



## Research on Critical Thinking of Pre-service Mathematics Education Teachers in Indonesia (2015-2023): A Bibliometric Review

Erika Yohanna Seventina Siahaan<sup>1\*</sup>, Ilham Muhammad<sup>2</sup>, Dadan Dasari<sup>3</sup>, Swasti Maharani<sup>4</sup>

<sup>1,2,3</sup> Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

<sup>4</sup> Department of Mathematics Education, Universitas PGRI Madiun, Indonesia

E-mail: <sup>1</sup>[erikasiahana@upi.edu](mailto:erikasiahana@upi.edu), <sup>2</sup>[ilhammuhammad@upi.edu](mailto:ilhammuhammad@upi.edu), <sup>3</sup>[dadan.dasari@upi.edu](mailto:dadan.dasari@upi.edu), <sup>4</sup>[swasti.mathedu@unipma.ac.id](mailto:swasti.mathedu@unipma.ac.id),

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\* *Corresponding author*

**Abstract:** Critical thinking involves being mentally organized and participating in a judgmental process to solve problems. The purpose of this study is to look at the focus of research related to critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia from 2015 to 2023. The method used in this study is a descriptive bibliometric analysis method. The Scopus database is used to obtain the necessary data. The results of the research show that publications related to the critical thinking of Pre-service Mathematics Education Teachers in Indonesia have increased from 2018 to 2020. Most of the publications were published in conference papers and some were in Q2 journals. The research focus is divided into 4 sections, namely, 1) mathematics teacher, mathematical problems, algebra, and qualitative research; 2) critical thinking skills, mathematics education, and learning systems; 3) problem based learning and STEM; 4) data analysis techniques, information analysis. The material that is the focus of research is algebra. New themes for this field are experimental research, digital platforms, quantitative methods, and group theory. The keywords of critical thinking skills are not directly connected with these new themes.

**Keyword:** Critical Thinking, Bibliometric, Pre-Service Teacher.

### Penelitian Berpikir Kritis Calon Guru Pendidikan Matematika

#### Di Indonesia (2015-2023): Tinjauan bibliometrik

**Abstrak:** Berpikir kritis melibatkan mental yang terorganisasi dan berpartisipasi dalam proses menilai untuk memecahkan masalah. Tujuan dari penelitian ini yaitu untuk melihat fokus penelitian terkait cara berpikir kritis calon guru pendidikan matematika khususnya di Indonesia dari tahun 2015 hingga tahun 2023. Metode yang digunakan dalam penelitian ini yaitu metode analisis bibliometrik deskriptif. Database scopus digunakan untuk memperoleh data yang diperlukan. Hasil penelitian menunjukkan bahwa publikasi terkait berpikir kritis calon guru Pendidikan matematika di Indonesia mengalami peningkatan dari tahun 2018 hingga tahun 2020. Publikasi Sebagian besar dipublikasikan pada konferensi dan Sebagian ada pada jurnal Q2. Fokus penelitian terbagi menjadi 4 bagian yaitu, 1) guru matematika, masalah matematika, aljabar, dan penelitian kualitatif; 2) kemampuan berpikir kritis, pendidikan matematika, dan sistem pembelajaran; 3) pembelajaran berbasis masalah, dan STEM; 4) teknik analisis data, analisis informasi. Materi yang menjadi fokus penelitian yaitu algebra. Tema baru untuk bidang ini adalah penelitian eksperimen, platform digital, metode kuantitatif, dan teori grup. Kata kunci kemampuan berpikir kritis belum terhubung secara langsung dengan tema-tema baru tersebut.

**Keywords:** Berpikir Kritis, Bibliometrik, Calon Guru

## INTRODUCTION

Mathematics is one of the subjects that must be taught at every level of education (Muhammad & Yolanda, 2022). The purpose of studying mathematics is to shape students'

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attitudes and put pressure on structuring reasoning and skills in applying mathematics in everyday life (Marchy et al., 2022; Mayani et al., 2022). The first vision directs mathematics learning to understand mathematical concepts and ideas that are applied to solving routine and non-routine problems, reasoning, communication, and making connections in mathematics and other sciences. The second vision directs the learning of mathematics into the future, namely reasoning logically, systematically, critically, carefully, honestly, disciplined, developing creativity, and developing an objective and open attitude (Marasabessy et al., 2021).

This modern era demands more than just conceptual knowledge. The ability to apply conceptual knowledge and critical thinking is essential to cope with the demands of modern society. In the modern era, every information needs to be processed intelligently and critically with someone's knowledge (Junianto & Wijaya, 2019). The 21st industrial revolution has become a hot topic for discussion, including in the field of education. A country must be able to compete globally from the aspect of modern science and technology, one of which is through education (Handayani et al., 2021). The development of technology today is very fast. Almost all sectors are affected by this technological development. The education sector is one of the fields that has felt the impact of technological developments (Kusharyadi et al., 2023). Many of the high-paying and highly-skilled jobs available to students in the 21st century rely heavily on reading, writing, and doing math. This career requires critical thinking and problem solving skills, as well as collaboration, communication, and creativity integrated with technology (Fitriati & Prayudi, 2021).

In the 21st century, mastering basic skills such as reading, writing and mathematics is not enough and there is a need for qualified workers who can solve intellectual and technical problems. In this way, educational programs should be organized for individuals to acquire 21st century skills and competencies such as critical thinking skills, creativity, collaboration, and problem solving (Koculu et al., 2022).

Math problem solving ability influenced by several factors, such as internal factors and external factors. Internal factors include intelligence, motivation, interest, talent and mathematical ability or gender differences. External factors such as tools, infrastructure, media, curriculum, lecturers or teachers, learning facilities and others. Students who have different backgrounds and abilities in mathematics also have different abilities in solving mathematical problems. A student will not be able to develop high-order thinking skills properly without being challenged to practice the use of learning. One of the higher order thinking skills is critical thinking. Critical thinking can be possessed by someone if it is trained consistently through focused discussions or facilitated by an instructor (Rasiman, 2015).

Critical thinking involves being mentally organized and participating in a judgmental process to solve problems. Critical thinking can be seen from the activities of analyzing and interpreting data in scientific investigations. The Secretary's Commission on Achieving Necessary Skills in 1990 stated that the competence to think critically, make decisions, solve problems, and reason is important in performance (Cahyono et al., 2019). In general, critical thinking has benefits in (1) solving problems, (2) helping to consider decision-making, (3)

distinguishing between facts and opinions, and (4) calm in facing difficult problems (Susilo et al., 2020 (Susilo et al., 2020)). In research conducted by (Suharno, 2020) most students ( $\pm 90\%$ ) have a tendency to be less active and the results of the assessment on aspects of critical thinking, collaboration, communication and creativity skills in the early stages of online learning have an average score of 68.78 including the category low. This is because the teacher has not been optimal in placing the position and function of the teacher as a facilitator (bridging learning), dynamicator (moving change) and giving encouragement (motivation) in the learning process, so efforts to increase the cognitive competence and skills of 21st century students (creative thinking, communicative, collaborative and creative) cannot be achieved optimally. Critical thinking has been considered as a key skill in the latest educational programs that have been practiced by the Indonesian Ministry of Education since 2013. Therefore, pre-service teacher teachers must be trained so that they can be involved in teaching critical thinking (Firdaus & Mukhtar, 2020).

Research related to critical thinking has continued to increase in recent years, especially in Indonesia (Muhammad, Himmawan, et al., 2023). For this reason, it is necessary to carry out a literature study related to this field. The method that can be used to analyze research results in certain fields is the bibliometric analysis method (Phoong et al., 2022). Many studies have conducted literature studies using analytical methods such as those carried out by (Muhammad, Elmawati, et al., 2023; Muhammad, Marchy, et al., 2022, 2023; Muhammad, Mukhibin, et al., 2022; Muhammad, Samosir, et al., 2023). There is no research that has conducted literature reviews, especially bibliometric analysis related to critical thinking, especially in Indonesia. In improving student learning achievement, especially in the aspect of critical thinking, it is very important to first improve the critical thinking skills of pre-service teachers of mathematics education in Indonesia. For this reason, researchers conducted research related to a bibliometric review to look at research trends related to critical thinking in Pre-service Mathematics Education Teachers from 2015 to 2023 using the Scopus database. The purpose of this research is to look at the focus of research related to the critical way of thinking critically for Pre-service Mathematics Education Teachers, especially in Indonesia from 2015 to 2023.

### **Research purposes**

The purpose of this research is to find out the research focus related to the critical thinking skills of Pre-service Mathematics Education Teachers in Indonesia in learning mathematics and its novelty from 2015 to 2023 with a data population of 223. The novelty can be seen from the connectedness of the links between keywords that are displayed from the VOSviewer application. Therefore, researchers conducted research on critical thinking skills in Pre-service Mathematics Education Teachers in Indonesia using the Scopus database for 2015-2023. The research questions are as follows.

1. What are the publication trends related to the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia?

2. What are the citation trends related to the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia ?
3. How is the ranking of journals related to the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia?
4. What are the higher education institutions that publish articles related to the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia?
5. What are the novelties and research focuses regarding the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia ?

**METHOD**

A descriptive bibliometric analysis method was used in this study, while the source of the data obtained came from the Scopus database which has been refined in several stages. According to (Moher et al., 2009) there are 4 main stages in the data collection process, namely identification, eligibility screening and inclusion. These stages can be seen in Figure 1.

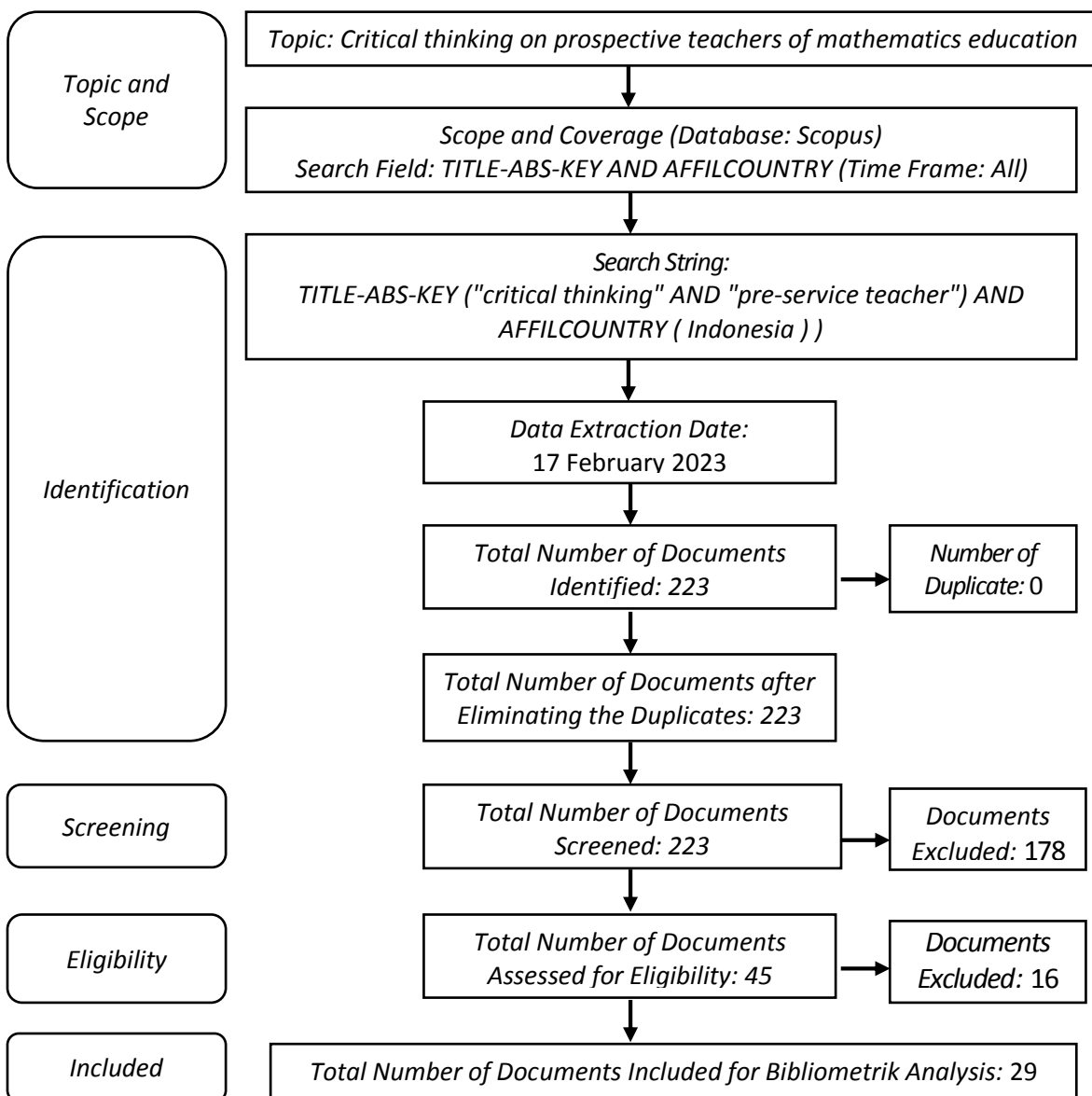


Figure 1. Data Collection Stages

The first stage the researcher carried out the identification process was by entering keywords in the Scopus database search. The arrows indicate the flow of data collection. The search string used can be seen in Figure 1. The data obtained from this first stage are 223 publications. Then the second stage is carried out, in this second stage the researcher conducts screening. In extracting the researcher sets the criteria, namely the published articles must be in English, published in journals or conference papers, then the articles are included in the area of mathematics. After the screening process was carried out, the 223 publications changed to only 45 publications. The feasibility process is carried out after screening, in this stage the researcher manually checks the 45 publications. Researchers check and ensure that articles discuss critical thinking in Pre-service Mathematics Education Teachers, articles that are inappropriate or do not contain this matter are not included in the next process. After eligibility, 29 publications that meet the requirements were obtained and can be continued at the inclusion stage.

## RESULTS AND DISCUSSION

The search results for data that have been refined from the Scopus database total 29 publications. These publications will then be analyzed using bibliometric analysis with various application aids, starting from publication trends, citations, distribution of journals and novelty, higher education institutions, as well as research focus related to critical thinking in Pre-service Mathematics Education Teachers from 2015 to 2023.

The data obtained from the Scopus database is then stored in 2 different formats, first we save it in CSV form and save it in RIS form, the CSV data will be entered and analyzed with the help of VOSviewer while the RIS data will be entered into Harzing's Publish or Perish Software. The tendency of publication and the tendency of critical thinking research citations for Pre-service Mathematics Education Teachers in Indonesia is seen from the year of publication, and the distribution of journals is seen based on their quartile values. Software Microsoft Exel and Software Harzing's Publish or Perish. VOSviewer is used to display keyword occurrence which describes the research focus. VOSviewer is also used to see what learning methods and materials are the focus of research. Harzing's Publish or Perish software is used to calculate h-index and g-index values and other data about citations and Microsoft excel software is used to display the distribution of journal ratings.

### What are the publication trends related to Critical thinking research on Pre-service Mathematics Education Teachers, especially in Indonesia?

The trend of publications related to Critical thinking research on Pre-service Mathematics Education Teachers from 2015 to 2023 can be seen in Figure 2.

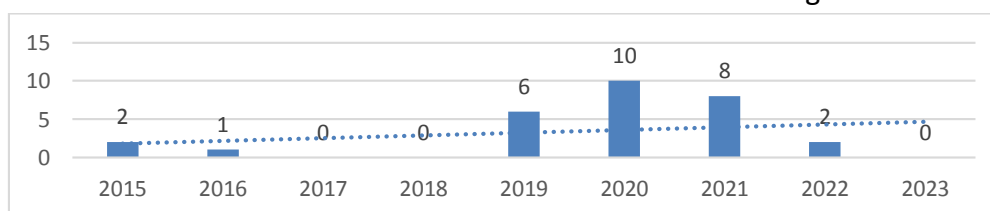


Figure 2. Publication Trends

From figure 2 above, it can be seen that 2020 was the highest peak in the number of publications related to this field. There were ten articles published in 2020. The highest increase occurred in 2018 to 2020, There were no publications in 2018, six publications the next year (2019), and ten publications the following year (2020). Even though publications related to critical thinking research on Pre-service Mathematics Education Teachers from 2015 to 2023 have begun to experience an increase in the number of publications from 2017 to 2020, there are still years with no publications at all like in 2017, 2018 and 2018. 2023. This is in accordance with what was conveyed by (Muhammad, Himmawan, et al., 2023) that research related to critical thinking is growing very rapidly.

### What are the trends in citations related to critical thinking research on Pre-service Mathematics Education Teachers, especially in Indonesia?

Publications related to this field have been detected since 2015 which has published 2 documents. The quotation trends can be seen in table 1 below as follows.

Table 1. Citation Trends

Year	TP	NCP	TC	C/P	C/CP	h	g
2023	-	-	-	-	-	-	-
2022	2	1	1	0.5	1	1	1
2021	8	5	9	1,13	1,8	1	2
2020	10	8	16	1.60	2	2	3
2019	6	6	41	6,83	6,83	3	6
2018	-	-	-	-	-	-	-
2017	-	-	-	-	-	-	-
2016	1	1	2	2	2	1	1
2015	2	2	21	10.5	10.5	2	2

Notes. TP=total publications, NCP=number of publications cited, TC=total citations, C/P=average citations per publication, C/CP=average citations per publication cited, h=h-index, g=g-index

In table 1, the trend of citations can be seen from the NCP value, the highest NCP value in 2020 is NCP = 8, followed by 2019 with NCP = 6, but when viewed from the total citations (TC) publications in 2019 have the highest number of citations among other years with 41 times quoted. means the publications in 2019 have been the most influential years in this field. While the C/P and C/CP values in 2015 were the highest, this was because the publications in 2015 had a large number of citations but a small number of publications. Quotation trends can also be seen from the h-index and g-index values. that the highest h-index and g-index values occurred in 2019 with h-index = 3 and g-index = 6.

Critical Thinking research on Pre-service Mathematics Education Teachers from 2015 to 2023 can be seen from several values. Publications in 2019 9 with the highest number of citations and the highest C/P and C/CP values and the highest h-index and g-index values. This means publications in 2019 had a major impact on this field. The publications in 2016 can be seen in table 2.

Table 2. Articles published in 2019

No	Author (year)	title	Sources	Citation
1	(Kusaeri & Aditomo, 2019)	Pedagogical beliefs about Critical Thinking among Indonesian mathematics pre-service teachers	International Journal of Instruction	12
2	(Aini et al., 2019)	Problem-Based Learning for Critical Thinking Skills in Mathematics	Young Scholar Symposium on Transdisciplinary in Education and Environment	3
3	(Kurniati et al., 2019)	Development and validity of problems with contradictory information and no specified universal set to measure the truth-seeking of pre-service mathematics teachers	TEM Journal	2
4	(Junianto & Wijaya, 2019)	Developing Students' Mathematical Literacy through Problem Based Learning	International Seminar on Innovation in Mathematics and Mathematics Education,	2
5	(Susilo et al., 2019)	Students' critical thinking skills toward the relationship of limits, continuity, and derivatives of functions	International Journal of Scientific and Technology Research	2
6	(Cahyono et al., 2019)	Analysis of critical thinking skills in solving algebraic problems in terms of cognitive style and gender	International Conference on Mathematics, Science and Education 2018	2

In table 2 above, it can be seen that the publications that have the highest number of citations are research conducted by (Kusaeri & Aditomo, 2019). Research conducted by (Kusaeri & Aditomo, 2019) is widely cited because it discusses beliefs about the value of teaching critical thinking and perceived readiness to teach critical thinking is measured using a Likert type scale, while preferences for constructivist instruction are assessed using sketches that describe teaching dilemmas. The research also highlights the need for mathematics teacher educators to place more emphasis on the importance of critical thinking, especially its dispositional dimension, and the role of constructivist instruction in developing critical thinking.

The second most cited publication in 2019 is research conducted by (Aini et al., 2019) entitled "Problem-Based Learning for Critical Thinking Skills in Mathematics", the article aims to find out how to develop students' critical thinking skills through problem-based learning and confirms that problem-based learning is an effective alternative for developing students' critical thinking skills in mathematics. Table 2 above also contains journal sources that can be used as a reference for further research that examines the same theme as this field, one of which is the journal "International Journal of Instruction".

### How is the distribution of journal ranking mapping from publications related to Critical thinking to Pre-service Mathematics Education Teachers ?

The ranking of journals is seen from their quartile values, for quartile values seen from the Scopus web or scimago, after sorting journals based on their quartile values the researcher calculates the number of publications in Q1 to Q4 as follows.

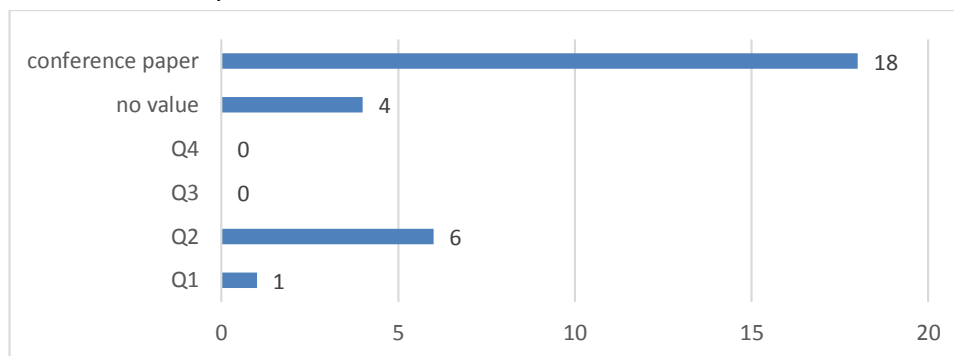


Figure 3. Distribution of Journal Ratings

From the figure above it can be seen that many publications related to Critical thinking for Pre-service Mathematics Education Teachers have been published in journals with Q2 quartile scores, namely 6 publications, while the fewest were publications in journals Q 3 and Q4 with no publications, but there are still several publications included in journals that do not have quartile values, namely as many as 4 publications. There are 18 publications in the conference paper.

Journal ranking is determined by quartile values, from 29 publications spread across various ratings starting from Q1 to those that do not yet have quartile values. Many publications related to Critical thinking in mathematics education teacher candidates have been published in Q2 journals totaling 6 publications. The highest number of publications in one journal can be seen in the table below.

Table 3. List of journals related to Critical thinking in Pre-service Mathematics Education Teachers

Journal name	Number of articles
Journal of Indonesian Science Education	3
Journal on Mathematics Education	2
Annual International Seminar on Trends in Science and Science Education	2
Young Scholar Symposium on Science Education and Environment	2

In the table above the journal "Indonesian Science Education Journal" has published articles related to critical thinking in mathematics education teacher candidates from 2015 to 2023 with 3 publications. These journals can be used as a publication destination for researchers who take the theme of discovery in mathematics education.



### What are the higher education institutions that publish articles related to the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia?

Publications related to the critical thinking skills of Pre-service Mathematics Education Teachers in Indonesia mathematics education in Indonesia from 2015 – 2023 have been written from various higher education institutions. Higher education institutions are seen based on the origin of the author's higher education institutions from publications. There are 37 higher education institutions that have published articles related to the focus of research in this field. The following is shown in table 4.

Table 4. Institution of Higher Education from the Author

No	Higher Education Institution	Number of articles	Number of Authors	Province
1	Mataram State Islamic University	1	1	Nusa West Southeast
2	Qamarul Huda Badaruddin University	1	1	Nusa West Southeast
3	Mandalika Education University	1	1	Nusa West Southeast
4	Semarang State University	3	5	Central Java
5	Telkom Purwokerto Institute of Technology	1	1	Central Java
6	Yogyakarta State University	2	3	Special Region of Yogyakarta
7	Indonesian education university	6	14	West Java
8	Kairun University	1	1	North Maluku
9	Lampung State Islamic University	1	1	Lampung
10	IAIN Metro Lampung	1	1	Lampung
11	Indonesian Institute of Education	1	1	West Java
12	Ibrahimi University, Situbondo	1	1	East Java
13	Jember State Islamic Institute	1	1	East Java
14	Bina Nusantara University	1	1	DKI Jakarta
15	Jember State Polytechnic	1	1	East Java
16	Wiralodra University	2	2	West Java
17	Sultan Idris Education University	1	2	Silver
18	Muhammadiyah Surakarta university	1	1	Central Java
19	Ahmad Dahlan University	1	1	Special Region of Yogyakarta
20	muhammadiyah Surakarta university	1	1	Central Java
21	Muhammadiyah University of Kendari	1	1	Southeast Sulawesi
22	Batusangkar State Islamic Institute	1	2	West Sumatra
23	sebelas Maret University	1	4	Central Java
24	Muhammadiyah University Prof. Dr. Hamka	1	1	Jakarta
25	Muhammadiyah Metro University	1	4	Lampung
26	Pringsewu Muhammadiyah University	1	2	Lampung
27	Mahasaraswati Denpasar University	1	2	Bali
28	Medan State University	2	3	North Sumatra
29	Nusantara Islamic University	1	1	West Java
30	Walisongo State Islamic University	1	1	Central Java
31	University of Jember	1	1	East Java
32	Malang State University	1	5	East Java
33	Raden Intan State Islamic University	1	5	Lampung
34	Sunan Ampel State Islamic University	1	1	East Java
35	Surabaya University	1	1	East Java
36	PGRI Semarang University	1	1	Central Java
37	Pakuan University, Bogor	1	1	West Java
<b>Total</b>		<b>47</b>	<b>77</b>	

From the table above it can be seen that the Indonesian University of Education has published 6 articles with as many as 14 authors, this is the largest number of publications compared to other universities. This is because in one article contains from one to four higher education institutions from the author and consists of one to six authors.

Judging from the province of the university where the author is from, of the 47 universities there are 23 of them from provinces on the island of Java, 7 universities from the island of Sumatra, 4 universities from the Nusa Tenggara Islands. This means that publications related to critical thinking for Pre-service Mathematics Education Teachers are still concentrated on the island of Java, more than half of the total, namely 23 out of 36 universities. Indonesia has five major islands, namely Java, Sumatra, Sulawesi, Kalimantan and Papua (Yuningsih et al., 2021). The islands of Kalimantan and Papua have not yet had writers from universities on the islands who have published articles related to critical thinking in pre-service teacher teachers in mathematics education. This is a challenge for researchers on the two islands to be able to conduct research related to this field. There is one university outside Indonesia, namely Perak, Malaysia. This means that there are writers who collaborate or collaborate with Malaysia. The number of collaborations carried out can be seen from the number of authors with a total of 77 authors, while the number of articles is not more than 30. This indicates high collaboration with an average of one article consisting of more than 2 authors with different affiliations.

**What are the research focuses and novelties related to the critical thinking of Pre-service Mathematics Education Teachers, especially in Indonesia ?**

Research on the critical thinking skills of Pre-service Mathematics Education Teachers especially in Indonesia from 2015 – 2023 is divided into 4 clusters, these clusters are displayed with the vosviewer application which shows the research focus in that field.

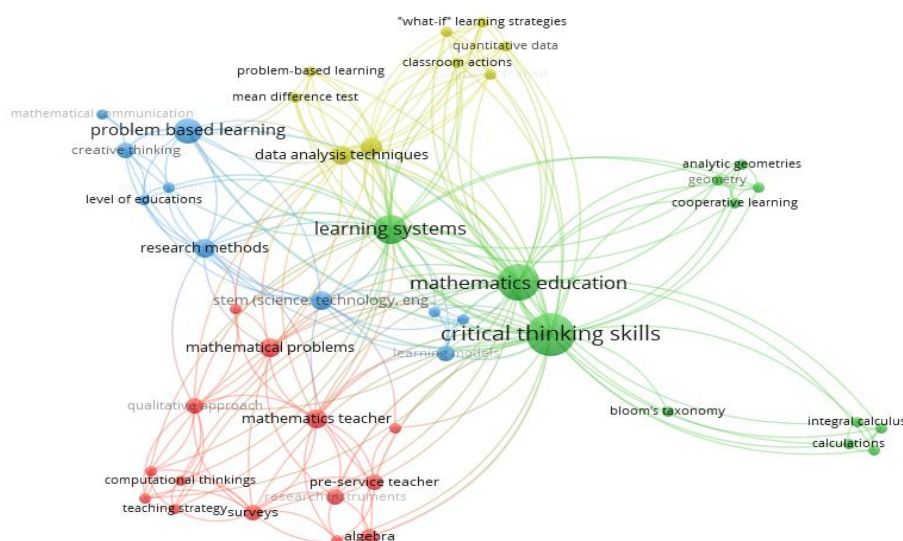


Figure 4. Network Visualization

From figure 4, there are 45 items and 4 types of colors displayed on the VOSviewer application, these colors indicate the distribution of research focus related to the critical thinking skills of Pre-service Mathematics Education Teachers in Indonesian mathematics education from 2015 – 2023. The first research focus is keywords with a red circle consisting of 14 items. The keywords with the largest circle diameter are mathematics teacher, mathematical problems, algebra, and qualitative research, meaning that these keywords are the focus of the first research. Several studies have linked the learning outcomes of Pre-service Mathematics Education Teachers' critical thinking skills in Indonesia with algebraic material in qualitative research such as those conducted by (Munawwarah et al., 2020) and (Rahaju et al., 2020), concluding that critical thinking skills of pre-service teacher education teachers Mathematics in Indonesia is still in the low category as shown by the results of the tests given. So, it is hoped that Pre-service Mathematics Education Teachers should develop their critical thinking skills which will ultimately have an impact on students' critical abilities.

The second research focus is the keywords with green circles which consist of 12 items with the keywords critical thinking skills, mathematics education, and learning systems which have larger circles compared to the circle. others, which means that those keywords are the focus of the second research. Research on the critical thinking skills of Pre-service Mathematics Education Teachers is suggested to use a learning system that utilizes skills in using technology. Support systems that are judged to be both effective and efficient in blended learning settings are those that provide access services to a variety of learning resources. Such a support system can facilitate critical thinking processes (Firdaus & Azis, 2020).

The third research focus is the blue circle, consisting of 10 items with the keywords problem-based learning and STEM. These three keywords are the focus of the third research. The focus of this research is not much different from the objectives of the second research focus, which is to utilize technology in the learning process to improve the critical thinking skills of pre-service teacher teachers which have an impact on students' critical thinking skills. The rapid development of technology is inevitable. The rapid development of the era also gave birth to a new civilization or era, namely the era of society 5.0 which replaced the era of the industrial revolution 4.0. The era of society 5.0 is an era of human-centered society with a technology base. Thus, an educator must be able to operate technology that is growing. One way to create such educators is to prepare them while still in college. Thus, universities must prepare as much as possible in order to be able to produce graduates who are able to compete in the era of society 5.0 (Hidayat et al., 2022). The research conducted (Hadi, 2021) concluded that the application of the STEM-integrated problem-based learning model was effective in students' thinking abilities. Meanwhile, at the tertiary level, there has not been a pattern of integration of the STEM approach to learning models (Rahmawati & Juandi, 2022).

The focus of the last research is the keywords with yellow circles which consist of 9 items, which have the largest circles are the keywords data analysis techniques, information analysis, quantitative methods and classroom actions. meaning that these keywords are the

focus of recent research in this field. Of the 29 articles taken from the Scopus database by researchers at this writing, it was found that research using qualitative methods was more dominant than quantitative methods.

### The focus of research is especially on the material being taught

To see the material that is the focus of research related to this field can be seen in Figure 4, the researcher entered clusters, number of links, total link strength, number of occurrences which can be seen in table 5 below.

Table 5. The focus of research on the material being taught

No	Material	Clusters	Link	Total Link Strength	Occurrences
1	Algebra	1	6	7	2
2	Group Theory	1	6	6	1
3	Analytic Geometry	2	6	6	1
4	Geometry	2	6	6	1
5	Integral Calculus	2	5	5	1
6	Integral Equation	2	5	5	1

In table 5, there are 3 main materials that are the focus of research, namely Algebra, Geometry and Calculus, the material that is in the largest cluster or the first cluster, namely algebraic material and group theory. Whereas in the second cluster there are four materials taught related to this field, namely Analytic Geometry, Geometry, Integral Calculus, and Integral Equation. There are 6 materials that are the focus of research in this field. When viewed from the linkage of the material with other keywords, algebraic material, Group Theory, Analytic Geometry, and Geometry have a total of 6 links each, algebraic material being the material that has the most Total Link Strength, with 7 total link strengths. If we look at the occurrences keyword, algebraic material is also material that has more than 1 occurrence, meaning that algebraic material has been studied more by previous researchers from 2015 to 2023 related to this field, such as research conducted by (Mellawaty & Taufan, 2021) (Mellawaty & Taufan, 2021) discusses The effect of self-concept and math anxiety on the critical thinking skills of future mathematics teachers during the Covid-19 pandemic in Indramayu Indonesia, namely by using a purposive sampling technique, the research samples taken were 4th semester students who took the Abstract Algebra Theory Ring course as many as 19 people.

### The research focus on the research method used

To see the research methods that are the focus of research related to this field can be seen in Figure 4, the researcher entered clusters, number of links, total link strength, number of occurrences which can be seen in table 5 below.

Table 6. The focus of research on the material being taught

No	Method	Clusters	Link	Total Link Strength	Occurrences
1	Qualitative	1	13	13	2
2	Quantitative	4	9	9	1
3	Experimental Research	3	6	6	1
4	Research and Development	1	3	3	1

In table 6, there are 4 methods that are the focus of research, namely qualitative, quantitative, research and development, and experimental research. The method in the first cluster is qualitative with the greatest link strength, namely 13. In terms of keyword occurrences, a qualitative method is a method that has an occurrence of more than 1, which means that qualitative methods are used more by researchers in research related to the critical thinking skills of pre-service teacher teachers, especially in Indonesia. Research conducted by (Aminudin & Basir, 2019) uses qualitative methods and aims to analyze the thinking abilities of pre-service teacher mathematics teacher students in assessing the truth of mathematical statements. The results of the research analysis indicate that there are six elements needed to have critical thinking skills, namely, focus, clarity, reason, situation, overview, and inference. However, this research suggests paying more attention to the response to a statement, besides that teachers need to develop students' critical thinking starting from childhood, and building the habit of asking investigative questions.

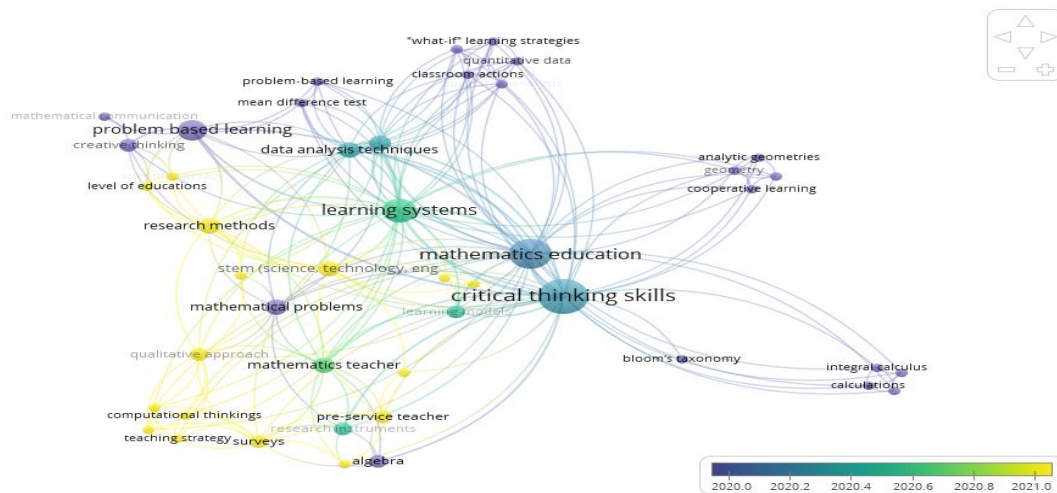


Figure 5. Overlay Visualization

In Figure 5, it can be seen that the color indicates the year of publication of the keywords used, which means that the blue keywords are old themes, while the yellow keywords are new themes that are examined in relation to the critical thinking skills of Pre-service Mathematics Education Teachers in Indonesia. New themes for this field are experimental research, digital platforms, quantitative methods, and group theory. Novelty related to research on critical thinking skills of Pre-service Mathematics Education Teachers in Indonesia can be seen from the connectedness between the keywords. Researchers look at the keywords that are the focus of research and new themes in determining research novelty. The keywords of critical thinking skills are not directly connected with these new themes. In addition, STEM keywords are not directly related to critical thinking skills in algebraic material using qualitative methods. From new theme keywords or those that are not directly related to other keywords, this is a Novelty that is useful for further research.

## CONCLUSION

From the results and discussion above, it can be concluded that publications related to the critical thinking of Pre-service Mathematics Education Teachers in Indonesia have

increased from 2018 to 2020. Publications in 2019 were most cited with a total of 14 times. Publications Most of them are published in conference papers and some are in Q2 journals. The journal " Indonesian Science Education Journal " has published the most articles related to this field with 3 publications, the Indonesian University of Education being the most influential in this field, namely with 6 publications with a total of 14 authors. The research focus is divided into 4 sections, namely, 1) mathematics teacher, mathematical problems, algebra, and qualitative research; 2) critical thinking skills, mathematics education, and learning systems; 3) problem-based learning and STEM; 4) data analysis, information analysis. The material that is the focus of research is algebra, the research method used is like a qualitative method, which is a trend from 2015 to 2023 with 13 total link strengths. New themes for this field are experimental research, digital platforms, quantitative methods, and group theory. The keywords of critical thinking skills are not directly connected with these new themes. In addition, STEM keywords are not directly related to critical thinking skills in algebraic material using qualitative methods. From new theme keywords or those that are not directly related to other keywords, this is a Novelty that is useful for further research.

#### **Suggestions and limitations of research**

In searching for data sources, researchers only use one database, this is not enough to describe the overall results of the research. For this reason, future researchers are expected to retrieve data from databases other than Scopus. The limitation of this research is that the data was taken on February 17, 2023, meaning that articles published or appearing after that date are not included in this analysis

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