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Systematic literature review: relational thinking ability in mathematics

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Abstract
Research on relational thinking has been widely conducted; however, no analysis of these studies has been carried out so far. This research aims to analyze the distribution of research related to relational thinking in mathematics at elementary and high school levels, which was conducted from 2016 to April 2024. This study employs the Systematic Literature Review (SLR) method, focusing on articles indexed in Scopus, ERIC, ScienceDirect, and Google Scholar. The results of the Systematic Literature Review (SLR) show that: (1) there were 30 studies on relational thinking ability in mathematics conducted; (2) eight studies were conducted abroad, while 22 were conducted in Indonesia; (3) arithmetic was the most common topic in research on relational thinking; (4) the majority of studies on relational thinking ability have been carried out at the junior high school level; (5) of the 30 articles, 14 are indexed in Sinta, 7 in Scopus, and 9 are indexed only in Google Scholar; (6) there are two definitions of relational thinking used by researchers. These findings serve as a basis for determining future research topics related to relational thinking ability.

Keywords: mathematics; relational thinking; systematic literature review

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I. Introduction

One type of thinking ability is relational thinking. Relational thinking builds connections between students' conceptual and procedural mathematical knowledge (Nimtrakul, Sangaroon & Inprasitha, 2014). In mathematics learning, relational thinking is closely related to arithmetic and algebra topics. It is described as a bridge between arithmetic and algebraic thinking (Kiziltoprak & Kose, 2017; Tri, Maitree & Narumon, 2022). The core of algebraic reasoning is relational thinking, which focuses on understanding mathematical expressions without necessarily performing calculations by using flexible reasoning to transform expressions into equivalent forms (Kindrat & Osana, 2018). Students are first introduced to arithmetic and then begin to learn algebra with symbols and connections (Kose & Kiziltoprak, 2020).

The concept of equality is one of the keywords in relational thinking. This is by Kindrat & Osana (2018), who stated that relational thinking involves an understanding of equality and number relationships. Harbour, Karp & Lingo (2016)

explained that relational thinking involves the meaning of the equal sign, the basic use of operational properties and number relationships, and strategic decision-making. Relational thinking focuses on viewing mathematical expressions and equations in their entirety rather than merely as steps for computation (Tri et al., 2022; Lenz, 2022; Carpenter, Levi, Franke & Zeringue, 2005). Comparing mathematical expressions about the equal sign is part of relational thinking (Lenz, 2022; Nainggolan, 2022). Therefore, to think relationally, students must first use the relational meaning of the equal sign (Ardiansari, Suryadi & Dasari, 2023; Tomé, Purwanto & Sa'dijah, 2019). Relational thinking aims to guide students in understanding that the two sides of an equation signify the same value, even without performing computations (Kiziltoprak & Kose, 2017). In relational thinking, students must understand that the equal sign refers to the relationship and balance between numbers, not the order of operations (Carpenter et al., 2005). Relational thinking means viewing mathematical expressions and equations as a whole, not as individual computational processes (Lenz, 2022).

In mathematics, relational thinking can also be interpreted as a mental process characterized by building connections between the information provided and previously owned mathematical concepts and knowledge of the nature or structure of mathematics to solve mathematical problems (Nafiah, Amin & Rahaju, 2022). Relational thinking is building relationships between mathematical elements and using them to solve existing problems (Lenz, 2022). Students can solve a problem or issue well through relational thinking (Ramadhan, Effendi & Ummah, 2021).

Relational thinking is important in helping students understand and solve mathematical problems (Nafiah et al., 2022). According to Zakaria, Budiarto & Sulaiman (2018), the characteristics of problem-solving procedures in relational thinking are creating a complete picture of the problem, analyzing to find the core structure of the problem, finding the main elements or relationships in the problem, developing a solution strategy after the elements or relationships are found. Relational thinking involves two or more mathematical ideas or objects, then looking for relationships between these ideas, analyzing or using these relationships to solve problems, make decisions, or learn more about the situations or concepts involved Molina & Castro (2021). Someone who thinks relationally will apply abstract rules in new situations (Wardani & Susanah, 2020).

According to the description of relational thinking, it can generally be understood as the ability to build connections between the information provided and mathematical concepts, apply abstract rules, and see the expression of mathematical equations as a whole to solve mathematical problems. The problem in question is relational, namely a mathematical problem that requires relational thinking ability in its solution. Relational thinking ability needs to be developed, including leading students to think arithmetically and algebraically.

Research on relational thinking abilities has been extensively conducted; however, no comprehensive analysis or synthesis of these studies exists. There has been no Systematic Literature Review (SLR) specifically focusing on research related to relational thinking. This lack of review makes identifying general trends, common limitations, or underexplored areas difficult. Therefore, it is important to systematically examine the existing literature to uncover potential research gaps, such as types of studies that may have been underrepresented. This prompted researchers to research relational thinking ability in mathematics using the Systematic Literature Review (SLR) method. The main objective of this study is to describe the research results related to relational thinking, reviewed from the year of publication, regional distribution, level of study, journal/proceedings indexer, material, type of research, and scope of the definition of relational thinking. An important stage in SLR is collecting data from research results related to relational thinking ability in

mathematics. Based on the data gathered from previous studies, this SLR aims to answer the following question: What is the overview of research findings regarding publication year, regional distribution, material, education level, journal/proceeding indexer, research type, and scope of the definition of relational thinking?

II. Research Methods

The method used in this study is a Systematic Literature Review (SLR). SLR systematically identifies, evaluates, and interprets findings on a research topic to answer predefined research questions (Aliyah & Mulawarman, 2020). SLR uses a qualitative descriptive approach, which is carried out by classifying the data based on specific categories, interpreting the content of the articles, and synthesizing the findings in a narrative form. The research procedure includes data collection, analysis, and conclusion (Juandi & Tamur, 2020). The data collected are research results published nationally and internationally in proceedings and journals collected from electronic databases, namely Scopus, ERIC, Science Direct, or those only indexed by Google Scholar. After collecting the articles, coding was done to determine which articles met the inclusion criteria. Articles that met the criteria were coded as 1, while those that did not were coded as 0. Only pertinent studies that satisfy the inclusion criteria advance to the analysis phase (Juandi & Tamur, 2020).

The inclusion criteria in this study are: (1) studies in the field of mathematics; (2) studies analyzing relational thinking ability (3) The studies should focus on students in elementary school (SD), junior high school (SMP), or senior high school (SMA) in Indonesia, or equivalent levels for international studies; (4) studies must include the type of research (qualitative, quantitative or development); (5) study publications in the period 2015 to April 2024. Studies not meeting the inclusion criteria are not used in the analysis process. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes) protocol was used as a guiding framework for the systematic review process related to inclusion and exclusion criteria based on publication year regional distribution, material, education level, journal/proceeding indexer, research type and scope of the definition of relational thinking.

The research selection process is carried out through four stages according to the PRISMA protocol: identification, screening, eligibility, and inclusion (Juandi & Tamur, 2020).

1. IdentificationThere are 309 articles identified from Scopus, ERIC, Science Direct databases, or those only indexed by Google Scholar.
2. Screening. There are 299 non-duplicated articles (10 articles were detected as duplicates, so they were not included in the next stage)
3. Eligibility. There are 33 articles after the elimination process (266 articles do not meet the inclusion criteria that have been set)
4. Included. 30 articles on relational thinking meet the inclusion criteria and are included in the analysis (3 articles are identified as duplicates or are the results of the same research and published in different articles with slight modifications, including language)

III. Results and Discussion

Studies by Publication Year

Based on the articles collected from the database and using the inclusion criteria of the publication year, namely the range 2015 - April 2024, 30 relevant articles were obtained for analysis, as can be seen in Figure 1 below.

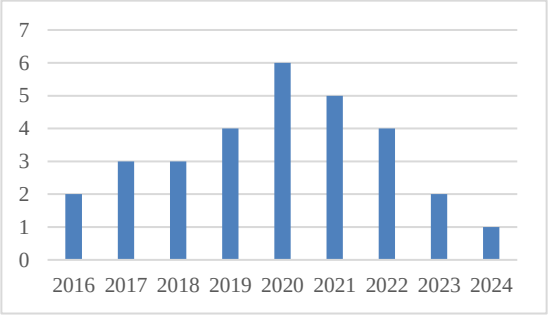

Figure 1. Studies based on publication year

Based on Figure 1, the research trend in

the field of mathematics related to relational thinking tends to be consistently carried out and is mostly carried out in 2020. Six articles were found. After that, there was a downward trend until April 2024. This shows that the issue of relational thinking ability has not been widely researched.

Study Based on Regional Distribution

The research on relational thinking that was traced was conducted not only in Indonesia but also in other countries. Of the 30 articles, 22 were the results of research conducted in Indonesia, and 8 were conducted in other countries. The distribution of the 22 articles whose research was conducted in Indonesia can be seen in Figure 2 below.

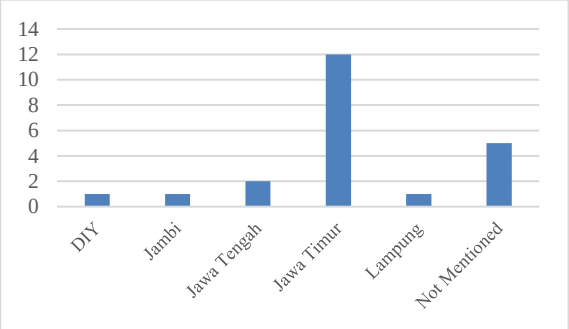

Figure 2. Study based on regional distribution

Based on Figure 2 above, most research related to relational thinking conducted in Indonesia was conducted in East Java province, which is 12 studies or 54.5% of the total research conducted in Indonesia. This information shows that many regions, especially in Indonesia, still have not become research locations related to relational thinking.

Studies Based on Material

Based on a study of 30 articles, there are 13 materials used in research related to relational thinking, which can be seen in Figure 3 below:

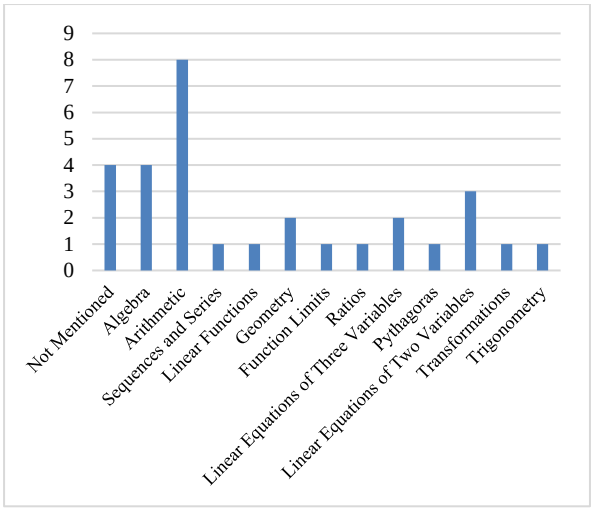

Figure 3. Study based on material

Based on the image above, the most research related to relational thinking was conducted on arithmetic, namely 8 studies. Research using algebraic material to measure students' relational thinking abilities was dominated by questions about understanding the meaning of the "=" sign. Do students see the "=" sign as a symbol of equality or see it as an operational command? and algebra. The questions used, for example, are 124 + 79 = ... + 75.

Study Based on Education Level

The research used in this SLR includes research conducted from elementary school to high school levels. The distribution of research based on education levels from elementary to high school is presented in Figure 4 below.

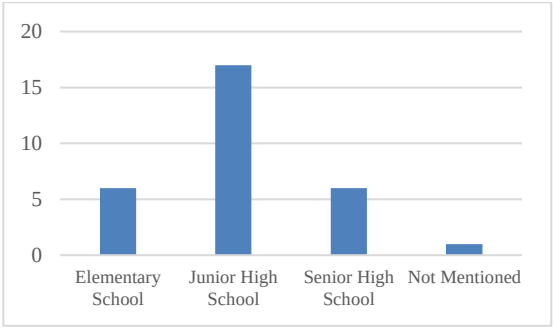

Figure 4. Study based on education level

Based on Figure 4, the most research was conducted at the Junior High School (SMP) level,

which was 17 studies. A total of 6 studies were conducted at the elementary school level, and 6 studies were conducted at the high school level. One study did not mention the research level in the sample used. If examined, research related to relational thinking is more suitable for the elementary and junior high school levels. This is because relational thinking abilities are closely related to arithmetic and algebraic materials. Relational thinking is said to be a bridge between arithmetic thinking and algebraic thinking (Kiziltoprak & Kose, 2017).

Study Based on Journal/Proceedings Indexer

Figure 5 below details the results of the research analysis related to relational thinking based on journal or proceedings indexing.

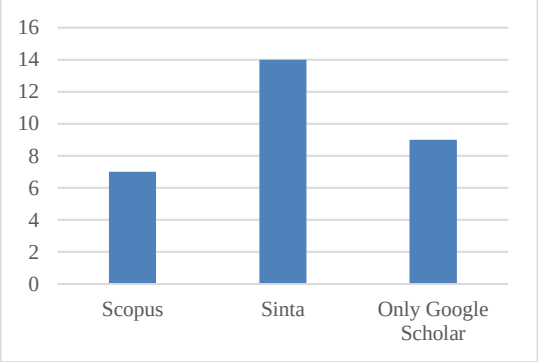

Figure 5. Study based on indexer

Based on the analysis of the study results of 30 articles, 14, or 47% of articles indexed by Sinta, 7 or 23% of articles were indexed by Scopus, and 9 or 30% of articles only indexed by Google Scholar. Based on Figure 5 above, the research results related to relational thinking are primarily published in Sinta-indexed journals, namely 14 articles. Of the 14 articles, two are indexed by Sinta 2, three are indexed by Sinta 3, eight are indexed by Sinta 4, and 1 article is indexed by Sinta 5.

Studies Based on Research Type

The following are details of the research analysis results related to relational thinking based on the type of research.

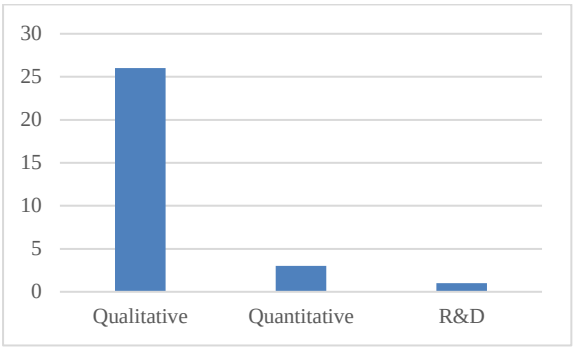

Figure 6. Study based on research type

There are 26 studies, or 86.67% of studies related to relational thinking, which are qualitative; three studies, or 10%, are quantitative studies; and the remainder, namely one study or 3.33%, are development studies. The existing qualitative research tendency is to describe how students' relational thinking abilities are by considering certain variables, including describing relational thinking abilities based on impulsive and reflective cognitive styles (Satriawan, Budiarto & Siswono, 2018; Wardani & Susanah, 2020) based on auditory learning styles (Agustini & Rahaju, 2022), based on visual quitter, visual camper and visual climber types (Pradika, Amin % Khabibah, 2019), based on field-independent and field-dependent cognitive styles (Bahri, Lukito & Masriyah, 2019), based on systematic and precise cognitive styles (Khoyimah, 2021), based on visual, auditory and kinesthetic learning styles (Nafiah et al., 2022) and based on self-efficacy (Fauziyah & Ismail, 2022). In addition to describing students' relational thinking abilities based on certain affective variables, other studies have tried to describe students' relational thinking abilities in solving mathematical problems in general (Hermanto, Budayasa & Lukito, 2020; Kurniawan & Rudhito, 2016; Ramadhan et al., 2021; Wicaksono & Linuhung, 2019).

Kindrat & Osana (2018) conducted an experimental study that tested the relationship between students' relational thinking ability and mental computation interventions. Meanwhile, Kose & Kiziltoprak (2020) conducted an experimental study to develop students' relational

thinking abilities. There is one study on relational thinking, a development study conducted by Santia (2017), which aims to develop a mathematics module based on relational thinking to improve the ability to solve algebraic equations. Based on a study of research on relational thinking, most of the studies were conducted using a qualitative approach to describe how students' relational thinking abilities are.

Study Based on the Scope of Definition of Relational Thinking Ability

Based on the definition of experts and analysis of the research results conducted by researchers, the scope of the definition of relational thinking can be divided into 1) understanding the meaning of the "=" sign as a concept of equality and understanding mathematical expressions and equations as a whole and 2) building connections between the information provided with mathematical concepts and developing strategies to solve mathematical problems. In other words, the scope of relational thinking abilities found in the studies can also be categorized as relational thinking, which emphasizes equality and the meaning of the "=" sign and relational thinking in problem-solving.

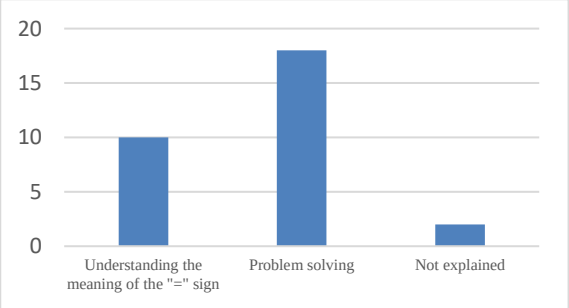

Figure 7. Study based on scope of relational thinking definition

The definition of relational thinking ability that emphasizes equality and the meaning of the "=" sign is widely used by researchers in describing students' relational thinking ability. The material used in the scope of this definition is arithmetic and algebraic material. In their research, Kindrat and Osana (2018) tested the relationship between students' relational thinking ability before and after mental mathematics intervention in the context of integer arithmetic. Their research explained the relationship between mental mathematics and relational thinking. Mental mathematics performs calculations through transformations outside of calculations or imagining standard algorithm steps Kindrat & Osana (2018). A person faced with a mental computation problem must first decide how to transform the numbers to reduce the cognitive load when calculating. For example, when faced with the problem $119 - 40$, a person can change 40 to $10 + 10 + 10 + 10$ first. This is because eliminating 10 four times is easier than eliminating 40 at once. Choosing a mental computational strategy is a relational act, but relational thinking is not centered on computation or calculation Kindrat & Osana (2018). Thus, relational thinking is a central component of mental computation.

Research related to relational thinking that limits the definition of relational thinking to the concept of equality and the meaning of the "=" sign was conducted by Kindrat & Osana (2018), Wicaksono & Linuhung (2019), Kose & Kiziltoprak (2020), Osana & Kindrat (2021), Purnomo & Ahiddieqy (2020), Harbour et al. (2016), Wilkie & Hopkins (2024), Kiziltoprak & Kose (2017), Lenz (2022) dan Molina & Castro (2021). Researchers used mathematical problems in arithmetic and algebraic materials to describe students' relational thinking abilities. Kindrat & Osana (2018) used questions like Figure 8 below to determine students' relational thinking abilities such as:

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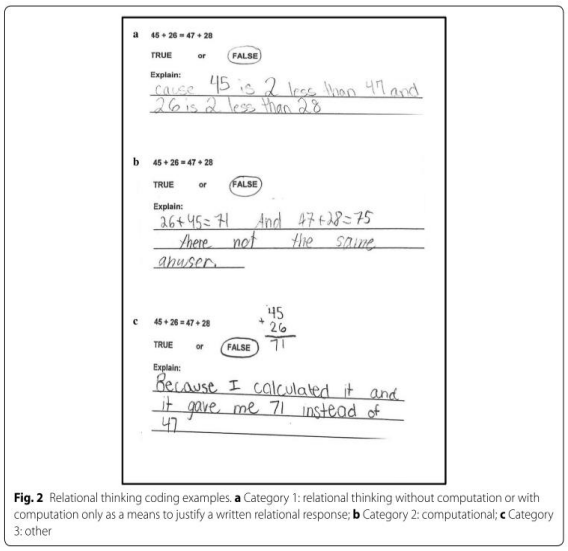

Fig. 2 Relational thinking coding examples. **a** Category 1: relational thinking without computation or with computation only as a means to justify a written relational response; **b** Category 2: computational; **c** Category 3: other

Figure 8. Relational thinking questions

In their research, Kindrat & Osana (2018) gave mathematical statements and asked students to determine whether the statement was true or false and explain the reasons. Then, he categorized students' relational thinking into relational thinking without computation or with computation only as a means to justify written relational responses, computational, and other categories.

Furthermore, Purnomo & Ahiddieqy (2020) conducted a study to describe the flexibility students use in relational thinking. In their study, Purnomo & Ahiddieqy (2020) divided the stages of relational thinking into emerging, consolidating, and established. Students meet flexibility when they reach the established stage in relational thinking. Max Stephens Purnomo & Ahiddieqy (2020) explain that established relational thinking is the ability to specifically determine the relationship between numbers, determine the correct number in an equation, specifically explain the relationship between numbers, and be able to generalize them. The questions used include the definition of relational thinking related to the meaning of the sign "=" such as "5× ... = 10× ...".

Another study was conducted by Harbour et al. (2016) to diagnose students' relational thinking ability about the "=" symbol. The questions related to the definition of relational thinking on equality and the meaning of the "=" sign he used were "solve 8+4 =⋯ + 5". The study he conducted aimed to determine students' understanding of the "=" symbol. In their study, Molina & Castro (2021) also tried to describe how students use relational thinking ability by using questions to understand the meaning of the "=" symbol. He emphasized that using relational thinking means considering mathematical expressions globally, from a structural perspective, and not as a process that must be done step by step.

In another study, Kiziltoprak & Kose (2017) provided questions to determine the development of students' relational thinking ability which is an important component in the transition from arithmetic to algebra. According to them, in relational thinking, the goal is to help students realize that both sides of the equation represent the same number without doing any calculations. Therefore, to think relationally, students must first use the relational meaning of the "=" sign. Examples of questions used are:

Table 1. Relational thinking questions

Question	Interview
True/false number sentences	$6 + 9 = 5 + 11$ $(5 \times 4) \times 7 = (7 \times 4) \times 5;$ $4 : 16 = 84 : 32$
Open number sentences	$3 + 4 = \square + 5$ $68 + 58 = 57 + 69 + \square$ $3 \times 21 = 7 \times \square$
Open number sentences (involve adding)	$42 + 54 + \square = 56 + 45$ $62 + 38 = 60 + \square$ $92 + \square = 95 + 85$
Open number sentences (involve subtracting)	$71 - 52 = 72 - \square$ $75 - 32 = 73 - 28 - \square$ $627 - 125 = 625 - 121 - \square$
Open number sentences (involve adding, multiplying, dividing)	$4 \times 3 = \square \times 3 + \square \times 3$ $(3 \times 4) + \square = 3 \times 7$ $15 : 5 = (10 : 5) + (5 : \square)$
Open number sentences (involve adding, multiplying,	$5 \times 9 = 10 + 10 + 10 + 10 + 10 - \square$ $2 \times 9 = (2 \times 10) - \square$ $(8 \times 9) + \square = 8 \times 10$

Question	Interview
subtracting	
Open number sentences	$5 \times (8+4) = (5 \times \square) + (5 \times 4)$ $\square \times (7+8) = (\square \times 7) + (\square \times 8)$ $\square - \square = \square + \square$

(Kiziltoprak & Kose (2017)

Still on the concept of equality and the meaning of the "=" sign in defining relational thinking, Lenz (2022), in his research, examined students' relational thinking abilities using non-symbolic representations in the form of boxes and marbles. He explained that relational thinking means seeing mathematical expressions as a whole, not as individual computational processes. This is characterized by the use of relationships between mathematical objects and refers to the relationship between equality and inequality. In his research, he asked students to solve equations containing variables without using algebraic notation, as shown in Figure 9 below (Lenz, 2022).

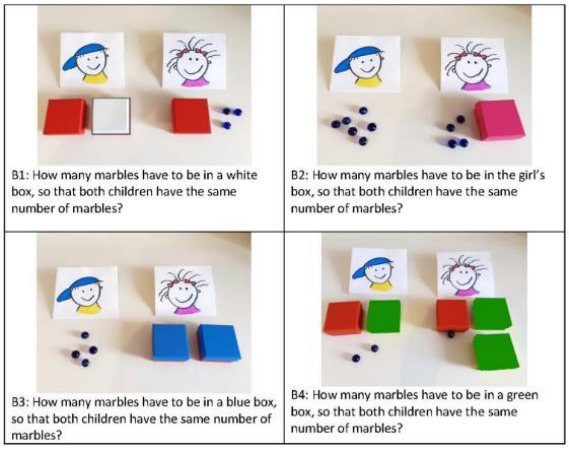

Figure 9. Relational thinking questions

The above question introduces students to equations without using algebraic notation or variables. After that, students are expected to be able to work on other equation problems in both arithmetic and algebraic materials. For example, when students are given the problem $42 + x = 48 + 71$, then students use the transformation strategy to the right side $(42 + 6) + 71$ and use associative addition and see the relationship between the two sides, then $x = 6 + 71 = 77$ is obtained. Such examples show that what marks relational thinking is the ability to use the possibility of variation in mathematical expressions (Santia, 2017).

In addition to emphasizing the understanding of the concept of equality and the meaning of the "=" sign, another scope in defining relational thinking used by other studies is relational thinking related to problem-solving. Researchers limit questions to simple arithmetic and algebraic materials to determine students' relational thinking abilities and problem-solving questions. Researchers use contextual questions to determine students' relational thinking abilities in this case. To solve contextual problems, students must be able to think relationally, namely, building relationships between real-world situations and formal mathematical situations and the mathematical knowledge they have and then looking for relevant solutions (Hermanto et al., 2020). The studies were conducted by Rindani (2023), Ramadhan et al. (2021), Kurniawan & Rudhito (2016), Wardani & Susanah (2020), Agustini & Rahaju (2022), Fauziyah & Ismail (2022), Tafrilyanto (2016), Pramesti & Rosyidi (2019), Khoyimah (2021), Nurrahmah (2020), Pradika et al. (2019), Bahri et al. (2019), Satriawan et al. (2018), Husnah (2021), Santia (2017), Saskia, Budayasa & Manuharawati (2023), Hermanto et al. (2020), Zakaria et al (2018) dan Bahri et al (2019).

According to Bahri et al. (2019), students often do not understand the problem when given a story problem and cannot relate the information in the story problem or with previous knowledge due to their low relational thinking ability. Relational thinking is important in helping students understand and solve mathematical problems. Shoseiki (Bahri et al., 2019) states that in relational thinking, students use the properties of addition, subtraction, multiplication, and division arithmetic operations. So, by thinking relationally, students are expected to be able to solve arithmetic problems in everyday life and solve arithmetic story problems (Bahri et al.,

2019).

Rindani (2023), in her research, tried to describe the relational thinking ability of climber students in solving mathematical problems. She adapted the relational thinking explained by Baiduri (2014) that relational thinking is the process of building relationships by utilizing elements of information provided (context), prior knowledge, and knowledge of mathematical characteristics/structures when facing mathematical problems. In line with, Nurrahmah (2020) and Agustini & Rahaju (2022), their research also adapted the relational thinking indicators from Baiduri, which were associated with Polya's problem-solving stages.

Table 2. Relational thinking indicators based on polya's stages

Polya Stages	Relational Thinking Activities	Indikator
Understanding/reading the problem	Building relationships between the information provided	1. Determine the important elements 2. Establish a relationship between the information known and the masked
Devising a plan	Building relationships between given information and prior knowledge	1. Build relationships to select resolution strategies
	Building relationships using mathematical properties or structures	1. Using symbols, concepts, properties, formulas or rules to develop a solution strategy 2. Establish relationships between unknown variables and algebraic operations
Carrying out the plan	Building relationships between given information and prior knowledge	1. Building relationships in implementing the resolution plan
	Building relationships using mathematical properties or structures	1.Using symbols, concepts, properties, formulas or rules to carry out the solution plan 2.Establish relationships between unknown variables and algebraic operations
Looking back	Building relationships between given information and prior knowledge	1.Build rapport by checking back
	Building relationships using mathematical properties or structures	1.Rationalize the use of algebraic properties or operations

Rindani (2023) used the following questions: "*Dina bought 7 books and 5 pencils at the School Cooperative for Rp33,500.00. Fatur also bought 2 books and 6 pencils at the same place for Rp17,800.00. Rara has Rp17,700.00 and plans to buy books and pencils at the School Cooperative. How many books and pencils can Rara buy with her money?"* Based on the questions used in the research conducted, Rindani (2023) sees relational thinking ability more as a thinking process in solving contextual problems, so he relates it to Polya's stages.

In line with this research, Saskia et al. (2023) stated that there are 4 steps in problem-solving according to Polya, namely: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back. Other studies that use the scope of the definition of relational thinking in the problem-solving process were conducted by Ramadhan et al. (2021), Fauziyah & Ismail (2022), Tafrilyanto (2016), Khoyimah (2021), Wardani & Susanah (2020), Satriawan et al. (2018) and Husnah (2021). They studied students' relational thinking ability based on Polya's stages (Rindani, 2023). Relational thinking is students' ability to understand each step in solving a problem and know the reasons for each step (Husnah, 2021).

Research that uses the scope of the definition of relational thinking in the problem-solving process was also conducted by Zakaria et al. (2018). In his research, he explained relational

thinking as the ability to solve mathematical problems. He formulated relational thinking indicators, which were also derived from Polya's stages with slight modifications, namely understanding the problem, planning a plan, implementing the plan and making conclusions. Supporting other research that links relational thinking ability with problem-solving, Pramesti & Rosyidi (2019) stated that Relational thinking is the cognitive process of connecting given data elements with existing knowledge of mathematical concepts and structures to address mathematical problems. This is supported by Agustini and Rahaju (2022), who, in their research, stated that relational thinking involves identifying how given data points relate and then converting that information into mathematical symbols and values based on existing understanding to tackle problems. Relational thinking involves transforming problem elements into symbolic and numeric representations based on understanding how these elements relate and drawing on existing knowledge to address mathematical concepts (Khoyimah, 2021).

IV. Conclusion

Through the Systematic Literature Review (SLR) method, articles on mathematical relational thinking were found, which showed that the topic of relational thinking received sufficient attention from researchers. From 2016 - to April 2024, 8 articles were identified on relational thinking ability in mathematics conducted abroad, and 22 research articles were conducted in Indonesia. Specifically in Indonesia, 54.5% of research was conducted in East Java. This shows that research on relational thinking has not been widely conducted. Most of the material researchers raised to describe relational thinking skills is arithmetic and algebra. In general, the scope of the definition of relational thinking used by researchers includes relational thinking that emphasizes equality and the meaning of the "=" sign and relational thinking in problem-solving. Of the 30 identified research results, 86.67% of the research was qualitative research aimed at describing students' relational thinking ability, and very little research was conducted as an effort to improve students' relational thinking ability. The results of this study provide recommendations to further researchers to conduct research to improve students' mathematical relational thinking ability.

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