

Mapping Research Trends on Mathematical Communication Skills in Algebraic Materials: Bibliometric Analysis with VOSviewer (2020-2026)

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ABSTRACT

This study aimed to map global and domestic research trends regarding students' mathematical communication skills in algebra for the 2020-2026 period. The method employed was quantitative bibliometric analysis. The mapping of article bibliographic metadata was conducted online using Publish or Perish software connected to the Crossref database, yielding a final dataset of 146 articles after a rigorous selection process based on inclusion and exclusion criteria. Quantitative descriptive analysis and conceptual network map visualization were performed using VOSviewer. The results showed that the number of publications fluctuated, with the peak of productivity occurring in 2023 (34 articles), while the highest annual total citations were recorded in 2020 (113 citations). Research in this field was dominated and widely disseminated through national journals specifically focusing on mathematics education. Visualizations of keyword co-occurrence and co-authorship indicated that the primary focus of current publications was on the implementation of the Problem-Based Learning (PBL) model to overcome students' algebraic mathematization difficulties, and the collaboration network was managed by a few key researchers as central hubs.

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INTRODUCTION

Mathematical communication is the ability of researchers to arrange, correlate, and convey ideas through mathematical language and symbols clearly, as well as being able to evaluate other people's problem-solving approaches (Rohid et al., 2019). Its role is vital because it reflects a deep level of understanding of concepts and influences better academic achievement (Anisa et al., 2023; Rohid et al., 2019). On the other hand, shortcomings in this ability often lead to students' lack of deep understanding, as well as obstacles in applying mathematical concepts to new problems or real contexts (Siswantari et al., 2025).

In developing this mathematical communication, algebra material is one of the most crucial yet challenging domains for students. The main obstacle in learning algebra lies in the difficulty of students doing math, especially converting story problems into proper equations, schemes, or diagrams (Jupri & Drijvers, 2016). These failures most often appear at the stage of text-to-model conversion as well as symbol manipulation,

not just final calculation errors (Fardian et al., 2024). This problem is exacerbated by weak understanding of the meaning of variables, symbols equal, and confusion in translating verbal sentences into symbolic forms, for example, distinguishing the operations of addition, multiplication or rank in geometric situations (Pramesti & Retnawati, 2019). Plus lagi, unfamiliar contexts and high visual-spatial demands on diagrams often add to students' cognitive load (Ying et al., 2020), all of which are closely related to mathematical communication weaknesses in composing, connecting, and expressing ideas through language and symbols clearly.

Therefore, mathematical communication skills are increasingly crucial today, as evidenced by global bibliometric data that recorded a significant surge in publications, especially in the last three years (Daningtyas et al., 2025; Yani & Soebagyo, 2023). The dominant trends include the relationship between communication and cognitive styles, mathematical expressions, and the application of Project-Based Learning (Madepera et al., 2024). Although algebra continues to be the center of attention in Realistic Mathematics Education and technology integration (Jamil et al., 2025; Veith et al., 2023), a review of recent studies shows a lack of specific research analyzing students' mathematical communication constraints on algebraic topics (Nguyen et al., 2025). On the other hand, there is an urgency to create representation-based learning media to strengthen understanding of concepts (Putra et al., 2023), as well as explore digital communication models that are still a gap in international research (Daningtyas et al., 2025).

To overcome this complexity, bibliometric analysis is indispensable to map global research trends such as algebraic thinking, technology utilization, and cutting-edge learning theories (Jamil et al., 2025; Veith et al., 2023). Bibliometric analysis is a quantitative approach to examining a collection of scientific publications such as articles, citations, authors, and keywords to map the evolution, framework, and trend patterns in a discipline (Donthu et al., 2021). The main objectives include measuring researcher productivity, evaluating the influence of research via citations and h-indexes, and depicting knowledge structures through themes and patterns of collaboration (Mejía et al., 2021). Applicatively, this method utilizes core techniques such as citation and co-citation analysis to identify influential works, bibliographic coupling to classify similarly referenced articles, and co-authorship and co-occurrence networks of keywords to visualize collaborations and topic linkages (Klarin, 2024; Van Eck & Waltman, 2017). The initial step usually involves extracting data from trusted sources such as Scopus or the Web of Science, followed by data cleansing and visualization for in-depth interpretation.

Among its various tools, one of the mainstay software for this analysis is VOSviewer, which excels in producing interactive visualizations in the form of intuitive bibliometric network maps (Husaeni & Nandiyanto, 2021; Van Eck & Waltman, 2014). This tool is powerful in compiling co-authorship maps, bibliographic couplings, as well as keyword co-occurrences, complete with theme cluster groupings (Bukar et al., 2023). The density and overlay maps feature make it easier for researchers to analyze research

concentration and topic development temporally (Kumar, 2025; Van Eck & Waltman, 2017).

Based on the description above, there is a real gap between the importance of mathematical communication skills and students' barriers to algebraic material, especially mathematics and symbolic representation. Although research continues to develop, systematic bibliometric reviews are still minimal. Therefore, this study analyzes publication trends (2020-2026), topic clusters via keyword occurrences, and intellectual networks using VOSviewer, in order to map knowledge structures and opportunities for further research.

METHODE

This study uses a bibliometric research design to quantitatively map trends in the scientific literature (Donthu et al., 2021). The bibliometric method was chosen because of its ability to process large amounts of publication data to identify development patterns, relationships between topics, and network of collaboration between researchers in the domain of mathematical communication skills in algebraic materials. Through this approach, researchers can conduct an objective analysis of bibliographic data available in scientific publication databases. Mapping this trend is crucial related to previous literature studies that explain that the study of mathematical communication globally continues to develop but requires more systematic mapping (Anisa et al., 2023). The target of this research includes all trends of scientific publications, both national and international, that focus on mathematics education. Document populations are all journal articles that discuss mathematical communication abilities on algebraic topics. Sampling was carried out by total sampling of articles that met the search criteria in the Crossref database through Publish or Perish, then the results were strictly selected based on the inclusion and exclusion criteria that had been set.

The type of data used in this study is secondary data, in the form of bibliographic metadata of journal articles which includes titles, authors of the year of publication abstract, keywords, and journal names. The data collection instrument consists of a search string documentation sheet and the Publis or Perish software as a permanent digital tool for data that extracts metadata directly from the Crossref database. The data collection technique is carried out sequentially through digital tracing stages using Publis or Perish software. The data search strategy is carried out using specific keywords, namely "mathematical communication" OR "mathematical communication skills" OR "mathematical communication" OR "mathematical communication" AND "algebra" OR "algebra learning" OR "algebraic thinking" OR "equations" OR "functions". The selection of these keywords is based on a theoretical framework and empirical evidence that links students' mathematical discourse skills to algebraic reasoning and thinking processes when solving problems (Pratiwi et al., 2025). The selection of Crossref is based on the breadth of the scope of the open-access journal article metadata index, thus allowing access to a wider scope of research.

The data collection procedure is carried out through several stages of strict selection to ensure the relevance of the analysis results. At the initial identification stage through the Crossref database, as many as 1,000 articles were found that were relevant to the specified keywords. However, in order to ensure the quality of the manuscript and its suitability with the purpose of the research, a process of cleaning and screening data was carried out. The inclusion criteria set include: (1) scientific journal articles published in the range of 2020 to 2026; (2) the manuscript is written in Indonesian or English; and (3) research topics are directly related to mathematical communication in algebraic materials, both from the perspective of general cognitive characteristics (Putri & Musdi, 2020) and those that classify them based on certain levels of mathematical ability (Dassa, 2021). Of the total 1,000 articles, 854 articles were excluded because they did not meet the inclusion criteria, such as duplication, lack of complete manuscripts, or were not relevant to mathematical communication in algebraic material were excluded from the dataset. After going through these stages, as many as 146 final articles were obtained that were declared worthy of analysis. A summary of the flow of the data collection process is presented in Figure 1.

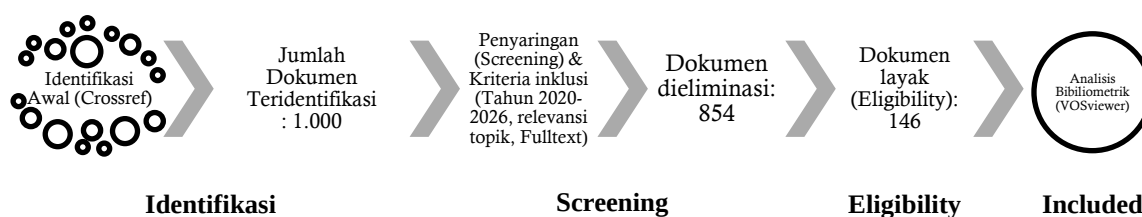


Figure 1. Data collection process

The main analysis tool used in this study is the VOSviewer software (Van Eck & Waltman, 2017). Metadata from 146 articles that had passed the selection was then extracted into a system-supported format (such as .ris or .csv) for processing. VOSviewer is used to generate network visualizations in the form of concept maps (co-occurrence) and co-authorship networks (Van Eck & Waltman, 2014). The stages of this research procedure as a whole are carried out systematically consisting of: (1) the identification stage through keyword search; (2) screening stage based on inclusion and exclusion criteria; (3) the stage of data extraction; and (4) data visualization and interpretation stage. All of these stages are visualized using flowcharts to provide a transparent picture of the research process.

RESULT AND DISCUSSION

Based on the analysis of 146 documents obtained from the Crossref database using the Publish or Perish software, the trend of research publications on mathematical communication skills in algebraic materials shows variable results in the period 2020 to 2026. The data from mapping the number of articles based on the year of publication is presented in detail in Table 1.

Table 1. Publication Trends for Mathematical Communication Skills in Algebra Materials in 2020-2026

No.	Year of Publication	Number of Articles ($N = 146$)
1.	2020	16
2.	2021	23
3.	2022	26
4.	2023	34
5.	2024	26
6.	2025	20
7.	2026	1

To provide a clearer picture of the rise and fall of the rate of publication development, the visualization of quantitative data from the distribution of publications per year is shown in the form of a graph in Figure 2.

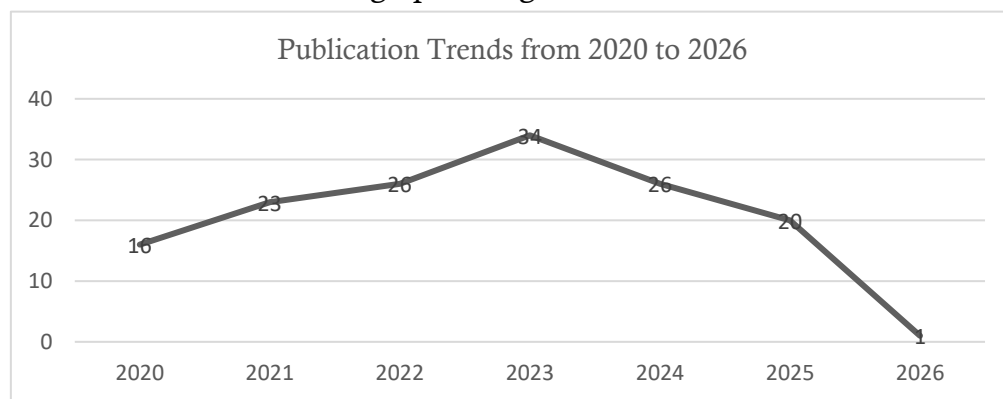


Figure 1. Publication Development Chart from 2020-2026

Based on Table 1 and Figure 2, the quantity of publications had experienced a stable increase since 2020 until reaching its peak in 2023 with a total of 34 articles published. After reaching this peak, the number of publications is likely to decline in 2024 and 2025. Meanwhile, the lowest publication was recorded in 2026 with a total publication of only 1 article. This is because at the time of taking data from that year was still ongoing, it was not fully indexed in the Crossref database. These findings are consistent with the bibliometric study of mathematics education for the period 1970-2024 which reported rapid growth to peak in 2019 and with the 1980-2020 review which showed a sharp increase especially in the last five years and placed 2020 as the highest pace point, so that overall evidence indicates an increase in research attention since

around 2020 which peaked at the beginning of the next decade before then declining (Chkana et al., 2025; Julius et al., 2021).

Profile Analysis of Publication Journals

Based on the results of the analysis of 146 documents in the dataset, the distribution of articles was concentrated in several domestic scientific journals that focused on education. The list of journals that have the most research on mathematical communication skills in algebraic materials is presented in Table 2.

Table 2. Dominant Journal Profile in Mathematical Communication Research
Publications of Algebraic Materials

No.	Name of the Journal of Publication	Number of Articles
1.	Pasundan Journal of Mathematics Education: Jurnal Pendidikan Matematika	8
2.	JURNAL PEMBELAJARAN DAN MATEMATIKA SIGMA (JPMS)	8
3.	Jurnal Edukasi dan Penelitian Matematika	7
4.	AKSIOMA: Jurnal Matematika dan Pendidikan Matematika	3
5.	Jurnal Fibonacci: Jurnal Pendidikan Matematika	3
6.	Jurnal Riset Pendidikan Matematika Jakarta	3
7.	Plusminus: Jurnal Pendidikan Matematika	3

Based on the data in Table 2, it was obtained that the most dominant journals in the publication of this study were *Pasundan Journal of Mathematics Education: Journal of Mathematics Education* and *JURNAL LEARNING DAN MATEMATIKA SIGMA (JPMS)* which each contributed as many as 8 articles. The next position was followed by the Journal of Mathematics Education and Research with a total of 7 articles. In addition, there are other journals such as *AXIOMA : Journal of Mathematics and Mathematics Education*, *Fibonacci Journal: Journal of Mathematics Education*, *Jakarta Journal of Mathematics Education Research Journal*, and *Plusminus: Journal of Mathematics Education* which each contributed 3 articles. The dominance of these journals shows that research on this topic is consistently published in journals that focus on the field of mathematics education.

These findings are in line with a Scopus-based analysis which shows that publications on mathematics learning in Indonesia are concentrated in a few specific journals and are mostly produced by the faculty of mathematics education at public universities (Supriyadi, 2022). This indicates that the topic studied is the main concern in the academic scope of mathematics education in Indonesia. The existence of journals such as Pasundan Journal, JPMS, and Aksioma shows that the contribution of research in this field is growing rapidly through national journals that focus on learning innovation and the development of mathematical skills. The focus of this publication on specific journals of mathematics education confirms that the results of the research

have a strong relevance to efforts to improve the quality of mathematics learning in schools and universities.

Quantitative Analysis of Citations

Based on the distribution of citations in the dataset, a number of key articles serve as the main reference for researchers in this field. The list of articles that made the greatest contribution from the accumulation of citations is presented in detail in Table 3.

Table 3. List of Main Articles by Highest Number of Citations

No.	Main Article Title	Number of Citations
1.	The Effect Of Problem-Based Learning (PBL) Model on Mathematical Communication Skills of Junior High School Students- A meta-Aanalysis Study	13
2.	Bibliometric Analysis of the Trend of Sociology of Communication Reasearch Topics	11
3.	Kemampuan Komunikasi Matematis Siswa Dalam Pembelajaran Matematika	8
4.	Kemampuan Komunikasi Matematis Siswa SMP pada Topik Penyajian Data di Pondok Pesantren	8
5	Toxic Relationship Dalam Komunikasi Interpersonal Di Kalangan Remaja	7
6	Kemampuan Komunikasi Matematis Siswa pada Pembelajaran Matematika	6
7.	Students' Self-Confidence and Their Mathematical Communication Skills in Solving Problems	6

Based on the data in Table 3, there are six main articles that make significant contributions with a total accumulation of 51 citations. The most cited article was a meta-analysis study on the influence of *the Problem-Based Learning* (PBL) model on the mathematical communication skills of junior high school students with 13 citations, followed by a bibliometric analysis article on communication sociology trends which obtained 11 citations. These findings are in line with a bibliometric analysis of 37,999 publications in ScienceDirect that map the dynamics of communication sociology topics during the period 2000-2023 and show that research topics change dynamically following social and technological phenomena and bibliometrics are used as a tool for mapping the research field and identifying gaps or new topics (Purnomo, 2024).

The main focus of this literature is centered on mathematical communication skills that are studied in various contexts, ranging from learning in Islamic boarding schools to their relationship with student confidence. Overall, these data show that research on the effectiveness of learning models and research trend mapping has a higher citation

impact, while expressive studies on communication skills remain a consistently referred subject in the academic realm.

Analisis Distribusi Sitasi Per Tahun

In addition to observing the number of publication documents, it is also important to analyze the distribution of annual citations to assess the impact and level of scientific references of this topic from year to year. Details of the development and distribution of total citations per year for the period 2020-2026 are presented in Figure 3.

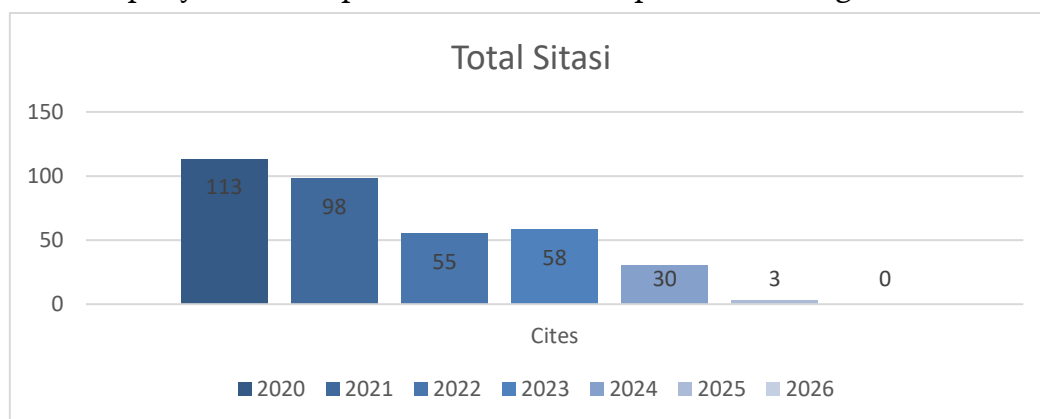


Figure 2. Annual Total Citation Distribution of Mathematical Communication Research of Algebraic Materials in 2020-2026

Based on the data in the figure, the distribution of total citations shows a downward trend after reaching its peak in 2020 with a total of 113 citations. In 2021, the number of citations began to decrease to 98 and decreased quite drastically in 2022 to reach 55. Although there had been an increase to 58 citations in 2023, the figure decreased significantly again in the following year, namely 30 citations in 2024 and only 3 citations in 2025. For 2026, the data shows a zero, which is likely caused by the current year period that has not yet ended so that the citation data has not been fully recorded. These findings are in line with a bibliometric study on *mathematical critical thinking skills* during the 2019-2024 period using Scopus data. The study found the highest peak in the 5-year analysis period with publications and citations occurring in 2020 with 55 publications and 777 citations. After 2020, the number of publications and citations decreased continuously from 2021 to 2024 (Tahmir et al., 2025).

Author Collaboration Network Analysis (C0-Authorship)

An analysis of collaboration between authors (co-authorship) was carried out to determine the level of interaction and intellectual partnership networks formed among researchers in the domain of mathematical communication skills in algebraic materials. Visualization of the author's collaboration network map as a result of the processing shot with VOSviewer is shown in Figure 4.

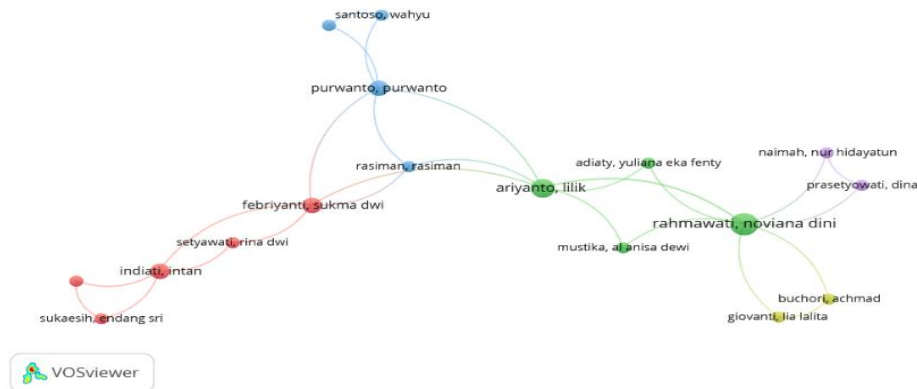


Figure 4. Processing with VOSviewer

Based on the color grouping in Figure 4, a number of key authors were quantitatively identified that showed the most prominent publication productivity and partnership strength. The indicators of the number of documents and the total link strength for the main authors are presented in detail in Figure 5. Based on the data in Figures 4 and 5, the mapping of collaboration between authors shows that there are several interconnected research groups (clusters) in the publication network. From this data, Noviana Dini Rahmawati was recorded as the author with the highest number of documents, namely 4 documents, which made her the main figure in the green network Bersama Lilik Ariyanto. Lilik Ariyanto himself has the highest total *link strength* of 4, which indicates the strongest collaboration intensity compared to the other authors in this dataset. The findings regarding this pattern of centralized partnerships are in line with a global co-authorship study in mathematics education with a total of 8,577 documents from the Scopus database found Nine main clusters in one large network, with some authors acting as central figures connecting other research subgroups (Cruz-ramírez et al., 2020). These characteristics are in line with the position of Noviana Dini Rahmawati with the most documents and Lilik Ariyanto with the highest total link strength as the main figure in the green cluster on the map.

Selected	Author	Documents	Total link strength
☒	ariyanto, lilik	3	4
☒	febriyanti, sukma dwi	2	3
☒	faizah, hanim	3	2
☒	purwanto, purwanto	2	2
☒	rahmawati, noviana dini	4	2
☒	sugandi, eko	2	2
☒	indiati, intan	2	1
☒	aklimawati, aklimawati	2	0
☒	apriliani, azha	2	0

Figure 5. Key Author Profiles and the Power of Collaborative Networks (Co-Authorship)

In addition, there are several other prominent collaborations such as the Sukma Dwi Febriyanti group which is connected to Intan Indiaty in the red network, and the Purwanto and Rasiman groups in the blue network. Although there are many contributing authors, most authors have low or zero *total strength* values, which indicates that there are still many researchers working independently or in small groups that have not been widely integrated into the main collaborative network. Overall, this mapping illustrates that research productivity and collaboration in this topic are dominated by a handful of key authors who serve as a bridge between researchers.

Analisis Peta Keterkaitan Kata Kunci (*Co-Occurrence*)

Keyword co-occurrence analysis was carried out to reveal the main concepts of the research domain, the relationship between variables, and the mapping of the topics that are most often studied in the domain of mathematical communication skills in algebraic materials. A visualization of the network of terms or keywords generated with VOSviewer is shown in Figure 6.

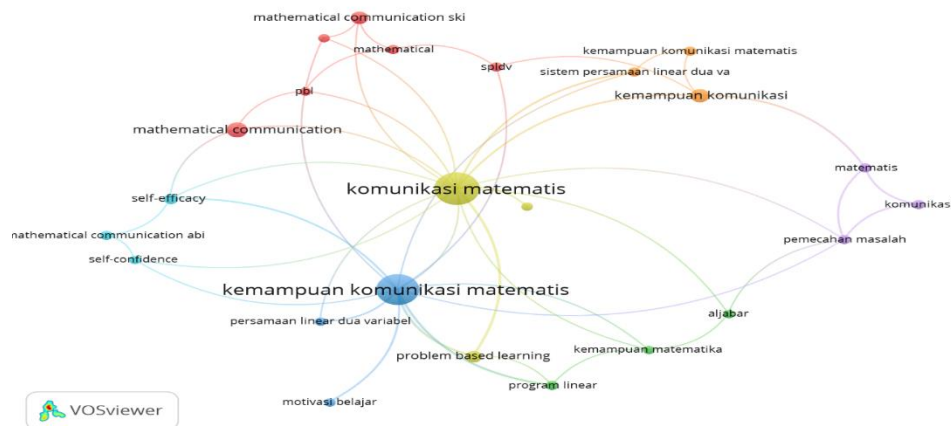


Figure 6. Visualization Map of Keyword Linkages (*Co-Occurrence*)

Based on the map of keyword interdependence (*co-occurrence*) formed in Figure 6, the results of the analysis show that the research topic is dominated by two main terms, namely "mathematical communication" and "mathematical communication ability", which are represented by the largest nodes. Both are bridges for various other variables that are divided into several color clusters. The blue and yellow clusters showed a strong relationship between communication skills and the material of the two-variable linear equation system (SPLDV), *Problem Based Learning* (PBL), and learning motivation. Meanwhile, the red and orange clusters associate mathematical communication with pedagogical aspects such as learning models and *self-efficacy*. The purple and green clusters complement this network by connecting the concept of mathematical ability to the problem-solving aspects and algebraic material.

The findings of this keyword mapping indicate that the main focus of the research in this dataset centers on how the interaction between learning models and students' mathematical communication skills is applied to specific materials in secondary schools.

The relationship of the results of this visualization is in line with the results of a meta-analysis of 12 studies on *Problem Based Learning* (PBL) and mathematical communication skills of junior high school students in Indonesia which found that PBL has a high influence on mathematical communication skills. PBL is also positioned as a consistent learning model in improving students' mathematical communication skills, especially at the junior high school level (Susanti et al., 2020).

CONCLUSION

This bibliometric mapping research shows that the trend of publications regarding mathematical communication skills in algebraic materials has fluctuated with a peak of productivity in 2023 of 34 articles. Despite the highest article productivity in 2023, the highest citation distribution occurred in 2020 with a total of 113 citations, which then tended to decline significantly in the following year. Research in this field is dominated by national journals of mathematics education such as the *Pasundan Journal of Mathematics Education* and the *Journal of Learning and Mathematics Sigma* (JPMS). In the collaboration network, Noviana Dini Rahmawati and Lilik Ariyanto emerged as key figures with the highest level of productivity and collaboration strength. The main focus of the current research is centered on the interaction between learning models, especially Problem Based Learning (PBL), on students' mathematical communication skills on algebraic topics and the two-variable linear equation system (SPLDV). Overall, this analysis confirms the urgency of conducting further research to overcome students' barriers in the mathematicization and symbolic representation of algebra through learning media innovations and digital communication models.

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