, English is the most widely used language in the dyscalculia document in the Scopus Elsevier database in the 2017-2022 period. The distribution of research documents related to dyscalculia in the last six years (2017-2022) can be seen in Figure 2.

Table 2. Number of documents of dyscalculia a crosswise affiliation

No.	Affiliation	Number of documents
1	Università degli Studi di Padova, Italia	16
2	Inserm, France	15
3	KU Leuven, Belgium	14
4	Kinderspital Zürich, Swiss	12
5	Università degli Studi di Firenze, Italia	12
6	Universite Paris-Saclay, France	11
7	Universität Zürich, Swiss	9
8	Università di Trento, Italia	9
9	ETH Zürich, Swiss	9
10	Universidade Federal de Minas Gerais, Brazil	9

Figure 2 shows the number of cross-border documents from 2017 to 2022 in the United States, with 75 documents, and in Italy, 74 papers. These two countries are more dominant on the topic of dyscalculia. Germany and the UK redounded to the dyscalculia topic with 58 and 40 articles, respectively. France and India have the same number of contributions, namely 30 documents. Meanwhile, Switzerland and Brazil contributed 29 and 28 documents, and China and Malaysia contributed 24 and 22 papers, respectively. Next, the number of keywords related to dyscalculia that appear the most in the 2017-2022 period is presented in Table 3.

As presented in Table 3, the keyword that appears the most is dyscalculia (411). Humans appear 311 times, and humans appear 221 times. Meanwhile, other keywords, such as female (195), male (183), article (174), child (151), dyslexia (136), adult (110), and mathematics appear 107 times. These are the top 10 keywords in the 2017-2022 period related to dyscalculia.

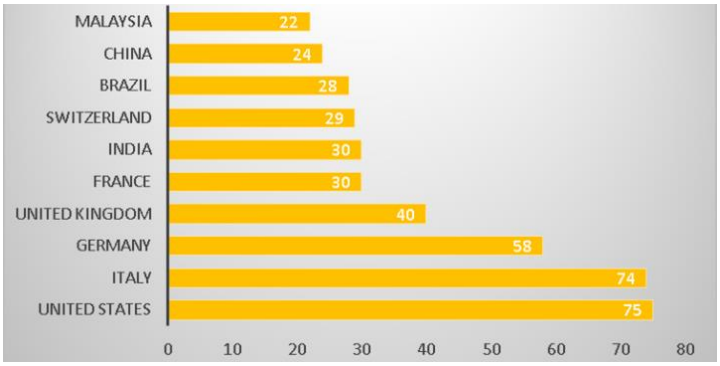

Figure 2. Number of documents of dyscalculia (2017-2022) across the country

Table 3. Keywords

No.	Keywords	Number of keywords
1	Dyscalculia	411
2	Human	311
3	Humans	221
4	Female	195
5	Male	183
6	Article	174
7	Child	151
8	Dyslexia	136
9	Adult	110
10	Mathematics	107

3.3. The top authors in research trend of dyscalculia in the world

Table 4 presents the top 10 authors, the number of documents they produced in the 2017-2022 period, and their country of origin. In terms of the most prolific authors, De Smedt and Kucian each had 10 documents, Haase nine documents, Anobile, and Carvalho, each had the same number, namely seven papers. Burr, Castaldi, Fuchs, Peters, and Santos, each have the same number, namely six documents. The authors are among the 10 most productive writers related to dyscalculia in 2017-2022. Based on Table 4, the most productive writer in the 2017-2022 period is De Smedt and Kucian. De Smedt from Belgium and Kucian from Switzerland are the first-place authors of dyscalculia in 2017-2022.

Table 4. First-place authors of dyscalculia (2017-2022) based on the number of documents

No.	Author	Number of documents	Country of origin
1	De Smedt	10	Belgia
2	Kucian	10	Swiss
3	Haase	9	Russia
4	Anobile	7	Italy
5	Carvalho	7	Brazil
6	Burr	6	Italy
7	Castaldi	6	Italy
8	Fuchs	6	United States
9	Peters	6	Canada
10	Santos	6	Ukraine

3.4. Dyscalculia publication pattern by source title

Table 5 shows the number of documents related to dyscalculia based on document sources and their number. The table describes the journals, records, or proceedings that contributed the most to publishing dyscalculia research. The journal that has contributed the most to publishing research results on dyscalculia is the "Journal of Learning Disabilities" with 31 documents. Meanwhile, "Lecture Notes in Computer Science, Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics", are the foremost lecture notes that record dyscalculia in their contents. Meanwhile, the leading handbook is the "International Handbook of Mathematical Learning Difficulties from The Laboratory to The Classroom", which writes about dyscalculia in its contents. The remaining journals are Frontiers in Psychology, Research in Developmental Disabilities, Brain Sciences, Frontiers in Human Neuroscience, Cortex, Neurological Sciences, and Neuropsychologia. Furthermore, Table 6 provides information regarding the five most cited article titles and authors from 2017 to 2022 by Peters and De Smedt [20] with 105 citations; Devine *et al*. [21] with 59; Szűcs and Goswami [22] with 56; Giofrè *et al*. [23] with (53); Nelson and Powell [24] with 49.

Table 5. Number of documents of dyscalculia (2017-2022) a crosswise source title

No.	Document sources	Number of documents
1	Journal of Learning Disabilities	31
2	Frontiers In Psychology	19
3	Research In Developmental Disabilities	12
4	Brain Sciences	10
5	Frontiers in Human Neuroscience	9
6	Cortex	7
7	Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	7
8	International Handbook of Mathematical Learning Difficulties from The Laboratory to The Classroom	6
9	Neurological Sciences	6
10	Neuropsychologia	6

Table 6. Most cited authors of articles

Study	Source	Number of citations
[20]	Developmental Cognitive Neuroscience	105
[21]	Journal of Educational Psychology	59
[22]	Trends in Neuroscience and Education	56
[23]	Journal of Learning Disabilities	53
[24]	Journal of Learning Disabilities	49

Table 7 shows the five most referenced paper titles and authors from 2017 to 2022. It can be seen that the author [25]–[29] of the dyscalculia document with the criteria of the top five citations in the 2017-2022 period. Based on Table 7, Peters and Ansari with 51 citations, Child *et al*. with 39 citations, and Zhang *et al*. with 33 citations. Next, Huin *et al*. with 28 citations, and Moll *et al*. with 26 citations.

Table 7. Top citation of the article in 2017-2022

Study	Source title	Number of citations
[25]	Trends in Neuroscience and Education	51
[26]	Journal of Learning Disabilities	39
[27]	Child Development	33
[28]	Brain	28
[29]	Journal of Child Psychology and Psychiatry and Allied Disciplines	26

3.5. Visualization of research tendencies on dyscalculia by using VoSViewer software

Visualization of the tendency of dyscalculia research using the VoSViewer software can be seen in Figures 3 to 8. As shown in Figure 3, there are five keyword clusters based on their color. Examples of keyword clusters colored Green are papers, learning, approaches, students, dyslexia, dysgraphia. Blue keyword clusters include diagnosis, patient, treatment, and features.

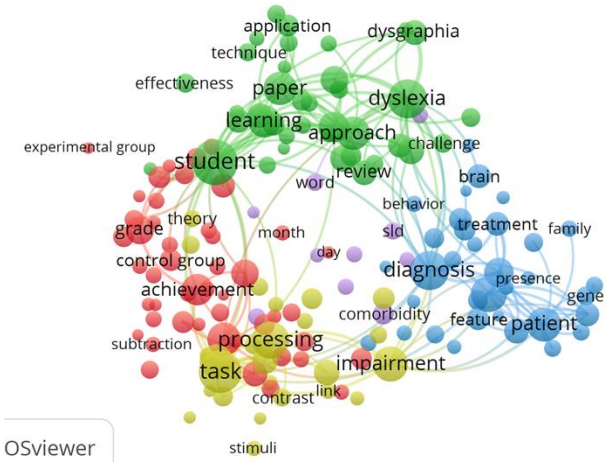

Figure 3. The whole picture of research on dyscalculia during 2017-2022

Next, examples of yellow color cluster keywords are processing, tasks, and distractions. Examples of red color cluster keywords are value, achievement, control group, and reduction. However, the purple color cluster is not closely related to other keywords, so it is not included in this discussion. Next, the density of research on dyscalculia in the previous six years (2017-2022) is depicted in Figure 4.

Among 2,075 documents correlated to the dyscalculia study in the Scopus Elsevier database, the research workers viewed trends on dyscalculia topics assisted by the VoSViewer application. This effort helps to discover new research in this domain. Figure 3 and Figure 4 show the overall picture of research on dyscalculia and the density of research on dyscalculia during 2017-2022. Researchers around the world produced five clusters. Four of the five clusters are potent clusters. The first cluster is patients as correlated to diagnosis, impairment and treatment. The second cluster is the approach related to dyslexia, student, learning and paper. The third cluster is a task connected to the processing, impairment, and achievement parameters. The fourth cluster is grades related to achievement, participant, and student.

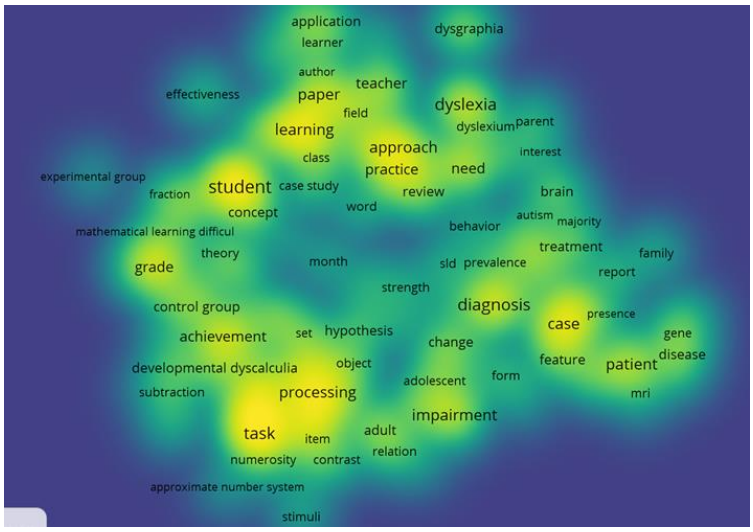

Figure 4. The whole picture of the density of research on dyscalculia during 2017-2022

Figure 5 provides dyscalculia research pertaining to the approach and its topics. Research about dyscalculia during 2017-2022 tends to be related to the approach. Syah *et al*. [30] research intervened in students with dyscalculia with repetition and number manipulation orientation. In addition, Amelia and Supena [31] stated that teachers use learning approaches to help dyscalculia students, namely the direct method, group approach, and individual approach. Verwimp *et al.* [32] described a new approach to dyslexia prevalence. However, Al-Makahleh [33] revealed that children with learning difficulties in fourth and fifth grade whose teachers used a direct instruction technique saw improvements in their fundamental skills success and their attitudes towards mathematics. Next, Figure 6 provides dyscalculia research on the processing and its topics.

Bowles [34] suggested the relationship between processing and impairment and Peters *et al*. [35] detailed the condition of children with dyslexia who present with reading difficulties. On the other hand, Rosenthal [36] described two model programs for high school and college students with learning disabilities. Furthermore, Figure 7 provides dyscalculia research related to developmental dyscalculia and its topics.

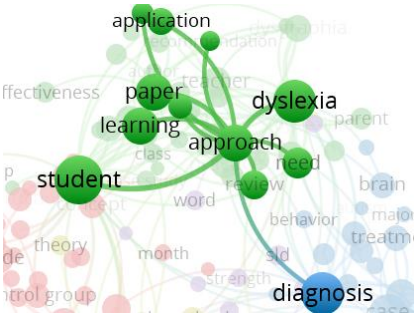

Figure 5. Dyscalculia research related to the approach

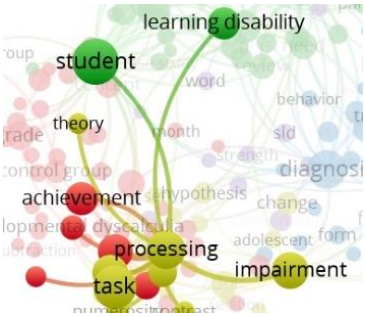

Figure 6. Dyscalculia research related to the processing

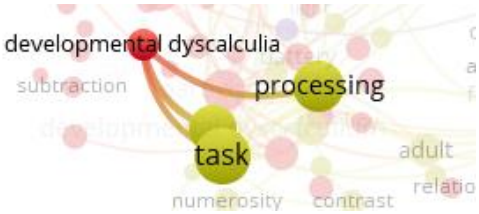

Figure 7. Dyscalculia research related to developmental dyscalculia

Kucian and von Aster [37] put forward the constraints and definitions related to developmental dyscalculia and the significance of taking dyscalculia's larger domain-general mechanisms into account during diagnosis and treatment [38]. According to Michels, Buechler, and Kucian [39], deficits in processing numerical and mathematical information characterize the developmental learning disorder known as developmental dyscalculia (DD). Furthermore, Kohn *et al*. [40] suggested that it is necessary to develop computer-based learning focusing on factors influencing individual responses. Again, Cárdenas *et al*. [41] stated that arithmetic processing in children with dyscalculia was measured using an arithmetic verification test recorded using event-related potential (ERP). Figure 8 provides research novelty in researching dyscalculia in three years (2020-2022).

If we detail the specific relationships between variables to capture trends and novelty in researching the topic of dyscalculia, we find several findings. The first is that in the last three years (2020-2022), no recent research related to dyscalculia. Figure 8 shows that the topic of dyscalculia is a topic that has news to be researched starting today. One novelty of research related to dyscalculia is connecting basic math concepts with real life. Besides, math teachers can use local wisdom as a learning resource for students with dyscalculia.

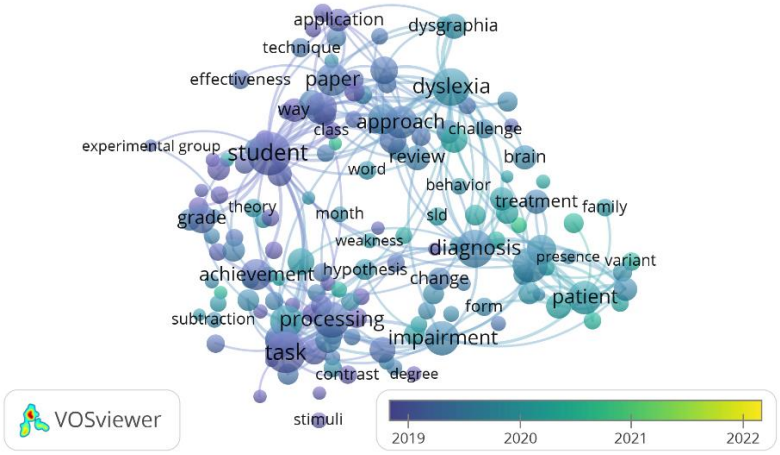

Figure 8. Research novelty in researching dyscalculia in three years (2020-2022)

3.6. Visualization of research trends in mathematics related to dyscalculia

This section explicitly presents a visualization of research trends in mathematics related to dyscalculia. As presented in Figure 9, there are three groups of keyword clusters based on the color. Examples of green keywords are deficit, task, difference, and developmental dyscalculium, while examples of red keywords are students, understanding, mathematics difficulties, learning, and elementary school.

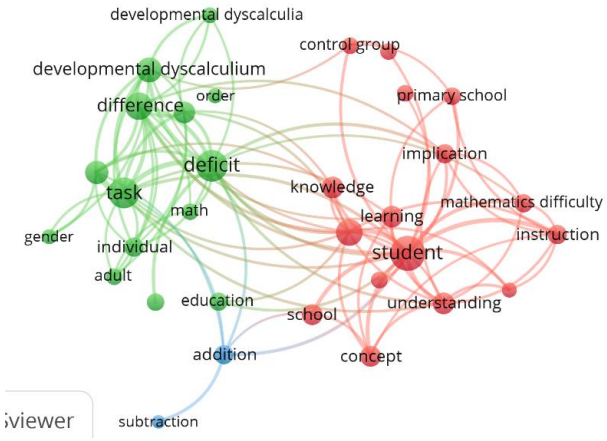

Figure 9. The whole picture of research on dyscalculia and mathematics during 2017-2022

Figure 9 displays three study clusters relating to dyscalculia and mathematics: deficit, student, and addition. Researchers found deficit mathematics difficulty [42]–[44]. Peng *et al*. [42] described a deficiency profile of phonological storage and executive processes in working memory in children with difficulty in arithmetic. On the other hand, Kunwar stated that students' deficits and dyscalculic learners face various difficulties due to their weak number sense, low essential mathematics fluency, reasoning, and accurate arithmetic calculations [45]. A dyscalculic learner is deficient in understanding sets and their numericities, which is fundamental to all aspects of primary school [2]. Furthermore, students with dyscalculia need learning resources that can help and direct the correct understanding of basic concepts [30], [46]. In addition, Chin and Fu [47] suggested that dyscalculic learners need early support, such as intervention to recognize numerical quantities, and perform counting.

Several studies on dyscalculia have been carried out by researchers [20]–[23], [25]–[29]. However, only some studies emphases on the bibliometric study and systematic literature review [13], [17], [18], [48]. Through bibliometric analysis, the results of this research provide fresh information on trends in dyscalculia research. This research uses the Scopus Elsevier database, a widespread database worldwide. Therefore, the upcoming study may compare Web of Science and Scopus data. Most articles were written in English in the

last five years (2017-2022). The finding shows the dominant author from the United States and the most significant number of documents from the United States (Figure 2). Italy closely follows the United States. Italy has several journals that focus on the topic of dyscalculia. Other countries contributing to this topic are Germany, the UK, France, India, Switzerland, Brazil, China and Malaysia. Chinnaraj's [13] bibliometric study related to dyscalculia (2011-2020) tends to decline. However, the results of this bibliometric study show that the number of dyscalculia documents in Scopus in the last five years (2017-2022) tends to fluctuate.

While the Journal of Learning Disabilities and Frontiers in Psychology are the top two journals contributing documents on dyscalculia in the last five years, this is in line with the findings of Chinnaraj [13], who found these two journals to be the journals most chosen by dyscalculia authors. Other sources of dyscalculia documents that the authors also choose are Research in Developmental Disabilities, Brain Sciences, Frontiers in Human Neuroscience, Cortex, "Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics". Next, International Handbook of Mathematical Learning Difficulties from The Laboratory to The Classroom, Neurological Sciences, and Neuropsychologia. The top author of dyscalculia (2017-2022) based on the number of documents is De Smedt. Based on this fact it can be claimed that De Smedt has been the most dominating author in the last five years.

As part of the discussion of this study, the researcher would like to provide three recommendations for future research: i) It is recommended to bear a comparison of data from the Web of Science and Scopus database in studying dyscalculia; and ii) It is crucial to research a more comprehensive range of years. For instance, research on dyscalculia in 2012-2022, studies on dyscalculia in 2022-2025, and predictions of future dyscalculia studies. However, the results of this study may not provide much help to the eagle eye in illuminating the body of knowledge directly relevant to the study of dyscalculia.

4. CONCLUSION

Several important emphases have been made on research trends in dyscalculia from 2017 to 2022. The number of dyscalculia documents throughout the year experienced fluctuating movements dominated by journal articles. Judging from the Country of origin, the USA's and Italy's dominance is clear. Especially for dyscalculia and mathematics, the topics discussed were deficit, student, addition, and mathematical difficulty. Italy and the United States have also contributed the most prolific dyscalculia writers. The Journal of Learning Disabilities is a leading article on dyscalculia. Regarding the visualization of dyscalculia research trends, there are four main clusters: approach, students, tasks, and patients.

The cause of dyscalculia is hemisphere dysfunction. Hemisphere dysfunction causes difficulties in understanding the abstract meaning of numbers and sequences of numerical, mathematical operations, the nature of quantities, spatial learning problems, and using arithmetic knowledge to solve daily life problems. So, teachers use learning approaches to help dyscalculia students, namely the direct method, group approach, and individual approach.

ACKNOWLEDGEMENTS

Thank you to the Directorate of Resources, Directorate General of Higher Education, Research, and Technology of the Republic of Indonesia through the college lecturer internship program (MDPT) in 2022. The author is grateful to the MDPT of UNESA coaches, who have accompanied and collaborated to complete this article. This article is also the result of preliminary research from Regular Fundamental Research (PFR) from the Directorate of Research and Community Service, Ministry of Research, Technology and Higher Education of the Republic of Indonesia with contract number 115/UN60/LPPM/PP/2023.

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