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Research Article

Trend of critical thinking skill researches in mathematics education in Scopus database across Indonesia: From research design to data analysis

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ABSTRACT

The ability to think critically is one of the goals of education in Indonesia by emphasizing students' ability to think and act uncritically for every element of life. This study uses content analysis of 28 articles published in the Scopus database from 2013 to 2023 regarding students' critical thinking skills in mathematics education as the main focus. This research reveals that 2020 saw a very significant increase in publications in Q2 and Q3. The Indonesian Education University is an institution that has a lot of cooperative relations with other institutions in this field. Among these publications, real material analysis is the most researched topic with RME as the most frequently used treatment. The dominant research design is quantitative. Tests and t-tests are the most commonly used data analysis instruments and techniques, respectively. There are various types of design, treatment, collection techniques and data analysis used, therefore future researchers are advised to choose the most appropriate method for conducting research.

Keywords: critical-thinking skills; Scopus database; data analysis; Indonesia

1. INTRODUCTION

The focus of learning mathematics in the 21st century era demands more conceptual understanding and the ability to provide justification than just applying mathematical rules, so that mathematics has a potential role for the development of thinking, including critical thinking (Darhim et al., 2020; Firdaus & Mukhtar, 2020; Hikayat et al., 2020; Marchy et al., 2022; Mayani et al., 2022). This is in line with one of the objectives of the education system in Indonesia, namely students can become critical thinkers (Peraturan Pemerintah RI, 2022) who always question, analyze, synthesize, criticize the arguments obtained, compare problems and solve problems (Agustina et al., 2020; Angraini, Lilis M., Wahyuni, 2021; Ridwan et al., 2022). In line with that, the ability to think critically is included in the 10 main competencies that have been formulated into the Assessment and Teaching of 21st Century Skills (ACT21S) (Griffin & Care, 2015). The Learning Metrics Task Force (LMTF) also includes critical thinking skills as a sub-domain of the Global Framework on Learning Domains a 21st century capability designed by UNESCO (Learning (Learning Metrics Task Force, 2013).

Critical thinking skills are very important for everyone to live in the global era because critical thinking skills are needed to evaluate the quality of information (Asari, 2015). A person with critical thinking skills can make connections between ideas, determine their relevance, build arguments, solve problems, and can justify their own beliefs and values. It is much more than gathering information and memory. A genuine understanding of how to use this information is a key requirement for critical thinking. Critical thinking really makes sense by thinking "out of the box", testing settings, and pursuing less popular systems (Ebiendele Ebosele Peter, 2012; Lata Sharma & Research Fellow, 2022). Contrary to the urgency of critical thinking skills, several studies report that students' critical thinking in several countries is still under-empowered. Research from Malaysia reports that the critical thinking skills of Malaysian students are still low or in other words less than optimal (Ghadi et al., 2015; Rashid, R, A., & Hashim, R, 2008). Low critical thinking skills of students are also found in Turkey (Aktaş & Ünlü, 2013; Sahin et al., 2016; Serin, 2013) and the Czech Republic (Kubiatko et al., 2022). Furthermore, similar cases were also reported by several studies conducted in several locations in Indonesia, such as Malang (As'ari et al., 2017), Surabaya (Saphira et al., 2022), and also in Subang (Santika et al., 2018). The lack of intensive attention to empowering critical thinking skills in some countries may be due to the design of the education system and its practical application which limits students from being actively involved in discussions, debates, and evaluating their thinking processes (Lata Sharma & Research Fellow, 2022). In fact, such activities are very important to create students who are able to think critically well.

Education should be able to accommodate optimizing the empowerment of students' critical thinking skills (Angraini et al., 2022; Sellars et al., 2018; Strauss, 2016). The development itself cannot be separated from a number of studies on improving the quality of the learning process. Several studies have also attempted to reveal the level of students' critical thinking skills in seeking potential solutions for optimizing the empowerment of critical thinking in learning activities (Payadnya & Atmaja, 2020; Syafari, 2020; Yulia et al., 2019). Information obtained from some of these research results is often used as a fundamental basis for government policies and lesson plans to be designed and implemented by teachers and lecturers.

In Indonesia, there are also many studies on critical thinking skills, especially in the context of mathematics education. several studies have focused on the distribution of students' critical thinking levels (Bayuningsih et al., 2018; Ghadi et al., 2015; Sahin et al., 2016), and other studies that discuss the effect of special learning designs on students' critical thinking abilities (Agustina et al., 2020; Marasabessy et al., 2021; Solodikhina & Solodikhina, 2019). There is also research that discusses the relationship between critical thinking skills and other parameters of student achievement (Palinussa, 2013). However, among all these studies, no one has attempted to review the information that has been reported in all of these studies. Therefore, using content analysis in several scientific journals in Mathematics education. This study aims to collect information on various studies that address critical thinking skills in Indonesia. In detail, this study is intended to answer the following questions: (1) What is the trend in the number of studies on critical thinking skills from year to year? (2) How is the distribution of journal rankings mapping from publications related to critical thinking skills? (3) How is the distribution of publication mapping and inter-organizational relations in critical thinking skills research in Indonesia? (4) What topics are most often used to investigate students' critical thinking skills? (5) What treatments did the researchers apply to improve students' critical thinking skills? (6) How diverse are the research designs used to investigate critical thinking skills in Indonesia? (7) What instruments do researchers use to measure students' critical thinking skills? (8) How is the data analysis technique used by researchers to analyze students' critical thinking skills? (9) What is the description of the series of studies that have been carried out by researchers in investigating critical thinking skills?. In several aspects, this study is different from previous studies that pay attention to critical thinking skills. Firstly, this study is focused on all published articles from 2013 to 2023; all accredited by Scopus taken from the Scopus database. Second, this study is devoted to investigating a number of articles with critical thinking skills as the main focus. Lastly, record various parameters that are used as the basis for content analysis.

2. RESEARCH METHOD

This study adheres to the principle of content analysis, which focuses on findings from various studies that have been published in scientific journals at Scopus. The method used is similar to that used by (Susetyarini & Fauzi, 2020). This study uses descriptive bibliometric analysis method. Publications related to Critical Thinking Skills in Mathematics Education taken from the Scopus database from 2013 to 2023 were analyzed using descriptive bibliometric analysis. The stages of data collection started from identification, screening, eligibility and inclusion (Moher et al., 2009).

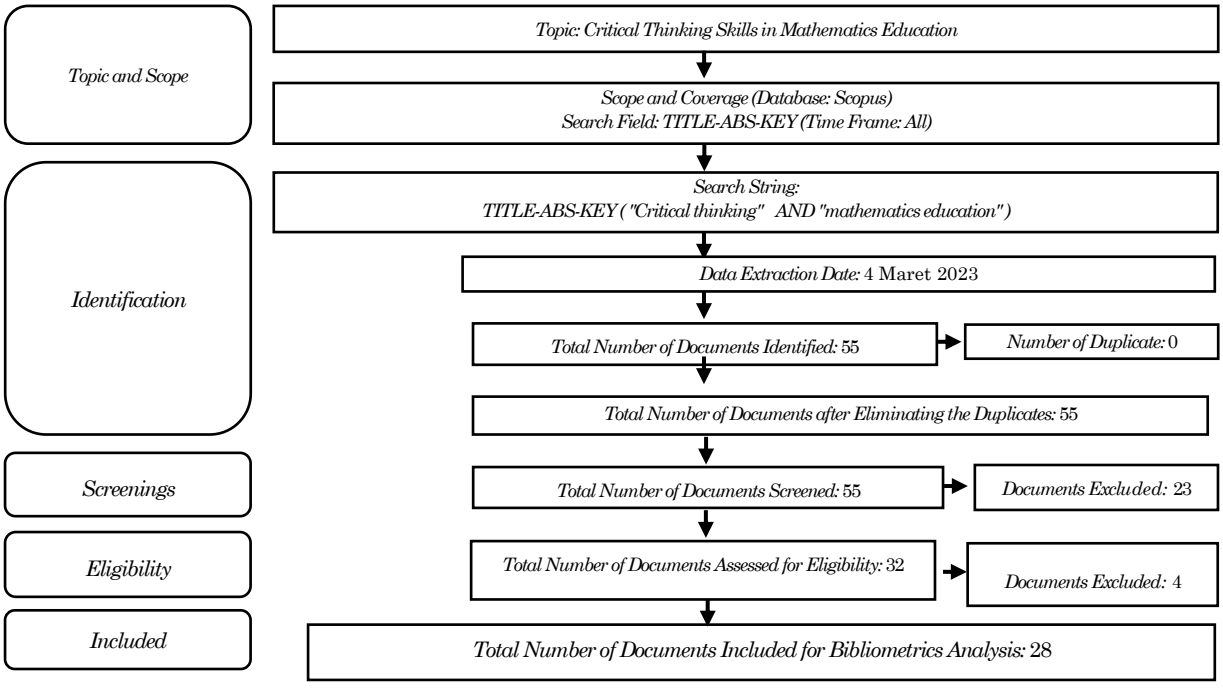

Figure 1. Data Collection Process

Identification is done by entering keywords according to the research theme to be studied. This research will discuss research on Critical Thinking Skills in Mathematics Education. For this reason, the researcher entered the keywords "Critical Thinking Skill" and "mathematics education" in the Scopus database. After entering the keywords, data obtained for 55 publications according to the specified criteria. The data from 55 publications was then examined whether there was duplicate data or not. Because there was no duplication of data, 55 publications could proceed to the next stage. Screening is carried out to select publications from the first stage, publications must meet the following criteria, namely publications in the form of articles and publications in English and research conducted in Indonesia. After screening, 23 articles were discarded and did not proceed to the next stage. A total of 32 that meet the next criteria will be carried out the eligibility stage. The third stage is conducting feasibility, the titles and abstracts of the 32 documents from the previous stage will be seen whether the documents meet the criteria, namely the title and abstract contain the words Critical Thinking Skills in Mathematics Education, after feasibility is carried out, 28 publications that meet the criteria are obtained which can be continued at the inclusion stage. 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. Each article is classified into a certain category based on certain aspects that meet the specified category. Decisions are based on the information shared by the authors in the abstract, methods, and discussion sections. Furthermore, the data that has been collected is presented in the form of bar and circle charts

3. RESULTS AND DISCUSSION

Number of Publications

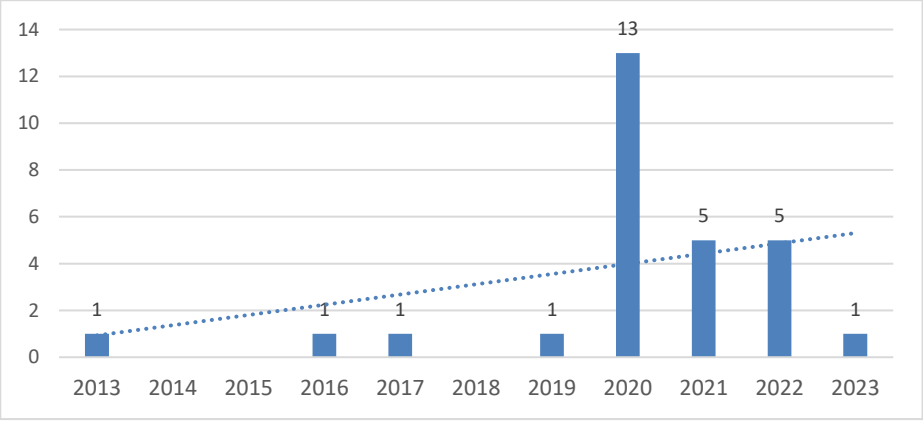

Figure 2. Trends in the increasing number of educational research publications with critical thinking skills in Indonesia

Based on **Figure 2,** it can be seen that the highest number of publications was in 2020 with 13 publications, second place, namely with 5 publications per year, namely in 2021 and 2022. Whereas in 2016, 2017, 2018 no documents were published. This means that from 2013 to 2019 there were not many changes. The increase occurred from 2019 to 2020, but then decreased. The number of publications starting from 2020 is more than in previous years, this is in accordance with what was stated by (Aktoprakac & Hursen, 2022) that research related to critical thinking has continued to increase in recent years. Next, citation trends will be seen by calculating 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, the trend of these quotes can be seen in **Table 1.**

Table 1. Citation Trends

Year	TP	NCP	TC	C/P	C/CP	H	G
2023	1	0	0	0	0	0	0
2022	5	1	1	0.2	1	1	1
2021	5	3	3	0.6	1	0	0
2020	13	10	30	2.30	3	4	5
2019	1	0	0	0	0	0	0
2018	0	0	0	0	0	0	0
2017	1	1	39	39	39	1	1
2016	1	1	0	0	0	1	1
2014-2015	0	0	0	0	0	0	0
2013	1	1	32	32	32	1	1

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

Based on the **Table 1**, the highest NCP value is in 2020, namely NCP = 10, this is because of the three publications in that year, 10 of them have been cited at least once. This value is far from the NCP value in other years. In addition to the NCP value, the citation trend can also be seen from the TC, namely the number of citations per year, publications in 2017 have been widely cited from other years, namely 39 times cited, and when viewed from the C/P and C/CP values, they are also the highest compared to other years, p. This is because the number of citations is large but the documents published are few, namely only one article published in 2017. This means that the article has the most influence on critical thinking research in mathematics learning on the Scopus database. The article is research conducted by (Aktoprakac & Hursen, 2022; As'ari et al., 2017; Samura et al., 2022)regarding the critical thinking skills of prospective mathematics teachers, where in the article it is said that teacher education institutions need to reform curriculum and their learning practices to improve students' critical thinking abilities and dispositions, because the results of the conclusions obtained say that prospective teachers have not thought critically. Therefore this can be used as a consideration for further research in order to be able to examine the curriculum and learning practices in order to improve the critical thinking skills of prospective teachers, especially in Indonesia.

Percentage of Journal Ranking

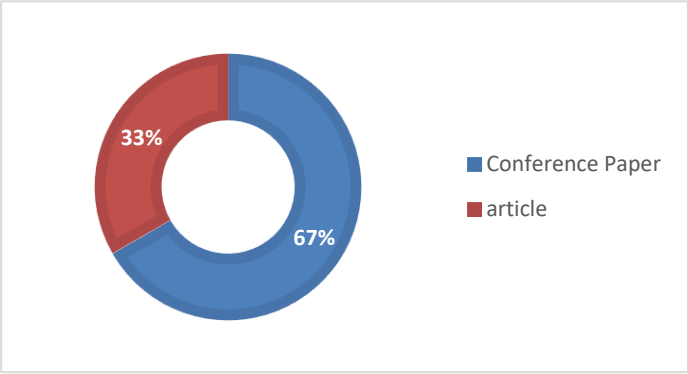

Figure 3. Types of documents published with a focus on research on critical thinking skills in Indonesia

Based on the **Figure 3,** it can be seen that the percentage of types of conference paper documents is higher than the type of article documents, where there are only two types of documents in the image, this is because the researcher set inclusion criteria where only those types of documents were included for further analysis. There are many other types of documents such as books and reviews, but the researchers did not include them because they only wanted to see the distribution of documents published in journals and proceedings. One third of the existing documents are conference paper types, namely 19 documents (67%) out of a total of 28. Article document types, namely 9 documents (32%) are spread across several journals. The researcher looks at the distribution of journals that publish documents related to this field by looking at the quartile values which are divided into four parts, namely Q1, Q2, Q3, and Q4 and there are several journals that do not yet have quartile values. The distribution of journal ratings can be seen in the table below as follows.

Table 2. List of journals related to critical thinking in learning mathematics

Journal of Name	Quartile Value	Number of Articles
Universal Journal of Educational Research	No Value	1
International Journal of Instruction	Q2	2
Frontiers in Education	Q2	1
International Journal of Evaluation and Research in Education	Q3	1
International Journal of Innovation, Creativity and Change	No Value	1
International Journal of Scientific and Technology Research	No Value	1
International Journal of Scientific and Technology Research	Q3	2

Based on the **Table 2**, can be seen that there are 9 journals which have published their documents related to critical thinking in mathematics learning. Of the nine journals, there are 2 journals with a Q2 rating and two journals with a Q3 rating, but there are 3 journals that do not have a quartile value. This means that future researchers must improve the quality of their writing so they can enter or publish their articles in reputable journals. One of the articles in a journal with a Q2 rating that has published two documents related to this field is the journal "International Journal of Instruction". Of the two documents published in the International Journal of Instruction, the most cited is research conducted by (Prabawanto & Susilo, 2020)with 27 cited. This research explains the effect of problem-based learning and posing mathematical problems in improving students' critical thinking skills. The table also does not show journals with a Q4 rating, let alone journals at Q1 or the highest rank. This spurred further research studies that wished to examine critical thinking, especially in learning mathematics, to publish articles in the journal Q1.

Publication Mapping and Institution Affiliation

To see the distribution of publications from the authors' organizations, the researchers sorted the organizations from the highest number of articles and the most authors. The organization of the authors who published their documents related to critical thinking in learning mathematics can be seen in **Table 4**.

Table 3. Author's institutional affiliation who conducts research on critical thinking skills in Indonesia

No.	University	Article	Writer
1	Indonesian education university	9	17
2	Medan State University	4	6
3	Semarang State University	4	4
4	Kairun University	3	3
5	Muhammadiyah University Prof. Dr. HAMKA	2	4
6	Riau Islamic University	2	3
7	Siliwangi Institute of Teacher Training and Education	2	3
8	Malang State University	2	2
9	Ahmad Dahlan University	2	2
10	Muhammadiyah Metro University	2	2
11	Imam Bonjol State Islamic University Padang	1	3
12	Mahasaraswati University Denpasar	1	2
13	Majalengka University	1	2
14	Muhammadiyah University of Pringsewu	1	2
15	Walisongo State Islamic University	1	2
16	Yogyakarta State University	1	1
17	Nahdlatul Ulama University Cirebon	1	1
18	Sriwijaya University	1	1
19	State University of Jakarta	1	1
20	State Islamic Institute of Ternate,	1	1
21	Indonesian Catholic University of Santu Paulus Ruteng	1	1
22	PGRI Madiun University	1	1
23	Muhammadiyah University of North Sumatra	1	1
	Total	45	65

Based on the **Table 4**, it can be seen that the Indonesian Education University is the organization with the highest number of articles, besides having the largest number of articles it is also the organization with the largest number of authors. The Indonesian University of Education has published 9 articles with 11 authors. Then in second place is Medan State University which has published four documents from 6 authors. However, there are still universities that have not collaborated with other universities such as universities that have only 1 article from one author such as Yogyakarta State University, Cirebon Nahdlatul Ulama University, Sriwijaya University, Jakarta State University, Ternate State Islamic Institute, Indonesian Catholic University Santu Paulus Ruteng, Madiun PGRI University, and North Sumatra Muhammadiyah University. In total there are 23 universities spread across various regions of Indonesia with 45 published documents from 59 authors. The cooperation between organizations or universities can be seen in **Table 4**.

Table 4. Cooperation between organizations conducting research on critical thinking skills in Indonesia

No.	Author 1	Author 2	Author 3	Author 4
1	Riau Islamic University	Riau Islamic University		
2	Mahasaraswati University Denpasar	Mahasaraswati University Denpasar		
3	Riau Islamic University	Indonesian education university	Indonesian education university	
4	Medan State University	Medan State University	Medan State University	
5	Malang State University	Yogyakarta State University	Indonesian education university	
6	Semarang State University	Indonesian education university	Indonesian education university	
7	Imam Bonjol State Islamic University Padang	Imam Bonjol State Islamic University Padang	Imam Bonjol State Islamic University Padang	
8	Muhammadiyah University Prof. Dr. HAMKA,	Nahdlatul Ulama University Cirebon		
9	Indonesian education university	Indonesian education university	Indonesian education university	
10	Medan State University			
11	Indonesian education university	Indonesian education university	Indonesian education university	Indonesian education university
12	Muhammadiyah University Prof. Dr. HAMKA,	Muhammadiyah University Prof. Dr. HAMKA,	Muhammadiyah University Prof. Dr. HAMKA,	
13	Kairun University	Indonesian education university		
14	Majalengka University	Majalengka University		
15	Siliwangi Institute of Teacher Training and Education	Sriwijaya University		
16	Semarang State University	Indonesian education university		
17	Siliwangi Institute of Teacher Training and Education	Siliwangi Institute of Teacher Training and Education		

18	Ahmad Dahlan University			
19	State University of Jakarta	Muhammadiyah Metro University		
20	Ahmad Dahlan University	Kairun University		
21	Patimura University			
22	Muhammadiyah Metro University	Muhammadiyah University of Pringsewu	Muhammadiyah University of Pringsewu	
23	Indonesian education university	State Islamic Institute of Ternate	Kairun University	Indonesian Catholic University of Santu Paulus Ruteng
24	Walisongo State Islamic University	Walisongo State Islamic University		
25	Medan State University			
26	PGRI Madiun University			
27	Indonesian education university	Indonesian education university	Semarang State University	
28	Medan State University	Medan State University	Medan State University	Muhammadiyah University of North Sumatra

Table 4, shows cooperation between universities, the number indicates the order of the articles, where it can be seen that the maximum number of authors for each article is 4 authors. This means that cooperative relations between universities in Indonesia have been well established in the field of education which aims to improve the quality of education. The distribution of the number of authors of the 28 articles obtained can be seen in **Table 5**.

Table 5. Distribution of the number of authors

No	Number of authors	Frequency	Percentage
1	1	5	18%
2	2	11	39%
3	3	9	32%
4	4	3	11%
	Total	28	100%

In **Table 5**, the researcher makes groupings based on the number of authors in one document. Documents with only one author if presented is 18% of the total. This means that there are around 18% of the articles where the universities have not cooperated with each other. More than a third of the total are documents with 2 authors. And only 11% have four authors per document. Even though there may be 4 articles with only one author, this means that the author has created 4 articles himself. It is possible that one document has 4 authors from different universities, for example in Figure 5, namely document 23 (number 23), it can be seen from the four authors, they have different universities, the first author is from the University of Education Indonesia, the second author is from the Ternate State Islamic Institute, the third author is from Khairun University, and the fourth author is from the Catholic University of Indonesia Santu Paulus Ruteng. The 23rd article (Samura et al., 2022)highlights the importance of innovating in the application of RME according to the characteristics and development of the student learning environment.

Mathematics topic chosen when conducting research

In looking at the existing material in a research result, the researcher reads the existing documents one by one. Be it from the research title, research abstract or other sections. The materials contained in the 28 articles obtained can be seen in **Table 6**.

Table 6. Selected Mathematics Topics in Educational Research with Critical Thinking Ability as Main Concern in Indonesia

No	Material	Number of articles
1	Real analysis	2
2	Univ. Statistics	1
3	Junior High School Statistics	1
4	Calculus	3
5	Calculus 2	1
6	set	1
7	SPLDV	1
8	Geometry	1
9	Trigonometry	1
10	Number Theory	1
11	UN Questions	1
12	Not mentioned	14
	Total	28

Based on **Table 6**, it can be seen that the material that is mostly taught is calculus material, although the 14 documents do not mention the material being taught. There are 3 documents that state that they teach calculus material, of course this calculus material is only taught in Higher Education. Apart from calculus, there are 9 other materials, namely statistics at university, junior high school, then there is calculus 2, sets, SPLDV, geometry, trigonometry and number theory as well as real analysis. One of the studies related to this field that teaches calculus material includes (Abdullah et al., 2020; Firdaus et al., 2021; Susilo et al., 2021). Research (Abdullah et al., 2020) is a quasi-experimental research with the aim of developing students' mathematical thinking abilities in calculus subjects where students develop mathematical concepts from their own experiences, data obtained from Student Worksheets, observation of student activity sheets in discussing solving problems , and draw conclusions through a critical thinking process.

Percentage of each treatment research

Giving treatment aims to test the research hypothesis or identify the significance of certain conditions in each parameter studied. Based on **Figure 4**, Realistic Mathematics Education (RME) and Problem Based Learning (PBL) are the most widely used treatments in critical thinking skills research. There are eight publications using RME, and four using PBL. Following these treatments, 4-D development, which consists of the Define, Design, Develop and Disseminate stages, is the third most used. This is in line with the bibliometric studies conducted (Aktoprakac & Hursen, 2022; Richards, 2009; Trinh Thi Phuong et al., 2022) with the findings obtained as a result of the analysis conducted showing that there has been an increase in interest in RME research after 2016 and The overall research findings indicate the need for further studies on RME because realistic mathematics education is considered a significant method of finding solutions to problems in the field of mathematics education.

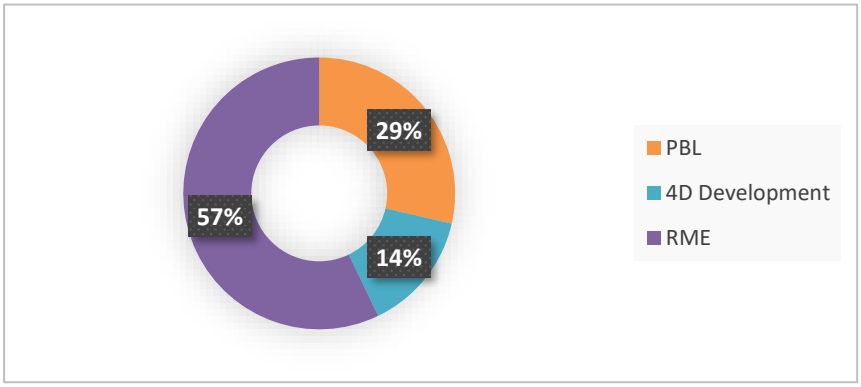

Figure 4. Three types of treatment or independent variables that are often chosen in educational research with critical thinking skills as the main concern in Indonesia

Percentage of each research design category

The research focus is determined by the type and research design used in the study.

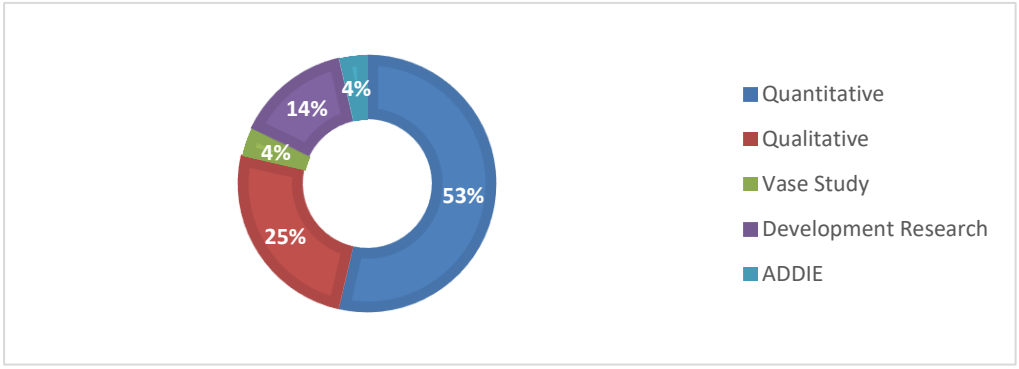

Figure 5. Distribution of Research Focus on Critical Thinking Skills by Type of Research

Based on **Figure 5**, the type and design of the research used by the researchers to investigate students' critical thinking skills was a quantitative study of 15 articles out of 28 articles or equivalent to 53% of the total. This is in line with several previous studies which have reported that researchers prefer quantitative research designs over other designs (Eğmir et al., 2017; Ozkan et al., 2022). On the other hand, qualitative research is considered relatively new in educational research (Sharma, 2013). However, the trend of qualitative research design is starting to increase in the field of education (Alnaim, 2018; Richards, 2009; Shakouri, 2014). Such conditions are closely related to the advantages of a qualitative approach to define a phenomenon in detail and comprehensively. Therefore, the lack of existence of qualitative research has opened up opportunities for future researchers to use qualitative research designs and focus research on critical thinking skills.

Percentage of each data collection technique

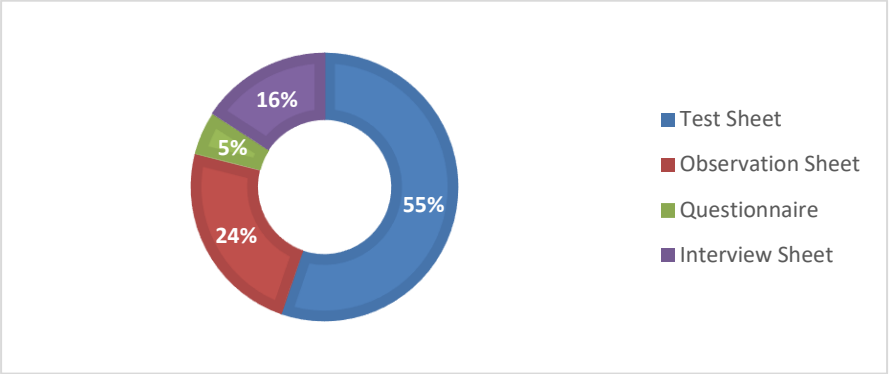

Figure 6. Distribution of the Selection of Data Collection Instruments in Several Educational Researches with Critical Thinking Skills as the Main Concern in Indonesia

In a study, researchers must have instruments as a tool in collecting data. Students' critical thinking skills can be measured by various types of instruments developed by previous researchers or developing new instruments. From Figure 6 above, the question sheet instrument is the most commonly used by examiners to collect data on students' critical thinking skills. In essence, critical thinking skills are ways of thinking that can be assessed based on students' answers to high-level questions (Susilo et al., 2020; Wikanengsih et al., 2020). Some researchers did not inform whether the instrument used had been tested for reliability and validity regarding the test used as the main technique in collecting data. Testing the reliability and validity of instruments in a study to collect any data is an important point so that it can convince every reader (Bajpai & Bajpai, 2014).

Percentage of each data analysis technique

Referring to **Figure 4**, of the 28 articles published in the Scopus database related to students' critical thinking skills in mathematics, 53% of the research used a quantitative design, 21% of the researchers used the t-test as a data analysis technique (Figure 7), meaning that researchers often using the t-test to analyze the data obtained. In the t-test to test the hypothesis, there are two general trends shown by the researchers, namely the first is to take post-test data only and the second is to take pre-test and post-test data. The accuracy of the selection of techniques used for data analysis determines the level of validity of a study (Abrami et al., 2008; Duru & Ozgungor, 2022).

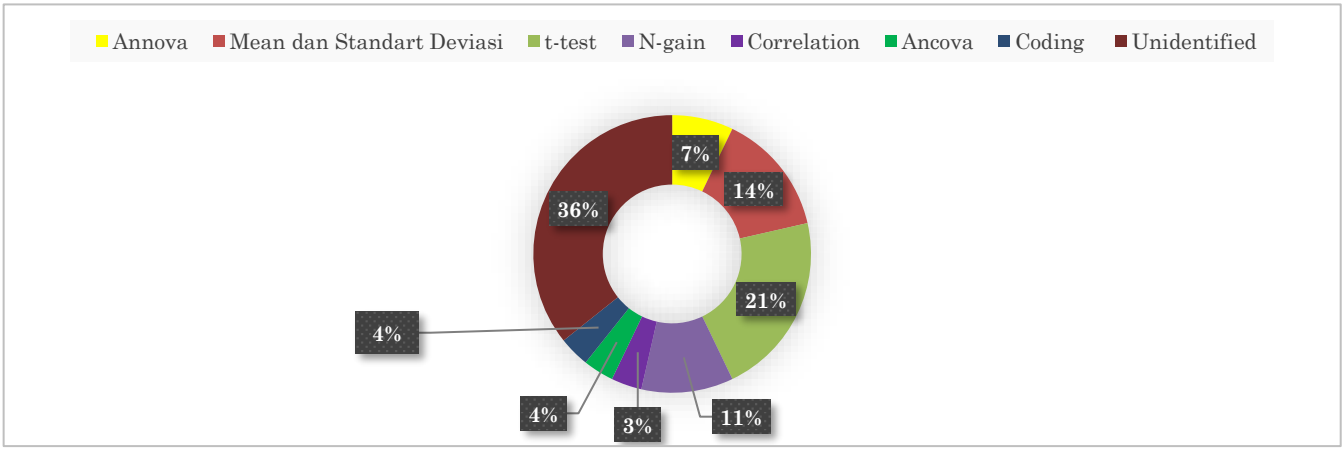

Figure 7. Distribution of the Selection of Data Analysis Methods in Several Researches on Education with Critical Thinking Skills in Indonesia.

4. CONCLUSION

This study is a content analysis study of articles in the field of mathematics education published in the Scopus database from 2013 to 2023 concerning students' critical thinking skills of 28 articles. There is an increasing diversity of publications, journal rankings, institutional affiliations, designs, topics, treatments, data collection techniques, and research data analysis techniques used in each article. It has been found that there has been a very significant increase in the number of publications in 2020. Out of all published publications, no articles have been included in Q1. This can be a motivation for researchers to improve the quality of writing the results of research that has been done. However, behind that institutional affiliation has been implemented between several institutions, such as the Indonesian Education University as an

institution that often collaborates with other institutions. Real analysis material is the most chosen topic with RME as the most widely applied treatment. Researchers tend to use a quantitative design, while tests and t-tests are the most commonly used instruments to collect data and analyze it. The limitation of this research is that data collection from one database allows the results to be different if you use more than one database or other databases. Some recommendations for future researchers from the results of this study are first, it is necessary to increase the frequency of qualitative research to investigate the progress of students' critical thinking skills. Second, the researcher should clearly inform about the instrument and the validity and reliability of the research instrument.

CONFLICT OF INTEREST

There are no conflicts of interest declared by the authors.

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