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Research Trends on Mathematical Reasoning: A Systematic Literature Review

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ABSTRACT

Mathematical reasoning is critical as a means of understanding mathematics. This literature study aims to determine the growth of students' mathematical reasoning abilities in the last three years. This literature study presents a literature review regarding the development of mathematical reasoning, including media, strategies, and measurement instruments to serve as a basis for future mathematical reasoning research. The literature study method used is SLR (Systematic Literature Review), utilizing a review procedure that refers to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework in the period 2021 to 2023 because the development of mathematical reasoning literature studies is very significant and recent. Data was collected by reviewing 20 Scopus-indexed articles from the Scopus database. The research results reveal that from the 20 selected pieces of literature, it can be seen that research on mathematical reasoning focuses on the analysis of mathematical reasoning abilities and their development. Developing mathematical reasoning abilities can be done by using learning models/strategies (such as STAD.), developing learning modules, and using media-assisted learning models.

Keywords: Mathematical reasoning, systematic literature review, content analysis

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INTRODUCTION

A person's ability to think logically, analyze mathematical information, and make the right decisions based on their understanding of mathematics is known as mathematical reasoning ability (Hasna et al., 2023; Tee & Rahim, 2018). Mathematical reasoning abilities include various aspects, such as the ability to think critically, creatively, and analytically in solving problems, recognizing patterns, making generalizations, and using mathematical concepts in real situations (Wulandari & Wutsqa, 2019; Firdausy & Indriati, 2021). Mathematical reasoning abilities also include the ability to formulate and solve mathematical problems.

A person with good mathematical reasoning skills can find relationships between mathematical concepts, make strong arguments, and correctly interpret mathematical results. This ability not only involves understanding mathematical concepts in isolation but also the ability to combine these ideas into a consistent and relevant framework of thinking. In education, improving mathematical reasoning abilities is essential to prepare students to better deal with mathematical problems and empower them with skills necessary in various areas of life, such as working in the professional world and making everyday decisions.

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Thus, researchers argue that a comprehensive review of research on mathematical reasoning in learning is needed. Literature research was carried out by thoroughly examining mathematical representations. Lusiana and Suryani (2014) also stated that SLR can function as a theoretical basis for future research; it can be used as a reference, research material, or to answer questions about a subject of interest by understanding previous research. Data collection consists of questions on the articles being analyzed and the results of literature research related to mathematical representations, which are then extracted.

Systematic Literature Review (SLR) is a type of secondary study that includes a variety of approaches to constructing, exploring, and summarizing evidence related to a specific research question. SLR is a rational, transparent, and replicable method for analyzing existing literature (Munn et al., 2018). Additionally, SLR has the potential to observe research trends and improve understanding (Lame, 2019; Suherman et al., 2021). Systematic Literature Review (SLR) is a quantitative descriptive method based on surveys (Tamur et al., 2023). Basic research on students' mathematical reasoning abilities is used as secondary data, collected and analyzed, and conclusions are drawn (Tamur & Juandi, 2020). The data collected comes from initial research published in national journal articles and electronic databases indexed and registered by Google Scholar, Semantic Scholar, ERIC, and national journals. Next, all found articles were extracted.

Ariati and Juandi (2022) have conducted literature research on mathematical reasoning abilities. This research analyzes qualitative studies on mathematical reasoning abilities between 2015 and 2021. All articles resulting from qualitative research are indexed in Google Scholar, Semantic, and ERIC using Systematic Literature Review (SLR). The search strategy was adapted to the selection criteria, and the PRISMA protocol guided the research instrument. Year of publication, level of education, research class, demographics, journal indexer, material analyzed, and type of reasoning ability used are moderator factors in this research. Any data obtained is presented in the form of a quantitative description. The results of SLR research show that in 2020 and 2021, there will be many publications about students' mathematical reasoning abilities. Most of this research was conducted in class VIII at the junior high school level. Research is also dominated by geometry and algebra material in the Java and Bali regions.

Researchers want to investigate more broadly based on the findings of the analysis. Researchers will examine articles published from 2021–2023 in the Scopus index. This study aims to observe mathematical reasoning research trends worldwide over the past three years through the following research questions:

RQ1. What topics are covered in research on mathematical reasoning?
RQ2. What are the aims of research on mathematical reasoning?
RQ3. Who are the respondents used for research on mathematical reasoning?
RQ4. What research methods are used in research on mathematical reasoning?
RQ5. What instruments are used in research on mathematical reasoning

METHOD

This literature study uses the method of Systematic Literature Review (SLR) using the review procedure referring to the framework of Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) used to answer the problem formula, the stage of the PRISMA framework: planning, implementation, and reporting. (Higgins et al., 2021; Newman & Gough, 2020). The article was extracted from the Scopus database with the mathematical reasoning keyword. The literature selection process refers to the inclusion and exclusion criteria. Inclusion and exclusion criteria are used in the selection of significant literature. The purposes of the inclusions and exclusions are to minimize ambiguity and reduce the possibility of bias in literature studies. These criteria are shown in Table 1.

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Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
- Articles published in the years 2021-2023	- Articles published before 2021
- Articles issued in English	- Articles in book form
- Articles existing in the field of mathematics	
- Articles containing keyword mathematical reasoning	
- Articles open access	

The search stream and the number of literature identified in the PRISMA framework are shown in Figure 1. The literature selection process is carried out through four stages: keyword search, then the selection of literature based on the title and abstract, and the inclusion and exclusion criteria as the complete text that will produce the literature referenced.

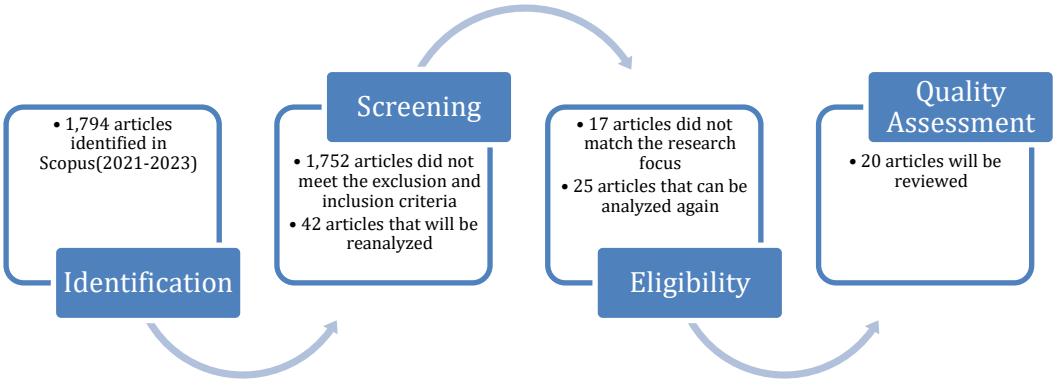

Figure 1. PRISMA Framework

Based on Figure 1. the PRISMA framework was obtained from 1,794 articles. Then, according to inclusion and exclusion criteria, 42 articles were received. Then, with filters corresponding to the title and abstract, 25 articles were received. At the end of the selection, 20 main articles were selected for further analysis. The chosen significant literature is then extracted to gather data that contributes to answering the research question that has been specified. Table 2 presents repeated data extraction to answer research questions with five properties.

Table 2. Research Questions

Research Question	Codes
Research Topics	RQ1
Research Purposes	RQ2
Research Respondents	RQ3
Research Methods	RQ4
Research Instrument	RQ5

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RESULT AND DISCUSSION

The research findings in this review literature are tabulations of documented article data related to mathematical reasoning (see Table 3).

Table 3. Articles corresponding to Mathematical Reasoning

Author and Year	Journal	Research result
Coskun & Kara (2022)	London Review of Education	According to the results, the COVID-19 pandemic-related school closures had a detrimental effect on students' mathematical thinking abilities. The results of Cattell's theory of intelligence and human interaction are examined.
Henriques & Martins (2022)	AIEM - Avances de investigación en educación matemática	The findings demonstrate that aspiring educators have progressed in their knowledge of linear systems and their ability to reason mathematically. The experiment's demonstrated benefits should prompt consideration of better integrating pre-service teacher education with other educational settings to help students overcome learning challenges and advance their pedagogical skills.
Herbert (2021)	Australian Journal of Teacher Education	This study has outlined a few of the difficulties faced by elementary school teachers when evaluating mathematical reasoning, including their understanding of the complexity of reasoning, identifying and analyzing students' reasoning, their capacity to explain it, the lack of adequate work samples, the curriculum's limited guidance, and difficulties in monitoring and documenting students' progress in reasoning.
Hidayat et al., (2022)	Journal on Mathematics Education	The outcomes demonstrated that the created e-module was legitimate and valuable for enhancing students' capacity for mathematical reasoning, particularly when resolving sequence and series-related issues. Using this ePub module enhanced the indicators of mathematical reasoning ability—proposing assumptions for problem-solving and coming to logical conclusions. Alternative solutions are provided by the module's development in the e-Pub format, which helps students' mathematical thinking skills.
Martins et al., (2023)	EURASIA Journal of Mathematics, Science and Technology Education	The prospective teacher gained knowledge by understanding the impact of her actions and the tasks assigned to students in fostering their reasoning as a result of reflecting on the work completed by the students in the lessons she had taught. In addition, the sequential format of the lesson studies helped her reevaluate her teaching methods and advance her career by enabling her to plan and implement her classes based on a thorough review of the preceding lessons.
Mukuka et al., (2021)	Journal on Mathematics Education	The findings show that mathematics self-efficacy and task-specific self-efficacy beliefs significantly and collectively moderate the effect of the instructional technique on students' mathematical reasoning. The Student Teams Achievement Division (STAD) effectively raised students' confidence in their ability to solve mathematics problems and think critically. These findings highlight the significance of selecting an instructional approach that develops students' cognitive abilities, like mathematical reasoning, and their affective traits, like math self-efficacy beliefs.

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Author and Year	Journal	Research result
Mukuka et al., (2023)	Heliyon	These findings highlight the need for more professional development opportunities to inform aspiring and in-service teachers about effective teaching techniques for developing students' mathematical reasoning.
Negara et al., (2022)	International Journal of Emerging Technologies in Learning (iJET)	According to the study's findings, pupils who studied with Geo-SCL increased their capacity for mathematical reasoning more than those who studied with Geo-PBL, with both groups' ability improvement criterion falling into the moderate range. Findings from studies on using Geo SCL as a learning paradigm can serve as a substitute in online learning environments.
Nhiry et al., (2023)	Cogent Education	In order to provide a worldwide perspective, this research included an analysis of every mathematical block to determine whether each kind is present in the Moroccan program. Knowing how to concentrate on a suitable methodological framework for one of these blocks in later articles is the first step toward becoming more profound and possibly developing a conceptual model of mathematical reasoning.
Poesia & Goodman (2023)	Philosophical Transactions of the Royal Society A: Mathematical, Physical, and Engineering Sciences	We suggest that the structure of procedural abstractions underpinning mathematics lies at the heart of both puzzles. As a case study, we investigate this concept using five sections of beginner algebra from the Khan Academy website. We introduce Peano, a theorem-proving environment where the collection of valid actions at any given instant is finite, to provide a computational foundation. We codify fundamental algebraic issues and axioms using Peano, yielding well-defined search problems. Current symbolic reasoning reinforcement learning techniques are insufficient to tackle more challenging tasks. When an agent can generate reusable abstractions, or "tactics," from its answers, it can move steadily and solve every issue. Moreover, these abstractions give the issues a previously arbitrary order during training. The expertly crafted Khan Academy curriculum and the recovered order show a strong agreement and second-generation agents who teach on the recovered curriculum acquire knowledge far more quickly. These findings highlight the complementary roles that abstractions and curricula play in disseminating mathematics across cultural boundaries. This piece is a component of the "Cognitive Artificial Intelligence" discussion meeting subject.
Rohati et al., (2023)	Education Sciences	The results of this study can motivate educators to concentrate on helping students develop the most advanced kind of mathematical reasoning—creative mathematical reasoning.
Ruiz et al., (2023)	European Journal of Psychology of Education	The findings confirm earlier research that greater accuracy on the number line estimation test indicates more substantial mathematical reasoning for the 0–10 and 0–100 number lines. Quantile regressions demonstrate that mathematical reasoning is similarly predicted across the performance distribution by performance on the number line problem. The prediction power of the 0–10 and 0–100 number lines is compared and contrasted.
Shure & Liljedahl, (2023)	Journal of Mathematics Teacher Education	On the other hand, the teacher movements of the cohort were examined in more detail by the cluster analysis. Although

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Author and Year	Journal	Research result
		exclusively in the low potential category, cluster one had the highest frequency of eliciting teacher moves, whereas clusters two and three mainly employed facilitating teacher moves with varying proportions of high and low potential moves. Cluster four focuses on encouraging, eliciting, and reacting to students' reasoning. With a few high-potential moves in every category but extending student thinking, which can better support reasoning, cluster five employs teachers from all major categories. The scripts of aspiring math instructors and the five clusters discovered during the research are examined, along with the consequences for educating future teachers and fostering the development of mathematical reasoning.
Smit et al., (2023a)	Learning and Instruction	Developing the mathematical reasoning skills of elementary school kids requires interactive discourse inside feedback episodes. Our objective was to gain a deeper understanding of the relationships between students' mathematical thinking, teachers' formative input, and discourse that has been witnessed. We used a two-step process, building a video-analysis tool first to evaluate the interactive conversations' quality and then merging the interaction data with teacher and student questionnaire data from 804 primary school pupils in 44 fifth- and sixth-grade classes. While perceived formative feedback predicted differences in students' reasoning competence, the quality of the observed dialogues indicated differences in students' self-efficacy for explaining.
Smit et al. (2022)	Research in Mathematics Education	At the individual level, formative feedback predicted self-efficacy but not reasoning; at the class level, formative feedback predicted reasoning, which was mediated by self-efficacy. Our theories were only partially supported by the data. We give implications for teaching mathematical reasoning and explore explanations for these findings.
Smit et al., (2023b)	The Curriculum Journal	We also demonstrated how, through students' interest in mathematics, task-level feedback predicted students' achievement in mathematical reasoning. One could conclude that teachers should apply the four levels of feedback in a way that centers on the issue currently being addressed while the student is working on a task.
Somuncu & Aslan, (2022)	Education and Information Technologies	The study's findings indicated that while there was a significant difference in favor of the experimental group in the post-test, there was no significant difference between the experimental and control groups in the pre-test. Consequently, it was found that coding exercises significantly impact children's mathematical reasoning abilities.
Szabo et al. (2024)	The Mathematics Enthusiast	The research demonstrates that all groups successfully solved given problems within various Joint Problem Spaces (JPS) that were socially negotiated. More important, however, is that students could express and demonstrate their mathematical thinking. Furthermore, it has been shown that using vertical whiteboards greatly aided in displaying students' mathematical reasoning.

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Author and Year	Journal	Research result
Tashtoush et al., (2022)	EURASIA Journal of Mathematics, Science and Technology Education	The study's results demonstrated statistically significant differences in the habits of mind scale and mathematical reasoning exam between the two study groups, favoring the experimental group. It was done to prove their effectiveness in developing their levels of mind habits and mathematical reasoning skills by subjecting them to training programs, courses, and workshops to train teachers to implement the training programs effectively. The study recommended that pre-service math teachers use programs based on international studies such as TIMSS, PISA, PIRLS, and TAILS.
Wirebring et al., (2022)	Trends in Neuroscience and Education	Independent of cognitive ability, encouraging students to participate in positive processes while learning mathematical reasoning results in long-lasting learning impacts on brain activation. However, the absence of a CMR effect on the low cognitive ability group's performance indicates that future research should concentrate on tailored learning interventions that allow deliberate CMR struggle.

After analyzing the results of 20 articles in Table 3, answer research questions. Besides, it will also reveal the kinds of research gaps that are key to opening up future research opportunities.

RQ1 Research Topics

Some of the basic overview obtained from the results of such analysis is the current mathematical representation research focus on the topics: 1) implementation of learning through STAD; 2) Development and validation of instruments for measuring mathematic reasoning such as teaching materials using Geogebra or; 3) Development of learning strategies oriented on mathematics reasoning in didactic design. Mathematical reasoning research tends to focus on mathematical activity. It is also a more specific development in generating mathematical reasoning in students. Mathematical rationale researchers for students must highlight various roles, such as STAD learning. The teaching material with Geogebra and didactic design can lead to a psychological study that questions the right step in developing mathematical reasoning.

RQ2 Research Purposes

After reviewing 20 research articles, we found five different research purposes (**Table 4**). One of the most common purposes of mathematical reasoning research is to look at the relationship between mathematic reasoning and other abilities. The purposes of this research are presented in six research articles. What is still very little discussed is the development of learning modules of mathematical reasoning. The use of technology in learning is one of the exciting ways to improve students' mathematical reasoning. Therefore, developing learning media using technology to enhance the ability to reason mathematically can be an exciting topic for further discussion.

Table 4. Research purposes on mathematical reasoning

Research purposes	Number of articles
Analyzing mathematical reasoning	2
Develop mathematical reasoning using learning strategies	5
Identifying teacher challenges in assessing and developing mathematical reasoning	5
Design and development of e-modules	1
Observing the relationship between mathematical reasoning and other abilities	6

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RQ3 Respondent Research

Analysis of respondents in this study shows that mathematical reasoning covers all levels of education and against teachers from the age of PAUD to the student level. Even teachers as facilitators to develop the ability of mathematical reasoning are also studied. Based on the analysis of these respondents, we can see that mathematical reasoning is an essential ability for every individual. The survey respondent spread can be seen in Table 5 below.

Table 5. Research Respondents

Research Respondent	Number of Articles
Teacher	3
Pre-services Teacher	4
Senior High School students	4
Junior High School students	2
Elementary school students	4
Early childhood students	1

RQ4 Research Methods

Based on the aspects of the research method, the article's analysis results show variations in the use of research methods. Some articles use qualitative approaches such as exploration, observation, and survey, as much as 40%. Some other articles use a quantitative approach, particularly related to experiments and comparisons of as many as 45%. In other contexts, mathematical reasoning has been studied extensively with a mixed method approach, for example, developing instruments for measuring 15 percent of mathematic reasoning.

RQ5 Research Instruments

After discussing the theory and learning strategies, the review of the development of mathematical reasoning measurement instruments aims to reveal the range of instruments that have been developed and exist today. Measurement is another element of learning mathematical reasoning that is important for analysis. Most instruments like creating geometric shapes to clarify problems and facilitate solutions, solving problems involving mathematical expressions, and creating problem situations based on data or reasoning.

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CONCLUSIONS AND RECOMMENDATIONS

This systematic literature review reveals how much research has advanced in mathematical reasoning over the last three years. Several research findings suggest that advances in mathematical reasoning have reached a wide range of fields of study, including psychology and technology. So, the study of mathematical reasoning can examine how these abilities are associated with other fields. In line with this, the development of learning strategies oriented toward mathematical reasoning is growing rapidly and increasingly varied. Besides, the development of media or teaching materials that support and facilitate learning mathematical reasoning has also developed a lot, such as e-modules and using Geogebra. Besides, learning design also needs to be developed.

It can be a reference in determining the learning and research of future mathematical reasoning, i.e., deepening how communication and reasoning skills can be enhanced, where students need to be more accustomed to introducing to mathematics problems with the help of appropriate methods, using reasoning in other fields of math, teachers can be oriented to facilitate student learning, understand the natural development of skills and problem-solving strategies, develop and pay attention to student representation in solving mathematic literacy problems or contextual problems, hypothetical didactic design, assessing students' ability to reason mathematically, teaching materials using Geogebra.

This research has significant implications for current mathematical reasoning, future research, and

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practical aspects of mathematics education. Researchers need to undertake research that will reveal how the ability of mathematical reasoning affects other aspects of the ability. Math educators should strive to create a learning environment responsive to mathematical reasoning. Current research targets articles in the Scopus database, but future research should have a broad view of sources of information better to understand the latest patterns of mathematical reasoning research.

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