

## RESEARCH ON STUDENTS' MATHEMATICAL ABILITY IN LEARNING MATHEMATICS IN THE LAST DECADE: A BIBLIOMETRIC REVIEW

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### ABSTRACT

Mathematical ability is a cognitive ability that needs to be developed in every student because the mathematical ability is closely related to solving problems that involve the relationship of numerical symbols with students' cognitive activities. This study aims to look at the description of previous research related to mathematical abilities in learning mathematics in the last decade using bibliometric analysis methods. The data taken from the Scopus database was refined so that it became 157 publications. The United States of America is the most influential country and has high cooperation with other countries in this field. The focus of this research is: 1) ICT, Augmented reality, Computational thinking, and university; 2) mathematical problems, pre-service teachers, and higher education; 3) mathematics abilities, mathematics literacy, and outcomes; 4) high mathematical ability, technology and critical thinking ability. The results of this study can be used as a reference for other researchers.

**Keywords:** mathematical ability, learning mathematics, bibliometric

### INTRODUCTION

Mathematical ability is a very important ability to support individual work results both in the academic field and in daily activities. (Özsoy et al., 2022). Meanwhile, according to (Hassan, 2021) mathematical ability becomes a cognitive ability that can be developed in every student, because it is closely related to solving problems that involve the relationship of numerical symbols with students' cognitive activities. Mathematical ability is defined as a skill possessed by students in completing tasks using concrete objects, abstract symbols, and logical reasoning that can be measured by tests of mathematical abilities (Febriana et al., 2019). According to (Barizah & Jupri, 2019) mathematical ability is a cognitive ability, namely the ability to perform calculations in the formal language of mathematics (non-verbal). So mathematical abilities are skills possessed by individuals in solving a problem by using numerical symbols or by logical reasoning.

Students' mathematical abilities have become the concern of the world of education at this time (Etang & Regidor, 2022). This is in line with what was conveyed by (Chen et al., 2022) that research is often carried out especially in terms of measuring students' mathematical abilities. This means that mathematical abilities have been in great demand

by researchers, especially in the field of education (Gunur et al., 2019). This resulted in an increasing number of publications related to mathematical ability in learning mathematics, giving rise to a large amount of academic literature (Primayanti et al., 2018).

Gaps in mathematical ability were most pronounced before children started school and have widened over time (Willingham, 2021). According to (Xie, 2020) Mathematical ability consists of four main abilities, namely numerical ability, arithmetic ability, geometric ability, and logical reasoning. In learning mathematics these four abilities are very necessary. This is in line with what was stated by (Fawziawati, 2022) that in learning mathematics numerical abilities must be developed and owned by students. The same goes for arithmetic skills (Elofsson et al., 2018), geometric ability (Larkin et al., 2019), and logical reasoning (Bezuidenhout & Henning, 2022).

In collecting existing knowledge, various methods of literature review can be used (Suseelan et al., 2022). One way is by bibliometric analysis. Bibliometric is a statistical method in analyzing publications (Phoong et al., 2022). Meanwhile according to (Zyoud et al., 2022) Bibliometrics is the basis for determining the most popular and most significant publications in a particular field. For researchers, doing bibliometric analysis will be very helpful in determining research gaps and study emphasis (Chen et al., 2019).

An existing research gap in the area of mathematical ability in mathematics learning, in the context of bibliometric research, is a lack of understanding of the trend of publications related to the topic over the last decade (Marchy et al., 2022). Although there are studies that have been conducted, there is no comprehensive bibliometric analysis that tracks and identifies related publications (Ramadhaniyati et al., 2023), influential authors (Sanusi et al., 2023), and institutions' contributions in advancing the understanding of mathematical ability in mathematics learning (Mayani et al., 2022).

In addition, the bibliometric research gap also includes the lack of research that analyzes in detail the dominant research topics, the interconnections between these topics, and the collaboration between the authors involved in the research (Muhammad et al., 2022). By conducting a bibliometric analysis, these gaps can be filled by identifying dominant research trends (Muhammad et al., 2023), describing the network of authors and institutions that work together, and identifying areas that need more attention and research development in the future.

Thus, bibliometric analysis can provide a more comprehensive understanding of the landscape of previous research on mathematical ability in mathematics learning over the last decade, as well as filling existing research gaps in the field. So the researcher seeks to conduct research related to bibliometric analysis in looking at the research landscape from previous studies on mathematical abilities in mathematics learning in the last decade.

## **LITERATURE REVIEW**

Mathematical ability has been interpreted as a multidimensional construct which involves the capacities for quantitative reasoning, causal reasoning, spatial rotation, spatial orientation, and qualitative reasoning (Isnani et al., 2020). Meanwhile according to (Hayyu

et al., 2020) Mathematical aptitudes include reasoning, communication, problem-solving, conceptual comprehension, mathematical understanding, as well as critical and creative thinking. Empirical research on mathematical ability has been extensively conducted in the past (Zandundo et al., 2020). The research was conducted to identify students' mathematical abilities at various levels of education (Bulos, 2021), and how the student's ability to solve math problems (Ernawati, 2020).

Previous research has also often linked mathematical abilities with spatial abilities. As done by (Young, 2018) which examines the relationship between spatial ability and mathematical ability, and what (Xie, 2020) did about meta-analysis related to spatial abilities and mathematical abilities. Further research conducted by (Zetriuslita, 2020) about self-regulates and self-efficacy in terms of students' mathematical abilities. And research related to mathematical abilities conducted by (Sanjaya et al., 2018) about students' thinking processes in solving mathematical problems based on their level of mathematical ability. From these studies, mathematical ability is not only associated with students' cognitive abilities, but also from a behavioral perspective, meaning that this mathematical ability is very interesting for further research.

While a bibliometric analysis is used in this study to illustrate research trends, previous related research is synthesized by analyzing the relevant literature to address the very particular research questions posed. The results of this study will help academics better comprehend the most recent studies on students' mathematical problem-solving in order to help them narrow their research focus.

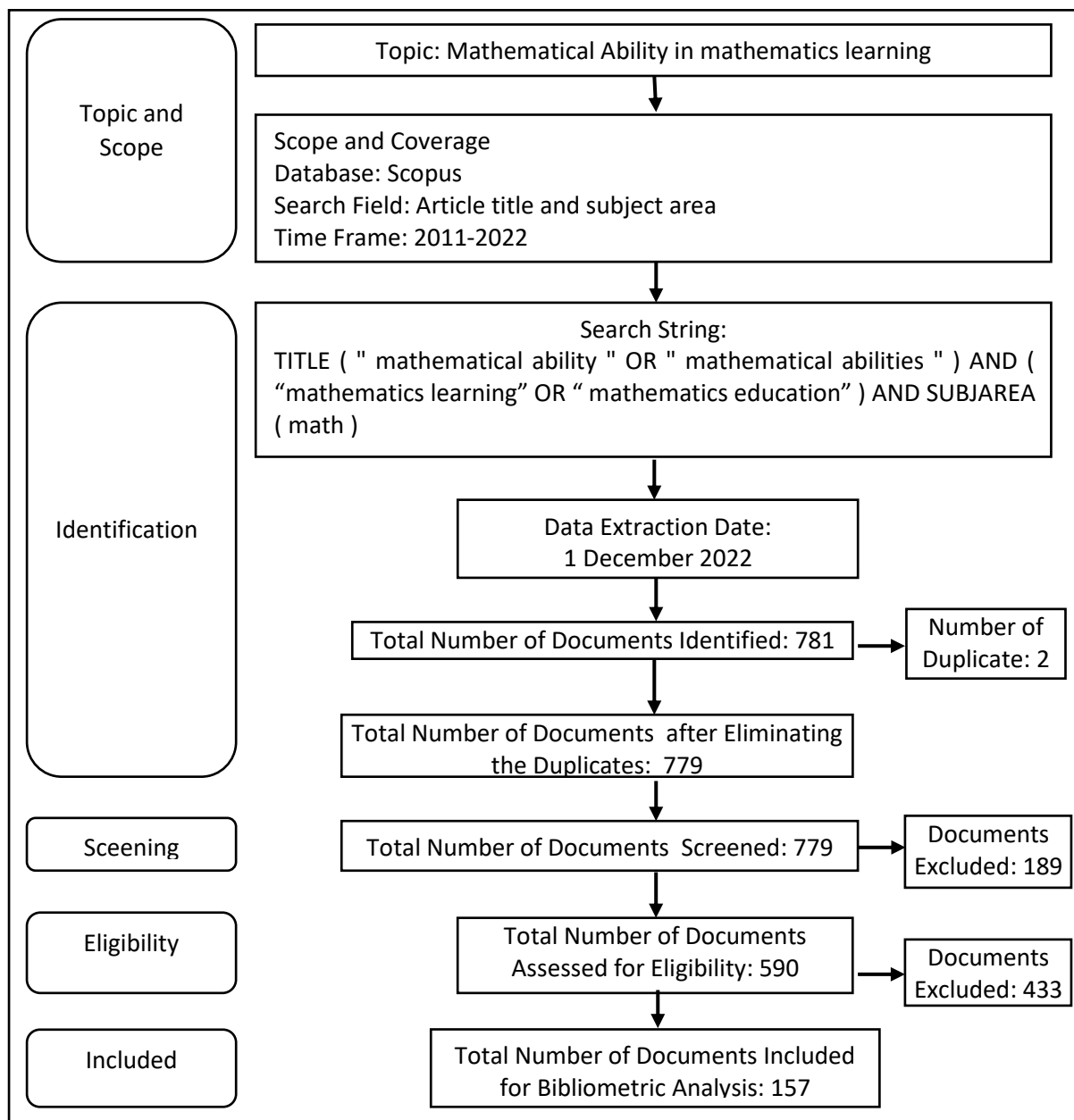
### **Aim of the Study**

This study attempts to provide the state of the art of research on students' mathematical skills as they acquire mathematics during the last ten years. The following research questions are covered in this study:

- 1) What are the current trends in research publications ?
- 2) What are the research citation trends related to mathematical ability in mathematics learning?
- 3) What is the distribution of publication mapping and relations between countries in research related to mathematical ability in mathematics learning?
- 4) What is the research focus on mathematical ability in mathematics learning?

### **METHODOLOGY**

In looking for data sources related to "students' mathematical abilities in learning mathematics", researchers used the scopus database because of its very broad interdisciplinary coverage. There are several steps in perfecting the data that has been collected as shown in Figure 1. The first is identification, then followed by screening, eligibility and finally the inclusion step (Moher et al., 2009).



**Figure 1.** Data Collection Process

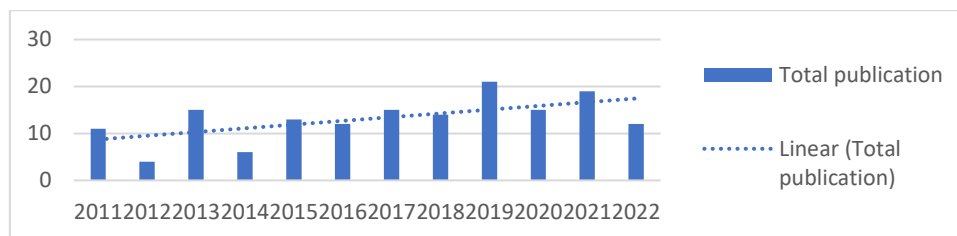
Trends in publication citations related to mathematical ability in learning mathematics are separated by year. The average publication citations were also calculated using Microsoft Excel software. As for finding the h-index and g-index of the publication, the researcher uses Publish or Perish (PoP).

In displaying the distribution of publications by country, researchers also use Microsoft Excel software to display a world map with the distribution of publications in various countries. As with the citation trend, to find the h-index and g-index of publications, researchers also use Harzing's Publish or Perish Software. VOSviewer software is used to produce network visualizations that show the relationship between countries.

Analysis of events with keywords related to mathematical ability in learning mathematics was carried out to determine the research focus. The data to be analyzed is taken from the Scopus database which must be processed first. The research focus can be determined from shared keywords visualized by the VOSviewer Software.

## RESULT AND DISCUSSION

The number of publications obtained at the inclusion stage was 157 selected publications from 2011 to 2022 at scopus database. The data sources were taken from articles with 98.09% then book chapters with 1.91%. Distribution of publications from 2011 to 2022 as shown in Figure 2 below. The highest number of publications occurred in 2019, namely 21 articles were published that year if presented in 2019 (13.37%), then in 2021 (12.10%).



**Figure 2.** Publications from 2011 to 2022

The increase occurred from 2018 to 2019, namely an increase of 50%. This means that there has been a two-fold increase from the previous number of publications. Judging from the linear line or the publication trend, it shows that publications are increasing every year. The lowest number of publications was in 2012 with only 4 publications.

### Citation Trend

The trend of quotations from 2011 to 2022 at scopus database related to students' mathematical abilities in learning mathematics as shown in table 1 is as follows.

**Table 1.** Citation Analysis of Publications

Year	TP	NCP	TC	C/P	C/CP	h	g
2022	12	7	12	1	1,71	2	2
2021	19	8	16	0,84	2	2	3
2020	15	11	102	6,80	9,27	4	10
2019	21	17	139	6,62	8,18	7	11
2018	14	13	126	9	9,69	6	11
2017	15	13	163	10,87	12,54	7	12
2016	12	11	133	11,08	12,09	7	11
2015	13	13	213	16,38	16,38	8	13
2014	6	5	200	33,33	40	5	6
2013	15	15	612	40,80	40,80	10	15
2012	4	4	88	22	22,00	3	4
2011	11	9	112	10,18	12,44	6	10

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

Table 1 above shows that the number of publications cited (NCP) in 2019 was the highest (NCP = 17). The highest total citations were in 2013 with 612 citations, followed by 2015 with 213 citations. The g-index and h-index, which are measured yearly, indicate that in 2013, when the h-index was 10 and the g-index was 15, they were at their greatest levels. This indicates that in 2013, when 15 papers were published with 612 citations and at least 15 publications had each been referenced at least 40 times, it had the greatest influence on research on students' mathematical ability in studying mathematics.

### Geographical Distribution of the Publications and Global Collaboration Pattern

The author's country of origin in documents related to mathematical abilities in the Scopus database will be shown in Figures 3 and 4. Figure 3 shows the geographical distribution of publications. Based on this figure, a total of 15 countries, namely countries with more than one publication. Figure 4 shows that the United States is the most influential country in this field. America with 24 articles published (15 percent of total publications).

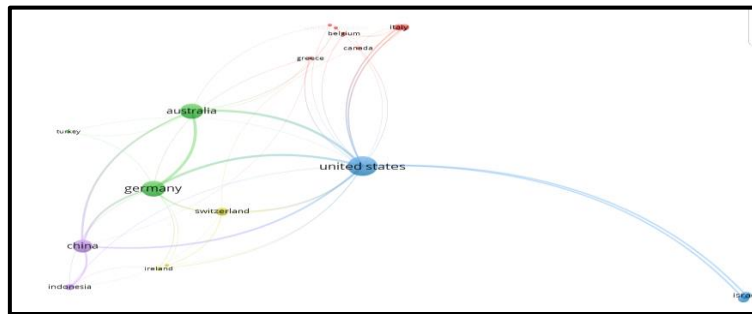
The Americas, Asia, Australia and Europe have published articles, while the African continent has not published articles related to students' mathematical abilities in learning mathematics in Scopus indexed journals. The Americas are the continent that publishes the most articles, because the country on the American continent, namely the United States, has the highest number of publications.



**Figure 3.** Geographic Distribution of Publications (Scopus Database)

In Figure 4, shows the pattern of global collaboration based on the author's country of origin which is displayed by network visualization with VOSviewer software, researchers do not set thresholds but researchers only display countries that cooperate with other countries, namely at least 1 collaboration with other countries, from 25 countries it shrinks to 18 countries after the threshold was set, of the 18 countries, the United States, Germany and Australia have the most relationships with other countries, this can be seen from the size of the circle in the countries shown in Figure 4, but not all countries are directly related to these three countries For example, there is an Italian country that is not related or has no links with Germany and Australia. The most important nation in this subject is the United States of America because it has collaborated with all countries that have published articles related to students' mathematical abilities in learning mathematics. Of the 18 countries,

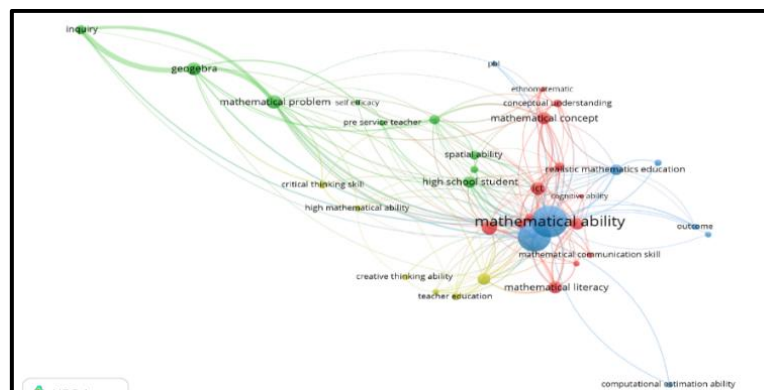
there are 5 clusters. With the largest cluster that is with a red circle. The other clusters are given a color (blue, yellow, green and purple).



**Figure 4.** Global Collaboration Patterns (Scopus database)

### Research Focus

Analysis of events with keywords was carried out to determine the research focus on students' mathematical abilities in learning mathematics. Researchers set a threshold that is at least 3 publications that contain the same keywords. From these results, the 257 keywords were reduced to 36 keywords.



**Figure 5.** Co-occurrence of keywords (Scopus database)

Figure 5's network visualisation findings demonstrate that there are four clusters with 36 items in the Mathematical Ability in Learning Mathematics category namely, 1) Cluster 1 (red in color) is the largest cluster consisting of 13 items, keywords such as ICT, Augmented reality, Computational thinking and university have the largest circle among the other cluster 1, meaning that the keyword reflects the focus of research related to mathematical ability in learning mathematics; 2) cluster 2 (colored green) consists of 9 items with the keywords mathematical problem, pre service teacher and higher education have a larger circle than the others, meaning that these keywords are the focus of research; 3) cluster 3 (dark blue) consists of 8 items where the circles on the keywords mathematics ability, mathematics literacy and outcomes are the largest in the cluster meaning these keywords are the focus of research; 4) cluster 4 (yellow) consists of 6 items with the keywords high mathematical ability, technology and critical thinking ability has the largest circle among cluster 4, meaning that these keywords are the focus of the fourth research.

### What are the current trends in research publications

The trend of publications related to mathematical abilities in learning mathematics from 2011 to 2022 shows that publications have increased from 2018 to 2019, the highest number of publications occurred in 2019 where there were 21 publications published. This is in accordance with what was stated by (Etang & Regidor, 2022) that the number of publications tends to increase from year to year related to research on mathematical abilities in learning.

The number of publications in 2019 totaled 21, but only 17 have been cited at least once, meaning that there are 4 publications that have not been cited at all. The h-index and g-index values in 2013 were the largest compared to other years. 2013 was also the year with the highest number of citations, namely 612 citations. The number of documents in 2013 was 15 documents. The 15 documents can be seen in table 2.

### What is the citation trend of research related to mathematical abilities in mathematics learning?

The publication that has the highest number of citations is in 2013 which is shown in table 2 with a total of 612 citations. In 2013 there were only 15 published articles. Research conducted by (Starr, 2013) with the title "Number sense in infancy predicts mathematical abilities in childhood" has been cited 225 times, meaning that the number of citations in one article has exceeded 35% of the number of citations in that year. Article written by (Starr, 2013) widely cited because the article supports the theory that mathematics is built on an intuitive sense of numbers that precedes language and validates many earlier studies claiming to show number sense in children. This research also demonstrates that nonverbal number sense is correlated with math ability in children and adults.

**Table 2.** Article published in 2013

No	Author (year)	Sources	Citation
1	(Starr, 2013)	<i>Proceedings of the National Academy of Sciences of the United States of America</i>	225
2	(Kattou et al., 2013)	<i>ZDM - International Journal on Mathematics Education</i>	73
3	(Ven, 2013)	<i>Learning and Individual Differences</i>	50
4	(Muldoon et al., 2013)	<i>Developmental psychology</i>	46
5	(Penner-Wilger & Anderson, 2013)	<i>Frontiers in Psychology</i>	43
6	(Tibber, 2013)	<i>Vision Research</i>	37
7	(Guillaume et al., 2013)	<i>Acta Psychologica</i>	36
8	(Fogliati, 2013)	<i>Psychology of Women Quarterly</i>	29
9	(Ludwig et al., 2013)	<i>Translational Psychiatry</i>	22
10	(Edwards, 2013)	<i>Child Neuropsychology</i>	21
11	(Vicente, 2013)	<i>Cultura and Educaci3n</i>	9
12	(Kessels & Steinmayr, 2013)	<i>Zeitschrift Fur Padagogische</i>	8
13	(Barbosa, 2013)	<i>International Journal of Instruction</i>	6



No	Author (year)	Sources	Citation
14	(Han, 2013)	<i>Magnetic Resonance Imaging</i>	4
15	(Solovieva et al., 2013)	<i>Cultura and Educación</i>	3

Article written by (Kattou et al., 2013) in 2013 it became the publication with the second most citations with 73 citations. This article has received a lot of attention since it looks at the structure of the link between mathematical creativity and ability, as well as if there is a relationship at all. Data research showed a relationship between mathematical creativity and aptitude that is favourable. A subcomponent of mathematical aptitude is mathematical creativity, according to the confirmatory factor analysis. Additionally, latent class analysis reveals that three distinct kinds of pupils with various mathematical aptitudes may be found. The three kinds of pupils who differ in mathematical inventiveness are also represented in this group of kids with a range of mathematical abilities. According to the yearly calculations for the g-index and h-index, 2013 also had the highest g-index and h-index readings. From table 2 above, 15 articles published in 2013 which have been widely cited can be used as references for further research that will examine mathematical abilities in learning mathematics.

**What is the geographical distribution of the publication and the collaboration pattern among countries in research related to mathematical abilities in mathematics learning?**

Two countries, namely the United States and Australia, are countries with the highest number of publications related to mathematical ability in learning mathematics. The top country by number of publications is the United States. The number of publications from the United States is 15% of the total, which is 24 publications. The country with the top order based on the number of publications is the United States of America. The total number of publications from the United States is 15% of the total, namely 24 publications.

Relations or collaboration between countries are also dominated by the United States, with two other countries namely Germany and Australia with a total of 26, 9 and 8 links respectively, where all countries that publish articles related to mathematical abilities in learning mathematics have collaborated with other countries. United States of America.

**What are the focus of the research on mathematical abilities in mathematics learning?**

The focus of research related to mathematical abilities in learning mathematics is divided into four parts, namely 1) ICT, Augmented reality, Computational thinking and university; 2) mathematical problems, pre service teachers and higher education; 3) mathematics abilities, mathematics literacy and outcomes; 4) high mathematical abilities, technology and critical thinking ability.

The first research focus is Augmented reality, Computational thinking and university, as research conducted by (Anistyasari et al., 2019) which analyzes the effective factors namely gender, mathematical ability, ICT, and language skills as predictors of computational thinking. The results of this study indicate that the level of computational thinking is

sequentially influenced by math ability, language skills, gender, and ICT literacy. This means that mathematical abilities and ICT affect computational thinking. Further research conducted by (Yunianto & Cahyono, 2021) who have described the development of learning media to improve the Mathematical Ability of mobile-assisted students using augmented reality and to determine the effectiveness of mobile-assisted learning media using augmented reality in team assisted individualization learning to improve student abilities. (Yunianto & Cahyono, 2021) also explained the importance of using technology in education that the main purpose of using technology is to increase the efficiency and effectiveness, transparency and accountability of learning, especially at the college or university level. For this reason, future research can make this a research theme related to mathematical ability.

The second research focus is mathematical problem, pre service teacher and higher education. According to (Yusupova, 2021) Students' mathematical abilities can be seen from their work in solving a mathematical problem or by analyzing written problem solving. Furthermore, the results of research conducted by (Agoro, 2015) shows that the four factors of mathematical ability provide the highest contribution ( $\beta=.221$ ) followed by an instructional strategy ( $\beta=.217$ ), then gender ( $\beta=.074$ ), while the method of entry gives the lowest contribution to the performance of the pre service teacher. According to (Boyd et al., 2014) teaching mathematics with confidence is associated with teachers' beliefs about their mathematical ability. For this reason, it is necessary for further researchers to choose research themes related to the mathematical abilities of pre-service teachers.

The third research focus is mathematics ability, mathematics literacy and outcomes. Research conducted by (Nurutami et al., 2018) said that students with high mathematical abilities could achieve PISA mathematical literacy levels 2 and level 4, students with average mathematical abilities could achieve PISA Mathematical Literacy level 2, and students with low mathematical abilities could not reach levels of mathematical literacy 2.3. or level 4 PISA. The last research focus is high mathematical ability, technology and critical thinking ability. Study (Benyamin et al., 2021) describes students' critical thinking abilities in solving word problems in terms of gender and mathematical ability, then the study suggests that further researchers conduct research at a higher level with more research subjects or on other variables.

## **CONCLUSION**

Based on results and discussion, the publication trend related to mathematical abilities in learning mathematics has increased from 2018 to 2019. The highest number of citations was in 2013 with 612 citations. Articles about this field seen from the geographic distribution by country show that the United States of America is the most influential country in this field which has collaborated with many countries. The focus of research in this field is as follows: 1) ICT, Augmented reality, Computational thinking and university; 2) mathematical problems, pre service teachers and higher education: 3) mathematics abilities, mathematics literacy and outcomes; 4) high mathematical ability, technology and critical thinking ability. The four research focuses are research gaps and an overview of the

research landscape related to mathematical ability in learning mathematics which encourages future researchers to determine their research focus and theme. This means that in the last decade the description of research on mathematical ability in mathematics learning has attracted great interest from researchers, they focus on computational abilities and research at the university level.

The limitations of this research are; 1) the data analyzed comes from the Scopus database, so there are many other databases that can be used such as Wos and others; 2) this research only discusses mathematical abilities in learning mathematics, so there are many other fields of education that can be further investigated; 3) data in this study taken on December 1, 2022 cannot reflect research after that time, so there may be slight differences

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