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A ten-year bibliometric study on mathematical ability

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ABSTRACT

Mathematical ability is a crucial aspect of modern life as it influences various fields such as economics, technology, and science. This study, spanning 2014-2023, examines articles on mathematical ability in leading journals. Using the bibliometric methods, it includes article searches in Scopus and Google Scholar via Publish or Perish (PoP), classification for bibliometric analysis, metadata checks, and bibliometric analysis using VOSviewer. The research shows a consistent trend in publications on mathematical ability, with minimal fluctuations and significant citation patterns. High-citation articles underscore the field's importance in knowledge advancement. Key terms are 'ability', 'mathematical ability', and 'student', indicating research focus areas. However, limited author collaboration suggests potential for increased interdisciplinary synergy and knowledge sharing. These findings highlight opportunities for enhancing cross-disciplinary collaborations and research networks. They offer insights for policymakers, educators, and researchers in understanding trends, developing effective learning strategies, and encouraging further research in mathematical ability. In summary, this bibliometric study provides a comprehensive overview of the significance of mathematical ability in research, emphasizing the need for collaborative, innovative educational and research practices. It underscores the importance of further research to deepen understanding and application of mathematical ability, promoting an integrative approach in this essential field.

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1. INTRODUCTION

This piece delves into mathematical ability, employing a bibliometric method to examine and discern patterns along with research traits spanning 2014 to 2023. Mathematical ability stands as a pivotal element in math education, enveloping the comprehension of mathematical ideas, the application of solutions, and the prowess of mathematical cognition [1]–[5]. Recognizing the intricacies of mathematical abilities holds immense significance in educational realms since mathematics distinctly aids in honing reasoning, analytical discernment, and aptitude in addressing challenges. By immersing in the essence of mathematical ability, mathematics education experts can devise teaching approaches that are both impactful and apt.

Mathematical ability is fundamental in shaping the cognitive and intellectual growth of students [6]–[8]. Beyond aiding in grasping intricate mathematical subjects, it also refines their rational thought, analytical capabilities, and problem-solving techniques [9]–[12]. An in-depth understanding of mathematical prowess is paramount in the educational sphere, equipping teachers and mathematics instructional professionals to devise more potent and appropriate teaching strategies [13]–[15]. By discerning the diversity in mathematical capabilities, they can tailor methods to cater to various learning approaches and proficiency levels, creating avenues for enhanced mathematical progression [16], [17]. Researchers regard bibliometric analyses as pivotal in delineating bibliographic details in specific sectors [18]–[20]. In the context of this investigation, the article leverages the bibliometric methodology to gather and scrutinize bibliographic content associated with mathematical ability. This strategy taps into pertinent scholastic and scientific literature databases, aiming to pinpoint publication counts, yearly publication distribution, journal ranking categorization, and research affiliations concerning mathematical ability [21]–[23]. Such a bibliometric assessment can spotlight the freshest research directions on mathematical ability and highlight the roles of diverse institutions and nations in enriching the comprehension of mathematical competencies [24]–[26]. This information can provide important insights for researchers, educators, and practitioners of mathematics education in designing syllabus and curricula as well as teaching strategies to enhance mathematical ability particularly among school children [27]–[30].

The realm of mathematics education research is continually expanding, as evidenced by recent studies focusing on various aspects of students' mathematical abilities. One such study aimed to understand mathematics teachers' perceptions of students' problem-solving abilities. The research also highlighted differences in students' problem-solving skills during online and offline learning, underscoring the need for further investigation and improvement in this area [31]. This study contributes to the growing body of literature on mathematics education and offers insights that can be used to enhance and evaluate students' mathematical problem-solving abilities in schools across Sumatra.

In another vein, research has delved into the design and quality assessment of digital learning platforms for diagnosing seventh-grade students' mathematical abilities in measurement and geometry. The findings affirmed the platform's high level of usefulness, suitability, and accuracy, although its feasibility was deemed moderately appropriate [2]. This digital tool stands as a valuable resource for diagnosing students' mathematical abilities. Additionally, studies have explored the relationship between cognitive flexibility and geometric abilities in problem-solving, advocating for the use of auxiliary lines to foster creative thinking skills in geometry [32]. Furthermore, investigations into students' mathematical connection abilities have revealed varying levels of proficiency across different indicators, highlighting areas for improvement [17]. Research employing an open approach to organize learning activities has also shown promise in developing students' mathematical problem-solving and reasoning skills, demonstrating the effectiveness of action research in achieving educational goals [32]. These studies collectively contribute to the enhancement of mathematics education, providing evidence-based strategies for improving students' mathematical abilities.

Despite the abundance of literature, no comprehensive bibliometric study of mathematical ability has been conducted in the last 10 years, particularly those using Scopus and Google Scholar as databases. In this context, this article aims to complement other important aspects of mapping research on mathematical ability, so that the mapping becomes more comprehensive. The focus of this study is a bibliometric analysis of the mathematics ability model by considering publication trends, significant journal contributions, citation patterns, author keywords, and collaboration of authors who publish articles. This research aims to explore the landscape of scholarly work on mathematical ability by addressing the following questions:

i) What are the trends in the publication of articles on mathematical ability from 2014 to 2023?
ii) What is the citation pattern for articles on mathematical ability from 2014 to 2023?
iii) What are the keyword trends used by authors in articles on mathematical abilities from 2014 to 2023?
iv) What is the pattern of collaboration between authors in articles on mathematical ability from 2014 to 2023?

2. LITERATURE REVIEW

Mathematical ability is a crucial cognitive competence in today's era. Numerous studies have attempted to explain various aspects related to mathematical abilities and their implications in different situations. The role of mathematical abilities in the realm of educational and academic growth has been investigated [33], [34]. Their work accentuates the need for adept mathematical problem-solving skills and an intricate grasp of mathematical concepts for triumph in mathematics and adjacent disciplines.

A separate study focuses on identifying factors that influence students' mathematical abilities and the effectiveness of innovative teaching methods in enhancing their academic performance. Emphasis is placed on the importance of engaging students in challenging and relevant mathematical situations, which

can cultivate a positive attitude towards mathematics [35], [36]. The research findings suggest that instructional approaches based on understanding, collaborative learning, and hands-on involvement can significantly improve students' mathematical abilities [37], [38]. The significance of deep and systematic learning in enhancing mathematical abilities is emphasized, highlighting the necessity for an educational approach focused on authentic problem solving tasks and the adoption of adaptable cognitive strategies [33], [34]. This research also highlights the crucial role that teachers play in providing ongoing support and feedback. This role is essential for students to hone their mathematical skills.

Significant research in the field of mathematical ability has been highlighted, focusing on the variables that shape mathematical ability, powerful pedagogical methodologies, and the importance of fostering a constructive mindset towards mathematics to achieve high mathematical competence. At the same time, there are other investigations that further enrich our understanding of mathematical abilities. One study explores the elements that influence students' achievements in mathematics. Their findings suggest that aspects such as student self-confidence, intrinsic motivation, and the efficacy of educators play a crucial role in shaping their mathematical abilities [39]–[41]. The context of evaluating mathematical competencies highlights the creation of evaluative tools capable of holistically measuring mathematical abilities [42], [43]. The primary focus is on developing instruments that cover both cognitive and conceptual mathematical dimensions. This includes problem-solving skills and mathematical communication abilities.

Emotional factors such as mathematics anxiety play a crucial role in the resolution of arithmetic problem-solving even during the early years of formal education [44]. Emotional intelligence, self-esteem, and self-efficacy have a significant influence in predicting students' academic achievement in mathematics, affirming that these factors are key determinants in their success in the field [45], [46]. These findings underscore the importance of addressing emotional and psychological aspects in mathematics education to enhance students' overall performance and confidence in the subject. Mathematics educators need to be skilled and use effective strategies to teach mathematical concepts. Their ability to link students' basic knowledge with advanced mathematical themes is key to their approach. These methods greatly enhance the overall development of learners' mathematical abilities [47], [48].

These investigations illustrate the intricacies of mathematical abilities and the myriad elements that shape them. A profound comprehension of mathematical ability, coupled with insights into its influencing factors, can aid in crafting efficient pedagogical methods, pinpointing student learning requirements, and formulating pertinent and stimulating educational tactics. Such strategies not only foster a deeper understanding of mathematical concepts but also promote a positive learning environment that encourages student engagement and perseverance.

3. RESEARCH METHOD

This study adopts a bibliographic research framework, utilizing systematic and explicit mapping techniques sourced from various previous publications [49]. The literature review is structured into four distinct phases: search procedure, filter bibliography, bibliographic completeness, and bibliometric analysis [50], [51]. The application of systematic mapping techniques in bibliometric studies, the integration of bibliometric evaluations with mapping the research landscape, the significance of bibliometric techniques in measuring research caliber and impact, and insights into using computational tools for bibliometric monitoring are all explored [52]. Through comprehensive bibliometric evaluation, this research aims to employ established methodologies and enhance understanding of mathematical abilities, leveraging the aforementioned scholarly works.

3.1. Search procedure

The software Publish or Perish (PoP) was utilized to probe bibliographic databases, specifically Scopus and Google Scholar. These databases stand out as the predominant reservoirs offering expert-reviewed literature. The selection of Scopus and Google Scholar stems from their comprehensive spectrum of content in comparison to other archives [23], [49]. Notably, they encompass roughly 70% more published works than Web of Science [50]. In this analysis, criteria were defined for all bibliographies to be included, including types of bibliographies consisting only of journals, article titles that included “mathematical ability”, and a year limit of searches for the past 10 years, i.e., between 2014 and 2023. Figure 1 illustrates the bibliographic search process using the PoP application.

Results from bibliographic searches are first stored in the Mendeley application, a popular reference management tool popular with researchers. Once the data has been successfully imported into Mendeley, it is then exported to a compatible format to open using the Excel application. Excel application is used because of its functionality that makes it easy to manage, sort, and filter data efficiently. Once the file is successfully opened in Excel, the next step is to carefully check each data entry to make sure there are no errors or

discrepancies. In addition, metadata that may be incomplete or inconsistent is also equipped to ensure the integrity and accuracy of the information in the analysis that will be carried out next.

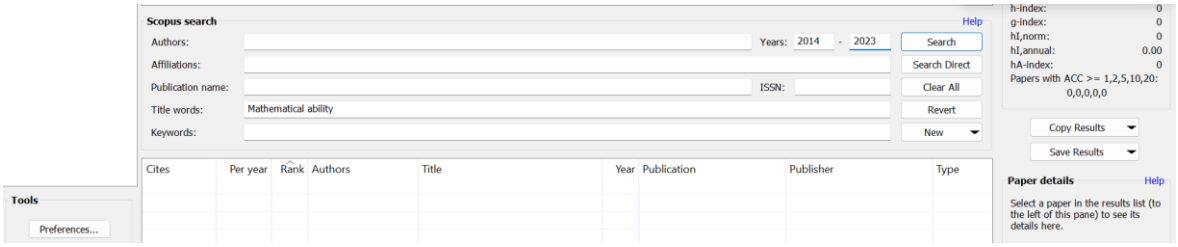

Figure 1. PoP application bibliography search

3.2. Filter bibliography

Several criteria are used as filters in the bibliographic sorting process, including: i) containing information about mathematical ability; ii) written in English or Indonesian; and iii) published by featured publishers from bibliographic databases. Any bibliographies to be included or excluded from bibliometric analysis were re-examined using data retrieved from PoP application in the Scopus and Google Scholar databases. Only journal and conference bibliographies are selected, while other types of bibliographies, such as erratum, notes, editorials, reviews, cloning, or articles without abstracts, are not included.

Initial search results using the PoP application resulted in 2,000 bibliographies, which were then filtered into 1,722 selected bibliographies according to specified criteria. A total of 278 bibliographies did not meet the criteria, so they were excluded. Table 1 displays the total number of bibliographies from 2014 to 2023 obtained through PoP application. Table 1 shows that in the 2014 to 2023 range, the paper on mathematical ability is relatively constant. In 2022, there will be an increase of 181 papers. In 2023, only 158 papers were recorded, because the search was carried out until May 2023.

Table 1. Bibliographic selection results

Year of publication	Inclusion	Percentage (%)	Exclusion	Percentage (%)	Total
2014	173	86.5	27	13.5	200
2015	171	85.5	29	14.5	200
2016	172	86.0	28	14.0	200
2017	172	86.0	28	14.0	200
2018	177	88.5	23	11.5	200
2019	172	86.0	28	14.0	200
2020	173	86.5	27	13.5	200
2021	173	86.5	27	13.5	200
2022	181	90.5	19	9.50	200
2023	158	79.0	42	21.0	200
Total	1,722		278		2,000

3.3. Bibliography completeness

Checking and completing the metadata of each article is carried out to ensure the completeness of the bibliography that has been filtered. In this examination, various aspects were reviewed, including article title, author name, affiliation and country of origin, abstract, author keywords, article link, publisher, and year of publication. Once metadata verification is complete, bibliometric analysis is then carried out.

3.4. Bibliometric analysis

Bibliometric analysis is carried out based on the following aspects: i) publication trends; ii) most frequently cited articles; iii) author keywords that appear most often in articles; and iv) collaboration between authors. In addition, it also analyzes the relationship between these aspects. To carry out bibliometric analysis and visualize the results, we used the VOSviewer application. VOSviewer is specifically designed to work efficiently with large volumes of data and offers a wide array of visualizations, analyses, and observations [53]. In addition, VOSviewer is able to generate maps for publications, authors, or journals by analyzing co-citation patterns, as well as creating keyword maps based on the framework of scattered topics [54]. For analysis in VOSviewer software, bibliographic files are used as the primary input file format.

These elements are analyzed not only independently but also in connection with each other to offer a comprehensive view of the field's dynamics. Publication trends reveal shifts in the research landscape over time, highlighting how new trends can spark scholarly interest. The most frequently cited articles provide insights into the foundational works that have shaped current research directions, linking historical impacts to contemporary trends. Author keywords show the thematic focus and consistency within the field, reflecting shifts towards new or evolving research topics. Collaboration among authors illustrates the networked nature of research, emphasizing how partnerships enhance the development of prominent topics reflected in publication and citation trends. By examining these aspects together, we gain a deeper understanding of how collaborative networks influence topic popularity, and how these topics drive publication trends, thereby offering a holistic view of the bibliometric landscape where scholarly output and collaboration are both influenced by and contribute to evolving research themes.

4. RESULTS AND DISCUSSION

4.1. Publication trend-based analysis

Figure 2 depicts the progression in the publication of journal articles addressing mathematical ability between 2014 and 2023. The chart highlights the annual fluctuations in the count of such articles. This trend reflects the growing interest and focus within the academic community on understanding and improving mathematical abilities.

Figure 2 displays the annual count of articles focused on mathematical ability between 2014 and 2023, ranging from 158 to 181 articles in any given year. On inspection, the volume of articles stays more or less consistent throughout these years. The zenith was in 2022 with 181 articles, while the troughs were seen in 2015 and 2020, registering 171 and 173 articles, respectively. It is crucial to mention that the 2023 data was accumulated only up to May, making the count for this year provisional and not necessarily representative of the entire year. However, the enduring pattern intimates a sustained research inclination towards mathematical ability over this duration.

The data indicates a relatively stable trend, despite variations in the number of articles each year. Although the peak occurred in 2022, it is important to note that the data for 2023 only includes articles published until May. This suggests that conclusions about the overall trend for that year need to be carefully considered. Furthermore, the focus on the top 10 journals featuring articles on mathematical ability research highlights the relevance and importance of this research in various aspects of life. However, to better understand the underlying factors driving these trends, further analysis of changes in research funding, educational policies, or emerging research areas in the field of mathematical ability is needed. Such analysis can provide deeper insights into the dynamics of research in this field.

Subsequent data present the leading 10 journals that featured articles on mathematical ability research from 2014 to 2023. Such research underscores a comprehensive desire to both comprehend and enhance mathematical abilities in diverse facets of existence. These journals serve as key platforms for disseminating critical findings and advancements in the field, further emphasizing the importance of this area of study.

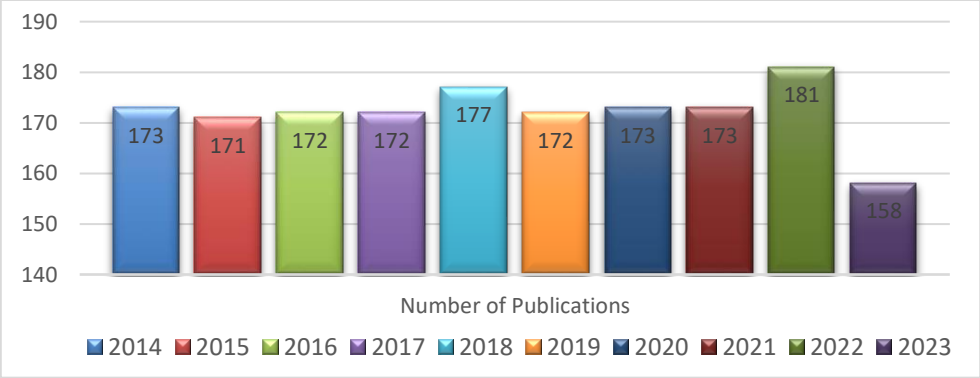

Figure 2. Publication trends per year

Table 2 indicates that studies on mathematical ability are disseminated across a range of journals. This includes those that exclusively delve into mathematics education, as well as those with a broader multidisciplinary focus. Taking the lead is the Journal of Experimental Child Psychology, featuring a total of

48 articles that center on mathematical abilities in the young demographic. Broadly speaking, these journals address multiple facets of mathematical ability. Topics span developmental psychology, education, sustainability, and distinctions at an individual level. Such a spread underscores the significance of adopting a comprehensive perspective when seeking to comprehend and nurture mathematical abilities across different scenarios. Given this array of publications, the academic and professional community is well-equipped with diverse sources to tap into the most recent findings in the realm of mathematical ability research. A more visual representation of this data, in the shape of a pie chart, can be found in Figure 3.

From Figure 3, the Journal of Experimental Child Psychology is a leading source for articles on mathematical abilities, comprising 18.6% of the publications, highlighting its significant role in this research area. PLoS ONE follows, accounting for 12.4%, reinforcing its importance in disseminating research related to mathematical ability. Other journals including Developmental Science, Frontiers in Psychology, Journal of Educational Psychology, Sustainability (Switzerland), Journal on Mathematics Education, Developmental Psychology, Early Childhood Research Quarterly, and Learning and Individual Differences, though contributing lower percentages, still play a crucial role in the ongoing study of mathematical abilities.

From the analysis, it is evident that the Journal of Experimental Child Psychology is a pivotal source for research on mathematical abilities. This journal's leading position can be attributed to its focus on comprehensive empirical studies that explore cognitive development processes, including mathematical skills, in children. The journal's rigorous peer review process and its reputation for publishing methodologically sound research contribute to its prominence in the field. Following closely, PLoS ONE accounts for 12.4% of the articles, highlighting its role in broadly disseminating diverse and interdisciplinary research on mathematical abilities. Other journals such as Developmental Science, Frontiers in Psychology, Journal of Educational Psychology, and Sustainability (Switzerland), though contributing smaller percentages, still significantly impact the field by covering various aspects of educational and psychological development that include studies on how children learn and develop mathematical skills. Each journal's unique editorial focus and commitment to advancing research in child development and educational psychology ensure their crucial roles in enriching the academic discourse on mathematical abilities.

From this diagram, it can be concluded that there are a number of journals that play an important role in the publication of articles related to mathematical ability. This highlights the widespread curiosity across multiple disciplines in comprehending and enhancing mathematical abilities in diverse settings. Such insights are valuable for researchers and educators, providing them with a gateway to the most recent materials and discoveries showcased in these journals.

Table 2. The journals that have published the most articles on mathematical abilities from 2014 to 2023

Journal	Number of articles
Journal of Experimental Child Psychology	48
PLoS ONE	32
Developmental Science	29
Frontiers in Psychology	27
Journal of Educational Psychology	24
Sustainability (Switzerland)	24
Journal on Mathematics Education	22
Developmental Psychology	18
Early Childhood Research Quarterly	17
Learning and Individual Differences	17
Total	258

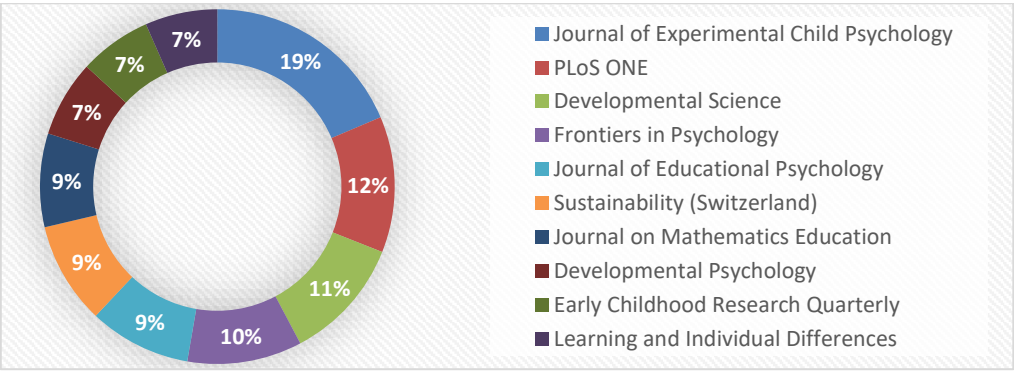

Figure 3. The proportion of journals that frequently feature articles about mathematical abilities

4.2. Citation count analysis (annual citations)

This section is the data detailing annual citation counts spanning from 2014 to 2023. This data provides valuable insights into the impact and recognition of research on mathematical abilities over the years. Analyzing these citation trends can help identify influential works and emerging themes within the field. Table 3 indicates a noticeable decline in annual citations over the years, with research on mathematical ability from 2014 to 2016 showing a greater influence through higher citation counts from those years. However, the citation count for 2023 stands at 141, which is significantly lower than earlier years, possibly because the data only covers up to May 2023, suggesting the year may not yet have reached its peak in citations. Despite this downward trend, the combined citations from 2014 to 2023 amount to 66,974, highlighting the sustained interest and recognition of research in mathematical ability within scholarly and research communities.

Evaluating based on citation counts, it is evident that studies concerning mathematical ability from 2014 to 2023 have left a considerable mark in terms of their citation impact. Even though there is a yearly decrease in citation counts, it does not diminish the importance and pertinence of these studies in enhancing our comprehension and development of mathematical abilities. Future studies will be paramount in further deepening this understanding, especially in educational and child development settings.

4.3. Top 10 most cited articles

In Table 4, there is a list of the 10 most cited articles on mathematical ability. The article with the most citations is ranked first, namely the article published by Raissi and Karniadakis [55] in 2018 with 580 citations, followed by Ceci *et al*. [56] in second place with 544 citations. Ranks third, fourth and fifth also show a high number of citations, above 400. Meanwhile, ranks sixth to tenth also have a fairly high number of citations, above 200 and below 400.

Table 4 shows the 10 most cited articles on mathematical ability research from 2014 to 2023 providing an important overview of topics that have received widespread attention and recognition within the academic community. These articles cover areas such as machine learning, changing academic landscapes, growth mindsets, numerical magnitude processing, gender equality in science, technology, engineering, and mathematics (STEM) education, spatial training, increasing resilience of minority students, and the relationship between early math knowledge and achievement in secondary schools. With a high number of citations, these articles make an important contribution to the understanding and development of the field of mathematical ability. Further research and discussion on these topics can help improve educational strategies and interventions to optimize mathematics learning in diverse contexts.

4.4. Author keyword-based analysis

Analysis based on the author's keywords was carried out using the VOSviewer application. The application allows visualization of relationships between keywords that frequently appear in publications, providing an overview of dominant themes and how they are interrelated in the context of research. Figure 3 illustrates the results of the analysis of 584 author keywords. To obtain a more significant measure, only the author's keywords that appear at least three times are analyzed. The results yield 15 author keywords that are strongly connected. The author's 15 keywords are then divided into 4 groups (clusters), each of which is given a different color. Group 1 (red) includes 4 items, while group 2 (green) consists of 4 items. In addition, group 3 (blue) has 4 items and group 4 (yellow) contains 3 items. Each group displays a set of data that has certain characteristics or relationships in the analysis performed.

Figure 4 shows that the keywords using the terms “ability”, “mathematical ability”, and “student” have produced the most results. The keywords “student mathematical problem” and “self-efficacy” are still little researched and are recommended for further research. This indicates a need for more focused studies on these less explored areas to broaden the understanding of factors affecting mathematical abilities.

Table 3. Number of citations per year

Year of publication	Number of citations	Number of articles
2014	11,990	173
2015	9,494	171
2016	9,642	172
2017	8,893	172
2018	8,358	177
2019	7,435	172
2020	5,435	173
2021	3,059	173
2022	1,258	181
2023	141	158
Total	66,974	1,722

Table 4. Most cited articles on mathematical ability in 2014 to 2023

No.	Study	Number of citations	Key findings/recommendations
1	[55]	580	This study's findings represent the introduction of a new paradigm in investigating partial differential equations from limited data sets. The researchers developed a hidden physics model that functions as an efficient learning machine capable of exploiting the underlying physics principles, which are represented as time-dependent and nonlinear partial differential equations [55].
2	[56]	544	Gender inequalities in views and expectations for mathematical jobs and talents begin as early as kindergarten and intensify with age, according to one study. This influences women's proclivity to pursue non-math-intensive science disciplines rather than math-intensive fields in college. For more than a decade, the overall percentage of women in STEM majors has been at or near 50%.
3	[57]	486	According to the findings of this study, a brief online growth mindset intervention that teaches that intellectual abilities can be developed has a positive effect on academic outcomes of students with lower achievement and increases the number of students taking advanced-level mathematics courses. The investigation was carried out with a sample of students from all over the United States [57].
4	[58]	431	This discovery adds significantly to our understanding of how numerical magnitude processing affects overall mathematical competence. It also gives critical information for the creation of methods and interventions to improve mathematical skills in people of all ages [58].
5	[59]	426	According to the study's findings, the underrepresentation of women in STEM sectors is a persistent problem for social scientists and policymakers. However, data from an international database on adolescent achievement in science, mathematics, and reading show that in two out of every three countries, girls perform similarly or better than boys in science, and in almost all countries, more girls appear to have the ability to pursue STEM education than those who have enrolled [59].
6	[60]	316	According to the findings of this study, there is a moderate but statistically significant association between number acuity, which is the capacity to estimate the quantity of things in a particular setting quickly and non-symbolically, and symbolic mathematics proficiency [60].
7	[61]	308	The results of this study show that a single session of mental rotation training utilizing an item completion task improves math ability in children aged 6 to 8. Children who underwent spatial instruction improved significantly on calculating difficulties [61].
8	[62]	300	The Joint Working Group on Improving Underrepresented Minorities (URMs) Persistence in STEM made five suggestions to improve URM persistence in STEM areas at the undergraduate level. These ideas center on removing institutional barriers and putting interventions in place to boost students' enthusiasm, commitment, and capacity to continue in STEM subjects [62].
9	[63]	290	According to the study, children's arithmetic ability at preschool age (54 months) have a substantial association with their mathematics accomplishment throughout adolescence (at the age of 15) [63].
10	[64]	270	According to the findings of this study, an innovative educational strategy that includes support for self-regulation, particularly executive functions, into reading, mathematics, and science learning activities for kindergarten children has a good influence on a variety of factors [64].

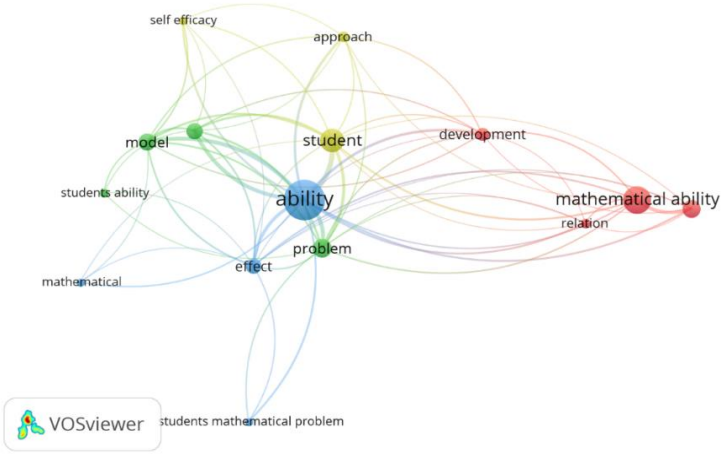

Figure 4. Keyword network visualization

4.5. Author collaboration-based analysis

The results of the analysis of author collaboration using VOSviewer with at least one document show that out of 183 authors, there are 2 authors who have strong connections. Each author has 1 link and one document. The pattern of author collaboration is illustrated in Figure 5. The figure illustrates how authors work together in the same document, resulting in a close link between them. Because there were 183 authors analyzed, this demonstrates a lack of collaboration in the study of mathematical ability. This limited collaboration suggests that increased interdisciplinary and joint research efforts could lead to more comprehensive insights and advancements in understanding mathematical ability.

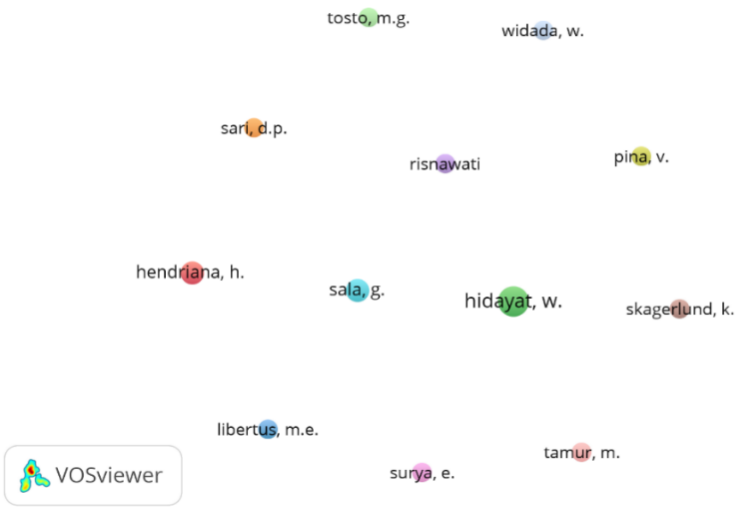

Figure 5. Visualization of the author collaboration network

During the last 10 years, the trend of publication of articles on mathematical ability from 2014 to 2023 shows relative stability in the number of publications. Although there are annual fluctuations in the number of articles, there does not appear to be a significant trend of consistent increase or decrease. However, it should be noted that in 2022 there has been a significant increase in the number of articles published. The citation pattern for articles on mathematical ability in the 2014-2023 period also shows an interesting trend. The article with the highest number of citations topped the ranking, showing recognition and the impact of research. Articles with high citations generally cover important and relevant topics, such as machine learning, the growth mindset, numerical magnitude processing, and gender equality in STEM education.

For the trend of keywords used by authors in articles about mathematical abilities in the 2014-2023 period, in the analysis of the trend of keywords used by authors in articles about mathematical abilities in the 2014-2023 period, it can be seen that terms such as “ability”, “mathematical ability”, and “student” are the keywords most often used. This shows that research in the area of mathematical ability focuses a lot on aspects of mathematical ability itself, both in the context of individual and group students. Over all, the keyword trends indicate a strong focus on understanding, evaluating, and developing math skills, especially in the student population. By understanding these trends, researchers can direct their studies in relevant directions and make valuable contributions to the understanding and development of mathematical abilities.

The pattern of collaboration between authors in articles about mathematical ability in the 2014-2023 period uses VOSviewer with a minimum number of appearances of one document. From the analysis of 183 authors, only a pair of authors seemed to have a close connection. This highlights a potential deficiency in collaboration within the realm of mathematical ability during the time frame observed. The data suggests these two authors may have worked together on a particular piece, establishing a strong bond between them. This signifies that co-operation in mathematical ability research appears to be infrequent, with very few authors joining forces.

This scarcity of collaborative efforts in the exploration of mathematical ability can lead to several repercussions. Firstly, limited collaboration could hinder the expansive sharing of ideas, insights, and comprehensive understanding in this arena. More inclusive and diversified collaborations could foster varied viewpoints, fresh ideas, and groundbreaking findings when it comes to understanding and cultivating mathematical abilities. Secondly, this lack of collaboration might also impede the progress of this domain in its entirety. Expanded teamwork can spur more advancements and pivotal revelations in mathematical ability research.

To bolster collaboration in mathematical ability research, fostering dialogue and partnerships among scholars in this domain is paramount. Venues such as symposiums, seminars, and colloquia can act as catalysts to spark collaboration among scholars with aligned interests and skills. Furthermore, securing funding and backing from institutions that promote collaboration and knowledge-sharing can be instrumental in fueling more dynamic teamwork in investigations surrounding mathematical abilities.

5. CONCLUSION

This study highlights the consistent interest in research on mathematical abilities over the period 2014-2023, despite minor fluctuations in the number of annual publications. The findings show that there is no significant trend of drastic increase or decrease in research publications, but certain articles have gained high citation numbers, underscoring their impact in this domain. Predominant keywords such as "ability", "mathematical ability", and "student" reflect a focus on enhancing mathematical skills among learners. However, collaboration patterns among authors reveal limited teamwork, suggesting the potential for increasing partnerships to enhance knowledge sharing in this field.

The research also acknowledges its limitations, including reliance on a single bibliometric analysis application and limited data sources (Scopus and SINTA). Future studies are encouraged to expand the tools and data sources, such as IEEE Xplore, Web of Science, and others, to provide a broader perspective. Collaborative research across disciplines educators, psychologists, and mathematicians is essential for innovative developments in mathematical ability. Additionally, exploring self-efficacy's influence, effective teaching models, and cross-national collaborations with prominent researchers can enrich future studies and contribute to improved mathematical learning strategies tailored to diverse educational needs.

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REFERENCES

[1] A. Fauzan, E. Z. Jamaan, and I. Schwank, "Improving the student's numerical reasoning by using mathematics cognition-based mathematical textbook development at elementary schools," in *Proceedings of the 2nd International Conference Innovation in Education (ICoIE 2020)*, 2020, pp. 105–110, doi: 10.2991/assehr.k.201209.201.

[2] S. Chinjunthuk, P. Junpeng, and K. N. Tang, "Use of digital learning platform in diagnosing seventh grade students' mathematical ability levels," *Journal of Education and Learning*, vol. 11, no. 3, pp. 95–104, 2022, doi: 10.5539/jel.v11n3p95.

[3] Marzuki, Wahyudin, E. Cahya, and D. Juandi, "Students' critical thinking skills in solving mathematical problems; a systematic procedure of grounded theory study," *International Journal of Instruction*, vol. 14, no. 4, pp. 529–548, 2021, doi: 10.29333/iji.2021.14431a.

[4] W. Hidayat, E. E. Rohaeti, A. Ginanjar, and R. I. I. Putri, "An ePub learning module and students' mathematical reasoning ability: a development study," *Journal on Mathematics Education*, vol. 13, no. 1, pp. 103–118, 2022, doi: 10.22342/jme.v13i1.pp103-118.

[5] Y. S. Kusumah, D. Kustiawati, and T. Herman, "The effect of GeoGebra in three-dimensional geometry learning on students' mathematical communication ability," *International Journal of Instruction*, vol. 13, no. 2, pp. 895–908, 2020, doi: 10.29333/iji.2020.13260a.

[6] R. M. M. Sari, N. Priatna, and D. Juandi, "Implementing project-based blended learning model using cognitive conflict strategy to enhance students' mathematical spatial literacy," *European Journal of Educational Research*, vol. 11, no. 4, pp. 2031–2041, 2022, doi: 10.12973/eu-jer.11.4.2031.

[7] D. Rais and Z. Xuezhi, "Human cognitive: learning mathematics through Python programming to support students' problem-solving skills," *Anatolian Journal of Education*, vol. 8, no. 2, pp. 85–98, 2023, doi: 10.29333/aje.2023.826a.

[8] M. S. Rahman, D. Juniati, and Manuharawati, "The quality of mathematical proficiency in solving geometry problem: difference cognitive independence and motivation," *Pegem Journal of Education and Instruction*, vol. 13, no. 3, pp. 255–266, Jan. 2023, doi: 10.47750/pegegog.13.03.27.

[9] N. Fatmanissa, T. Y. E. Siswono, A. Lukito, R. Ekawati, and Masriyah, "Prospective teachers' perspectives on collaborative problem solving in mathematics," *Mathematics Teaching-Research Journal*, vol. 15, no. 3, pp. 34–49, 2023.

[10] A. Hidayatullah and C. Csíkos, "Mathematics related belief system and word problem-solving in the Indonesian context," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 18, no. 4, p. em2094, 2022, doi: 10.29333/ejmste/11902.

[11] A. Çayir and E. Balci, "The effect of differentiated instruction on gifted students critical thinking skills and mathematics problem solving attitudes," *Educational Research and Reviews*, vol. 18, no. 12, pp. 392–398, 2023, doi: 10.5897/err2023.4375.

[12] C. Huan, C. C. Meng, and M. Suseelan, "Mathematics learning from concrete to abstract (1968-2021): a bibliometric analysis," *Participatory Educational Research*, vol. 9, no. 4, pp. 445–468, 2022, doi: 10.17275/per.22.99.9.4.

[13] Wardono, Rochmad, K. Uswatun, and S. Mariani, "Comparison between generative learning and discovery learning in improving written mathematical communication ability," *International Journal of Instruction*, vol. 13, no. 3, pp. 729–744, 2020, doi: 10.29333/iji.2020.13349a.

[14] D. Anjariyah, D. Juniati, and T. Y. E. Siswono, "How does working memory capacity affect students' mathematical problem solving?" *European Journal of Educational Research*, vol. 11, no. 3, pp. 1427–1439, 2022, doi: 10.12973/eu-jer.11.3.1427.

[15] C. Khairunnisak, R. Johar, Yuhasriati, C. M. Zubainur, Suhartati, and P. Sasalia, "Learning trajectory of algebraic expression: supporting students' mathematical representation ability," *Mathematics Teaching Research Journal*, vol. 13, no. 4, pp. 27–41, 2021.

[16] A. L. Son, "The students' abilities on mathematical connections: a comparative study based on learning models intervention," *Mathematics Teaching Research Journal*, vol. 14, no. 2, pp. 72–87, 2022.

[17] A. Rafiepour and N. Faramarzpour, "Investigation of the mathematical connection's ability of 9th grade students," *Journal on Mathematics Education*, vol. 14, no. 2, pp. 339–352, 2023, doi: 10.22342/jme.v14i2.pp339-352.

[18] K. G. Yığ, "Research trends in mathematics education: a quantitative content analysis of major journals 2017-2021," *Journal of Pedagogical Research*, vol. 6, no. 3, pp. 137–153, 2022, doi: 10.33902/JPR.202215529.

[19] M. Suseelan, C. M. Chew, and H. Chin, "Research on mathematics problem solving in elementary education conducted from 1969 to 2021: a bibliometric review," *International Journal of Education in Mathematics, Science and Technology*, vol. 10, no. 4, pp. 1003–1029, 2022, doi: 10.46328/ijemst.2198.
[20] S. Gökçe and P. Güner, "Forty years of mathematics education: 1980-2019," *International Journal of Education in Mathematics, Science and Technology*, vol. 9, no. 3, pp. 514–539, 2021, doi: 10.46328/IJEMST.1361.
[21] R. Julius *et al.*, "Bibliometric analysis of research in mathematics education using Scopus database," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 17, no. 12, P. em2040, 2021, doi: 10.29333/EJMSTE/11329.
[22] A. A. Saefudin, A. Wijaya, and S. I. A. Dwiningrum, "Mapping research trends in mathematical creativity in mathematical instructional practices: a bibliometric analysis," *Journal of Pedagogical Research*, vol. 7, no. 4, pp. 439–458, 2023, doi: 10.33902/JPR.202322691.
[23] K. Karampelas, "Examining the relationship between TPACK and STEAM through a bibliometric study," *European Journal of Science and Mathematics Education*, vol. 11, no. 3, pp. 488–498, 2023, doi: 10.30935/scimath/12981.
[24] H. Kartika, M. T. Budiarto, Y. Fuad, and E. Bonyah, "Bibliometrics analysis of research on argumentation in mathematics education," *International Journal of Education in Mathematics, Science and Technology*, vol. 11, no. 5, pp. 1346–1365, 2023, doi: 10.46328/ijemst.2904.
[25] M. C. Aktaş, "Problem-posing research in mathematics education: a bibliometric analysis," *Journal of Pedagogical Research*, vol. 6, no. 4, pp. 217–233, Sep. 2022, doi: 10.33902/JPR.202217414.
[26] A. A. Rafiq, M. B. Triyono, I. W. Djatmiko, R. Wardani, and T. Köhler, "Mapping the evolution of computational thinking in education: a bibliometrics analysis of Scopus database from 1987 to 2023," *Informatics in Education*, vol. 22, no. 4, pp. 691–724, 2023, doi: 10.15388/infedu.2023.29.
[27] M. Shareefa and V. Moosa, "The most-cited educational research publications on differentiated instruction: a bibliometric analysis," *European Journal of Educational Research*, vol. 9, no. 1, pp. 331–349, 2020, doi: 10.12973/eu-jer.9.1.331.
[28] A. Bayrak and S. Aslanci, "Realistic mathematics education: a bibliometric analysis," *Shanlax International Journal of Education*, vol. 10, no. 4, pp. 52–62, 2022, doi: 10.34293/education.v10i4.5174.
[29] G. Aydemir, K. Orbay, and M. Orbay, "A bibliometric analysis of geometry education research based on Web of Science core collection database," *Shanlax International Journal of Education*, vol. 11, no. 2, pp. 1–9, 2023, doi: 10.34293/education.v11i2.4483.
[30] E. Dede and E. Ozdemir, "Mapping and performance evaluation of mathematics education research in Turkey: a bibliometric analysis from 2005 to 2021," *Journal of Pedagogical Research*, vol. 6, no. 4, pp. 1–19, 2022, doi: 10.33902/JPR.202216829.
[31] P. Wulansari and A. Jupri, "Students' mathematical problem-solving ability: mathematics teachers' perception in Sumatra," in *Proceedings of ICEMST 2022-- International Conference on Education in Mathematics, Science and Technology*, Mar. 2022, pp. 113–129.
[32] M. Muzaini, S. Rahayuningsih, M. Ikram, and F. A. Z. Nasiruddin, "Mathematical creativity: student geometrical figure apprehension in geometry problem-solving using new auxiliary elements," *International Journal of Educational Methodology*, vol. 9, no. 1, pp. 139–150, 2023, doi: 10.12973/ijem.9.1.139.
[33] K. Seepiwsiw and Y. Seehamongkon, "The development of mathematical problem-solving and reasoning abilities of sixth graders by organizing learning activities using open approach," *Journal of Education and Learning*, vol. 12, no. 4, p. 42, 2023, doi: 10.5539/jel.v12n4p42.
[34] H. Jacinto and S. Carreira, "Knowledge for teaching mathematical problem-solving with technology: an exploratory study of a mathematics teacher's proficiency," *European Journal of Science and Mathematics Education*, vol. 11, no. 1, pp. 105–122, 2023, doi: 10.30935/scimath/12464.
[35] M. Maamin, S. M. Maat, and Z. H. Iksan, "Analysis of the factors that influence mathematics achievement in the ASEAN countries," *Cypriot Journal of Educational Sciences*, vol. 16, no. 1, pp. 371–389, 2021, doi: 10.18844/cjes.v16i1.5535.
[36] Wawan and H. Retnawati, "Empirical study of factors affecting the students' mathematics learning achievement," *International Journal of Instruction*, vol. 15, no. 2, pp. 417–434, 2022, doi: 10.29333/iji.2022.15223a.
[37] B. Cerezci, "The impact of the quality of early mathematics instruction on mathematics achievement outcomes," *Journal of Childhood, Education and Society*, vol. 1, no. 2, pp. 216–228, 2020, doi: 10.37291/2717638X.20201248.
[38] K. Barba, "The mathematical mindsets and mathematical identities revealed in social media discourse," *Journal of Mathematics Education at Teachers College*, vol. 11, no. 2, pp. 23–34, 2020.
[39] A. Heyder, A. F. Weidinger, A. Cimpian, and R. Steinmayr, "Teachers' belief that math requires innate ability predicts lower intrinsic motivation among low-achieving students," *Learning and Instruction*, vol. 65, p. 101220, 2020, doi: 10.1016/j.learninstruc.2019.101220.
[40] R. C. H. Chan, "A social cognitive perspective on gender disparities in self-efficacy, interest, and aspirations in science, technology, engineering, and mathematics (STEM): the influence of cultural and gender norms," *International Journal of STEM Education*, vol. 9, no. 1, p. 37, 2022, doi: 10.1186/s40594-022-00352-0.
[41] S. A. Elsayed and H. I. Al-Najrani, "Effectiveness of the augmented reality on improving the visual thinking in mathematics and academic motivation for middle school students," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 17, no. 8, pp. 1–16, 2021, doi: 10.29333/ejmste/11069.
[42] İ. Özpınar and S. Arslan, "Teacher-based evaluation of students' problem solving skills," *International Journal of Psychology and Educational Studies*, vol. 10, no. 2, pp. 543–560, 2023, doi: 10.52380/ijpes.2023.10.2.1160.
[43] S. Rahayuningsih, S. Sirajuddin, and M. Ikram, "Using open-ended problem-solving tests to identify students' mathematical creative thinking ability," *Participatory Educational Research*, vol. 8, no. 3, pp. 285–299, 2021, doi: 10.17275/per.21.66.8.3.
[44] M. C. Passolunghi, E. Cargnelutti, and S. Pellizzoni, "The relation between cognitive and emotional factors and arithmetic problem-solving," *Educational Studies in Mathematics*, vol. 100, no. 3, pp. 271–290, 2019, doi: 10.1007/s10649-018-9863-y.
[45] A. Kuzle, "Drawing out emotions in primary grade geometry: an analysis of participant-produced drawings of grade 3-6 students," *Lumat*, vol. 9, no. 1, pp. 844–872, 2021, doi: 10.31129/LUMAT.9.1.1620.
[46] C. S. Ugwuanyi, C. I. O. Okeke, and C. G. Asomugha, "Prediction of learners' mathematics performance by their emotional intelligence, self-esteem and self-efficacy," *Cypriot Journal of Educational Sciences*, vol. 15, no. 3, pp. 492–501, 2020.
[47] M. U. Gusteti, R. Rifandi, T. G. Manda, and M. Putri, "The development of 3D animated video for mathematics learning in elementary schools," *Journal of Physics: Conference Series*, vol. 1940, no. 1, p. 012098, 2021, doi: 10.1088/1742-6596/1940/1/012098.
[48] Sudirman, Mellawaty, R. P. Yaniwati, and R. Indrawan, "Integrating local wisdom forms in augmented reality application: impact attitudes, motivations and understanding of geometry of pre-service mathematics teachers'," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 11, pp. 91–106, 2020, doi: 10.3991/ijim.v14i11.12183.
[49] L. Andrade-Arenas, M. M. M. Bogdanovich, D. H. Celis, K. R. Jaico, and G. B. A. Peña, "University learning style model: bibliometrics and systematic literature review," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 4, pp. 2302–2315, 2023, doi: 10.11591/ijere.v12i4.25859.

[50] J. Julia *et al.*, "Flipped classroom educational model (2010-2019): a bibliometric study," *European Journal of Educational Research*, vol. 9, no. 4, pp. 1377–1392, 2020, doi: 10.12973/eu-jer.9.4.1377.
[51] A. Kaban, "An examination of the studies on learning analytics: a bibliometric mapping analysis," *International Journal of Technology in Education and Science*, vol. 7, no. 2, pp. 211–229, 2023, doi: 10.46328/ijtes.477.
[52] K. Ma and B. H. Hui, "A bibliometric analysis of literature on attitudes in STEM education in 2008-2022," *Journal of Baltic Science Education*, vol. 22, no. 6, pp. 1038–1049, 2023, doi: 10.33225/jbse/23.22.1038.
[53] M. B. Triyono, A. A. Rafiq, I. W. Djatmiko, and G. Kulanthaivel, "Vocational education's growing focus on employability skills: a bibliometrics evaluation of current research," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 4, pp. 1791–1809, 2023, doi: 10.11591/ijere.v12i4.26001.
[54] B. D. Saputra, M. Murdino, and E. Tohani, "Nationalism education in elementary school: a systematic literature review," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 12, no. 2, pp. 739–749, 2023, doi: 10.11591/ijere.v12i2.24609.
[55] M. Raissi and G. E. Karniadakis, "Hidden physics models: machine learning of nonlinear partial differential equations," *Journal of Computational Physics*, vol. 357, pp. 125–141, 2018, doi: 10.1016/j.jcp.2017.11.039.
[56] S. J. Ceci, D. K. Ginther, S. Kahn, and W. M. Williams, "Women in academic science: a changing landscape," *Psychological Science in the Public Interest, Supplement*, vol. 15, no. 3, pp. 75–141, 2014, doi: 10.1177/1529100614541236.
[57] D. S. Yeager *et al.*, "A national experiment reveals where a growth mindset improves achievement," *Nature*, vol. 573, no. 7774, pp. 364–369, 2019, doi: 10.1038/s41586-019-1466-y.
[58] M. Schneider *et al.*, "Associations of non-symbolic and symbolic numerical magnitude processing with mathematical competence: a meta-analysis," *Developmental Science*, vol. 20, no. 3, p. e12372, 2017, doi: 10.1111/desc.12372.
[59] G. Stoet and D. C. Geary, "The gender-equality paradox in science, technology, engineering, and mathematics education," *Psychological Science*, vol. 29, no. 4, pp. 581–593, 2018, doi: 10.1177/0956797617741719.
[60] Q. Chen and J. Li, "Association between individual differences in non-symbolic number acuity and math performance: a meta-analysis," *Acta Psychologica*, vol. 148, pp. 163–172, 2014, doi: 10.1016/j.actpsy.2014.01.016.
[61] Y. L. Cheng and K. S. Mix, "Spatial training improves children's mathematics ability," *Journal of Cognition and Development*, vol. 15, no. 1, pp. 2–11, 2014, doi: 10.1080/15248372.2012.725186.
[62] M. Estrada *et al.*, "Improving underrepresented minority student persistence in STEM," *CBE Life Sciences Education*, vol. 15, no. 3, p.es5, 2016, doi: 10.1187/cbe.16-01-0038.
[63] T. W. Watts, G. J. Duncan, R. S. Siegler, and P. E. Davis-Kean, "What's past is prologue: relations between early mathematics knowledge and high school achievement," *Educational Researcher*, vol. 43, no. 7, pp. 352–360, 2014, doi: 10.3102/0013189X14553660.
[64] C. Blair and C. C. Raver, "Closing the achievement gap through modification of neurocognitive and neuroendocrine function: results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten," *PLoS ONE*, vol. 9, no. 11, p. e112393, 2014, doi: 10.1371/journal.pone.0112393.

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