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MATHEMATICAL REASONING ABILITIES DURING PANDEMIC COVID-19: LITERATURE REVIEW

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Abstract

The purpose of this article is to describe the profile of students' mathematical reasoning abilities during the COVID-19 pandemic. Mathematical reasoning is an important aspect of learning mathematics, especially in the 21st century. By using adequate reasoning abilities, students can become proficient communicators and defend arguments using their reasoning and proofs in various contexts of everyday life. The method used in this article is literature review with a focus on empirical experience published in ERIC, Google Scholar and Crossref. The results showed that there were 26 articles on students' mathematical reasoning abilities during the Covid-19 pandemic published in 2020-2022. The articles included used quantitative, qualitative, and mixed methods. Each article came from a different country and was dominated by Indonesia with research subjects from elementary, secondary, high school, college, and teacher levels. The mathematical content used is mostly for studying geometry. The profile of mathematical reasoning abilities during the Covid-19 pandemic, namely students with high reasoning abilities were able to fulfill all reasoning indicators well and solve all questions correctly. Students with moderate reasoning abilities are able to meet the indicators of submitting conjectures, collecting evidence, and providing reasons. Students with low reasoning abilities only meet the indicators of presenting mathematical statements properly and cannot solve all the questions correctly.

Keywords: Covid-19 pandemic; mathematical reasoning ability; literature riview

Abstrak

Tujuan dari artikel ini adalah untuk mendeskripsikan profil kemampuan penalaran matematis siswa pada masa pandemi Covid-19. Penalaran matematis merupakan aspek penting dalam pembelajaran matematika, terutama di abad 21. Dengan menggunakan kemampuan penalaran yang memadai, siswa dapat menjadi komunikator yang cakap dan mempertahankan argument dengan penalaran dan pembuktiannya dalam berbagai konteks kehidupan sehari-hari. Metode yang digunakan dalam artikel ini adalah literature review dengan focus pada pengalaman empiris yang dipublikasikan di ERIC, Google Scholar and Crossref. Hasil penelitian menunjukkan terdapat 26 artikel mengenai kemampuan penalaran matematis siswa pada masa pandemi Covid-19 diterbitkan pada tahun 2020-2022. Artikel yang terhimpun menggunakan metode penelitian kuantitatif, kualitatif, dan mixed method. Artikel berasal dari negara yang berbeda dan didominasi oleh Indonesia dengan subjek penelitian dari jenjang SD, SMP, SMA, Kuliah, dan Guru. Adapun konten matematika yang digunakan lebih banyak mempelajari geometri. Profil kemampuan penalaran matematis pada masa pandemic Covid-19 yaitu siswa dengan kemampuan penalaran tinggi dapat memenuhi semua indikator penalaran dengan baik dan menyelesaikan semua soal dengan benar. Siswa dengan kemampuan penalaran sedang mampu memenuhi indikator mengajukan dugaan, mengumpulkan bukti, dan memberikan alasan. Siswa dengan kemampuan penalaran rendah hanya memenuhi indikator penyajian pernyataan matematis dengan baik dan tidak dapat menyelesaikan semua soal dengan benar.

***Kata kunci**: Kemampuan penalaran matematis; pandemi covid-19.*

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INTRODUCTION

The National Council of Teachers of Mathematics (NCTM) sets five standards for the mathematics learning process, which are problem solving, reasoning, communication, connection, and representation (NCTM, 2000). Based on this, mathematical reasoning in mathematics is a necessity and is the main part of mathematics that must be owned and developed by students (Tauran, 2018). The curriculum objectives also emphasize the importance of mathematical reasoning. Mathematical reasoning ability is the ability to think logically to obtain a conclusion (Kartono & Shora, 2020). According to Brodie (Niswah & Qohar, 2020) mathematical reasoning is a thinking process to reconstruct the knowledge obtained from the results of connecting new knowledge with existing knowledge. Through reasoning abilities, students can develop their capacity to reason and act logically, such as analyzing, proving, evaluating, explaining, drawing conclusions, justifying, and making generalizations (Herbert, 2021). In line with NCTM, mathematical reasoning plays a role in formulating, evaluating mathematical arguments, selecting and utilizing various representations (Bozkuş & Ayvaz, 2018). The results of Wai, Lubinski, & Benbow's research showed that reasoning skills could be a key aspect of advanced studies in mathematics, science, technology and/or engineering (Siemon et al., 2018).

The urgency of the mathematical reasoning ability is not in accordance with the facts in the field which show that the mathematical reasoning ability is not optimal. Previous findings stated that most students had difficulty in expressing ideas and developing logical arguments (Sumarsih et al., 2018). Students still have weaknesses in mathematical reasoning where indicators that are less controlled by students include following the rules of inference, giving examples of opponents, and checking the validity of arguments in sequence (Darta & Saputra, 2018). Another reason could be due to the adaptation of the new learning environment faced by students, especially during the COVID-19 pandemic. The adaptation process takes time and can have an impact on these abilities. In addition, the 2015 Trend In International Mathematics And Science Study (TIMSS) data shows that the mathematical ability of Indonesian students is ranked 44th out of 49 countries (Akrom & Triyanto, 2021). Meanwhile, the results of the 2018 PISA study released by the OECD in 2019 showed that the mathematical reasoning ability of Indonesian students was ranked 72 out of 78 countries (Nurjanah et al., 2021).

Many research studies on mathematical reasoning abilities have been carried out, but not many publications have discussed the profile of students' mathematical reasoning abilities during the Covid-19 pandemic. Likewise, in terms of methodology, as far as is known, not too many studies on students' reasoning abilities during the pandemic have been revealed using literature reviews. Therefore, this research was conducted as a means and effort for researchers and teachers who are interested in creating solutions to develop students' reasoning abilities.

The purpose of this study was to describe the profile of mathematical reasoning abilities in articles published in 2020-2022 contained in the ERIC, Google Scholar, and Crossref databases. In this study, the following research questions were discussed: (1) How is he

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distribution of articles by year of publication? (2) How is the distribution of articles based on research methods, origin of articles by country, and research subjects? (3) How is math content used? and (4) What is the profile of students' mathematical abilities?

RESEARCH METHOD

The purpose of this study is to review the published literature that provides information on the reasoning ability profile of students during the Covid-19 pandemic. The subjects of this research are articles or national and international journals related to the reasoning abilities during the pandemic. This type of research is descriptive research with a systematic literature review method. Systematic literature review is a scientific process governed by an explicit and demanding set of rules, oriented towards demonstrating completeness, immunity from bias, and transparency and accountability of techniques and practices (Bicer, 2021).

The systematic literature review protocol used in this study followed the PRISMA (Preferred Recording Items for Systematic Review and Meta-analysis) guidelines which consisted of a sequence of steps starting from inclusive and exclusive criteria, electronic database, study selction, collecting data, and extracting data (Page et al., 2021), (Prill et al., 2021).

1. Inclusive & Exclusive Criteria

We included research articles published starting in 2020 that have abstracts and full texts in English, Indonesian, or spanish to test mathematical reasoning skills during the COVID-19 pandemic. We excluded research articles using languages other than English or Indonesian and other exclusion criteria that fit the purpose of this article (Table 1).

Table 1. Inclusion and exclusion criteria

Inclusion Criteria (IC)	Exclusion Criteria (EC)
IC1 : Published in 2020-2022	EC1 : Duplicate articles
IC2 : About mathematical reasoning skills	EC2 : Outside mathematics education
IC3 : Written in English, Indonesian, or Spanish journals	EC3 : Written in journals other than English, Indonesian, or Spanish
IC4 : Have abstracts and full texts	EC4 : Incomplete article
IC5 : Conducted during the COVID Pandemic	EC5 : Not conducted during the COVID Pandemic

2. Electronic Database

The relevant literature was reviewed following a search of 3 databases, namely the Education Resource Information Center (ERIC), the Google Scholar search engine and Crossref. The limitation of literature search started since the Covid-19 pandemic entered Indonesia, namely March 2020 until the literature search was carried out, namely May 2022. This was intended to keep the included research up to date. Literature searches in the Google Scholar and Crossref search engine databases are carried out through Publish or Perish. The three databases used keyword: "Mathematical Reasoning" or "Mathematical Reasoning Ability", and "Mathematics" or "Mathematical Education", and "Pandemic" or "Covid".

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3. Study Selection

A systematic review was carried out as a further screening effort based on the keywords, inclusion and exclusion criteria listed in Table 1 to minimize bias in article selection while minimize bias in article selection while limiting the sample. Scientific literature was extracted by reading the title and abstract by the researcher and assisted by the second researcher if there was uncertainty in determining which articles should be included.

4. Collecting Data

Data collection on the Google Scholar and Crossref databases was carried out in Publish and Perish which was saved in the form of a RIS file then articles from the three databases (ERIC, Google Scholar, and Crossref) were collected in one folder to be checked for duplication through Mendeley's assistance. Furthermore, the researcher carried out the extraction manually. This process resulted in 26 articles being included.

5. Extracting Data

The data obtained from each study include the research period, country of origin, research design, educational level of research subjects, mathematical content used, as well as the process of data obtained and the results.

RESULTS AND DISCUSSION

The identification study from the database using keywords that match the article titles obtained 1.345 articles (145 from ERIC, 200 from Google Scholar, and 1.000 from Crossref). Based on the PRISMA procedure, duplicate data (EC1) is applied at the identification stage. At the screening stage, scientific articles were searched that focused on research on mathematical reasoning abilities (IC2, EC2) in order to obtain 355 articles. Furthermore, the application of inclusion criteria IC3, IC4 resulted in 296 articles. In the Inclusion stage, articles that were not carried out during the COVID Pandemic (EC5) were omitted so that 26 samples of articles were obtained for analysis. The following is a flow chart showing the study process from a systematic literature review (see Fig.1).

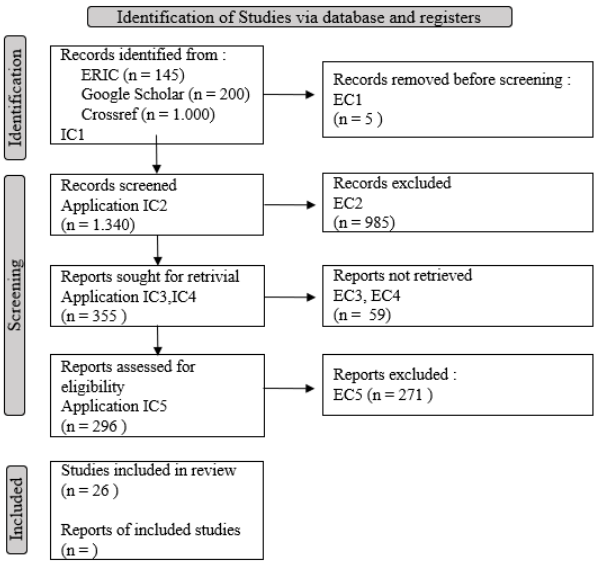

Figure 1. Flowchart

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1. Study Characteristics

The 26 articles reviewed were published from 2020 to 2022 and came from various countries, which are Taiwan, Mexico, Latvia, Indonesia, Brazil, and Indonesia. The article uses quantitative, qualitative, and mixed methods with subjects from elementary, secondary, highschool, collage, and teacher.

2. Result of Syntheses

Based on the year the article was published, it is known that the most articles about the ability to reason during the Covid-19 pandemic were in 2021, which was 18 articles. In 2020, 2 articles were found, while until May 2021 there were 6 articles.

In Fig. 2 regarding the research methods used, articles that used qualitative and quantitative methods had the same number of 12 articles. Meanwhile, there were 2 articles that used mixed methods. Furthermore, in Fig. 3, it is known that the country that published the most articles on mathematical reasoning ability during the pandemic is Indonesia with 20 publications, followed by Brazil with 2 publications and 1 publication each from Taiwan, Switzerland, Latvia, and Australia. Fig. 4 shows the percentage of research subjects conducted on junior high school students as much as 54% dominate the research reviewed. Meanwhile, at the high school level the percentage reached 23%, followed by elementary school students as much as 7%. The research was also conducted at the tertiary level with a percentage of 8% and at least (4%) was conducted on teachers, teachers and students.

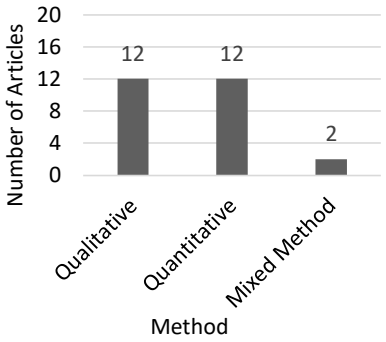

Figure 2. The research methods used

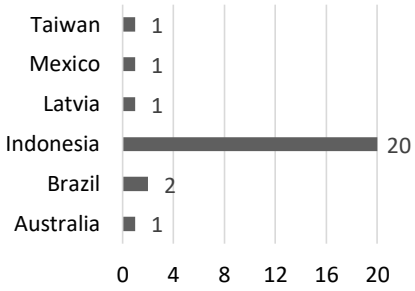

Figure 3. Origin of articles by country

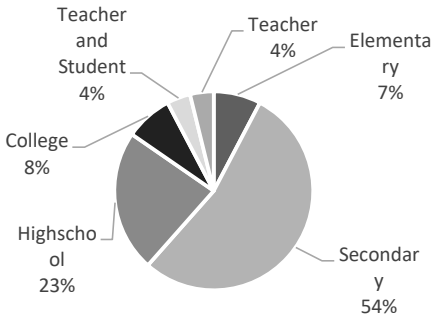

Figure 4. Percentage of research subjects conducted

Based on the mathematical content in table 1, there are 5 articles that examine mathematical reasoning with geometry material. Geometry was chosen because it has the potential to study and support reasoning (Azzahrah et al., 2020), (Novianda et al., 2021), spatial reasoning (Thom et al., 2021). According to Kaplar et al. (2022) the effect of the Triangle of Interactive Learning Materials (iLMT) on the topic of geometry through the use of

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GeoGebra for solving tasks that require various types of mathematical reasoning does not rule out the possibility of having a significant effect of interactivity on learning, especially during the COVID-19 pandemic. The most important thing is the availability of digital versions of learning materials. The reasoning ability mobilized using GeoGebra has great potential to stimulate the evolution of students' geometric thinking through the development of geometric perception, intuition, and visualization (Sousa et al., 2021), (Sousa et al., 2022). The choice of geometry topics in research Novianda et al. (2021) is motivated by the mathematical reasoning abilities of high school students in geometry material through direct learning in class is not optimal, so the purpose of the research is to find out the mathematical reasoning abilities of high school students in distance learning. In addition, circle material, and statistics are also included in learning mathematical reasoning with a total of 3 articles each. Two articles covered the context of Covid-19, eight other mathematical content including fractions, Pythagorean theorem, ratios and proportionals, equivalence, 3D modeling and matrices, and 6 articles covering various subjects.

Table. 2 Mathematics content at every level of education

No	References	Math Content
1	(Atiyah et al., 2021)	Fraction
2	(Nst & Julyanti, 2022)	Pythagoras Theorem
3	(Pamungkas & Sutarni, 2021),(Sihombing et al., 2021), (Rumahorbo et al., 2020)	Circle
4	(Kaplar et al., 2022), (Sousa et al., 2021), (Sousa et al., 2022), (Azzahrah et al., 2020), (Novianda et al., 2021)	Geometry
5	(Rohati et al., 2021)	Ratio and Proportion
6	(Nurviani1 et al., 2021)	Congeniality
7	(Fowler et al., 2021)	The 3D modeling
8	(Pratiwi et al., 2021)	Two-variable Linear Equation Systems
9	(Linda & Asyura, 2021), (Nurazizah & Zulkardi, 2022)	Mathematics Problem COVID-19 Context
10	(Kurniawan et al., 2021)	Matrix
11	(Ariwinanda et al., 2022), (Jayanti & Jumroh, 2021), (Lugo-Armenta & Pino-Fan, 2021)	Statistics
12	(Hacatrjana, 2022), (Khairunnisa & Amry, 2021), (Dewi, 2021), (Ramadhany, 2021), (Septaria & Dewanti, 2021), (Buwono et al., 2022)	Other

The results of several studies showed that the mathematical reasoning ability of high school students during the COVID-19 pandemic is not optimal, especially when measured using the PISA Post-Covid-19 mathematical models (Linda & Asyura, 2021) or statistical problems (Ariwinanda et al., 2022), as well as the reasoning abilities of elementary school students (Atiyah et al., 2021) and college students (Ramadhany, 2021). Other studies show the opposite where students' arithmetic and mathematical reasoning abilities are quite good. Likewise, junior high school students seem to have a fairly good flow

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of proportional reasoning when the context of the problem is related to the COVID-19 pandemic (Rohati et al., 2021). In terms of gender, the mathematical reasoning ability of female students is better than male students (Nurviani1 et al., 2021),(Kaplar et al., 2022) with self-concept students are in the good category.

Profile Of Student Mathematics Reasoning Ability

Based on indicators of mathematical reasoning ability, most students who have high mathematical abilities are able to fulfill all indicators of mathematical reasoning well and solve all questions correctly. Students with moderate mathematical reasoning abilities are able to fulfill the indicators of submitting conjectures, collecting evidence, and providing reasons. Students with low mathematical reasoning abilities are only able to meet the indicators of presenting mathematical statements well and are not able to solve all questions correctly (Pamungkas & Sutarni, 2021), (Pratiwi et al., 2021), (Ramadhany, 2021). Indicators of mathematical reasoning abilities that are less mastered by students are drawing conclusions from a statement, assessing argument validation, and making generalizations (Novianda et al., 2021), (Nurazizah & Zulkardi, 2022).

The students' reasoning abilities before the pandemic on the results of the mathematics exam were classified as high (Sumarsih et al., 2018). Subjects in PBL with Dyadic Interaction Approach with very high confidence can fulfill all reasoning indicators properly and completely. Subjects with high confidence can fulfill 4 indicators with 1 imperfect indicator. Subjects with low confidence can fulfill the 3 reasoning indicators well. Subjects with very low confidence can only fulfill 1 reasoning indicator well. (Kusumawardani et al., 2018). Meanwhile, interactive mathematical multimedia significantly improves students' mathematical reasoning on indicators of analyzing data, making conjectures, verifying, drawing conclusions, and testing the validity of arguments. (Amir et al., 2018). So far, no significant changes have been found in mathematical reasoning abilities before and during the pandemic. But to optimize mathematical reasoning ability, reasoning indicators need to be improved on.

The efforts to optimize students' reasoning abilities cannot be separated from the role of the teacher. According to Ellis, zgür, and Reiten (Jazby & Widjaja, 2019), teachers have an important role in supporting students' mathematical reasoning through pedagogical steps carried out by eliciting, responding, facilitating and expanding students' reasoning abilities. Clarke (Loong et al., 2018) states that what teachers can do to monitor students' reasoning abilities is to provide formative assessments. Through these assessments, teachers can obtain information about students' reasoning abilities so that they can take further action to develop these abilities through regular task planning and eliciting various reasoning actions. In addition, teachers can apply the methods or learning strategies used, create a comfortable learning atmosphere, create interactive teaching materials, and other steps. The learning method used can be in the form of online learning. E-Learning methods that can be applied to learning can be in the form of Google Suite Applications and Geogebra

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(Rumahorbo et al., 2020),(Sousa et al., 2022). GeoGebra application was chosen because the category of intuitive reasoning mobilized from using GeoGebra has great potential to stimulate the evolution of students' geometric thinking, through the development of perception, intuition and geometric visualization (Sousa et al., 2021). In line with Fowler et al. (2021), learning environments that use technology have the potential to improve spatial reasoning. Another learning method that can be applied to improve mathematical reasoning skills is Project Based Learning (Septaria & Dewanti, 2021) and STAD type cooperative learning model (Azzahrah et al., 2020), PMRI approach. In addition to learning methods, interactive learning materials are also needed (Kaplar et al., 2022) so that students get continuous feedback so that learning is more effective and meaningful.

CONCLUSION

There were 26 articles submitted from various countries and dominated by Indonesia. These article, published in 2020-2022, used quantitative, qualitative, and mixed methods with research subjects from elementary, secondary, highschool, collage, and teacher. The content of mathematics that was used to test mathematical reasoning abilities is more in learning geometry. The profile of students' reasoning abilities during the Covid-19 pandemic, namely the profiles of high-level students' reasoning abilities were able to fulfill all indicators of mathematical reasoning well and solve all questions correctly. The profile of moderate level students' reasoning ability is able fulfill the indicators of submitting conjectures, collecting evidence, and providing reasons. The low-level students' reasoning ability profiles were only able to meet the indicators of compiling mathematical statements well and were not able to solve all the questions correctly. The limitation of this study is that the sources of articles regarding mathematical reasoning abilities during the COVID-19 pandemic in relatively few data sources so that a small research sample is obtained. However, this research is expected to provide information regarding the profile of students' mathematical reasoning abilities during the COVID-19 pandemic. Mathematical reasoning abilities that are considered less than optimal can be found solutions through the application of learning methods that can improve reasoning, use technology, innovation at the didactic level, and other ideas.

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